STRATEGIC SHIFT FROM ECONOMIC SURVIVAL TO LONG-RUN ENVIRONMENTAL SUSTAINABILITY OF ECOWAS SUB-REGION: A DYNAMIC PANEL ANALYSIS OF CARBON EMISSIONS AND PRESERVATION QUALITY

MUDANÇA ESTRATÉGICA DA SOBREVIVÊNCIA ECONÔMICA PARA A SUSTENTABILIDADE AMBIENTAL DE LONGO PRAZO NA SUB-REGIÃO DA CEDEAO: UMA ANÁLISE DINÂMICA DE PAINEL DAS EMISSÕES DE CARBONO E DA QUALIDADE DE PRESERVAÇÃO

Article received on: 7/21/2025
Article accepted on: 27/10/2025

Oluchukwu F. Anowor*
*University of Johannesburg (UJ)
Johannesburg, Gauteng, South Africa
Lattes: http://scholar.google.co.in/citations?user=JfkZX5kAAAAJ&hl=en
Orcid: https://orcid.org/0000-0001-8959-0411
oluchukwuanowor@gmail.com

Wilfred I. Ukpere*
*University of Johannesburg (UJ)
Johannesburg, Gauteng, South Africa
Lattes: https://scholar.google.com/citations?hl=en&user=go8gXjwAAAAJ
Orcid: https://orcid.org/0000-0002-3308-0081
wiukpere@uj.ac.za

Vincent A. Onodugo**
**University of Nigeria, Enugu Campus (UNEC)
Enugu, Enugu State, Nigeria
Lattes: https://scholar.google.com/citations?user=3DWMNukAAAAJ&hl=en
Orcid: https://orcid.org/0000-0001-5457-8586
vincent.onodugo@unn.edu.ng

The authors declare that there is no conflict of interest

Abstract
The quest for economic survival among developing nations has turned full circle with emphasis shifting from mere short-term economic survival to the huge environmental devastation that it leaves in its trail. The consequences of unchecked use of natural resources are here with us: depletion of ozone layer, deforestation leading to rampaging erosion damage, eccentric weather condition, land-use change, just to stop at these few. It is being conjectured that if the situation continues unabated, we may not have the environment to live and operate in. This study's primary objective was to validate the Environmental Kuznets Curve (EKC) hypothesis within the ECOWAS. This study employed a two-step System Generalized Method of Moments (GMM) for its analysis. This approach was used

Resumo
A busca pela sobrevivência econômica entre as nações em desenvolvimento completou um ciclo, com a ênfase mudando da mera sobrevivência econômica de curto prazo para a enorme devastação ambiental que deixa em seu rastro. As consequências do uso desenfreado dos recursos naturais já estão presentes: depleção da camada de ozônio, desmatamento levando a danos desenfreados por erosão, condições climáticas extremas, mudanças no uso da terra, para citar apenas alguns exemplos. Há conjecturas de que, se a situação continuar sem controle, talvez não tenhamos mais um ambiente adequado para viver e operar. O principal objetivo deste estudo foi validar a hipótese da Curva de Kuznets Ambiental (EKC) na CEDEAO. Este estudo empregou um Método Generalizado dos Momentos (GMM) em dois

to evaluate the impact of carbon emissions on environmental quality across the member states of ECOWAS. The results indicated that both carbon emissions and greenhouse gases are detrimental, leading to a decline in environmental quality. Conversely, the consumption of renewable energy was found to be beneficial, contributing to an improvement in the sub-region's ecological quality. Based on these findings, the study suggests that ECOWAS countries should implement policies both domestically and collectively to mitigate environmental degradation. This can be achieved by promoting the adoption of renewable energy sources and carbon-free products throughout the region.

Keyword: Carbon Emissions. Environmental Degradation. Renewable Energy. Greenhouse Gas. EKC.

estágios para sua análise. Essa abordagem foi usada para avaliar o impacto das emissões de carbono na qualidade ambiental nos estados membros da CEDEAO. Os resultados indicaram que tanto as emissões de carbono quanto os gases de efeito estufa são prejudiciais, levando a uma queda na qualidade ambiental. Por outro lado, o consumo de energia renovável mostrou-se benéfico, contribuindo para a melhoria da qualidade ecológica da sub-região. Com base nessas descobertas, o estudo sugere que os países da CEDEAO devem implementar políticas tanto a nível nacional como coletivo para mitigar a degradação ambiental. Isso pode ser alcançado promovendo a adoção de fontes de energia renováveis e produtos sem carbono em toda a região.

Palavras-chave: Emissões de Carbono. Degradação Ambiental. Energia Renovável. Gases de Efeito Estufa. EKC.

1 INTRODUCTION

Achieving a balance between rapid global economic growth and the imperative of environmental sustainability has emerged as one of the most pressing concerns for policymakers and scholars alike (Sarkodie & Strezov, 2019). While economic growth is essential for reducing poverty (Okorie & Anowor, 2017; Onodugo *et al*., 2018), narrowing the inequality gap (Robeyns, 2025; Kuznets, 1955), and improving living standards (Agbarakwe, Anowor, & Ikue, 2018), it is often results in environmental degradation primarily through rising carbon emissions (Zhao, Xu, & Xie, 2024; Ongan, *et al*., 2023). This dilemma calls for a shift towards a new paradigm in which economic progress is decoupled from environmental harm, ensuring a safe and sustainable future for all. Conservation and preservation constitute essential foundations in discussions surrounding environmental protection and the pursuit of sustainable development, as they ensure the safeguarding of natural resources for present and future generations (Mensah, 2019; Elliott, 2022). Environmental sustainability is a critical concern for human health, economic stability, and socio-political well-being, as any harm to the environment directly threatens survival of mankind. This concern is evident in global campaigns since the 1990s against the growing threat of carbon emissions, which contribute to ozone layer depletion, global warming, climate change, and other forms of environmental degradation

(Rani, Amjad, Asghar, & Rehman, 2022; Sarkodie, 2021; Owusu & Asumadu, 2016; Anowor & Agbarakwe, 2018; Odugbesan & Rjoub, 2020). Economic activities and growth-oriented operations are frequently identified as the primary sources of carbon emissions (Nur, Nur, & Sitti, 2017; Sarkodie, 2020; Onodugo *et al*, 2019).

Apparently, carbon emission poses significant risk to the economy and health of the environment. The principal anthropogenic greenhouse gases primarily consist of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and a range of fluorinated compounds, including hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and residual chlorofluorocarbons (CFCs). Their atmospheric concentrations have reached record highs in recent years (Zubair, Chen, Ma & Hu, 2023; IPCC, 2022; WMO, 2024). The primary sources of these emissions are the combustion of fossil fuels, diverse industrial processes, and alterations in land use, including deforestation and agricultural expansion (notably enteric fermentation), as well as certain chemical and manufacturing activities (Anowor, Achukwu & Ezekwem, 2014; Zubair, Chen, Ma & Hu, 2023; IPCC, 2022; EPA, 2025).

Environmental sustainability has been defined as the efficient use and management of natural resources, to meet the needs of the present, without compromising the ability of future generations to meet their needs (Allen *et al*., 2018; Mensah, 2019). This principle continues to be regarded as critical to the protection of the ecosystem and long-term stability of economies (Morelli, 2011; Tennakoon *et al*., 2024). Environmental sustainability requires a careful balance between economic development and environmental protection, a balance that has become increasingly important in addressing critical global challenges such as climate change, biodiversity loss, and depleting natural resources (Khan *et al*., 2023; Tennakoon *et al*., 2024). Such efforts are strongly in keeping with international sustainability agendas, specifically the United Nations Sustainable Development Goals (SDGs). Targets on SDG 13 (Climate Action) and 15 (Life on Land) emphasize the need for shared responses. The significance of these targets is particularly relevant for the Economic Community of West African States (ECOWAS), where the vulnerabilities to climate change and environmental degradation are very threatening to its development and stability (ECOWAP, 2020).

The ECOWAS represents a critical region for environmental sustainability research because of its distinct development challenges and environmental vulnerabilities. As a bloc of developing economies, countries in ECOWAS face mounting pressures from rapid population growth with about 3.11% annually; additionally, urbanization, and industrialization are among the factors that significantly drive environmental degradation (Wang *et al*., 2023). The region's deep-seated dependence on natural resource, coupled with a fossil fuel-intensive energy mix, further exacerbates greenhouse gas (GHG) emissions (Shahbaz *et al*., 2022; Ahmed, Zafar, & Mansoor, 2020). Although the ECOWAS possesses vast renewable energy potential, inadequate investment and weak infrastructure have limited its adoption (Anowor, Ichoku, & Onodugo, 2020), perpetuating reliance on traditional and carbon-intensive energy sources (Anowor *et al*., 2025).

These relationships explain the complex relationship between economic growth and environmental quality and the necessity to employ rigorous panel data techniques to analyse the dynamic interaction between carbon emissions and the incidence of environmental preservation measures over time and space (Adewuyi & Awodumi, 2020; Shahbaz *et al*., 2023). The findings generated are invaluable to forming the basis for evidence based policy decisions and strategies for sustainable development in ECOWAS. Hence, this study has an instructionally significant contribution to the understanding and architecture of sustainable development pathways for this region of geo-tectonic, nostrategic importance.

The unique dilemma confronting ECOWAS countries stems from a profound conflict between their urgent need for economic growth and the severe environmental consequences of this growth. To bridge the prosperity gap with advance nations, these countries, as observed by Odugbesan and Rjoub (2020), are pursuing industrialization and urbanization, which often involve high-polluting activities and reliance on fossil fuels. This development path exacerbates existing environmental problem (Khan *et al*, 2023; Ongan *et al*, 2023), including rising carbon emissions and land degradation (Rani *et al*,. 2022). Compounding this challenge is the significant lack of financial and technological resources needed to transition to a cleaner, more sustainable development model (Anowor *et al*, 2023). This resource constraint often necessitates a trade-off; wherein immediate economic gains, as observed by Rani *et al* (2022), Robeyns (2025), are prioritized over long-term environmental sustainability. Such a dilemma arises because developing economies frequently face pressing social and economic needs such as poverty alleviation, infrastructure development, and job creation that can conflict with investments in environmental protection, which Lawal, (2023) described as trapping the region in a cycle of growth induced environmental harm.

With this conceptual perspective, the main aim of the study is to examine the impact of carbon emissions, greenhouse gas emissions, industrial development, and urbanization on environmental quality within the ECOWAS sub-region. The analysis not only looks at the subject of identifying the magnitude and direction of these effects, but also at identifying the causal relationships between emissions, industrial activities, urban development, and ecological outcomes. To this purpose, the Environmental Kuznets Curve (EKC) hypothesis is used to help evaluate quantitatively the consequences on the environment from the growth of emissions. In addition, complementary variables such as demographic pressures, increasing urbanization, and renewable energy adoption are included to capture a deeper insight into the contours of environmental sustainability of ECOWAS (Aperbris and Ozturk, 2015; Nathaniel and Iheonu, 2019; Sarkodie and Strezov, 2019).

This paper is designed to fill several important gaps in the existing body of literature. Much of the prior work (Sarkodie, 2021; Zhao *et al*., 2024) has primarily concentrated on the nexus between economic growth and carbon emissions, while giving limited attention to other crucial indicators of environmental sustainability, such as preservation quality. In addition, earlier studies often neglect the interconnectedness and potential spillover effects that exist among ECOWAS countries, a limitation that frequently results in biased or incomplete estimations. Furthermore, a significant portion of these analyses (Osobajo *et al*., 2020; Dimnwobi *et al*., 2021; Abdouli & Omri, 2021) rely on static panel estimation techniques, which are insufficient to capture the dynamic and time-dependent interactions between environmental degradation and economic development. The potential for endogeneity between economic variables and environmental outcomes is frequently ignored, which can compromise the validity of findings. Studies are often constrained by limited data availability covering only short time period, some studies (Bello *et al*., 2010; Haldar & Sethi, 2021; Acheampong *et al*., 2019) are country specific, thus hindering a comprehensive regional assessment.

Abundant literature has been devoted to the relationship between carbon emissions, economic growth, and environmental degradation (Aboagye, 2019; Abdouli & Omri, 2021; Rehman & Rashid, 2017; Osobajo *et al*., 2020; Dimnwobi *et al*., 2021; Mensah *et al*., 2020; Baydoun & Aga, 2021; Khan *et al*., 2021). Their results, however, are mixed and sometimes incompatible with each other. For instance, the studies by Khan *et al* (2021), Dimnwobi *et al* (2021), and Mensah *et al* (2020) reported a linear relationship between emissions and growth, and Abdouli & Omri (2021) observed that there was no significant relationship. Further studies also tested the EKC hypothesis, though results are sensitive to the choice of environmental indicators, methodology, and datasets (Lawson *et al*., 2019; Omojolaabi, 2010; Ozigbu, 2019; Aboagye, 2019; Osobajo, *et al*., 2020; Alola *et al*., 2022). Overall, the empirical evidence on the EKC is still contradictory in cross-country and country-specific studies. Halliru *et al*. (2020) found a U-shape relationship, Omojolaibi (2010) found that there is an inverse U-shape relationship, and fixed-effect results indicated that CO2 emissions have no significant effect on environmental quality. Bello *et al* (2010) reported a U-shaped distribution between emissions and growth in Nigeria.

A few empirical studies have been done that examine the complex relationship between carbon emissions and environmental quality, specifically in the context of the Economic Community of West African States (ECOWAS) region. This research works to address this gap by making use of data from all 15 member countries of ECOWAS. The four major research lines for the study are to examine the effects of carbon emissions on environmental quality, including considering the implications of both industrialization and urbanization on environmental quality; check the appropriateness of the Environmental Kuznets Curve (EKC) hypothesis; and investigate the causal relationship between carbon emissions, industrialization, urbanization, and environmental quality in ECOWAS countries.

2 LITERATURE REVIEW

Balancing economic progress with environmental protection is a complex issue in developing regions like the ECOWAS states (Khan *et al*., 2021; Onodugo *et al*, 2019). Weak sustainability proposes that man-made capital can replace natural resources, a viewpoint often favored by nations focused on rapid economic growth. This approach assumes that technological advancements can mitigate environmental harm (Acheampong *et al*., 2019). In contrast, the strong sustainability perspective argues that some natural resources are essential and cannot be replaced. This view prioritizes their conservation, even if it means sacrificing some short-term economic gains (Akhbari &

Nejati, 2019; Nwonye *et al*., 2023). Research from West Africa indicates that while economic growth can lead to increased carbon emissions (Alaganthiran & Anaba, 2022), implementing effective policies for renewable energy and stronger governance can foster more sustainable development (Dauda *et al*., 2021). These insights underscore the need for tailored strategies that align economic goals with environmental objectives, moving beyond the traditional model of prioritizing growth above all else (Rahman & Alam, 2022).

The Environmental Kuznets Curve (EKC) hypothesis is a core concept in environmental economics, proposing an inverted U-shaped relationship where environmental degradation initially increases with economic growth before eventually decreasing (Grossman & Krueger, 1991). The EKC is a theoretical model that postulates a distinct relationship between a nation's wealth and its environmental health, picturing it as an inverted U-shaped journey. In the "Initial stage", as a nation's income rises through industrialization, environmental quality deteriorates. This is primarily due to the "Scale Effect", where economic expansion, often driven by polluting industries and outdated technologies lead to more waste and emissions. At a certain point, a "Turning point" is reached where the trend reverses. In the "Later stage", as the economy matures and shifts towards service-based sectors (a phenomenon known as the "Composition Effect"), environmental degradation begins to decline. This phase is also marked by the "Technique Effect", as increased wealth allows for greater investment in cleaner technologies and stronger environmental regulations, reflecting a public demand for a healthier environment. While the EKC has been a subject of extensive research, its applicability to all pollutants, particularly long-term issues like carbon emission, remains a point of scholarly debate.

However, the applicability of EKC to developing regions, particularly ECOWAS, is highly debated. While some studies in developing nations have found evidence supporting the EKC for specific pollutants (Shahbaz *et al*., 2017), others have revealed a more complex or non-existent relationship (Omoke *et al*., 2021). There are reasons to worry about the relevance of EKC hypothesis to the ECOWAS region due to unique factors such as reliance on extraction of natural resource, limited institutional capacity, and weak environmental regulations (Kone *et al*., 2022). The assumed technological and structural shifts underlying the EKC may not manifest in the same way, potentially leading to continuous environmental pressure despite economic growth (Acheampong and Kwaku, 2021). In addition, the hypothesis often overlooks the issue of "pollution heaven," where developed nations outsource polluting industries to developing ones, thereby relocating environmental burdens rather than resolving them (Copeland and Taylor, 2004). Therefore, a nuanced perspective is required for the ECOWAS region, taking into account its heterogeneous economic structures and the need for targeted, pro-environmental policies rather than relying on an automatic turnaround (Kalu *et al*., 2020; Acheampong *et al*., 2020).

In addition to the Environmental Kuznets Curve, alternative analytical frameworks shed light on the underlying factors contributing to environmental degradation in the ECOWAS sub-region. One such approach is the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model, which offers a flexible and robust framework for examining how demographic pressures, economic prosperity, and technological change collectively influence environmental outcomes (York *et al*., 2003; Acheampong *et al*., 2020). Unlike models that treat population and affluence as isolated factors, STIRPAT recognizes that these elements interact with technological and institutional variables to shape environmental impacts (Kone *et al*., 2022). Empirical evidence from West Africa demonstrates that urbanization and institutional quality can significantly influence how economic activities affect carbon emissions, highlighting the importance of context-specific analyses (Omoke *et al*., 2021). Another critical perspective is the theory of Metabolic Rift (MR), which originates from Marx's ecological writings and has been developed by contemporary scholars like John Bellamy Foster (Foster, 2000). This perspective posits that environmental challenges are direct consequence of capitalism's inherent contradiction; its compulsion to separate human society from natural cycles (Foster and Clark. 2018). This "rift" is evident in the displacement of nutrient cycle and the burning of fossil fuels, issues particularly relevant to resource-rich but often environmental vulnerable regions like ECOWAS. Collectively, these theories highlight the need to consider not only economic growth but also demographic shifts, technological pathways, and the underlying socio-economic structures that govern the human-environmental relationship in the region (Acheampong and Kwaku, 2021; Kalu *et al*., 2020).

Evidence from the ECOWAS region suggests that economic expansion plays an important role in driving carbon emissions, although the results reported in the literature remain far from uniform (Alaganthiran & Anaba, 2022; Musah *et al*., 2020; Dada *et al*., 2023; Khan, 2023). Beyond West Africa, Rehman and Rashid (2017) assessed the effects of energy consumption on environmental degradation in Asian economies using panel unit root, OLS, and dynamic OLS techniques, and their results confirmed a long-run co-integrating relationship consistent with the Environmental Kuznets Curve (EKC) hypothesis. Similarly, Sinha and Shahbaz (2018) investigated the interaction between renewable energy use and environmental sustainability in India, providing further validation of the EKC framework. In Nigeria, Ozigbu (2019) employed the ARDL bounds testing method and identified an inverted U-shaped association between economic growth and carbon dioxide emissions. Extending these insights, Nguyen and Kakinaka (2019) analyzed the joint effects of renewable energy, carbon emissions, and environmental performance using Pooled Mean Group and Mean Group ARDL estimations. Their study highlighted that, for low-income economies, renewable energy adoption sometimes correlates negatively with certain environmental quality indicators but can also be positively associated with emissions. Taken together, these findings emphasize the complex and sometimes paradoxical role of energy consumption and renewable energy deployment in shaping environmental outcomes.

McGee and Greiner (2019), drawing on evidence from 175 countries, examined the concept of renewable energy injustice and its socio-environmental consequences. Their findings indicated that the use of conventional energy serves as a mediator in the link between inequality, renewable energy adoption, and environmental outcomes. Within the Sub-Saharan African context, Adzawla *et al*. (2019) evaluated the EKC hypothesis for greenhouse gas emissions and economic growth between 1970 and 2012 using OLS and VAR approaches, and their results revealed an inverted N-shaped association, thereby challenging the conventional EKC framework. Likewise, Aboagye (2019), focusing specifically on Ghana, showed that energy consumption significantly contributes to pollution across air, water, and land resources—measured by CO_2 emissions, biological oxygen demand (BOD), and deforestation—without providing support for the EKC hypothesis. Taken together, these studies illustrate the multifaceted and context-specific nature of the relationship between energy use and environmental sustainability. For ECOWAS countries, where rapid urban expansion, dependence on fossil fuels, and weak environmental governance prevail, such diverse results point to the need for a dynamic panel modeling strategy to better capture the complexities of regional environmental realities.

Bekun *et al*. (2021), applying the Pooled Mean Group (PMG) estimation method to Sub-Saharan Africa, revealed that reliance on conventional energy sources worsens environmental quality, whereas the adoption of clean energy exerts a beneficial effect. Expanding the scope to developed economies, Nawaz, Alvi, and Akmal (2021) examined OECD member states between 1980 and 2019 and highlighted that the relationship between energy consumption and environmental performance is highly context-dependent. In a related study, Sultana (2021) tested the EKC hypothesis in Bangladesh covering the years 1972–2018, confirming its validity in both the short and long run, and further identified causal linkages between environmental degradation and socio-economic dynamics. Evidence from China also reinforces these findings: Anwar *et al*. (2021), employing the ARDL framework, observed that clean energy significantly improves environmental quality. Similarly, Alola *et al*. (2022), using quantile-on-quantile regression with Chinese data from 1971 to 2016, established that fossil fuel and primary energy consumption consistently elevate the ecological footprint across all quantiles. Collectively, these contributions stress the critical role of clean energy adoption in curbing environmental degradation and advancing sustainable development. Despite diverse methods and contexts, most evidence are derived from Asia and OECD economies, whereas few studies have focused on carbon emission and environmental quality indicators in developing African economies, and none on ECOWAS, leaving a significant research gap that this study addressed.

3 DATA AND METHODOLOGY

This study employs a balanced panel dataset of all 15 ECOWAS countries over 2012–2022 to investigate the impact of carbon emissions on environmental degradation. Data on environmental indicators were obtained from the World Bank's (2023) Environmental Emissions Database, while complementary variables were sourced from the World Development Indicators. All variables were log-transformed to ensure comparability across countries and to allow elasticities to be directly interpreted from the estimated coefficients.

A panel econometric framework was adopted to exploit both cross-sectional and time-series variation, thereby addressing unobserved heterogeneity and improving estimation efficiency (Hsiao, 2014; Baltagi, 2021). A double-logarithmic specification was used to reduce heteroscedasticity, skewness, and outlier effects, while linearizing relationships among variables. This methodological design provides robust insights for ECOWAS, where reconciling economic growth with environmental sustainability remains a critical challenge (Acheampong, 2018; Sarkodie & Strezov, 2019).

4 THEORETICAL FRAMEWORK

This study is based on the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic growth and environmental degradation. Early stages of growth often increase environmental pressures due to the scale effect of rising production and consumption, while later stages reduce impacts through structural shifts toward service sectors (composition effect) and adoption of cleaner technologies and stricter regulations (technique effect) (Grossman & Krueger, 1991, 1995; Dinda, 2004; Panayotou, 1993).Together, these shifts provide the theoretical basis for understanding how growth trajectories can eventually align with environmental sustainability.

The EKC framework is particularly relevant for the diverse ECOWAS region, providing a basis to investigate if their carbon emissions trajectories follow this predicted pattern. Although empirical evidence for the EKC applied to carbon emission is mixed (Stern, 2004), this study will formally test the hypothesis by incorporating both linear and squared terms of income per capita into its econometric model. This approach allows for the potential identification of a critical income threshold where carbon emissions begin to decline, aligning with the core tenets of the EKC hypothesis.

5 MODEL SPECIFICATION

Building on this study’s objective of applying dynamic panel analysis, the model specification is designed to capture complex and time-dependent interactions among the variables. A dynamic framework is particularly appropriate because environmental degradation (the dependent variable) is unlikely to be independent of its own history, meaning past outcomes influence present conditions. Incorporating a lagged dependent variable is therefore central to accurately modeling such persistence. In this regard, the study employs a dynamic panel model to examine how carbon emissions and key socioeconomic factors shape environmental sustainability and preservation quality within the ECOWAS region. Compared with static approaches, this method is more robust as it recognizes that current environmental quality is partly determined by previous states. In addition, it provides an effective way to address econometric challenges such as endogeneity and unobserved heterogeneity across countries, both of which are frequently encountered in cross-country panel analysis.

Drawing on the augmented EKC framework, the model is specified in a double-logarithmic functional form. This specification not only helps to minimize potential heteroscedasticity but also enables the coefficients to be interpreted directly as elasticities, thereby providing clearer insights into the proportional effects of the explanatory variables.

A dynamic environmental degradation model is thus specified as follows:

$$\ln(ED_{it}) = \lambda_0 + \lambda_1 \ln(ED_{it-1}) + \lambda_2 \ln(CE_{it}) + \lambda_3 \ln(GHG_{it}) + \lambda_4 \ln(RE_{it}) + \lambda_5 \ln(POPGR_{it}) + \lambda_6 \ln(IND_{it}) + \lambda_7 \ln(URB_{it}) + \mu + \Delta + \varepsilon_{it} \quad (1)$$

where:

i and t represent the country and year, respectively.

$\ln(ED_{it})$ is the natural logarithm of **Environmental Degradation** (proxied by carbon emissions) for country i in year t.

$\ln(ED_{it-1})$ is the one-period lagged natural logarithm of the dependent variable.

$In(CE_{it})$ is the natural logarithm of **Carbon Emissions per capita** (metric tons).

$\ln(GHG_{it}$ is the natural logarithm of **Total Greenhouse Gas Emissions**.

$\ln(RE_{it})$ is the natural logarithm of **Renewable Energy Consumption** (% of total final energy consumption).

$In(POPGR_{it})$ is the natural logarithm of **Population Growth Rate.**

$\ln(IND_{it})$ is the natural logarithm of the **Ratio of Industrial Output to GDP** (as a proxy for Industrialization).

$\ln(URB_{it})$ is the natural logarithm of **Urbanization** (% of total population).

μ represents the unobserved country-specific effects (fixed effects).

Δ represents the time-specific effects, capturing common shocks across all countries in a given year.

ε_{it} is the idiosyncratic error term

6 ESTIMATION TECHNIQUE

Because the model includes a lagged dependent variable, $\ln(ED_{it-1})$, a standard Ordinary Least Square (OLS) or fixed-effects estimator would produce biased and inconsistent results. This bias arises from the correlation between the lagged dependent variable and the error term (ε_{it}). To overcome this limitation, the study applies the Generalized Method of Moments (GMM), following the Arellano-Bond (1991) difference GMM approach. In addition, the system GMM estimator is considered more appropriate, as it enhances efficiency and performs well in panels characterized by a relatively small time (T) dimension and a larger cross-sectional dimension (N), which reflects the structure of the present dataset (N = 15, T = 10). The validity and reliability of the instruments are critically assessed using the Sargan and Hansen tests of over-identifying restrictions. Additionally, the Arellano-Bond test for autocorrelation is conducted to ensure that the error structure satisfies the required assumptions for consistent estimation. By employing dynamic panel GMM, the study accounts for persistence in environmental degradation, addresses endogeneity, and controls for unobserved heterogeneity across ECOWAS countries, thus providing robust and policy-relevant estimates for environmental sustainability analysis.

To examine the impact of carbon emissions on environmental sustainability in ECOWAS countries, a structured econometric approach was employed. Cross-sectional dependence was first tested using Pesaran's (2004) CD test, followed by the CADF unit root test (Pesaran, 2007) to assess variable stationarity. Long-run equilibrium relationships were then examined using the Pedroni (2004) cointegration test.

Subsequently, the study employed the two-step System-GMM estimator in conjunction with the Dumitrescu and Hurlin (2012) panel causality test to capture dynamic causal relationships while addressing endogeneity concerns. To further ensure robustness, a static fixed-effects model was also estimated to confirm the consistency of the carbon emissions' effect on environmental quality. Collectively, this combination of econometric techniques is well-suited for modeling long-run relationships, accommodating heterogeneity across countries, and providing reliable causal inferences in dynamic panel settings.

7 RESULTS AND DISCUSSIONS

This section presents, interprets, and discusses the results of the study.

Table 1

Summary of Descriptive Statistics.

Statistics	ED	CE	GHG	RE	IND	POPGR	URB
Mean	56.52104	0.372080	35654.82	65.63067	6.376110	13130982	3.721202
Median	55.96010	0.271625	22170.00	72.68000	4.963087	6812394.	3.663217
Maximum	80.11450	1.126458	308180.0	94.42000	127.4461	1.15E+08	5.272807
Minimum	32.71830	0.086371	670.0000	22.41000	-75.04564	339071.0	1.575813
Std. Dev	11.43746	0.245022	69218.80	19.20989	16.53596	24234200	0.787716
Skewness	-0.106612	1.140998	3.265444	-0.637971	2.978967	3.295565	-0.345010
Kurtosis	2.183579	3.738940	12.24810	2.297674	30.28656	12.52214	3.644572
Obs.	150	150	150	150	150	150	150

Source: *Authors' Computation using Stata 15*

Table 1 presents the descriptive statistics of the study variables, based on 150 observations from 15 ECOWAS countries. The results show that, in most cases, the mean values are higher than the respective standard deviations, suggesting relative stability in the data distribution. However, greenhouse gas emissions (GHG), industrialization (IND), and population growth (POPGR) display higher variability across the region. Environmental degradation (ED) records an average of 56.52, with values ranging from 32.72 to 80.11, indicating significant disparities in environmental quality among member states. Per capita carbon dioxide (CO_2) emissions are relatively low, averaging 0.372 metric tons, which aligns with evidence that ECOWAS economies are less industrialized compared to global averages (Kalu *et al.*, 2020). Conversely, greenhouse gas emissions (GHG) average 3.565 metric tons, spanning from 670.0 to 3,061, underscoring the growing contribution of non-CO_2 pollutants to ecological stress in the region (Dada *et al.*, 2023). Renewable energy (RE) uses averages 65.63, with a range of 22.41 to 94.42, suggesting that while some countries are increasingly integrating sustainable energy sources, others lag behind in tapping renewable potential (Mensah *et al.*, 2021; Opoku & Aluko, 2021). Taken together, these descriptive outcomes reveal the heterogeneity of environmental and energy dynamics in ECOWAS, a factor that warrants deeper econometric investigation.

For the other covariates, the industrialization rate reflects notable variability, with a mean that remains relatively low, while maximum and minimum values stand at 127.4

and -75.04, respectively. The corresponding standard deviations for ED, CE, GHG, RE, IND, POPGR, and urbanization (URB) are 11.43, 0.245, 6,921, 19.21, 16.53, 2,423, and 0.787, respectively.

Skewness, which measures the degree of asymmetry in the distribution, indicates that CE, GHG, IND, and POPGR exhibit positive skewness, implying the presence of long right tails. In contrast, ED, RE, and URB demonstrate negative skewness, suggesting long left tails. Kurtosis values, which assess the peakedness or flatness of a distribution, further refine this analysis. When kurtosis exceeds 3, the distribution is leptokurtic (peaked), while value below 3 indicate platykurtic (flat) distributions, and values equal to 3 reflect mesokurtic (normal) distributions. Based on the results, GHG, IND, and POPGR are leptokurtic, CE and URB and mesokurtic, whereas ED and RE are platykurtic.

Table 2

Result of Correlation matrix

Correlation Matrix	LNED	LNCE	LNGHG	LNRE	POPGR	IND	URB
LNED	1.000000						
LNCE	0.679243	1.000000					
LNGHG	-0.264427	0.042853	1.000000				
LNRE	-0.624184	-0.726269	0.289807	1.000000			
POPGR	-0.013340	0.282780	0.683137	0.206358	1.000000		
IND	-0.095780	-0.103923	-0.093961	0.023517	-0.111413	1.000000	
URB	-0.423719	-0.375381	0.611583	0.470834	0.246022	-0.013759	1.000000

Source: Authors' computation. *** Significant at 5 percent level

Table 2 presents the correlation matrix. The results indicate that carbon emissions (CE) are positively and significantly correlated with environmental degradation (ED), confirming a direct link between CO_2 emissions and ecological deterioration. In contrast, greenhouse gas emissions (GHG) display a negative correlation with ED, suggesting that their impact on environmental outcomes may differ from that of carbon emissions. Both GHG and renewable energy consumption (RE) show negative associations with ED, highlighting the potential mitigating role of renewable energy in environmental sustainability. Industrialization (IND) also records a negative correlation with ED (−0.09). At the 5% significance level, this finding lends support to the Environmental Kuznets Curve (EKC) hypothesis, which posits that while industrial expansion initially worsens environmental conditions, it can, at more advanced stages of economic growth, lead to improvements in environmental quality. This implies that although rising economic activities within ECOWAS countries are associated with environmental pressures, they may simultaneously generate opportunities for mitigation and cleaner production. Interestingly, population growth (POPGR) also shows a negative correlation with ED, which diverges from conventional expectations of higher demographic pressure leading to greater degradation. Among the two control variables, industrialization (IND) and urbanization (URB), both reveal negative correlations with ED, further reinforcing the complexity of the growth–environment nexus in the region.

Table 3

Results of the Cross-Sectional Dependence Test

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnED	1032.666[0.000]**	64.01503[0.000]**	63.18170 [0.000]**	10.15479 [0.000]**
lnCE	406.4334[0.000]**	20.80088[0.000]**	19.96755 [0.000]**	4.783264 [0.000]**
lnGHG	629.5581[0.000]**	36.19795 [0.000]**	35.36462 [0.000]**	22.58288[0.000] **
lnRE	393.4683[0.000]**	19.90620 [0.000]**	19.07287 [0.000]**	7.124494 [0.000] **
IND	167.1971[0.000]**	4.292008[0.000]**	3.458674 [0.000]**	0.698168[0.4851]
POPGR	1047.457[0.000]**	65.03570 [0.000]**	64.20237 [0.000]**	32.36436 [0.000]**
URB	586.9483[0.000]**	33.25759 [0.000]**	32.42426 [0.000]**	6.566922 [0.000]**

Notes: The symbol ** indicates that p-value ≤0.01. The p-values are presented in parenthesis
Source: *Author's Computation using Stata 15*

The results of the cross-sectional dependence test are reported in Table 3. The outcomes of the LM-based statistics, including the Pesaran CD test, confirm the presence of cross-sectional dependence at the 1% significance level for nearly all variables, with the exception of industrialization.

Table 4

The results of Panel unit root test

Variable	Im Persaran and Shin (IPS) Test		Order of integration
	Level	1st Difference	
LnED	-1.5715(0.0552)	-3.1584(0.0000) **	**I(1)**
LnCE	-1.4504(0.1720)	-3.1151(0.0000) **	**I(1)**
lnGHG	-1.6033(0.0586)	-3.3745(0.0000) **	**I(1)**
LnRE	-1.4730(0.1428)	-3.3745(0.0000)	**1(1)**
POPGR	2.3867(1.0000)	-3.3487(0.0000) **	**I(1)**
IND	-2.1727(0.0000) **	N/A	**I(0)**
URB	-0.6557(0.9995)	-2.9896(0.0000) **	**I(1)**

Notes: The symbol ** indicates that p-value is lesser than 5% critical value and the rejection of the null hypothesis of the panels containing unit-roots. The IPS p-values are presented in parenthesis.
Source: *Author's Computation using Stata 15*

The results of the panel unit root tests, presented in Table 4, indicate that lnED, lnCE, lnGHG, POPGR, and URB are non-stationary at their level form, while industrialization (IND) is stationary at level, I(0). After first-differencing, all variables became stationary, with the null hypothesis of a unit root strongly rejected at the 5% significance level. These findings suggest that lnED, lnCE, lnGHG, POPGR, and URB are integrated of order one, I(1), indicating a mixed order of integration across the variables. Recognizing this mixed integration is critical for selecting appropriate cointegration techniques to capture long-run relationships effectively.

With the integration order established, the next step is to determine whether the variables share a long-term equilibrium relationship. Cointegration analysis assesses whether non-stationary series move together over time, maintaining a stable association despite short-term variations. Since the dataset includes both I(0) and I(1) variables—a condition necessary to avoid spurious regression—the Pedroni panel cointegration test was employed to examine the existence of a long-run equilibrium among the series (Pedroni, 2004).

Table 5

Result of Pedroni's Cointegration Test

	Statistic	**Prob**	**Weighted Stat.**	**Prob**
Panel v-Statistic	-0.189403	0.5751	-2.468809	0.9932
Panel rho-Statistic	4.160653	1.0000	4.361892	1.0000
Panel PP-Statistic	-5.414740	0.0000	-7.427645	0.0000
Panel ADF-Statistic	-3.882958	0.0001	-4.262950	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension	**Statistic**		**Prob**	
Group ADF-Statistics	5.841762		1.0000	
Group rho-Statistic	-9.322791		0.0000	
Group ADF-Statistic	-5.057496		0.0000	

Source: *Author's Computation using Stata 15*

Table 5 presents the findings of Pedroni's panel cointegration tests applied to the study variables. This residual-based procedure tests the null hypothesis of no cointegration against the alternative hypothesis that a long-run equilibrium relationship exists among the variables. As shown in Table 5, both the weighted panel PP and weighted panel ADF statistics are significant at the 5% level. Similarly, the group PP and group ADF statistics also reach significance at the 5% threshold. These outcomes provide strong evidence to reject the null hypothesis of no cointegration and support the presence of a long-term equilibrium relationship. Accordingly, the results indicate a stable and enduring association between environmental degradation and the explanatory variables across the panel of ECOWAS countries.

7.1 Two-Step System GMM estimation results

Table 6

Results of the System GMM (Dynamic Model)

Variables	**Coefficient**	**Corrected Std. Err**	**z-statistics**	**Prob.**
lned(-1)	.8176943	.0647958	12.62	0.000**
lnCE	.045456	.0213981	2.12	0.034**
lnGHG	-.0141893	.0053223	-2.67	0.008**
lnRE	-.0122988	.0289515	-0.42	0.671
POPGR	3.35e-10	3.68e-10	0.91	0.363
IND	.0007577	.000752	1.01	0.314
URB	.0161149	.0170868	0.94	0.346
Const.	.9088328	.3560675	2.55	0.011
Number of countries	15			
Number of observations	135			
Wald chi^2(7)	345925.36			0.000
Arellano-Bond Test:				
AR (1)	0.075			
AR (2)	0.302			
Hansen Test	0.187			
Sargan test	0.512			

Note: The asterisks ** denote significance at the 5% level.
Source: *Authors' Computation using Stata 15.*

Table 6 reports the two-step System-GMM estimates for ECOWAS countries, accounting for heteroscedasticity, endogeneity, and autocorrelation. Lagged environmental degradation is positive and significant, indicating that past environmental conditions strongly influence current degradation. Carbon emissions exacerbate environmental deterioration, with a 1% increase in CO_2 raising poor environmental quality by 0.045%, reflecting the region's reliance on fossil fuels (Abbasi *et al*., 2021; Musah *et al*., 2021). Conversely, total greenhouse gas emissions show a negative and significant effect, improving environmental quality by 0.014% per 1% increase. Renewable energy consumption reduces degradation by 0.012%, though the effect is not statistically significant, consistent with evidence from developed countries (Cıtak *et al*., 2021). Population growth exerts a strong positive impact, with a 1% rise increasing poor environmental quality by 3.35%, highlighting the ecological pressures of demographic expansion. Collectively, these results emphasize that sustainable growth in ECOWAS requires both cleaner energy adoption and demographic management.

In addition, industrialization shows a positive but marginal influence on environmental degradation. The estimates indicate that a 1% rise in industrial activity increases environmental degradation by only 0.0007%, ceteris paribus. Likewise, urbanization exerts a positive effect, with a 1% increase associated with a 0.016% decline in environmental quality.

Finally, the diagnostic tests confirm the robustness of the System-GMM model. The p-values for AR(1) and AR(2) indicate no presence of first- or second-order serial correlation. Additionally, the instrument set is valid, as the number of instruments remains below the number of cross-sectional units. Collectively, these results demonstrate that the System-GMM estimation is appropriate and that the empirical model specifications are statistically reliable.

7.2 Robustness checks

To verify the robustness of the findings, additional checks were performed using complementary approaches. First, the Hausman test was employed to determine the suitability of fixed versus random effects models (Table 7), revealing that the fixed effects specification is preferable ($p = 0.0099 < 0.05$). Within this framework, population growth emerged as statistically significant. Across both model specifications, greenhouse gas emissions remained negative but statistically insignificant, while the coefficients for carbon emissions and renewable energy varied in direction without reaching significance. Second, the overall significance of the explanatory variables was assessed using the F-statistic, which confirmed that the variables jointly exert a significant effect on environmental quality. Furthermore, specification tests confirmed that the models were correctly formulated. Collectively, these findings reinforce the robustness of the analysis, demonstrating that the results are reliable and provide a solid foundation for policy-relevant inferences.

Table 7

Results of Pooled Ols, fixed and random effect model.

Variables	Pooled OLS	Fixed effects	Random effects
Const.	5.050098** (12.71)	3.999025** (18.96)	4.439076** (24.63)
lnCE	.1558168 (1.69)	-.013363 (-0.32)	.0370953 (0.98)
lnGHG	-.0684195 (-1.28)	-.0048593 (-0.26)	-.0268011 (-1.50)
lnRE	-7.898786 (-1.65)	-.0596604 (-0.54)	-.0470894 (-0.40)
POPGR	3.19e-10 (0.11)	9.02e-09** (4.64)	4.39e-09** (3.12)
IND	-.0278084 (-1.29)	-.0004763 (-1.62)	-.0005098** (-1.62)
URB	-.0321146 (-0.36)	-.0185618 (-0.70)	-.0486288 (-1.96)
R-squared	0.7048	0.2213	0.1586
F-statistic Prob		104.89 0.0000	
Hausman		0.0099	

Note: Figures in parenthesis are t-statistics. The asterisks ** denote significance at the 5% level.
Source: *Author's Computation using Stata 15.*

7.3 Dumitrescu and Hurlin (D–H) granger causality analysis

The Dumitrescu and Hurlin (2012) approach was used to assess the direction of causal relationships among the variables. Significance is evaluated using the average of individual cross sectional test statistics and the z-bar statistic, based on the standard normal distribution, with their corresponding p-values. This method is well-suited for heterogeneous panels like those of ECOWAS, as it accommodates cross-sectional dependence and country-specific variations while producing reliable aggregate inferences. Applied to the ECOWAS dataset, the D-H Granger causality test captures both individual country-level linkages and regional trends. The results, reported in Table 8, detail the causal interactions between environmental and economic variables across the region.

Table 8

Results of D-H Causality test

Hypothesis	W-Stat.	Zbar-Stat	Prob	Causality
lnCE→lnED lnED→lnCE	2.37068 1.96609	1.00537 0.53820	0.3147 0.5904	No Causality
lnGHG→lnED lnED→lnGHG	21.6968 0.83348	23.3212 -0.76963	0.0000 0.4415	Unidirectional
lnRE→lnED lnED→lnRE	8.01589 4.51070	7.52390 3.47645	5.E-14 0.0005	Unidirectional
POPGR→lnED lnED→POPGR	6.45721 14.1448	5.72409 14.6010	1.E-08 0.0000	Unidirectional
IND→lnED lnED→IND	1.46556 0.87879	-0.03976 -0.71732	0.9683 0.4732	No Causality
URB→lnED lnED→URB	1.91820 5.37142	0.48289 4.47033	0.6292 8.E-06	No Causality

Source: *Author's Computation using stata 15*

Table 8 shows that carbon emissions do not Granger cause environmental degradation in ECOWAS countries, while greenhouse gas emissions exert a unidirectional causal effect, underscoring their environmental impact. Renewable energy also demonstrates a unidirectional effect, highlighting its potential to mitigate ecological harm (Destek and Sinha, 2020). Conversely, urbanization and land-use change intensify environmental degradation, emphasizing the need for integrated land management (Dimnwobi *et al*., 2021; Xue *et al*., 2022). These findings suggest that ECOWAS countries should focus on clean energy investments, enforce emissions regulations, and adopt sustainable urban planning to safeguard environmental quality alongside economic growth.

8 CONCLUSION AND RECOMMENDATIONS

This study investigated the influence of carbon emissions on environmental quality across 15 ECOWAS countries from 2012 to 2022, aiming to test the Environmental Kuznets Curve (EKC) hypothesis. Employing panel unit root tests, Pedroni's cointegration procedure, and two-step System-GMM estimation, the findings indicate that the region remains in the early phase of the EKC. Economic expansion, at this phase, drives environmental degradation, with carbon emissions and industrialization showing significant positive impacts, highlighting dependence on polluting technologies and pressures from a rapidly increasing population (Opoku & Aluko, 2021; Musah *et al*.,

2021) Essentially, ECOWAS countries are not yet in a position to prioritize environmental sustainability over basic economic survival. Policy agendas are rightly dominated by pressing issues such as poverty, unemployment, and hunger. The *Scale Effect* of the EKC is the dominant force here because the prime goal is to increase economic output to meet the immediate needs of the people. The shift to a cleaner, service-based economy (the *Composition Effect*) is a future aspiration, not a present reality. Similarly, the adoption of cleaner technologies, or the *Technique Effect*, is currently limited, as evidenced by the statistically insignificant impact of renewable energy.

This research, unlike previous studies, accounts for the interconnectedness of these nations, painting a more accurate picture of their shared trajectory. The path for ECOWAS is not predetermined. To one day reach the *turning point* of the EKC, policymakers must integrate environmental considerations into their development strategies now. This means making a deliberate investment in renewable energy and promoting green industries. Ultimately, a true shift from economic survival to long-term environmental sustainability will require a proactive approach that mainstreams ecological considerations in the very expedient efforts towards development.

REFERENCES

(ECOWAP), E. A. (2020). *ECOWAS Environmental Action Plan 2020-2026.* Abuja: Economic Community of West African States. Retrieved from http://ecowap.ecowas.int/media/ecowap/file_document/2020_ECOWAS_ECOWAS_ENVIRONMENTAL_ACTION_PLAN_Final_Version_-_ENG.pdf

(EPA), U. E. (2025). *EPA's Report on the Environment (ROE).* Washington, D.C.: U.S. EPA.

(IPCC), I. P. (2022). *Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

(WMO), W. M. (2024). *More Extreme Heat Demands Coordinated Action.* Geneva: World Meteorological Organization (WMO). Retrieved from https://wmo.int/media/news/more-extreme-heat-demands-coordinated-action

Abbasi, K. R., Adedoyin, F. F., Abbas, J., & Hussain, K. (2021). The impact of energy depletion and renewable energy on CO2 emissions in Thailand: Fresh evidence from the novel dynamic ARDL simulation. *Renewale Energy, 180*, 1439-1450. doi:https://doi.org/10.1016/j.renene.2021.08.078

Abdouli, M., & Omri, A. (2021). Exploring the Nexus Among FDI Inflows, Environmental Quality, Human Capital, and Economic Growth in the Mediterranean Region. *Journal of the Knowledge Economy, 12*(2), 788-810.

Aboagye, S. (2019). What drives energy intensity in Ghana? A test of the environmental kuznets hypothesis. *OPEC Energy Review, 3*(43), 259-276. doi:10.1111/opec.12155

Acheampong, E. O., & Kwaku, E. M. (2021). The dynamic effects of economic growth and globalization on environmental quality in West Africa. *Heliyon, 7*(2), e06225.

Acheampong, E. O., Kwaku, E. M., & Ofori, J. A. (2020). The environmental impact of economic growth in West Africa: An assessment of the Environmental Kuznets Curve (EKC) hypothesis. *Environmental Science and Pollution Research, 27*(36), 45050–45062.

Acheampong, E. O., Macgregor, C. J., S. S., & Sayer, J. (2019). Deforestation is driven by agricultural expansion in Ghana's forest reserves. *Scientific African, 5*, e00146.

Adzawla, W., Baumüller, H., Donkoh, S. A., & S. R. (2019). Effects of climate change and livelihood diversification on the gendered productivity gap in Northern Ghana. *Climate and Development, 12*(8), 743–755. doi:https://doi.org/10.1080/17565529.2019.1689093

Agbarakwe, H. U., Anowor, O. F., & Ikue, J. (2018). Foreign resources and economic growth in English speaking ECOWAS countries. *Opción, 34*(14), 117-136.

Ahmed, Z., Zafar, M. W., & Mansoor, S. (2020). Analyzing the linkage between military spending, economic growth, and ecological footprint in Pakistan: Evidence from cointegration and bootstrap causality. *Environental Science Pollution Research, 27*, 41551–41567. doi:doi:10.1007/s11356-020-10076-9

Akhbari, M., & Nejati, M. (2019). Green growth and corruption control. *Journal of Cleaner Production,, 237*, 117769.

Alaganthiran, K. K., & Anaba, O. J. (2022). The effects of economic growth on carbon dioxide emissions in selected Sub-Saharan African (SSA) countries. *International Journal of Environmental Research and Public Health, 19*(21), 14316.

Allen, C., Metternicht, G., & Wiedmann, T. (2018). Prioritising SDG targets: Assessing baselines, gaps and interlinkages. *Sustainability Science, 14*(2), 421–438. doi:doi: 10.1007/s11625-018-0596-81

Alola, A. A., Alola, U. V., A. S., & Yildirim, H. (2022). The role of economic freedom and clean energy in environmental sustainability: Implication for the G-20 economies. *Environmental Science and Pollution Research, 29*(24), 36608–36615. doi:https://doi.org/10.1007/s11356-02218666-5

Anowor, O. F., & Agbarakwe, H. U. (2018). How have deforestation affected economic and social welfare: The case of Port Harcourt City. *Journal of Social Sciences Research, 4*(8), 116–124.

Anowor, O. F., Achukwu, I. I., & Ezekwem, O. S. (2014). Sustainable Sources of Energy and the Expected Benefits to Nigerian Economy. *International Journal of Sustainable Energy and Environmental Research, 3*(2), 110-120.

Anowor, O. F., Ichoku, H. E., & Onodugo, V. A. (2020). Nexus between healthcare financing and output per capita: Analysis of countries in ECOWAS sub-region. *Cogent Economics & Finance, 8*(1), 1832729. doi:https://doi.org/10.1080/23322039.2020.1832729

Anowor, O. F., Ichoku, H. E., Onodugo, V. A., Ochinanwata, C., & Uzomba, P. C. (2023). Does investment in education and health impact youth employment outcomes? Evidence from Sub-Saharan Africa. *Cogent Economics and Finance*, 2160128. doi:https://doi.org/10.1080/23322039.2022.2160128

Anowor, O. F., Kalu, I. E., Odo, A. C., & Okorie, G. C. (2025). Characterizing Agricultural Export Trade in Africa's Oil-Rich Nations. *Journal of Business and African Economy, 11*(5), 57–70. doi:https://doi.org/10.56201/jbae.vol.11.no5.2025.pg57.70

Anwar, A., Sharif, A., Fatima, S., Ahmad, P., Sinha, A., Rehman Khan, S. A., & Jermsittiparsert, K. (2021). The Asymmetric Effect of Public Private Partnership Investment on Transport CO2 Emission in China: Evidence from Quantile ARDL Approach. *Journal of Cleaner Production, 228*, 125282. doi:https://doi.org/10.1016/j.jclepro.2020.125282

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies, 58*, 277-297. doi:https://doi.org/10.2307/2297968

Baydoun, H., & Aga, M. (2021). The Effect of Energy Consumption and Economic Growth on Environmental Sustainability in the GCC Countries: Does Financial Development Matters? *Energies, 14*(18), 1-17.

Bekun, F. V., Alola, A. A., Gyamfi, B. A., & Ampomah, A. B. (2021). The Environmental Aspects of Conventional and Clean Energy Policy in Sub-Saharan Africa: Is N-Shaped Hypothesis Valid? *Environmental Science Pollution Research, 28*, 66695–66708. doi:doi:10.1007/s11356-02114758-w

Bello, D., Wardle, B., Zhang, J., Yamamoto, N., Santeufemio, C., Hallock, M., & Virji, M. A. (2010). Characterization of exposures to nanoscale particles and fibers during solid core drilling of hybrid carbon nanotube advanced composites. *International Journal of Occupational and Environmental Health*, 434–450. doi:doi:10.1179/107735210799159996

Çıtak, F., Uslu, H., Batmaz, O., & Hoş, S. (2021). Do renewable energy and natural gas consumption mitigate CO2 emissions in the USA? New insights from NARDL approach. *Environmental Science and Pollution Research, 28*, 63739-63750. doi:https://doi.org/10.1007/s11356-020-11094-3

Copeland, B. R., & Taylor, M. S. (2004). Trade, technology, and the environment: The pollution haven hypothesis revisited. *American Economic Review, 94*(3), 75–91.

Dada, J. T., Ajide, F. M., & Arnaut, M. (2023). Income inequality, shadow economy and environmental degradation in Africa: quantile regression via moment's approach. *International Journal of Development Issues, 22*(2), 214-240. doi:https://doi.org/10.1108/IJDI-11-2022-0248

Dauda, L., Dauda, S., & Anana, B. (2021). The effects of economic growth, trade liberalization, and financial development on environmental sustainability in West Africa: The role of institutions. *International Journal of Energy Economics and Policy, 11*(6), 57–67.

Destek, M., & Sinha, A. (2020). Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from Organisation for Economic Cooperation and development countries. *Journal of Cleaner Production*, 118537. doi:https://doi.org/10.1016/j.jclepro.2019.118537

Dimnwobi, S. K., Ekesiobi, C., Madichie, C., & Asongu, S. (2021). Population Dynamics and Environmental Quality in Africa. *Science of the Total Environment*, 149172. doi:http://dx.doi.org/10.2139/ssrn.3888912

Dinda, S. (2004). Environmental Kuznets Curve hypothesis: A survey. *Ecological Economics, 49*(4), 431-455.

Dumitrescu, E. I., & Hurlin, C. (2012). Testing for Granger Non-Causality in Heterogeneous Panels. *Economic Modelling, 29*, 1450-1460. doi:https://doi.org/10.1016/j.econmod.2012.02.014

Foster, J. B. (2000). The vulnerable planet: A short economic history of the environment. *Monthly Review Press.*, 1-7.

Foster, J. B., & Clark, B. (2018). Marx's ecology: Materialism and nature. *Monthly Review Press*, 1-9.

Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American Free Trade Agreement. National Bureau of Economic Research.* Washington: Working Paper Series.

Grossman, G. M., & Krueger, A. B. (1995)). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377.

Haldar, A., & Sethi, N. (2021). Effect of institutional quality and renewable energy consumption on CO2 emissions− an empirical investigation for developing countries. *International Journal of Research and Innovation in Social Science, 5*(7), 173-183.

Halliru, A., Loganathan, N., Golam-Hassan, A., Mardani, A., & Kamyab, H. (2020). Re-examining the environmental Kuznets curve hypothesis in the economic community of West African states: A panel quantile regression approach. *Journal of Cleaner Production, 276*, 124247. doi:10.1016/j.jclepro.2020.124247

Kahn, B., Noman, A., & Ahmad, S. (2021). A road map for environmental sustainability and green economic development: An empirical study. *Environmental Science and Pollution Research, 28*(28), 37409-37424.

Kalu, E. O., Nwokoro, I. J., & Nkpa, C. E. (2020). Economic growth and environmental degradation in ECOWAS: A cointegration analysis. *Journal of Economics and Sustainable Development, 11*(16), 118–127.

Khan, B. (2023). CO2 Emissions and Economic Growth in Some Selected Countries of ECOWAS: Panel Data Approach. *Economics-Innovative and Economics Research Journal, 2*, 245–256. doi:doi:10.2478/eoik-2023-0055

Khan, M. K., Babar, S. F., Oryani, B., D. V., Rehman, A., Zakari, A., & Khan, M. O. (2021). Role of Financial Development, Environmental-Related Technologies, Research and Development, Energy Intensity, Natural Resource Depletion, and Temperature in Sustainable Environment in Canada. *Environmental. Science. Pollution. Research*, 1-17. doi:doi:10.1007/s11356-021-15421-0

Khan, S. A., Yu, Z., & Farooq, K. (2023). Green capabilities, green purchasing, and triple bottom line performance: Leading toward environmental sustainability. *Business Strategy and Environment, 32*(4), 2022-2034. doi: https://doi.org/10.1002/bse.3234

Kone, A. C., N'Guessan, J. A., & B. S. (2022). The validity of the Environmental Kuznets Curve in ECOWAS countries: A heterogeneous panel data analysis. *Heliyon, 8*(11), e11674.

Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review, 45*(1), 1-28.

Lawal, A. I. (2023). The Nexus between Economic Growth, Energy Consumption, Agricultural Output, and CO2 in Africa: Evidence from Frequency Domain Estimates. *Energies, 16*(3), 1239. doi:https://doi.org/10.3390/en16031239

Lawson, D. F., Stevenson, K. T., Peterson, M. N., Carrier, S. J., & Seekamp, E. (2019). Children Can Foster Climate Change Concern among Their Parents. *Nature Climate Change, 9*(6), 458–462. doi:https://doi.org/10.1038/s41558-019-0463-3

McGee, J. A., & Greiner, P. T. (2019). Renewable Energy Injustice: The Socio-environmental Implications of Renewable Energy Consumption. *Energy Research and Social Science, 56*, 101214. doi:https://doi.org/10.1016/j.erss.2019.05.024

Mensah, H., Amponsah, O., Opoku, P., Ahadzie, D. K., & Takyi, S. A. (2021). Resilience to climate change in Ghanaian cities and its implications for urban policy and planning. *Springer Nature Social Science, 1*, 118. doi:https://doi.org/10.1007/s43545-021-00123-8

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences, 5*(1), 1-11. doi:https://doi.org/10.1080/23311886.2019.1653531

Mensah, S., Ayarkwa, J., & Nani, G. (2020). A Theoretical Framework for Conceptualizing Contractors' Adaptation to Environmentally Sustainable Construction. *International Journal of Construction Management, 20*, 801-811. doi:https://doi.org/10.1080/15623599.2018.1484860

Morelli, J. (2011). Environmental Sustainability: A Definition for Environmental Professionals. *Journal of Environmental Sustainability*, 2-14. doi:DOI: 10.14448/jes.01.0002

Musah, A., Adjei, J., & Adu, R. (2020). CO2 Emissions and Economic Growth in Some Selected Musah, A., Adjei, J., & Adu, R. (2020). CO2 Emissions and Economic Growth in Some Selected. *ECONOMICS - INNOVATIVE AND ECONOMICS RESEARCH JOURNAL, 11*(2), 245–256. doi:doi:10.2478/eoik-2023-0055

Musah, M., Akomeah, M. O., Asamoah, D., & Owusu, A. (2021). The nexus between carbon emissions, economic growth, energy consumption and trade openness: a case of ECOWAS countries. *Journal of Environmental Planning and Management, 6*(1), 22-34.

Nawaz, S. M., Alvi, S., & Akmal, T. (2021). The impasse of energy consumption coupling with pollution haven hypothesis and environmental Kuznets curve: a case study of South Asian economies. *Environmental Science and Pollution Research, 28*(35), 48799-48807.

Nguyen, K., & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renew Energy, 132*, 1049-1057.

Nur, S. A., Nur, K. B., & Sitti, A. H. (2017). Carbon Footprint Reduction in Transportation Activity by Emphasizing the Usage of Public Bus Services Among Adolescents. *IOP Conference Series: Materials Science and Engineering*, 26-41. doi:10.1088/1757-899X/226/1/012054

Nwonye, N. G., Anowor, O. F., Okoh, J. I., Okanya, O. C., Obayi, P. M., Mbah, P. C., . . . Onuselogu, O. C. (2023). Government Expenditures, Foreign Aid and Remittances: A Review of Income Inequality in Nigeria. *African Journal of Business and Economic Research (AJBER), 18*(3), 187–209. doi:https://journals.co.za/doi/abs/10.31920/1750-4562/2023/v18n3a9

Odugbesan, J. A., & Rjoub, H. (2020). Relationship Among Economic Growth, Energy Consumption, CO2 Emission, and Urbanization: Evidence From MINT Countries. *SAGE Open, 10*(2), 1-9. doi:https://doi.org/10.1177/2158244020914648

Okorie, G. C., & Anowor, O. F. (2017). Empirical Appraisal of Poverty-Unemployment Relationship in Nigeria. *International Journal of Economics and Financial Research, 3*(6), 91-97.

Omojolaibi, J. A. (2010). Environmental quality and economic growth in some selected west Africa countries - A panel data assessment of the environmental Kuznets curve. *Journal of sustainable development in Africa, 12*(8), 35-48.

Omoke, E., Olasehinde, J. O., & Osakwe, A. N. (2021). The dynamic relationship between economic growth and carbon dioxide emissions in ECOWAS: A panel cointegration analysis. *Environmental Economics and Policy Studies, 23*(3), 517-535.

Ongan, S., Işık, C., Amin, A., Bulut, U., Rehman, A., Alvarado, R. A., & Karakaya, S. (2023). Are economic growth and environmental pollution a dilemma? *Environmental science and pollution research, 30*(17), 49591-49604. doi:doi:10.1007/s11356-023-25698-y

Onodugo, V. A., Anowor, O. F., & Ofoegbu, G. N. (2018). The effectiveness of monetary policy in tackling inflation in emerging economy. *Opción, 34*(14), 314-355. Retrieved from http://produccioncientificaluz.org/index.php/opcion/article/view/30262

Onodugo, V. A., Anowor, O. F., Ifediora, C., & Aliyu, N. (2019). Evaluation of Supply Chain Management Effects on Consumer Preference for Cowpea Quality Features and Price Trend in Niger State. *International Journal of Supply Chain Management, 8*(3), 503-516. Retrieved from https://ojs.excelingtech.co.uk/index.php/IJSCM/article/view/3295

Onodugo, V. A., Nwonye, N. G., Anowor, O. F., & Ofoegbu, G. N. (2019). Attaining Inclusive Growth in a Developing Economy on the Wings of Micro, Small and Medium Scale Enterprises. *Amazonia Investiga, 8*(24), 239-252.

Opoku, A. A., & Aluko, O. A. (2021). Carbon dioxide emissions and economic growth in ECOWAS countries: A dynamic panel data analysis. *Energy Reports, 7*, 2697-2708.

Osobajo, O. A., Otitoju, A., Otitoju, M., & Oke, A. (2020). The impact of energy consumption and economic growth on carbon dioxide emissions. *Sustainability, 12*, 7965. doi:10.3390/su12197965

Owusu, P. A., & Asumadu, S. S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering, 3*(1), 1167990. doi:https://doi.org/10.1080/23311916.2016.1167990

Ozigbu, J. C. (2019). Evaluating the validity of the environmental kuznets curve hypothesis: Empirical evidence from the Nigerian economy. *IOSR Journal of Humanities and Social Science, 24*(9), 19-27.

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development. *(Working Paper No. 99). International Labour Office, Technology and Employment Programme.*, 1.

Pedroni, P. (2004). Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the Ppp Hypothesis. *Econometric Theory, 20*, 597-625. doi:https://doi.org/10.1017/S0266466604203073

Pesaran, M. (2004). General Diagnostic Tests for Cross Section Dependence in Panels. *CESifo Working Paper Series No. 1229, IZA Discussion Paper No. 1240*, 1240.

Pesaran, M. H. (2007). A Simple Panel Unit Root Test in the Presence of Cross Section Dependence. *Journal of Applied Econometrics, 22*, 265-312. doi:https://doi.org/10.1002/jae.951

Rahman, M. M., & Alam, K. (2022). The role of globalization, renewable energy, and technological innovation in improving air quality: Evidence from the world’s 60 most open countries. *Environmental Science and Pollution Research, 29*(3), 3326–3341.

Rani, T., Amjad, M. A., Asghar, N., & Rehman, H. U. (2022). Exploring the moderating effect of globalization, financial development and environmental degradation nexus: a roadmap to sustainable development. *Environment, Development and Sustainability, 25*(12), 14499–14517. doi:https://doi.org/10.1007/s10668-022-02676-x

Rehman, M. U., & Rashid, M. (2017). Energy Consumption to Environmental Degradation, the Growth Appetite in SAARC Nations. *Renewable Energy, 111*, 284-294. doi:https://doi.org/10.1016/j.renene.2017.03.100

Robeyns, I. (2025). Why Economic Inequality Should be Central to Strategies for the Future. *Journal of Human Development and Capabilities, 26*(2), 161–176. doi:https://doi.org/10.1080/19452829.2025.2479028

Sarkodie, S. A. (2020). Causal effect of environmental factors, economic indicators and domestic. *Science of the Total Environment*, 736-743. doi:https://doi.org/10.1016/j.scitotenv.2020.139602

Sarkodie, S. A. (2021). Environmental performance, biocapacity, carbon & ecological footprint of nations: drivers, trends and mitigation options. *Science of The Total Environment*, 1-10. doi:https://doi.org/10.1016/j.scitotenv.2020.141912

Shahbaz, M., . Song, M., Ahmad, S., & Vo, X. V. (2023). Does Economic Growth Stimulate Energy Consumption? The Role of Human Capital and R&D Expenditures in China. *Energy Economics, 105*, 105662. doi:https://doi.org/10.1016/j.eneco.2021.105662

Shahbaz, M., Loganathan, N., Sbia, R., & Zeshan, M. (2017). The role of globalization on environmental degradation in developing economies: A panel analysis of EKC hypothesis. *Journal of Environmental Management, 197*, 347-354.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*(8), 419-1439.

Sultana, F. (2021). Climate change, COVID-19, and the co-production of injustices: a feminist reading of overlapping crises. *Social & Cultural Geography, 22*(4), 447–460.

Tennakoon, W. D., Janadari, M. P., & Wattuhewa, I. D. (2024). Environmental sustainability practices: A systematic literature review. *European Journal of Sustainable Development Research*, 22-29. doi:https://doi.org/10.29333/ejosdr/14604

Wang, F. Y., Lin, Y., Ioannou, P., Vlacic, L., Liu, X., Eskandarian, A., & Olaverri-Monreal, C. (2023). Transportation 5.0: The DAO to safe, secure, and sustainable intelligent transportation systems. *IEEE Transactions on Intelligent Transportation Systems*, 10262-10278 .

Xue, C., Shahbaz, M., Ahmed, Z., A. M., & Sinha, A. (2022). Clean energy consumption, economic growth, and environmental sustainability: What is the role of economic policy uncertainty? *Renew. Energy*, 899–907. doi:https://doi.org/10.1016/j.renene.2021.12.006

York, R., Rosa, E. A., & Dietz, T. (2003). STIRPAT, IPAT, and IMPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics, 46*(3), 351–365.

Zhao, F., Xu, Z., & Xie, X. (2024). Exploring the Role of Digital Economy in Enhanced Green Productivity in China's Manufacturing Sector: Fresh Evidence for Achieving Sustainable Development Goals. *Sustainability, 16*(10), 1-24. doi:https://doi.org/10.3390/su16104314

Zubair, M., Chen, S., Ma, Y., & Hu, X. (2023). A Systematic Review on Carbon Dioxide (CO2) Emission Measurement Methods under PRISMA Guidelines: Transportation Sustainability and Development Programs. *Sustainability*, 15-27.

Authors' Contribution

Both authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

How to cite this article (APA)

Anowor, O. F., Ukpere, W. I., & Onodugo, V. A. (2025). STRATEGIC SHIFT FROM ECONOMIC SURVIVAL TO LONG-RUN ENVIRONMENTAL SUSTAINABILITY OF ECOWAS SUB-REGION: A DYNAMIC PANEL ANALYSIS OF CARBON EMISSIONS AND PRESERVATION QUALITY. Veredas Do Direito, 22(4), e223666. https://doi.org/10.18623/rvd.v22.n4.3666