



Unravelling the Conditional Effects of Institutional Quality in ECOWAS in the Assessment of the Influence of Financial Development on Environmental Sustainability

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ABSTRACT

This study investigates whether institutional quality conditions the effect of financial development on environmental sustainability in the fifteen ECOWAS countries during 1990–2024. Existing research largely assumes a direct finance–environment relationship, overlooking how governance shapes environmental outcomes of financial development. Addressing this gap, the study develops an institutional moderation framework and estimates a cross-sectionally augmented autoregressive distributed lag model, complemented by augmented mean group and common correlated effects mean group estimators for robustness. Results show that financial development increases environmental degradation under weak institutional conditions but significantly improves sustainability when governance strengthens. Specifically, better rule of law, regulatory quality, and government effectiveness enhance resource allocation, regulatory compliance, and investment in environmentally sustainable activities. The significant error-correction term confirms long-run equilibrium, while robustness tests support the stability of the findings. However, the study demonstrates that institutional quality is the critical mechanism through which financial development advances environmental sustainability, highlighting governance reforms as a priority.

Keywords: Institutional Quality, Financial Development, Environmental Sustainability

JEL Classifications: O17, B15, G1, G2, Q10

1. INTRODUCTION

Environmental quality (EQ) has become one of the most pressing sustainability challenges confronting the member states of the Economic Community of West African States (ECOWAS), largely due to the region's continued dependence on natural resource exploitation, rapid urbanisation, population growth, and accelerating industrialisation (Intergovernmental Panel on Climate Change, 2023; United Nations Environment Programme, 2024). These structural transformations have intensified environmental pressures, resulting in increasing air and water pollution, deforestation, biodiversity loss, land degradation, and inadequate waste management systems that threaten ecosystem resilience and human well-being (Adebayo et al., 2022; Ali et al., 2023). Such environmental deterioration

extends beyond ecological concerns and constitutes a significant impediment to sustainable economic development by adversely affecting public health, agricultural productivity, food security, energy sustainability, and climate resilience across the sub-region (World Bank, 2024; Intergovernmental Panel on Climate Change, 2023). The challenge is particularly pronounced in many ECOWAS economies, where weak institutional capacity, inadequate environmental governance, limited regulatory enforcement, and ineffective monitoring mechanisms allow environmentally harmful activities to persist with minimal accountability (Yameogo et al., 2021; Aberu and Taiwo, 2025).

Consequently, despite numerous regional and international commitments aimed at promoting sustainable development,

including the Sustainable Development Goals (SDGs) and the Paris Climate Agreement, environmental degradation continues to intensify across the region, suggesting a persistent disconnect between economic expansion and environmental protection (United Nations, 2015; United Nations Environment Programme, 2024). This continuing deterioration raises an important policy question: why has sustained economic and financial expansion in ECOWAS failed to translate into improved environmental outcomes? Addressing this question is particularly important because environmental sustainability constitutes a fundamental prerequisite for achieving inclusive growth and the Sustainable Development Goals throughout the region. Accordingly, this study is motivated by the need to resolve the unresolved empirical question of whether economic development, financial development, and institutional quality jointly promote or undermine environmental quality in ECOWAS and, more importantly, under what institutional conditions these outcomes emerge. Unlike the conventional perspective that regards environmental degradation as an inevitable consequence of economic growth, this study argues that the environmental consequences of growth depend fundamentally on the quality of financial systems and institutional governance. Therefore, identifying the determinants of environmental quality within ECOWAS is essential for designing effective policies capable of simultaneously promoting economic transformation, environmental sustainability, and long-term development resilience.

Financial development (FD) has long been recognised as a critical driver of economic transformation and has increasingly been identified as a potential mechanism for improving environmental quality through the mobilisation of financial resources towards renewable energy, clean technologies, and environmentally sustainable infrastructure (Shahbaz et al., 2013; Tamazian and Rao, 2010; Aytun et al., 2023). By improving financial intermediation, reducing financing constraints, and enhancing access to capital, well-developed financial systems can facilitate technological innovation, promote energy-efficient production processes, and stimulate investments in green industries (Zhang et al., 2023; Liu et al., 2024). Nevertheless, the empirical evidence remains inconclusive, particularly in developing regions such as ECOWAS, where financial systems are relatively shallow, capital markets remain underdeveloped, and access to formal financial services is highly uneven (Acheampong et al., 2020; Elatroush, 2025). On the one hand, financial development may improve environmental outcomes by supporting investments in renewable energy, facilitating technological upgrading, and encouraging environmentally responsible production practices (Kostakis, 2024; Yang et al., 2024). On the other hand, it may exacerbate environmental degradation by expanding credit to pollution-intensive industries, increasing energy consumption, and encouraging resource-intensive economic activities where environmental regulations are weak or poorly enforced (Ali et al., 2023; Cai and Wei, 2023). This dual role creates a theoretical ambiguity that remains unresolved within the environmental finance literature.

Accordingly, this study advances the following hypotheses: H_1 : Financial development has a significant effect on environmental

quality in ECOWAS countries. H_{1a} : Financial development improves environmental quality through enhanced financing of environmentally sustainable investments and cleaner production technologies. H_{1b} : Financial development worsens environmental quality when financial resources are predominantly channelled towards environmentally intensive and pollution-generating activities. Beyond financial development, institutional quality (IQ) is expected to play a decisive role in shaping environmental outcomes by influencing regulatory effectiveness, policy implementation, and the allocation of financial resources (North, 1990; Acemoglu and Robinson, 2012). Weak institutions characterised by corruption, inadequate regulatory enforcement, weak rule of law, and political instability often permit environmentally harmful activities to persist with limited accountability, thereby accelerating environmental degradation (Yameogo et al., 2021; Aberu and Taiwo, 2025). Conversely, stronger institutions are expected to strengthen environmental governance, enforce regulatory compliance, and redirect financial resources towards environmentally sustainable investments (Christoforidis and Katrakilidis, 2021; Toufique, 2025). Consequently, this study further hypothesises that H_2 : Institutional quality significantly improves environmental quality in ECOWAS countries through stronger governance, more effective environmental regulation, and improved allocation of financial resources. Despite these theoretical expectations, existing empirical studies have largely examined financial development and institutional quality independently, providing only limited understanding of their combined influence on environmental outcomes.

A major unresolved issue in the existing literature is the absence of an integrated analytical framework capable of simultaneously examining the interactive effects of financial development and institutional quality on environmental quality, particularly within the ECOWAS region. Although numerous empirical studies have investigated the individual effects of financial development or institutional quality on environmental outcomes, most rely on additive specifications that implicitly assume these variables operate independently (Acheampong et al., 2020; Balsalobre-Lorente et al., 2023). Consequently, existing evidence remains fragmented, with many studies focusing on individual countries, Asian economies, OECD members, or broader multi-country samples, thereby limiting the generalisability of their findings to West African economies characterised by weaker institutions and less developed financial systems (Ali et al., 2023; Elatroush, 2025). Furthermore, the conflicting empirical evidence—where financial development improves environmental quality in some countries but worsens it in others—suggests that institutional quality may constitute the missing transmission mechanism underlying these divergent outcomes (Yang et al., 2024; Makhadmeh et al., 2022). Against this backdrop, this study addresses an important gap by explicitly examining whether institutional quality moderates the environmental effects of financial development within ECOWAS countries.

Accordingly, the study proposes the following hypothesis: $H3$: Institutional quality significantly moderates the relationship between financial development and environmental quality in ECOWAS countries such that improvements in institutional quality

strengthen the environmental benefits of financial development or mitigate its adverse environmental consequences. The central empirical question addressed in this study is therefore not simply whether financial development affects environmental quality, but rather why countries experiencing similar levels of financial expansion often exhibit markedly different environmental outcomes. By focusing on ECOWAS—a region characterised by substantial heterogeneity in governance quality, financial sector development, environmental regulation, and institutional effectiveness—this study provides an appropriate setting for investigating this conditional relationship. In doing so, it moves beyond conventional linear explanations of the finance–environment nexus and advances a more comprehensive framework that emphasises the importance of institutional heterogeneity in shaping environmental outcomes. Consequently, the study contributes to the growing environmental finance literature by providing new empirical evidence on the institutional conditions under which financial development promotes environmental sustainability within developing regional economic communities.

This study contributes to the existing literature both methodologically and empirically by developing an integrated framework that examines the conditional role of institutional quality in the relationship between financial development and environmental quality in ECOWAS countries. Methodologically, the study employs the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) estimator developed by Chudik and Pesaran (2015) as the baseline estimation technique because it simultaneously captures both the short-run dynamics and long-run equilibrium relationships while effectively addressing cross-sectional dependence, slope heterogeneity, and unobserved common factors that characterise macro-panel data. The reliability of the estimated results is further evaluated using the Augmented Mean Group (AMG) estimator proposed by Eberhardt and Teal (2010) and the Common Correlated Effects Mean Group (CCEMG) estimator of Pesaran (2006), both of which provide robust estimates in the presence of heterogeneous panel structures and cross-sectional interdependence. These estimation techniques are particularly appropriate for ECOWAS countries because the region is characterised by strong economic integration, common external shocks, regional policy spillovers, and increasing financial interconnectedness, all of which may generate cross-country dependence if ignored in conventional panel estimators (Pesaran, 2021). Furthermore, the empirical framework explicitly incorporates interaction terms between financial development and institutional quality to evaluate the moderating role of governance, thereby extending beyond conventional additive specifications that dominate the existing finance–environment literature.

The analysis also accounts for potential structural breaks arising from major financial reforms, institutional changes, and environmental policy shifts, thereby enhancing the robustness and credibility of the empirical findings. Consequently, this study makes three principal contributions to the literature. First, it develops a unified analytical framework that simultaneously integrates financial development, institutional quality, and environmental quality within a single empirical model. Second, it advances the environmental finance literature by demonstrating

that institutional quality is not merely an additional explanatory variable but a critical conditioning mechanism through which financial development influences environmental outcomes, thereby providing a plausible explanation for the inconsistent findings reported in previous empirical studies. Third, by focusing on ECOWAS—one of the least explored regions in the environmental finance literature—the study provides robust policy-relevant evidence on how strengthening institutional capacity can enhance the environmental benefits of financial sector development and support the achievement of sustainable development objectives. The remainder of the paper is organised as follows. Section 2 reviews the theoretical and empirical literature. Section 3 describes the data, variable measurement, model specification, and estimation strategy. Section 4 presents and discusses the empirical findings, while Section 5 concludes with policy recommendations and identifies directions for future research.

2. LITERATURE REVIEW

2.1. Theoretical Literature

2.1.1. *Environmental Kuznets curve (EKC) theory*

The Environmental Kuznets Curve (EKC) hypothesis argues that environmental degradation first increases with economic growth and later declines after income reaches a certain threshold, forming an inverted-U relationship (Panayotou, 2003). The theory is built on three main channels: scale, composition, and technique effects (Grossman and Krueger, 1995). At early development stages, the scale effect dominates as expanding production increases resource extraction and emissions. Over time, structural change (composition effect) may shift economies toward less polluting sectors, while technological advancement (technique effect) can reduce emissions intensity. In addition, rising incomes are assumed to increase environmental awareness and political demand for environmental regulation (Selden and Song, 1994). Despite its popularity, the EKC framework has important limitations that weaken its suitability for ECOWAS contexts. First, the assumption of automatic improvement in environmental quality after a specific income threshold is overly deterministic and ignores structural constraints typical of developing economies. In ECOWAS countries, economies remain heavily dependent on primary commodities, informal sectors, and extractive industries, meaning structural transformation is neither automatic nor guaranteed. Second, the theory underestimates the role of weak institutions and policy failures in shaping environmental outcomes. Even when income rises, poor regulatory enforcement may prevent the “turning point” from materializing, resulting in a continuously rising or unstable pollution path rather than an inverted-U shape. Third, the EKC assumes technological progress is accessible and evenly distributed, which is not the case in ECOWAS, where technological diffusion is constrained by weak financial systems and low innovation capacity. Empirical applications also show mixed and context-specific results, with EKC turning points varying widely across countries and pollutants (Chimeli and Braden, 2002). This inconsistency suggests that income alone is not a sufficient predictor of environmental improvement. In the ECOWAS context, therefore, the EKC is better interpreted as a conditional relationship rather than a universal law, requiring institutional and financial factors to explain why some countries

fail to experience environmental improvement even at higher income levels.

2.1.2. *Institutional theory*

Institutional theory explains environmental outcomes through the role of formal rules, governance structures, enforcement mechanisms, and informal norms that shape economic behaviour (North, 1990; Scott, 2014). The central argument is that institutions determine how resources are allocated, how policies are implemented, and how compliance is enforced, thereby influencing environmental performance. In principle, strong institutions enhance environmental quality by enforcing regulations, reducing corruption, and ensuring accountability, while weak institutions permit environmental degradation through regulatory failure and rent-seeking behaviour. However, a critical limitation of institutional theory is that it often assumes institutions operate uniformly and effectively transmit policy intentions into outcomes. In reality, especially in ECOWAS countries, institutional capacity is highly uneven, fragmented, and often constrained by political instability and weak bureaucratic systems. This creates a gap between formal environmental policies and actual enforcement, meaning that institutional presence does not necessarily translate into institutional effectiveness. Moreover, the theory tends to treat institutional quality as exogenous, whereas in ECOWAS, institutions themselves evolve in response to economic and financial pressures, making causality more complex and bidirectional. Another limitation is that institutional theory alone does not explain how financial systems interact with governance structures to produce environmental outcomes. While it correctly predicts that weak institutions may lead to environmental degradation through poor enforcement, it does not specify how financial development alters incentives within these institutional environments. This is particularly relevant for ECOWAS, where financial systems are underdeveloped but expanding, and where the environmental consequences of financial deepening depend heavily on governance quality. Empirical evidence supports this conditional role of institutions but also reveals inconsistencies. For example, some studies show that stronger institutions reduce emissions (Toufique, 2025), while others find that improvements in governance yield only marginal environmental gains in contexts with structural economic constraints (Yameogo et al., 2021). This suggests that institutional quality is necessary but not sufficient for environmental improvement. In ECOWAS, therefore, institutional theory must be integrated with financial and structural explanations to fully capture environmental outcomes.

2.1.3. *Financial development theory*

Financial development theory is traditionally framed around two competing hypotheses: the supply-leading and demand-following perspectives (Chow et al., 2019, Demircuc-Kunt & Levine, 2009). The supply-leading hypothesis argues that financial systems drive economic growth by mobilising savings, improving capital allocation, and facilitating investment (Schumpeter, 1911; Levine & Zervos, 1998). In environmental terms, this implies that financial development can either improve environmental quality by financing clean technologies or worsen it by expanding credit to polluting industries. A major weakness of the supply-leading argument is that it assumes financial expansion automatically improves efficiency in

capital allocation (Crichton & De Silva, 1973, Obstfeld 1994). This assumption is problematic in ECOWAS, where financial markets are shallow, credit allocation is often politically influenced, and green investment opportunities are limited. As a result, financial deepening may disproportionately benefit extractive and high-emission sectors, reinforcing environmental degradation rather than mitigating it (Dasgupta et al. 2002b, Christopoulos & Tsionas 2004, Cihak et al. 2012). Furthermore, the theory does not account for institutional constraints that determine whether financial resources are directed toward sustainable or unsustainable activities. The demand-following hypothesis, on the other hand, argues that financial development is a response to economic growth rather than its driver (Boulila & Trabelsi, 2002). While this perspective highlights the endogeneity between finance and growth, it also implicitly suggests that environmental improvements depend on income growth reaching a level where demand for environmental protection emerges (Vazakidis & Adamopoulos, 2009, Waqabaca 2004). However, this assumption is equally problematic in ECOWAS because rising income does not necessarily translate into environmental demand when governance structures are weak and environmental awareness is low. A key limitation of both hypotheses is that they treat financial development in isolation from institutional conditions. Neither adequately explains why financial systems sometimes worsen environmental outcomes even in periods of economic expansion. Empirical evidence is equally mixed, with some studies showing positive growth-finance links and others reporting weak or bidirectional causality (Demetriades & Hussein, 1996; Akbas, 2015). This inconsistency suggests that financial development cannot be meaningfully analysed without considering institutional quality as a conditioning factor. In ECOWAS, therefore, financial development theory is insufficient on its own to explain environmental outcomes. Its relevance depends on governance quality, regulatory enforcement, and the capacity of financial institutions to channel resources toward sustainable investments. This limitation justifies a more integrated theoretical framework that combines finance, institutions, and environmental dynamics rather than treating them as independent forces.

2.2. *Empirical Literature*

2.2.1. *Financial development and environmental quality*

Empirical evidence on the nexus between financial development (FD), institutional quality, and environmental quality (EQ) remains mixed, with outcomes strongly shaped by country context, income level, and measurement choices. A first strand of studies generally finds that financial development tends to increase environmental degradation, particularly in developing and emerging economies. For instance, Wijethunga et al. (2025) show that in Australia, FD worsens environmental quality and amplifies the negative impact of economic growth on emissions, although trade openness improves environmental outcomes. Similarly, Ali et al. (2023) report that in E-7 countries, FD and growth increase CO₂ emissions, while renewable energy reduces them. Comparable results are found in Cai and Wei (2023), where FD, financial inclusion, FDI, and urbanisation all increase emissions across Belt and Road countries. Zhang et al. (2023) further demonstrate pollutant-specific effects, with FD increasing CO₂ and CH₄ but reducing N₂O, indicating heterogeneous environmental impacts. These findings collectively support the view that financial expansion often fuels environmentally

intensive production in the absence of strong regulatory frameworks. In contrast, another strand of literature suggests that financial development can improve environmental quality under certain conditions. Aytun et al. (2023) find that in middle-income countries, FD and human capital reduce ecological footprints, while economic growth worsens environmental outcomes. Similarly, Kostakis (2024) shows that financial openness combined with renewable energy reduces CO₂ emissions in ASEAN countries, although EKC validity varies across countries. Liu et al. (2024) provide further nuance, showing that financial inclusion improves environmental quality in China and Vietnam, whereas fintech expansion and resource dependence degrade it. These mixed results indicate that the environmental effect of financial systems is not uniform but depends on the structure and inclusiveness of financial development.

A third group of studies emphasises the moderating role of structural and institutional factors. Acheampong et al. (2020) show that FD moderates the growth–emissions relationship differently across country groups, increasing emissions in developed and emerging economies but having insignificant effects in frontier economies, though their analysis is limited by focusing only on financial market indicators. Elatroush (2025) similarly finds heterogeneous effects across 60 countries, highlighting that income and structural differences determine whether FD improves or worsens emissions. Balsalobre-Lorente et al. (2023) further show that FD reduces ecological footprints when supported by strong institutions and environmental regulations, while FDI and trade increase environmental pressure under weak governance. Finally, several studies highlight the importance of complementary factors such as institutions, technology, and energy structure. Yang et al. (2024) find that digitalisation, financial development, and institutional quality promote green growth in South Asia, while mineral dependence constrains sustainability. Destek et al. (2023) confirm that renewable energy and strict environmental laws can offset the pollution effects of FDI. Saqib et al. (2023) also reveal complex causality patterns among growth, ICT, renewable energy, and emissions, reinforcing the non-linear and multidimensional nature of the finance–environment relationship. Despite the richness of evidence, a clear limitation is the lack of consensus on the direction and magnitude of the finance–environment relationship. Most studies agree that effects are conditional, but few explicitly integrate financial development and institutional quality within a unified analytical framework. Additionally, existing literature is dominated by global, Asian, and multi-regional samples, with limited focus on ECOWAS, where institutional fragility and financial underdevelopment may produce distinct dynamics. This study addresses these gaps by synthesising finance, institutions, and environmental quality in a single model, thereby clarifying the conditions under which financial development supports or undermines sustainability in West Africa.

2.2.2. Institutional quality and environmental quality

The empirical literature consistently recognises institutional quality (IQ) as a key determinant of environmental outcomes, but the direction and magnitude of its effects vary significantly across countries, governance dimensions, and methodological approaches. A first strand of studies provides strong evidence that improved institutional quality reduces environmental degradation.

For instance, Toufique (2025) finds that in Bangladesh, stronger institutions significantly reduce CO₂ emissions, although GDP growth and natural gas consumption increase emissions, confirming a long-run equilibrium relationship. Similarly, Ali et al. (2020) report that institutional quality reduces ecological footprints in 47 OIC countries, while Christoforidis and Katrakilidis (2021) show that institutional strength improves environmental outcomes across OECD economies. In Sub-Saharan Africa, Yameogo et al. (2021) also emphasise that governance quality is central to environmental sustainability. Collectively, these findings support the conventional view that institutions enhance environmental performance through enforcement, accountability, and regulation. Moreover, a contrasting body of evidence highlights that the effectiveness of institutions is not uniform and may depend on context and structural conditions. Kisman et al. (2025), using EU data, find no short-run impact of institutional quality on environmental outcomes, although long-run improvements are observed in selected countries such as Finland, Ireland, and Spain. This suggests delayed and heterogeneous institutional effects even in high-governance settings. Similarly, Yaman and Çetin (2025) reveal that institutional quality dimensions have mixed effects: while corruption control, rule of law, and voice and accountability reduce emissions, government effectiveness, regulatory quality, and political stability are paradoxically associated with higher emissions in developing countries. This divergence challenges the assumption that all institutional improvements are uniformly beneficial for environmental quality.

A third strand of literature focuses on developing and structurally constrained economies, where institutional effects are closely linked with energy systems, financial structure, and resource dependence. Aberu and Taiwo (2025) show that in Nigeria, weak institutional quality exacerbates environmental degradation and undermines sustainable development, with long-run effects being particularly significant. Danpome et al. (2025) further demonstrate that institutional quality supports energy sector development in Nigeria, although renewable energy expansion remains limited, indicating weak translation of governance improvements into green energy outcomes. Makhdum et al. (2022) similarly find that in China, strong institutions combined with renewable energy reduce environmental harm, whereas financial development and natural resource dependence increase degradation. Halder and Sethi (2021) reinforce this view by arguing that institutions must operate jointly with renewable energy adoption to achieve emission reductions in developing countries. Finally, evidence on the Environmental Kuznets Curve (EKC) within institutional settings remains mixed, further reinforcing the conditional nature of the institutions–environment relationship. Sreenu (2022) supports the EKC hypothesis in India, suggesting long-run improvements in environmental quality with income growth, whereas Sajeev and Kaur (2020) find that such relationships are only evident in the short run. This inconsistency indicates that institutional quality alone does not guarantee EKC-type transitions unless complemented by structural transformation and energy transition. This empirical literature converges on a key insight: institutional quality matters for environmental outcomes, but its effect is highly conditional, dimension-specific, and context-dependent. While stronger institutions generally improve environmental

performance, their effectiveness is mediated by energy structure, financial systems, and economic development level.

2.3. Knowledge Gaps

The empirical literature on financial development (FD), institutional quality (IQ), and environmental quality (EQ) has expanded considerably, but several precise and structurally important gaps remain that justify the present study. First, existing studies provide inconsistent evidence on the FD–environment relationship, with outcomes varying across income groups, regions, and pollutants (Wijethunga et al., 2025; Acheampong et al., 2020; Elatrash, 2025; Zhang et al., 2023). However, these inconsistencies are not systematically explained because most studies rely on single-channel or linear specifications, limiting their ability to capture nonlinear and conditional effects. Second, the literature remains heavily biased toward financial market indicators, with insufficient attention to financial institutional development (e.g., credit access, banking depth), resulting in an incomplete representation of how finance actually transmits environmental effects (Acheampong et al., 2020). Third, although several studies acknowledge the role of renewable energy, human capital, and innovation, these variables are often introduced in isolation rather than within an integrated framework, making it difficult to identify their combined or interacting influence on environmental outcomes (Aytun et al., 2023; Liu et al., 2024; Yang et al., 2024). Fourth, very few studies explicitly model nonlinearities such as threshold or EKC-consistent dynamics in a unified financial–institutional–environmental framework, leaving a methodological gap in capturing long-run adjustment paths (Zhang et al., 2023; Kostakis, 2024). Most importantly, there is a complete lack of empirical focus on ECOWAS countries, despite their pronounced institutional heterogeneity, financial underdevelopment, and high environmental vulnerability.

Similarly, the institutional quality literature confirms that governance matters for environmental outcomes but remains fragmented in three key ways. First, most studies treat institutional quality as a single aggregate index, despite evidence that its dimensions (rule of law, corruption control, regulatory quality, and political stability) have divergent and sometimes opposing effects on emissions (Yaman and Çetin, 2025; Kisman et al., 2025). Second, empirical evidence is largely drawn from either single-country cases or broad global panels, limiting the ability to capture region-specific institutional constraints such as those prevalent in ECOWAS (Aberu and Taiwo, 2025; Danish and Ulucak, 2020). Third, and most critically, existing research rarely integrates institutional quality into the financial development–environment nexus as a moderating mechanism, even though theory suggests that the environmental effect of finance is conditional on governance strength (Haldar and Sethi, 2021; Makhdom et al., 2022).

The present study directly addresses these gaps in a tightly specified empirical framework. It integrates both financial market and financial institutional development, models institutional quality as a multidimensional construct, and explicitly incorporates an interaction term between FD and IQ to capture conditional effects. In addition, it applies a nonlinear EKC-consistent

specification within a heterogeneous panel framework suited to ECOWAS realities. Methodologically, the use of CS-ARDL, supported by AMG and CCEMG estimators, directly responds to concerns about cross-sectional dependence, slope heterogeneity, and unobserved common shocks that are largely ignored in prior studies. This design ensures that the estimated relationships reflect both structural diversity and long-run equilibrium dynamics, rather than biased or overly restrictive linear assumptions.

3. METHODOLOGY

3.1. Theoretical Framework

This study is theoretically anchored on the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted-U-shaped relationship between economic growth and environmental degradation (Panayotou, 2003). The EKC provides a useful starting point for analysing environmental change, but it is insufficient for explaining environmental dynamics in ECOWAS because it reduces a complex, institutionally driven process to income levels alone. In reality, environmental outcomes in developing regions are shaped not only by growth but also by the quality of governance and the structure of financial systems, which determine how growth translates into environmental pressure or improvement. The EKC framework, therefore, serves as a baseline rather than a complete explanation. The theory explains environmental degradation through scale, composition, and technique effects (Grossman and Krueger, 1995). At low-income levels, the scale effect dominates as expanding production increases energy use, emissions, and resource depletion. As economies industrialize, the composition effect intensifies environmental stress through a shift toward manufacturing and extractive activities. At higher income levels, the technique effect is expected to reduce degradation through cleaner technologies and stronger environmental preferences supported by institutional capacity. However, this transition is not automatic in ECOWAS, where weak institutions and financial constraints often prevent the technique’s effect from materializing, thereby delaying or even distorting the expected EKC turning point. Formally, the baseline EKC specification is expressed as

$$EQ_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDP_{it}^2 + \varepsilon_{it} \quad (1)$$

Where environmental quality (EQ) is proxied by the Environmental Performance Index (EPI). The choice of EPI is deliberate and theoretically justified. Unlike single-pollutant measures such as CO₂ emissions or ecological footprint indicators, EPI is a composite index that captures multiple dimensions of environmental health (air quality, water quality, biodiversity, ecosystem vitality, and climate change performance). This is particularly important for ECOWAS countries where environmental degradation is multidimensional and cannot be adequately represented by carbon emissions alone. CO₂-based measures overemphasise industrial emissions while ignoring land degradation, deforestation, and water pollution, which are critical environmental challenges in the region. Similarly, ecological footprint indicators tend to aggregate resource use without distinguishing institutional and policy responsiveness. EPI, therefore, provides a broader and more policy-relevant measure of environmental performance, aligning

better with sustainable development objectives and allowing a more realistic assessment of environmental quality.

Given the objectives of this study, the traditional EKC is extended to incorporate financial development (FD) and institutional quality (IQ), recognising that income alone does not fully explain environmental outcomes in developing economies. The extended functional form is specified as:

$$EQ_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 FD_{it} + \beta_4 IQ_{it} + \beta_5 (FD_{it} \times IQ_{it}) + \mu_{it} \quad (2)$$

In this augmented framework, financial development influences environmental quality through its role in mobilising and allocating capital across sectors, thereby affecting both the scale and technique effects of production. Institutional quality determines whether financial resources are directed toward environmentally harmful activities or sustainable investments by shaping regulatory enforcement, accountability, and corruption control. The interaction term captures the critical argument that financial development is not inherently environmental-friendly or harmful; its impact depends on the institutional environment in which it operates. This is particularly relevant for ECOWAS, where financial systems are expanding but governance capacity remains uneven.

Within this context, the EKC does not operate as a purely income-driven mechanism but as an institutionally conditioned and finance-mediated process. Weak institutions in ECOWAS may prevent the expected turning point by allowing environmentally damaging investments to persist, even as income rises. In contrast, strong institutions can shorten the transition to environmental improvement by ensuring that financial development supports green innovation and regulatory compliance. Accordingly, EPI is used as the dependent variable because it captures these broader institutional and systemic effects on environmental performance, rather than narrowly focusing on emissions alone. This integrated framework, therefore, provides a more appropriate theoretical basis for examining how growth, finance, and governance jointly determine environmental quality in ECOWAS countries.

3.2. Data and Sources

This study basically explored the empirical relationships between institutional quality, financial development, and environmental quality in the 15 member countries of the Economic Community of West African States (ECOWAS) using annual time series data from 1990 to 2024. After conducting a review of the literature—both theoretical and empirical—we employed the environmental performance index (EPI) to measure environmental quality, while indicators such as the rule of law (ROL), regulatory quality (REQ), government effectiveness (GEF), political stability and absence of violence (PSAV), and voice and accountability (VAC) measured institutional quality. In addition, financial development was measured using both indicators of financial markets—stock market capitalisation (SMC), value of shares traded (VST), and shares bond market development (BMD)—as well as financial institution indicators such as domestic credit to the private sector (DCPS) and the number of commercial bank branches (NCBB)

were used to measure financial development. We controlled for financial deepening by using the ratio of broad money (M2) and gross domestic product (M2/GDP), urbanisation rate (UR), and population growth (POPgrt). These indicators were sourced from the World Bank's World Development Indicators (WDI), the World Bank's World Governance Indicators (WGI), and the International Monetary Fund (IMF). However, to improve the understanding of our study data and their sources, we defined each of the model variables, their acronyms and respective repositories for ease in the readers' understanding in Table 1 below.

3.3. Model Specifications

The model specification for this study is structured to capture the dynamic, heterogeneous, and cross-sectionally dependent nature of the finance–institution–environment nexus in ECOWAS countries. Anchored on the extended Environmental Kuznets Curve (EKC) framework, environmental quality is modelled as a function of income, its squared term, financial development, institutional quality, and their interaction term, while controlling for other relevant macroeconomic factors. Given the likelihood of cross-sectional dependence arising from regional integration, common shocks, and shared policy regimes, the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model is employed as the baseline estimator to obtain both short-run and long-run dynamics while accounting for unobserved common factors. To ensure robustness and address slope heterogeneity across countries, the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators are further applied. Additionally, structural break tests are incorporated to control for regime shifts associated with financial reforms, political transitions, and environmental policy changes within the region, thereby enhancing the stability, reliability, and policy relevance of the estimated parameters.

3.3.1. Baseline cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model

To rigorously estimate the dynamic relationship between financial development, institutional quality, and environmental quality in ECOWAS, this study employs the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model developed by Chudik and Pesaran (2015) and grounded in the Common Correlated Effects (CCE) framework of Pesaran (2006). The CS-ARDL estimator is particularly suitable for macro-panel data characterised by cross-sectional dependence, slope heterogeneity, and mixed order of integration, all of which are common in regional panels such as ECOWAS (Granger & Newbold 1974, Eng & Habibullah 2011). By augmenting the traditional ARDL structure with cross-sectional averages of both dependent and independent variables, the estimator controls for unobserved common factors and global shocks that may bias conventional panel estimators.

The general CS-ARDL (p, q) specification is expressed as:

$$EQ_{it} = \alpha_i + \sum_{j=1}^p \phi_{ij} EQ_{i,t-j} + \sum_{j=0}^q \beta_{ij} X_{i,t-j} + \gamma_i \bar{Z}_t + \varepsilon_{it} \quad (3)$$

where EQ_{it} represents environmental quality for the country i at time t ; X_{it} is a vector of explanatory variables including income,

Table 1: Definition of the model variables

Acronym	Definition	Repository
EPI	Environmental Performance Index	https://epi.yale.edu/downloads
ROL	The Rule of Law	https://www.worldbank.org/en/publication/worldwide-governance-indicators
REQ	Regulatory Quality	https://www.worldbank.org/en/publication/worldwide-governance-indicators
GEF	Government Effectiveness	https://www.worldbank.org/en/publication/worldwide-governance-indicators
PSAV	Political Stability and Absence of Violence	https://www.worldbank.org/en/publication/worldwide-governance-indicators
VAC	Voice and Accountability	https://www.worldbank.org/en/publication/worldwide-governance-indicators
SMC	Stock Market Capitalisation	https://data.worldbank.org/indicator/CM.MKT.LCAP.GD.ZS
VST	Value of Shares Traded	https://data.worldbank.org/indicator/CM.MKT.TRNR
BMD	Bond Market Development – a measure of the share turnover ratio	https://databank.worldbank.org/metadataglossary/global-financial-development/series/GFDD.DM.03
DCPS	Domestic Credit to the Private Sector	https://data.worldbank.org/indicator/FS.AST.PRVT.GD.ZS
NCBB	Number of Commercial Bank Branches	https://data.worldbank.org/indicator/FB.CBK.BRCH.P5
M2/GDP	Financial Deepening – a ratio of broad money and GDP	https://data.worldbank.org/indicator/FM.LBL.BMNY.GD.ZS and https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
UR	Urbanisation Rate	https://data.worldbank.org/indicator/SP.URB.TOTL
POPgrt	Population Growth	https://data.worldbank.org/indicator/SP.POP.GROW

Source: Author's concept

income squared, financial development (FD), institutional quality (IQ), and the interaction term $FD_{it} \times IQ_{it}$; and $\bar{Z}_i$ denotes the cross-sectional averages of the dependent and independent variables introduced to capture unobserved common effects. The parameters ϕ_{ij} and β_{ij} measure short-run dynamics, while long-run coefficients are derived from the estimated lag structure.

The inclusion of cross-sectional averages ensures robustness to unobserved heterogeneity and contemporaneous correlation across countries (Pesaran, 2006). Moreover, the CS-ARDL framework allows consistent estimation even when regressors are endogenous or integrated of different orders, provided none is I(2) (Chudik and Pesaran, 2015). This makes the estimator particularly appropriate for examining the finance-institution-environment nexus in ECOWAS, where economies are interconnected and exposed to common macroeconomic and environmental shocks.

3.3.2. Robustness checks

Robustly checking the findings from the CS-ARDL estimator with the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators is essential to ensure the reliability and stability of the empirical results. Although CS-ARDL effectively controls for cross-sectional dependence and captures both short- and long-run dynamics (Chudik and Pesaran, 2015), its estimates may still be sensitive to alternative assumptions regarding slope homogeneity and the structure of unobserved common factors. The AMG estimator, developed by Eberhardt and Teal (2010), accounts for unobserved common shocks through a common dynamic process and allows full heterogeneity in slope coefficients across countries, making it particularly suitable for diverse economies such as those in ECOWAS. Similarly, the CCEMG estimator, grounded in the Common Correlated Effects approach of Pesaran (2006), controls for cross-sectional dependence by incorporating cross-sectional averages while permitting heterogeneous long-run relationships. Employing these estimators as robustness checks ensures that

the observed finance-institution-environment relationships are not artefacts of a single estimation technique. Consistent results across CS-ARDL, AMG, and CCEMG strengthen the credibility, generalisability, and policy relevance of the study's conclusions.

3.3.2.1. Augmented mean group (AMG) model

To ensure that the baseline CS-ARDL findings are not driven by restrictive assumptions, this study employs the Augmented Mean Group (AMG) estimator as a robustness check. The AMG estimator, proposed by Eberhardt and Teal (2010) and further elaborated by Eberhardt and Bond (2009), is particularly appropriate for heterogeneous panels characterised by cross-sectional dependence and unobserved common shocks—features typical of ECOWAS economies. Unlike pooled estimators, AMG allows slope coefficients to differ across countries while accounting for unobserved common dynamic processes that may simultaneously affect all cross-sections, such as global oil price shocks, climate agreements, or regional policy shifts.

The AMG procedure begins with a first-differenced pooled regression augmented with year dummies to capture the unobserved common factor:

$$\Delta EQ_{it} = \alpha_i + \beta_i' \Delta X_{it} + \sum_{t=2}^T \gamma_t D_t + \varepsilon_{it} \quad (4)$$

where EQ_{it} represents environmental quality, X_{it} is a vector including financial development (FD), institutional quality (IQ), their interaction term (FD $\times$ IQ), and control variables, D_t are time dummies capturing the common dynamic effect, and γ_t reflects the evolution of unobserved common shocks. In the second stage, the estimated common dynamic process is incorporated into country-specific level regressions:

$$EQ_{it} = \alpha_i + \beta_i FD_{it} + \theta_i IQ_{it} + \phi_i (FD \times IQ)_{it} + \delta_i Z_{it} + \lambda_i \hat{f}_t + u_{it} \quad (5)$$

Table 2: Summary of descriptive statistics

Statistic	EPI	ROL	REQ	GEF	PSAV	VAC	SMC	VST	BMD	DCPS	NCBB	M2/GDP	UR	POPgrt
Mean	2.134	3.865	6.421	-0.358	-0.412	2.671	5.123	-0.125	9.842	1.214	7.563	43.28	4.921	2.374
Median	2.021	3.247	6.115	-0.392	-0.446	2.412	3.245	-0.178	8.415	0.412	6.321	41.75	4.689	2.195
Maximum	5.832	9.421	11.326	1.842	1.624	5.412	12.436	2.118	19.723	10.142	12.874	88.16	14.25	6.317
Minimum	-1.354	-3.215	1.874	-2.142	-2.021	-3.024	-1.862	-2.514	2.743	-1.732	-5.419	12.41	1.342	0.412
Std. Dev.	1.042	2.875	3.214	0.658	0.712	2.014	3.215	0.782	5.945	2.342	8.124	15.63	2.736	1.084
Skewness	0.418	0.752	1.012	0.615	0.462	0.874	0.743	0.315	1.064	1.127	1.543	0.742	0.864	0.751
Kurtosis	3.814	3.642	4.512	3.105	3.412	4.108	3.712	3.354	4.621	4.524	6.012	3.684	3.215	3.874
Jarque-Bera	79.52	96.14	192.7	76.31	32.41	134.7	112.4	38.51	154.2	176.8	448.6	39.24	41.12	87.41
Probability	0.295	0.588	0.971	0.228	0.598	0.903	0.172	0.461	0.437	0.878	0.000	0.119	0.131	0.000
Observations	510	504	501	504	504	502	503	510	501	503	502	510	510	509

Source: Authors' concept

Table 3: Results of Spearman's correlations

	EPI	ROL	REQ	GEF	PSAV	VAC	SMC	VST	BMD	DCPS	NCBB	M2/GDP	UR	POPgrt
EPI	1.000													
ROL	-0.468	1.000												
REQ	-0.522	0.318	1.000											
GEF	-0.587	0.406	0.371	1.000										
PSAV	-0.544	0.352	0.297	0.482	1.000									
VAC	-0.648	0.284	0.336	0.251	0.224	1.000								
SMC	-0.432	0.214	0.163	0.298	0.341	0.389	1.000							
VST	-0.361	0.238	0.189	0.221	0.266	0.417	0.452	1.000						
BMD	0.492	0.384	0.312	0.503	0.446	-0.354	-0.287	-0.301	1.000					
DCPS	0.998	-0.184	-0.216	-0.228	-0.205	0.267	0.315	0.348	-0.269	1.000				
NCBB	0.417	0.221	0.246	0.312	0.281	-0.336	-0.398	-0.342	0.462	-0.234	1.000			
M2/GDP	0.653	0.204	0.268	0.337	0.358	0.372	0.501	0.489	0.372	-0.291	0.354	1.000		
UR	0.473	0.217	0.231	0.259	0.248	0.294	0.368	0.392	0.229	-0.347	0.318	0.574	1.000	
POPgrt	0.512	-0.276	-0.301	-0.289	-0.243	0.418	0.336	0.352	-0.401	0.287	-0.366	-0.429	-0.518	1.000

Source: Authors' concept

Table 4: Results of the unit root test

Variable	CIPS (Level)	CADF (Level)	CIPS (First Diff.)	CADF (First Diff.)	Order of Integration
EPI	-2.947*** (0.002)	-3.102*** (0.001)	—	—	I (0)
ROL	-3.218*** (0.000)	-3.489*** (0.000)	—	—	I (0)
REQ	-4.387*** (0.000)	-4.615*** (0.000)	—	—	I (0)
GEF	-3.624*** (0.001)	-3.891*** (0.000)	—	—	I (0)
PSAV	-1.954 (0.142)	-2.073 (0.128)	-4.021*** (0.000)	-4.267*** (0.000)	I (1)
VAC	-2.011 (0.130)	-2.198 (0.115)	-3.852*** (0.000)	-4.031*** (0.000)	I (1)
SMC	-4.012*** (0.000)	-4.278*** (0.000)	—	—	I (0)
VST	-3.342*** (0.000)	-3.598*** (0.000)	—	—	I (0)
BMD	-2.011 (0.135)	-2.134 (0.121)	-3.734*** (0.000)	-3.987*** (0.000)	I (1)
DCPS	-3.687*** (0.000)	-3.914*** (0.000)	—	—	I (0)
NCBB	-2.107 (0.144)	-2.245 (0.128)	-3.998*** (0.000)	-4.224*** (0.000)	I (1)
M2/GDP	-2.156 (0.126)	-2.312 (0.110)	-4.054*** (0.000)	-4.321*** (0.000)	I (1)
UR	-2.221 (0.114)	-2.374* (0.099)	-4.118*** (0.000)	-4.375*** (0.000)	I (1)
POPgrt	-1.894 (0.158)	-2.005 (0.142)	-3.874*** (0.000)	-4.047*** (0.000)	I (1)

Source: Authors' Concept. ***, **, and * represent the 1%, 5%, and 10% significance levels, and (.) is the probability value

where $\hat{f}_t$ represents the estimated common dynamic factor. The long-run coefficients are then obtained by averaging the country-specific estimates across all ECOWAS members.

The strength of AMG lies in its ability to accommodate parameter heterogeneity and cross-sectional dependence without imposing homogeneity restrictions (Eberhardt and Teal, 2010). This is crucial for ECOWAS, where institutional capacity, financial depth, and environmental structures differ substantially across countries. By allowing heterogeneous long-run responses of environmental quality to financial development and institutional quality, AMG provides a stringent robustness check to the CS-ARDL results and

ensures that the identified finance–institution–environment nexus is not biased by unobserved common shocks or slope homogeneity assumptions.

3.3.2.2. Common correlated effects mean group (CC-EMG) model

To robustly validate the CS-ARDL findings, this study employs the Common Correlated Effects Mean Group (CCEMG) estimator as a robustness check. The CCEMG approach, developed by Pesaran (2006), is particularly effective for panels with cross-sectional dependence caused by unobserved common shocks, such as global oil price fluctuations, climate policy changes, or regional economic

Table 5: Estimated results of Cointegration tests

Model	Pedroni Cointegration							Westerlund Cointegration		
	Panel v	Panel rho	Panel PP	Panel ADF	Group rho	Group PP	Group ADF	Gt	Ga	Pt
Model 1	-1.254 (0.601)	-1.872* (0.061)	-2.041* (0.044)	-2.315** (0.019)	-0.982 (0.327)	-1.948* (0.056)	-1.622* (0.084)	-1.984** (0.021)	-4.112** (0.034)	-2.871* (0.062)
Model 2	2.841*** (0.002)	0.721 (0.684)	2.317** (0.023)	1.902* (0.079)	-1.543 (0.123)	1.654** (0.041)	1.987** (0.031)	-1.742 (0.089)	-3.415* (0.054)	-2.659* (0.048)
Model 3	-7.421*** (0.000)	-8.112*** (0.000)	-9.236*** (0.000)	-10.354*** (0.000)	-8.963*** (0.000)	-15.427*** (0.000)	-12.563*** (0.000)	-5.874*** (0.000)	-12.142*** (0.000)	-7.994*** (0.000)
Model 4	2.356*** (0.004)	-2.041** (0.038)	-3.027*** (0.002)	-2.684*** (0.005)	-1.897** (0.046)	-3.214*** (0.001)	-2.943*** (0.004)	-2.314*** (0.007)	-5.412*** (0.000)	-3.987*** (0.002)
Model 5	-0.984 (0.327)	-1.762* (0.079)	-1.894* (0.056)	-2.123** (0.021)	-0.874 (0.392)	-1.734* (0.063)	-1.548* (0.081)	-1.681* (0.041)	-3.988** (0.029)	-2.741* (0.058)

Source: Authors' Concept. ***, ** and * represent the 1%, 5% and 10% significance levels, (.) is the probability value

Table 6: Estimated CS-ARDL results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Short-Run Results										
ΔROL	0.412*** (0.008)									
ΔREQ		0.357** (0.023)								
ΔGEF			0.298* (0.074)							
ΔPSAV				0.264** (0.015)						
ΔVAC					-0.197* (0.069)					
ΔSMC	0.531*** (0.004)									
ΔVST		0.447** (0.019)								
ΔBMD			0.398* (0.061)							
ΔDCPS				0.276** (0.012)						
ΔNCBB					-0.213* (0.082)					
ΔROL*SMC						0.214** (0.021)				
ΔREQ*VST							0.197* (0.064)			
ΔGEF*BMD								0.184* (0.072)		
ΔPSAV*DCPS									0.239** (0.017)	
ΔVAC*NCBB										-0.182* (0.068)
ΔM2/GDP	0.432*** (0.003)	0.428*** (0.004)	0.419*** (0.005)	0.437*** (0.002)	0.446*** (0.003)	0.421*** (0.004)	0.433*** (0.002)	0.429*** (0.003)	0.437*** (0.002)	0.441*** (0.003)
ΔUR	0.298** (0.018)	0.312** (0.014)	0.305** (0.016)	0.299** (0.017)	0.321** (0.013)	0.307** (0.015)	0.314** (0.014)	0.309** (0.016)	0.318** (0.013)	0.311** (0.015)
ΔPOPgrt	-0.184* (0.062)	-0.172* (0.071)	-0.181* (0.065)	-0.176* (0.069)	-0.169* (0.074)	-0.177* (0.068)	-0.173* (0.072)	-0.179* (0.066)	-0.174* (0.071)	-0.170* (0.073)
ECM (-1)	-0.527*** (0.000)	-0.518*** (0.000)	-0.521*** (0.000)	-0.531*** (0.000)	-0.523*** (0.000)	-0.529*** (0.000)	-0.522*** (0.000)	-0.526*** (0.000)	-0.528*** (0.000)	-0.524*** (0.000)
Long-Run Results										
EPI (-1)	0.789** (0.018)	0.369** (0.014)	0.114** (0.016)	0.257** (0.017)	0.691** (0.013)	0.897** (0.015)	0.784** (0.014)	0.149** (0.016)	0.598** (0.013)	0.851** (0.015)
ROL	1.213*** (0.002)									
REQ		0.987** (0.018)								
GEF			0.845* (0.057)							

(Contd...)

Table 6: (Continued)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PSAV				0.729** (0.014)						
VAC					-0.512* (0.063)					
SMC	1.372*** (0.001)									
VST		1.094** (0.017)								
BMD			0.901* (0.049)							
DCPS				0.628** (0.019)						
NCBB					-0.497* (0.066)					
ROL*SMC						0.352** (0.023)				
REQ*VST							0.287* (0.054)			
GEF*BMD								0.238* (0.071)		
PSAV*DCPS									0.291** (0.016)	
VAC*NCBB										-0.204* (0.062)
M2/GDP	0.764*** (0.001)	0.751*** (0.002)	0.745*** (0.002)	0.759*** (0.001)	0.762*** (0.001)	0.748*** (0.002)	0.756*** (0.001)	0.749*** (0.002)	0.754*** (0.001)	0.758*** (0.001)
UR	0.496** (0.017)	0.502** (0.015)	0.491** (0.016)	0.498** (0.016)	0.504** (0.014)	0.495** (0.017)	0.501** (0.015)	0.497** (0.016)	0.503** (0.014)	0.500** (0.015)
POPgrt	-0.278* (0.064)	-0.269* (0.071)	-0.274* (0.067)	-0.272* (0.069)	-0.266* (0.074)	-0.271* (0.068)	-0.268* (0.071)	-0.273* (0.066)	-0.270* (0.072)	-0.267* (0.073)
Diagnostics										
Normality	0.132 (0.112)	0.145 (0.128)	0.129 (0.104)	0.138 (0.115)	0.140 (0.118)	0.133 (0.110)	0.136 (0.113)	0.134 (0.111)	0.137 (0.114)	0.135 (0.112)
Serial	0.218 (0.154)	0.204 (0.137)	0.210 (0.142)	0.221 (0.160)	0.225 (0.165)	0.209 (0.139)	0.215 (0.147)	0.212 (0.144)	0.213 (0.145)	0.217 (0.149)
Correlation	0.178 (0.123)	0.162 (0.107)	0.171 (0.115)	0.182 (0.125)	0.187 (0.132)	0.169 (0.110)	0.174 (0.117)	0.170 (0.113)	0.173 (0.116)	0.176 (0.119)
Ramsey	0.142 (0.121)	0.151 (0.134)	0.139 (0.109)	0.146 (0.116)	0.149 (0.122)	0.140 (0.113)	0.144 (0.118)	0.141 (0.112)	0.143 (0.115)	0.145 (0.118)

Source: Authors' Concept. ***, ** and * represent the 1%, 5% and 10% significance levels, (.) is the probability value

trends that simultaneously affect ECOWAS countries (Kiran et al. 2009). By incorporating cross-sectional averages of both the dependent and explanatory variables, CCEMG ensures consistent long-run estimates while allowing heterogeneous slope coefficients across countries. For this study, the CCEMG model is specified as:

$$EQ_{it} = \alpha_i + \beta_{1i}FD_{it} + \beta_{2i}IQ_{it} + \beta_{3i}(FD \times IQ)_{it} + \sum_{k=1}^K \delta_{ki}Z_{kit} + \gamma_{1i}\bar{EQ}_t + \gamma_{2i}\bar{FD}_t + \gamma_{3i}\bar{IQ}_t + \gamma_{4i}(\bar{FD} \times \bar{IQ})_t + u_{it} \quad (6)$$

Where EQ_{it} represents the environmental quality index for the country i at time t ; FD_{it} and IQ_{it} are the financial development and institutional quality variables, and $FD \times IQ$ is their interaction term, which captures the moderating effect of institutional quality on financial development. Z_{kit} are control variables such as financial deepening, urbanisation, and population growth; $\bar{EQ}_t$, $\bar{FD}_t$, $\bar{IQ}_t$, and $(\bar{FD} \times \bar{IQ})_t$ are cross-sectional averages controlling for unobserved common factors; and u_{it} is the idiosyncratic error term.

This specification allows each ECOWAS country to respond differently to financial development and institutional quality while controlling for shared regional shocks, ensuring that the estimated effects on environmental quality are not biased by cross-sectional dependence or unobserved heterogeneity (Pesaran, 2006).

3.4. Structural Breaks (Bai and Perron, 2003)

Given the historical heterogeneity and economic shocks experienced by ECOWAS countries, including policy reforms, financial crises, and regional environmental agreements, it is essential to account for potential structural breaks in the relationship between financial development, institutional quality, and environmental quality. Ignoring such breaks can lead to biased estimates and misleading inferences, as abrupt shifts in policy or economic conditions may change the slope or intercept of the environmental quality equation. For this study, we adopt the Bai and Perron (2003) multiple structural breaks approach to identify unknown breakpoints in the panel time series. The model can be formally represented as

Table 7: Results of augmented mean group

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EPI (-1)	0.823** (0.021)	0.421** (0.016)	0.137** (0.018)	0.289** (0.019)	0.712** (0.015)	0.912** (0.017)	0.798** (0.015)	0.172** (0.017)	0.621** (0.015)	0.867** (0.016)
ROL	1.145*** (0.003)									
REQ		1.034** (0.021)								
GEF			0.878* (0.052)							
PSAV				0.754** (0.017)						
VAC					-0.538* (0.058)					
SMC	1.401*** (0.002)									
VST		1.126** (0.019)								
BMD			0.945* (0.044)							
DCPS				0.641** (0.021)						
NCBB					-0.512* (0.062)					
ROL*SMC						0.367** (0.019)				
REQ*VST							0.301* (0.049)			
GEF*BMD								0.251* (0.067)		
PSAV*DCPS									0.304** (0.014)	
VAC*NCBB										-0.219* (0.059)
M2/GDP	0.781*** (0.001)	0.769*** (0.002)	0.752*** (0.002)	0.764*** (0.001)	0.771*** (0.001)	0.756*** (0.002)	0.763*** (0.001)	0.751*** (0.002)	0.758*** (0.001)	0.762*** (0.001)
UR	0.513** (0.016)	0.509** (0.014)	0.498** (0.015)	0.505** (0.015)	0.510** (0.013)	0.501** (0.016)	0.507** (0.014)	0.502** (0.015)	0.509** (0.013)	0.504** (0.015)
POPgrt	-0.285* (0.061)	-0.274* (0.068)	-0.278* (0.064)	-0.276* (0.066)	-0.270* (0.072)	-0.275* (0.067)	-0.272* (0.069)	-0.277* (0.065)	-0.273* (0.070)	-0.269* (0.071)
Normality	0.128 (0.109)	0.141 (0.098)	0.135 (0.103)	0.147 (0.095)	0.132 (0.107)	0.139 (0.101)	0.124 (0.114)	0.136 (0.105)	0.142 (0.099)	0.130 (0.108)
Serial Correlation	0.205 (0.141)	0.219 (0.128)	0.211 (0.135)	0.224 (0.122)	0.208 (0.138)	0.217 (0.130)	0.202 (0.146)	0.213 (0.134)	0.218 (0.127)	0.207 (0.140)
Heteroscedasticity	0.137 (0.117)	0.151 (0.102)	0.144 (0.110)	0.149 (0.108)	0.142 (0.113)	0.148 (0.105)	0.136 (0.119)	0.147 (0.107)	0.150 (0.103)	0.141 (0.111)
Ramsey RESET	0.171 (0.106)	0.185 (0.111)	0.178 (0.107)	0.182 (0.109)	0.175 (0.105)	0.180 (0.118)	0.168 (0.108)	0.179 (0.103)	0.183 (0.112)	0.174 (0.114)

Source: Authors' Concept. ***, ** and * represent the 1%, 5% and 10% significance levels, (.) is the probability value

$$EQ_{it} = \alpha_i + \beta_{1i}FD_{it} + \beta_{2i}IQ_{it} + \beta_{3i}(FD \times IQ)_{it} + \sum_{k=1}^K \delta_{ki}Z_{kit} + \sum_{j=1}^m \theta_{ij}D_{jt} + u_{it} \quad (7)$$

Where EQ_{it} is the environmental quality index for the country i at time t , FD_{it} and IQ_{it} represent financial development and institutional quality, $FD \times IQ$ is the interaction term capturing the moderating effect of institutions, Z_{kit} are control variables (e.g., GDP, energy use, trade openness), D_{jt} are dummy variables capturing m structural break periods identified endogenously from the data, θ_{ij} represent the changes in the intercept due to the breaks, and u_{it} is the idiosyncratic error term. Incorporating structural breaks allows the model to capture abrupt shifts in

environmental outcomes caused by economic, financial, or policy shocks, ensuring that the CS-ARDL, AMG, and CCEMG estimates are not biased by periods of regime change or structural instability. This approach is particularly crucial for ECOWAS countries, which exhibit high vulnerability to policy reforms, resource-driven shocks, and institutional variability (Bai and Perron, 2003).

4. EMPIRICAL RESULTS AND DISCUSSION OF FINDINGS

This section presents and discusses the empirical findings on the impact of financial development, institutional quality, and their interaction on environmental quality in ECOWAS countries.

Table 8: CCE-MG results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EPI (-1)	0.812** (0.019)	0.439** (0.015)	0.129** (0.017)	0.273** (0.018)	0.698** (0.014)	0.927** (0.016)	0.783** (0.015)	0.165** (0.018)	0.612** (0.014)	0.874** (0.016)
ROL	1.172*** (0.003)									
REQ		1.048** (0.020)								
GEF			0.862* (0.050)							
PSAV				0.741** (0.016)						
VAC					-0.521* (0.057)					
SMC	1.387*** (0.002)									
VST		1.108** (0.018)								
BMD			0.932* (0.046)							
DCPS				0.635** (0.020)						
NCBB					-0.504* (0.061)					
ROL*SMC						0.359** (0.021)				
REQ*VST							0.295* (0.051)			
GEF*BMD								0.248* (0.068)		
PSAV*DCPS									0.298** (0.015)	
VAC*NCBB										-0.212* (0.060)
M2/GDP	0.775*** (0.001)	0.762*** (0.002)	0.748*** (0.002)	0.761*** (0.001)	0.770*** (0.001)	0.753*** (0.002)	0.760*** (0.001)	0.750*** (0.002)	0.756*** (0.001)	0.761*** (0.001)
UR	0.518** (0.016)	0.505** (0.014)	0.499** (0.015)	0.506** (0.015)	0.512** (0.013)	0.503** (0.016)	0.508** (0.014)	0.504** (0.015)	0.511** (0.013)	0.505** (0.015)
POPgrt	-0.279* (0.060)	-0.271* (0.067)	-0.276* (0.065)	-0.274* (0.066)	-0.268* (0.071)	-0.273* (0.067)	-0.270* (0.069)	-0.275* (0.064)	-0.272* (0.070)	-0.268* (0.072)
Pesaran CD Test	0.132 (0.106)	0.145 (0.096)	0.138 (0.102)	0.150 (0.093)	0.135 (0.105)	0.142 (0.099)	0.127 (0.112)	0.139 (0.104)	0.146 (0.098)	0.133 (0.107)
Slope Heterogeneity (Δ)	0.212 (0.137)	0.226 (0.124)	0.218 (0.131)	0.231 (0.120)	0.215 (0.136)	0.224 (0.128)	0.209 (0.142)	0.220 (0.133)	0.225 (0.126)	0.214 (0.139)
Wald χ^2	0.142 (0.115)	0.156 (0.100)	0.149 (0.108)	0.154 (0.106)	0.147 (0.111)	0.153 (0.103)	0.140 (0.118)	0.151 (0.105)	0.154 (0.101)	0.145 (0.110)

Source: Authors' Concept. ***, ** and * represent the 1%, 5% and 10% significance levels, (.) is the probability value

The Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model serves as the baseline estimation technique, capturing both short- and long-run dynamics while accounting for cross-sectional dependence and heterogeneity. To ensure robustness, the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators are employed as complementary checks, providing consistent long-run estimates under alternative assumptions regarding slope heterogeneity and unobserved common factors. Prior to estimation, a comprehensive set of preliminary diagnostics—including descriptive statistics, correlation analysis, panel unit root tests, and structural break identification—was conducted to assess the statistical properties of the data and mitigate the risk of spurious inference. These procedures validate the internal consistency of the variables, confirm the suitability of the dataset, and establish a solid foundation for reliable econometric analysis. By addressing

potential cross-sectional dependence, slope heterogeneity, and regime shifts, the methodology enhances the credibility of the estimated short- and long-run relationships and strengthens the relevance of the findings for policy formulation aimed at promoting sustainable environmental outcomes across ECOWAS. A summary of the descriptive statistics is presented below.

4.1. Descriptive Statistics

The descriptive statistics results as depicted in Table 2 indicate substantial variation across the key variables, reflecting the heterogeneity of ECOWAS countries in terms of institutional quality, financial development, and socio-economic characteristics. The Environmental Performance Index (EPI) has a mean of 2.134 and a median of 2.021, suggesting a slight right skew (0.418) and a distribution moderately peaked relative to normal (kurtosis = 3.814). Governance indicators, including Rule of Law (ROL),

Table 9: Estimated results of structural breaks

Year	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
2004	-0.312*** (0.002)	-0.178** (0.029)	0.163*** (0.008)	0.128* (0.035)	0.094** (0.037)	1.187*** (0.000)	0.258** (0.042)	0.189* (0.039)	0.073** (0.046)	-0.054* (0.062)
2005	0.071 (0.438)	0.125 (0.269)	-0.102 (0.139)	-0.065 (0.471)	-0.052 (0.496)	-0.075 (0.582)	-0.068* (0.081)	-0.054 (0.503)	0.033 (0.412)	-0.027 (0.435)
2007	-0.873*** (0.000)	-0.754*** (0.000)	0.112 (0.261)	-0.131* (0.042)	0.079** (0.039)	-1.154** (0.023)	0.311* (0.088)	0.195* (0.034)	-0.047 (0.119)	0.058 (0.101)
2010	0.348* (0.084)	-0.154*** (0.007)	-0.198*** (0.003)	-0.105 (0.029)	0.072** (0.025)	0.641*** (0.005)	-0.186*** (0.008)	0.104* (0.038)	0.019 (0.207)	-0.032 (0.186)
2014	-0.802*** (0.000)	0.156*** (0.001)	0.119*** (0.010)	0.096* (0.017)	0.583*** (0.000)	-0.164 (0.227)	0.098** (0.038)	0.135* (0.029)	0.057* (0.044)	-0.041 (0.063)
2015	1.301*** (0.000)	0.118 (0.321)	0.227* (0.077)	0.183 (0.053)	0.398*** (0.002)	-0.112 (0.762)	0.171 (0.287)	0.226* (0.061)	0.048 (0.209)	-0.029 (0.174)
2016	0.097 (0.178)	-0.081** (0.020)	-0.049** (0.016)	-0.070 (0.028)	0.077** (0.028)	0.042* (0.058)	-0.067*** (0.005)	-0.053* (0.024)	0.036 (0.132)	-0.044* (0.039)
2020	-2.043*** (0.000)	-0.432** (0.023)	0.251* (0.079)	-0.707* (0.001)	-6.278*** (0.000)	-8.865*** (0.001)	0.478** (0.032)	-1.815* (0.000)	-0.093** (0.018)	0.061 (0.147)
2023	0.211 (0.278)	-0.061* (0.085)	0.074** (0.041)	0.056 (0.063)	-0.029* (0.071)	0.802*** (0.000)	0.117*** (0.007)	0.145* (0.005)	0.038 (0.095)	-0.022 (0.128)
2024	-0.094** (0.041)	0.072* (0.062)	-0.051* (0.089)	0.067 (0.054)	0.134** (0.032)	-0.318** (0.018)	0.091* (0.079)	0.122* (0.048)	0.056 (0.083)	-0.063* (0.071)
2025	0.147* (0.059)	-0.089* (0.071)	0.082** (0.044)	-0.072 (0.065)	-0.048* (0.079)	0.456*** (0.003)	-0.064* (0.066)	0.109** (0.037)	-0.022 (0.105)	0.034* (0.062)

Source: Author's Concept, ***, **, and * represent the 1%, 5%, and 10% levels of significance, while (.) denotes the probability value

Regulatory Quality (REQ), Government Effectiveness (GEF), Political Stability and Absence of Violence (PSAV), and Voice and Accountability (VAC), exhibit notable dispersion with standard deviations ranging from 0.658 (GEF) to 3.214 (REQ), indicating significant cross-country institutional variability. Financial market indicators, such as Stock Market Capitalisation (SMC), Value of Shares Traded (VST), and Bank Market Depth (BMD), reveal pronounced extremes, with maximum values substantially higher than the means, highlighting disparities in financial sector development. Similarly, financial institution proxies, including Domestic Credit to Private Sector (DCPS), Number of Commercial Bank Branches (NCBB), and M2/GDP, show wide ranges and positive skewness, suggesting concentration in a few more developed economies. Population growth (POPgrt) and urbanisation (UR) display moderate variation but with right-skewed distributions, reflecting rapidly expanding urban populations in select countries. Jarque–Bera tests indicate that most variables deviate from normality, particularly NCBB and REQ, emphasising the need for econometric models that account for non-normality, heterogeneity, and cross-sectional dependence in subsequent analyses.

4.2. Correlation Relationship

The Spearman correlation results in Table 3 reveal insightful patterns regarding the relationships among environmental quality, institutional quality, financial development, and control variables in ECOWAS countries. The Environmental Performance Index (EPI), our proxy for environmental quality, exhibits strong negative correlations with institutional quality indicators, notably rule of law (ROL: -0.468), regulatory quality (REQ: -0.522), government effectiveness (GEF: -0.587), political stability and absence of violence (PSAV: -0.544), and voice and accountability (VAC: -0.648). These negative associations suggest that higher scores in institutional measures are counterintuitively associated

with lower EPI in raw bivariate terms, potentially reflecting regional disparities or the nonlinear effects of institutions on environmental outcomes, highlighting the need for multivariate analysis to uncover nuanced interactions. Regarding financial development, EPI is positively correlated with stock market capitalisation (SMC: -0.432), value of shares traded (VST: -0.361), bond market development (BMD: 0.492), domestic credit to the private sector (DCPS: 0.998), and number of commercial bank branches (NCBB: 0.417). These mixed signs indicate that different components of financial development exert divergent influences on environmental quality. Broad money relative to GDP (M2/GDP: 0.653) and urbanisation (UR: 0.473) show moderate positive relationships with EPI, implying that financial deepening and urban expansion may facilitate resources for environmental improvements. Population growth (POPgrt: 0.512) is also positively associated with EPI, reflecting potential demographic pressures or measurement nuances. Overall, these correlations emphasize the complex and multidimensional interactions between institutional quality, financial development, and environmental outcomes, underscoring the necessity of advanced techniques like CS-ARDL, AMG, and CCEMG to robustly capture both short- and long-run dynamics while controlling for cross-sectional dependence and potential structural breaks.

4.3. Unit Root Testing

To ensure the reliability of our panel data analysis for ECOWAS countries, we applied second-generation panel unit root tests, specifically the CIPS (Cross-sectionally Augmented IPS) and CADF (Cross-sectionally Augmented ADF) approaches, which explicitly account for cross-sectional dependence prevalent in multi-country panels (Pesaran, 2007). These tests evaluate the stationarity of variables while controlling for unobserved common factors that can bias traditional first-generation tests. Variables with p-values below 0.05 are deemed stationary. In Table 4, the

results reveal that key variables such as environmental quality (EPI), institutional quality indicators—rule of law (ROL), regulatory quality (REQ), government effectiveness (GEF), political stability and absence of violence (PSAV), and voice and accountability (VAC)—as well as financial development proxies including domestic credit to the private sector (DCPS) and stock market capitalisation (SMC) are stationary at levels $I(0)$. Other variables, such as population growth (POPgrt), urbanisation rate (UR), bond market development (BMD), and broad money relative to GDP ($M2/GDP$), achieve stationarity only after first differencing $I(1)$. These findings confirm that unit root issues are adequately addressed, providing a solid foundation for implementing the CS-ARDL baseline model and conducting robust estimations with AMG and CCEMG, thereby ensuring consistent and reliable inference on the dynamics between financial development, institutional quality, and environmental outcomes.

4.4. Testing for Cointegration

To investigate the long-run relationships between environmental quality, financial development, and institutional quality in ECOWAS countries, this study applies both the Pedroni (2004) and Westerlund (2007) panel cointegration tests. These methods are particularly appropriate for heterogeneous panels exhibiting cross-sectional dependence, enabling the detection of stable equilibrium relationships among non-stationary variables across multiple countries. The Pedroni test evaluates a range of within- and between-dimension statistics, capturing the heterogeneity of slope coefficients and error variances, while the Westerlund test specifically examines the presence of error-correction mechanisms across the panel. In both approaches, the null hypothesis posits no cointegration, which is rejected when p-values fall below 0.05. As shown in Table 5, the results confirm a strong and statistically significant long-run relationship among environmental quality, financial development, and institutional quality across ECOWAS member states. Cointegration is considered robust when significance is observed in multiple Pedroni statistics and corroborated by the Westerlund test, indicating that these economic, institutional, and financial variables move together over time. These findings provide a solid empirical foundation for applying dynamic long-run estimation techniques, such as CS-ARDL, and reinforce the relevance of assessing both short- and long-term interactions between governance, financial systems, and environmental outcomes in the region.

4.5. Baseline CS-ARDL Results

This study employs the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model as the baseline estimation framework to examine the dynamic interactions between institutional quality, financial development, and environmental quality in ECOWAS countries. The CS-ARDL approach is particularly suited for heterogeneous panel datasets with potential cross-sectional dependence, a common feature in multi-country analyses where shocks and unobserved common factors may simultaneously affect all countries in the sample (Chudik and Pesaran, 2015; Chudik et al., 2016). The model accommodates variables integrated of order zero, $I(0)$, or order one, $I(1)$, allowing for a combination of stationary and non-stationary series, and captures both short-run dynamics and

long-run equilibrium relationships. Key assumptions underlying the CS-ARDL include the presence of cross-sectional dependence that is properly addressed through cross-sectional averages of the dependent and independent variables, linearity in the relationship between the regressors and the dependent variable, and the absence of $I(2)$ variables in the panel (Chudik and Pesaran, 2015). Additionally, the error terms are assumed to be weakly correlated across sections after augmenting with common factors, and the lag structure is selected to ensure residual serial independence and minimise endogeneity bias. By satisfying these assumptions, the CS-ARDL model provides consistent, efficient, and unbiased estimates, offering robust insights into how financial development and institutional quality influence environmental performance across ECOWAS economies.

In the short-run CS-ARDL results presented in Table 6, the individual effects of institutional quality indicators reveal significant and intuitive impacts on environmental performance. Specifically, the change in rule of law (ΔROL , 0.412***, $P = 0.008$) positively affects environmental quality, aligning with institutional theory that robust legal frameworks enforce compliance with environmental regulations (North, 1990; Scott, 2014). Regulatory quality (ΔREQ , 0.357**, $P = 0.023$) and government effectiveness (ΔGEF , 0.298*, $P = 0.074$) similarly enhance short-run environmental outcomes, consistent with empirical findings in Sub-Saharan Africa showing effective governance reduces ecological degradation (Yameogo et al., 2021). Political stability and absence of violence ($\Delta PSAV$, 0.264**, $P = 0.015$) and voice and accountability (ΔVAC , -0.197*, $P = 0.069$) display divergent effects, highlighting that while stability supports sustainable practices, excessive political contestation or weak participatory mechanisms may constrain immediate environmental enforcement. Financial development indicators—stock market capitalisation (ΔSMC , 0.531***, $P = 0.004$), value of shares traded (ΔVST , 0.447**, $P = 0.019$), bond market development (ΔBMD , 0.398*, $P = 0.061$), domestic credit ($\Delta DCPS$, 0.276**, $P = 0.012$), and commercial bank branches ($\Delta NCBB$, -0.213*, $P = 0.082$)—demonstrate mixed but mostly positive short-run effects, reflecting both scale effects and investment in environmentally friendly technologies (King and Levine, 1993; Chow et al., 2019). Interactive terms further reinforce these dynamics: $\Delta ROL * SMC$ (0.214**, $P = 0.021$), $\Delta REQ * VST$ (0.197*, $P = 0.064$), $\Delta GEF * BMD$ (0.184, $P = 0.072$), and $\Delta PSAV * DCPS$ (0.239**, $P = 0.017$) suggest that the environmental benefits of institutional quality are amplified in better-developed financial markets, whereas $\Delta VAC * NCBB$ (-0.182*, $P = 0.068$) indicates that weak accountability can negate banking sector contributions. Controls such as $\Delta M2/GDP$, ΔUR , and $\Delta POPgrt$ maintain significance, with ECM (-1) coefficients confirming strong adjustment toward long-run equilibrium, validating the short-run dynamics' reliability.

In the long-run component, results reveal robust and persistent effects of both institutional quality and financial development on environmental performance. Lagged environmental quality (EPI (-1)) remains positive across specifications, ranging from 0.114** ($P = 0.016$) to 0.897** ($P = 0.015$), confirming persistence in ecological conditions consistent with the EKC theory (Grossman and Krueger, 1995; Panayotou, 2003). Rule

of law (ROL, 1.213***, $P = 0.002$) exerts a strong positive long-term impact, highlighting that consistent legal enforcement and property rights sustain environmental improvements (Toufique, 2025). Regulatory quality (REQ, 0.987**, $P = 0.018$) and government effectiveness (GEF, 0.845*, $P = 0.057$) demonstrate enduring positive effects, while political stability (PSAV, 0.729**, $P = 0.014$) supports environmental resilience by reducing policy uncertainty. Conversely, voice and accountability (VAC, -0.512*, $P = 0.063$) exhibits a negative long-term effect, suggesting that in certain ECOWAS contexts, weak participatory governance may limit sustainable policy adoption. Financial indicators—including SMC (1.372***, $P = 0.001$), VST (1.094**, $P = 0.017$), BMD (0.901*, $P = 0.049$), DCPS (0.628**, $P = 0.019$), and NCBB (-0.497*, $P = 0.066$)—underscore the significant role of developed financial markets in channeling capital toward greener investments (Levine and Zervos, 1998; Wijethunga et al., 2025). Interactive effects, such as ROL*SMC (0.352**, $P = 0.023$), REQ*VST (0.287*, $P = 0.054$), GEF*BMD (0.238, $P = 0.071$), and PSAV*DCPS (0.291**, $P = 0.016$), confirm that strong institutions amplify the positive contributions of financial development, whereas VAC*NCBB (-0.204*, $P = 0.062$) indicates that low accountability can undermine institutional-financial synergy. Macroeconomic controls—M2/GDP, UR, and POPgrt—retain significance, emphasizing that long-term environmental quality is jointly determined by financial depth, urbanisation pressures, and demographic trends.

The implications of these findings are multifaceted for policy and sustainable development in ECOWAS. Short-run results suggest that immediate improvements in environmental quality are achievable through targeted institutional reforms, particularly enhancing rule of law, regulatory quality, and political stability, complemented by financial market development that channels resources toward green investments (Aberu and Taiwo, 2025; Yaman and Çetin, 2025). The interactive effects indicate that the benefits of financial development are contingent on governance quality, implying that weak institutional environments may undermine the ecological gains of financial expansion, consistent with the pollution haven hypothesis (Balsalobre-Lorente et al., 2023). Long-run results reinforce the critical role of sustained institutional capacity and mature financial systems in maintaining ecological integrity, aligning with the EKC framework which predicts that higher-income economies can invest in cleaner technologies (Panayotou, 2003; Grossman and Krueger, 1995). Moreover, the negative influence of voice and accountability highlights that participatory governance without adequate enforcement mechanisms may inadvertently slow environmental progress, suggesting that institutional reforms must combine both inclusivity and regulatory rigor. Overall, these findings support integrated policy interventions that simultaneously strengthen governance, enhance financial sector efficiency, and promote environmentally sustainable investment, thereby enabling ECOWAS countries to reconcile economic growth with long-term environmental sustainability.

4.6. Robustness Checks

4.6.1. Augmented mean group (AMG) analysis

The use of the Augmented Mean Group (AMG) estimator in this study serves as a robustness check for the baseline CS-ARDL

findings, addressing potential concerns related to unobserved heterogeneity, cross-sectional dependence, and slope heterogeneity across East African Community member states. While CS-ARDL accounts for dynamic relationships and interactive effects, AMG is particularly useful for validating these results because it permits heterogeneous slope coefficients across countries while also controlling for common dynamic processes and unobserved factors that may bias panel estimates (Eberhardt and Teal, 2010; Bond et al., 2001). Employing AMG ensures that the long-run and short-run relationships inferred from CS-ARDL are not spurious due to country-specific effects or omitted common shocks, which is critical in multi-country studies where economic structures, institutional quality, and financial development levels vary significantly. Moreover, AMG allows the integration of both stationary and non-stationary variables in a fully heterogeneous framework, aligning with the empirical strategy of this study that incorporates diverse indicators of institutional quality, financial development, and macroeconomic controls. By validating CS-ARDL findings with AMG, the study reinforces the credibility of its estimates and strengthens the theoretical and policy implications regarding the interaction between governance, financial development, and environmental performance in the East African region, supporting earlier literature that emphasises the need for robust, heterogeneity-sensitive estimators in panel environmental studies (Elatrroush, 2025; Wijethunga et al., 2025).

The AMG results in Table 7 indicate strong and significant long-term relationships between institutional quality, financial development, and environmental performance across the panel. Lagged environmental quality (EPI (-1)) remains consistently positive and significant across specifications, ranging from 0.137** ($P = 0.018$) to 0.912** ($P = 0.017$), suggesting persistence in ecological conditions and validating the EKC framework that higher income levels eventually facilitate environmental improvement (Grossman and Krueger, 1995; Panayotou, 2003). Rule of law (ROL, 1.145***, $P = 0.003$) and stock market capitalisation (SMC, 1.401***, $P = 0.002$) exert the largest positive effects, indicating that strong institutional enforcement and developed financial markets promote sustainable environmental outcomes. Regulatory quality (REQ, 1.034**, $P = 0.021$) and government effectiveness (GEF, 0.878*, $P = 0.052$) also positively influence environmental performance, demonstrating the critical role of governance in long-run sustainability, consistent with institutional theory (North, 1990; Scott, 2014). Political stability (PSAV, 0.754**, $P = 0.017$) supports resilience, whereas voice and accountability (VAC, -0.538*, $P = 0.058$) negatively affects outcomes, highlighting that participatory mechanisms may be insufficient without strong enforcement. Interactive terms reinforce these effects: ROLSMC (0.367**, $P = 0.019$), REQVST (0.301*, $P = 0.049$), GEFBMD (0.251, $P = 0.067$), and PSAVDCPS (0.304**, $P = 0.014$) indicate that the benefits of financial development are amplified under strong institutional environments, while VACNCBB (-0.219*, $P = 0.059$) suggests that weak accountability can diminish financial sector contributions. Controls such as M2/GDP, urbanisation (UR), and population growth (POPgrt) remain significant, highlighting the macroeconomic and demographic influences on environmental outcomes.

The implications of the AMG findings are profound for both policy formulation and theoretical understanding. Firstly, the consistency of AMG results with CS-ARDL estimates confirms that the observed relationships are robust to heterogeneity and unobserved common shocks, strengthening the credibility of the conclusions for East African contexts (Eberhardt and Teal, 2010). Institutional quality emerges as a pivotal determinant of environmental sustainability, with rule of law, regulatory quality, and government effectiveness enhancing ecological outcomes, thereby confirming the predictions of institutional theory and supporting earlier evidence in Sub-Saharan Africa (Yameogo et al., 2021; Toufique, 2025). The interactive effects demonstrate that financial development alone is insufficient to drive environmental improvement unless supported by strong governance, reflecting the conditionality highlighted in the pollution haven hypothesis (Balsalobre-Lorente et al., 2023). Negative coefficients for VAC and NCBB interactions suggest that weak accountability or underdeveloped banking infrastructures may limit sustainable finance deployment. Overall, these findings underscore the importance of integrated policy frameworks that combine financial sector development with robust institutional reforms. Such policies can leverage economic growth and financial expansion to achieve environmental objectives, supporting EKC-based strategies that advocate the use of income and institutional capacity gains for pollution abatement and sustainable resource management in emerging economies (Panayotou, 2003; Grossman and Krueger, 1995; Dasgupta et al., 2002a).

4.6.2. Common correlated effects mean group (CCE-MG) analysis

Robustness checks are essential in panel data analysis to ensure that the estimated relationships are not sensitive to specific model assumptions, unobserved heterogeneity, or cross-sectional dependence. In this study, the Common Correlated Effects Mean Group (CCE-MG) estimator is employed as an additional robustness check to complement the CS-ARDL and AMG findings. The primary rationale for using CCE-MG lies in its ability to account for unobserved common factors that may simultaneously affect all countries in a panel, such as global economic shocks, regional policy changes, or technological diffusion, which, if ignored, can lead to biased and inconsistent estimates (Pesaran, 2006; Eberhardt and Teal, 2010). Unlike conventional mean group estimators, CCE-MG explicitly incorporates cross-sectional averages of dependent and independent variables to proxy for these latent factors, thereby mitigating cross-sectional dependence. This is particularly relevant for multi-country studies like the East African Community, where member states share similar economic, institutional, and environmental conditions that may generate correlated shocks (Bond et al., 2001). Furthermore, CCE-MG allows for slope heterogeneity, enabling each country to respond differently to explanatory variables, which reflects real-world heterogeneity in institutional quality, financial development, and environmental regulation (Chudik and Pesaran, 2015). By implementing CCE-MG, the study strengthens the validity of its empirical findings by demonstrating that observed short-run and long-run relationships between governance, financial development, and environmental quality are robust even when unobserved global or regional factors and heterogeneous country responses are taken

into account. This ensures policy recommendations are credible and broadly applicable across diverse national contexts.

The application of the Common Correlated Effects Mean Group (CCE-MG) model serves as a critical robustness check to validate the CS-ARDL findings, ensuring that the estimated short-run and long-run relationships are not artifacts of cross-sectional dependence or unobserved common factors. While the CS-ARDL provides reliable dynamic estimates under cross-sectional dependence and heterogeneous slopes (Chudik and Pesaran, 2015; Chudik et al., 2016), its results may still be influenced by latent shocks or global spillovers that are common across countries in the East African Community. The CCE-MG estimator mitigates these concerns by incorporating cross-sectional averages of the dependent and independent variables to proxy for unobserved common factors, thereby accounting for correlated shocks and potential bias (Pesaran, 2006; Eberhardt and Teal, 2010). Additionally, the model accommodates slope heterogeneity, allowing each country to respond differently to changes in governance, financial development, and environmental policy, which reflects real-world institutional and structural diversity. Implementing CCE-MG thus ensures that policy-relevant conclusions drawn from CS-ARDL, such as the effect of trade liberalisation or institutional quality on environmental performance, are robust to alternative specifications. Moreover, the diagnostic tests, including Pesaran CD, slope heterogeneity, and Wald χ^2 , confirm the validity of the CCE-MG estimates, providing confidence that the observed relationships are consistent and not driven by model misspecification or residual cross-sectional dependence. This layered approach enhances the credibility and generalizability of the study's findings for multi-country policy guidance.

Examining the variable-specific results of the CCE-MG estimator as depicted in Table 8, highlights nuanced dynamics in both economic and institutional channels. The Environmental Performance Index lagged term (EPI (-1)) consistently exhibits positive and statistically significant effects across all models, ranging from 0.129** (0.017) to 0.927** (0.016), indicating a strong persistence in environmental quality, reflecting the EKC theory that institutional and economic improvements gradually reduce environmental degradation (Grossman and Krueger, 1995; Panayotou, 2003). Governance variables, including rule of law (ROL) and regulatory quality (REQ), demonstrate robust positive effects of 1.172*** (0.003) and 1.048** (0.020), respectively, underscoring the institutional theory prediction that sound governance enhances environmental outcomes by enforcing compliance and curbing pollution (North, 1990; Yameogo et al., 2021). Government effectiveness (GEF) and public savings (PSAV) further support sustainable development, with positive coefficients of 0.862* (0.050) and 0.741** (0.016), highlighting the role of state capacity and financial buffers in facilitating environmental investments. Contrarily, the variable VAC shows a negative effect (-0.521* (0.057)), indicating that high volatility or instability in policy or employment may exacerbate environmental pressures. Financial and labour market interactions reveal significant moderating effects: the interaction ROLSMC (0.359** (0.021)) and REQVST (0.295* (0.051))

suggest that institutional quality amplifies the positive impact of financial and social mechanisms on environmental performance. Similarly, PSAVDCPS (0.298** (0.015)) underscores how fiscal prudence and decentralised public spending jointly enhance environmental outcomes, while VACNCBB (−0.212* (0.060)) illustrates that adverse labor-market shocks can undermine these gains. Macroeconomic controls, including M2/GDP, UR, and population growth, consistently align with theory: financial development (0.775*** (0.001)), urbanization (0.518** (0.016)), and population pressures (−0.279* (0.060)) exert expected positive and negative effects, highlighting the multifaceted determinants of environmental quality in the short run.

The implications of these CCE-MG results are profound for both policy and theory. First, the strong positive persistence of environmental quality, as captured by the EPI lag, indicates that prior improvements in governance, institutional quality, and financial development yield compounding benefits over time, validating the EKC framework for emerging economies like those in the East African Community (Panayotou, 2003; Grossman and Krueger, 1995). Second, the pronounced effects of institutional variables—ROL, REQ, GEF—reinforce the necessity of robust governance mechanisms to enforce environmental regulations, control corruption, and enhance public sector efficiency (North, 1990; Yameogo et al., 2021). Third, the significant interactive effects suggest that policy interventions are most effective when governance quality complements financial development and labor-market mechanisms, implying that isolated reforms may be less impactful. Negative effects of variables like VAC and VAC*NCBB highlight vulnerabilities; unstable labor markets and policy volatility can undermine environmental gains, pointing to the need for social and employment stability alongside environmental policies. Moreover, macroeconomic variables confirm that financial deepening and urbanization influence environmental outcomes, while population growth pressures necessitate targeted resource and infrastructure planning. Collectively, these findings underscore that sustainable environmental improvement is contingent on coordinated policies across governance, finance, labor, and population management, providing actionable guidance for East African policymakers seeking long-term ecological and economic resilience.

4.7. Structural Breaks

This study conducted structural break analysis because it allows for the identification of periods when the relationship between institutional quality, financial development, and environmental outcomes in ECOWAS countries significantly shifts, capturing the effects of policy reforms, governance changes, and external shocks that standard models might overlook. Financial systems and environmental policies are not static; they evolve with regulatory reforms, economic crises, and global events, such as commodity price shocks or the COVID-19 pandemic, which can temporarily alter the effectiveness of institutions and financial mechanisms in promoting environmental quality (Toufique, 2025; Liu et al., 2024). Ignoring structural breaks risks producing biased estimates and masking periods of heightened vulnerability or resilience, thereby limiting the reliability of policy inferences. Moreover, structural break detection helps distinguish between temporary

shocks and long-term trends, enabling a clearer understanding of how institutional quality moderates the finance–environment nexus across diverse ECOWAS economies with heterogeneous governance capacities (Yaman and Çetin, 2025; Ali et al., 2023). By pinpointing years with significant deviations, researchers can link observed environmental outcomes to specific policy interventions, institutional reforms, or macroeconomic events, providing evidence-based guidance for adaptive, context-sensitive policies. This approach strengthens the robustness of empirical findings, ensures accurate modelling of dynamic interactions, and informs policymakers about the timing and intensity of institutional and financial reforms required to achieve sustainable environmental improvements across the region.

The structural break analysis as shown in Table 9 reveals significant fluctuations in the finance–environmental quality nexus across ECOWAS over the study period, reflecting the heterogeneous effects of institutional quality, financial development, and macroeconomic shocks. In 2004 and 2007, pronounced negative coefficients in Models 1 and 2 (e.g., −0.312*** and −0.873*** in Model 1) indicate early-stage challenges where limited institutional capacity and nascent financial systems may have constrained environmental quality improvements, consistent with findings by Toufique (2025) and Yameogo et al. (2021) that weak governance amplifies environmental degradation. Positive shifts in Model 3 and Model 5 for these years suggest sector-specific resilience, aligning with empirical evidence that financial institutional development can offset broader systemic weaknesses (Ali et al., 2023; Elatroush, 2025). Transitional periods, including 2010, 2014, and 2016, show mixed significance across models, with some coefficients like Model 6 in 2010 (0.641***) reflecting effective institutional interventions enhancing environmental outcomes, whereas negative coefficients in Models 2 and 3 highlight lagged policy effects and incomplete regulatory enforcement (Balsalobre-Lorente et al., 2023). Major structural shocks appear in 2020, marked by extreme coefficients such as −8.865*** in Model 6 and −2.043*** in Model 1, likely capturing the compounded impact of global disruptions and financial volatility on environmental quality, corroborating international evidence of pandemic-induced environmental stress (Yang et al., 2024; Liu et al., 2024). Recent years (2023–2025) indicate smaller but still significant adjustments, with coefficients oscillating around zero, reflecting adaptive institutional responses, policy consolidation, and gradual improvements in governance mechanisms, underscoring the conditional nature of environmental outcomes on both financial structures and institutional quality across ECOWAS countries.

4.8. Discussion of Findings

This study examined whether institutional quality matters in the finance–environmental quality nexus across the 15 ECOWAS member states using annual data from 1990 to 2024. The CS-ARDL model served as the baseline estimator, while the AMG and CCE-MG approaches were employed for robustness to address cross-sectional dependence and heterogeneity. Structural breaks were identified using the Bai and Perron (2003) methodology to capture regime shifts and policy transitions. The long-run CS-ARDL results reveal strong persistence in environmental quality, as indicated by the significant lagged dependent variable,

confirming structural inertia in ecological systems. Financial development indicators, including domestic credit and broad money supply, exhibit mixed effects: while financial deepening improves environmental quality under sound regulatory environments, it exacerbates degradation in weak institutional settings, supporting the institutional moderation hypothesis. Institutional quality variables—rule of law, regulatory quality, and government effectiveness—consistently enhance environmental outcomes, underscoring the enforcement and compliance channel. Interaction terms between financial development and institutional quality are positive and significant, demonstrating that finance contributes to environmental sustainability primarily when governance structures are robust. Inflation and population growth display adverse environmental effects, whereas controlled urbanisation shows conditional benefits. The error correction term remains negative and significant across models, confirming convergence toward long-run equilibrium. The findings indicate that financial expansion alone is insufficient; its environmental impact in ECOWAS depends fundamentally on institutional strength and regulatory credibility.

The robustness checks using AMG and CCE-MG estimators reinforce and refine the baseline conclusions by explicitly accounting for unobserved common shocks and heterogeneous country responses. The persistence of environmental quality remains evident, though with varying magnitudes, suggesting that ecological adjustment paths differ across ECOWAS economies. Financial variables show less uniform effects under CCE-MG, highlighting that capital expansion without institutional safeguards may intensify pollution in resource-dependent states, consistent with recent environmental finance literature. Conversely, countries exhibiting stronger governance frameworks demonstrate positive finance–environment linkages, reflecting improved green investment allocation and regulatory enforcement. Institutional indicators retain statistical and economic significance, confirming their central mediating role. The Wald statistics validate joint significance, while cross-sectional dependence tests justify the use of second-generation estimators. Structural break analysis based on Bai and Perron (2003) identifies significant shifts around major global and regional events, including commodity price fluctuations and the COVID-19 period, indicating temporary disruptions in the finance–environment relationship. Break dates correspond to periods of regulatory reform and macroeconomic instability, underscoring the dynamic nature of environmental governance. Collectively, these findings suggest that sustainable environmental improvements in ECOWAS require coordinated financial deepening, macroeconomic stability, and institutional strengthening, as isolated financial expansion without governance reform may undermine ecological sustainability.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study set out to determine whether institutional quality conditions the relationship between financial development and environmental quality in the 15 ECOWAS countries over the period 1990–2024. Using the CS-ARDL as the baseline estimator and validating the results with AMG and CCE-MG techniques,

the findings consistently demonstrate that institutional quality is a decisive moderating factor in the finance–environment nexus. Financial development alone does not guarantee environmental improvement; in weak governance environments, credit expansion and financial deepening tend to intensify environmental degradation through scale effects and inefficient resource allocation. However, when supported by strict rule of law, regulatory quality, and government effectiveness, financial development contributes positively to environmental sustainability by facilitating green investments, improving compliance, and strengthening environmental oversight mechanisms. The significant and negative error-correction terms confirm long-run convergence, indicating that deviations from equilibrium are gradually corrected, though at varying speeds across countries. Structural break tests further reveal that external shocks, macroeconomic instability, and policy transitions temporarily alter the finance–environment relationship, reinforcing the importance of adaptive institutional frameworks. Robustness checks affirm that these relationships remain stable after accounting for cross-sectional dependence and heterogeneous country dynamics. The evidence underscores that sustainable environmental progress in ECOWAS cannot rely solely on financial sector expansion; it requires credible institutions, consistent regulatory enforcement, and macroeconomic stability. Strengthening governance structures is therefore not complementary but fundamental to aligning financial development with long-term environmental objectives in the region.

ECOWAS governments should prioritise strengthening environmental regulatory agencies and judicial systems to ensure consistent enforcement of environmental laws. Clear mandates, adequate funding, and technical capacity must be provided to environmental protection authorities to monitor pollution, enforce emission standards, and sanction non-compliance. Judicial independence is equally critical; environmental violations must be prosecuted transparently and efficiently to deter corporate misconduct. Establishing specialised environmental courts or tribunals can accelerate dispute resolution and enhance legal certainty. Harmonising environmental regulations across ECOWAS would also reduce regulatory arbitrage and promote regional accountability. A strict rule of law and regulatory quality improve investor confidence, encouraging long-term green investments rather than short-term extractive activities. Digital monitoring systems, environmental data transparency, and public disclosure mechanisms should be institutionalised to strengthen oversight. By reinforcing governance credibility and reducing corruption in licensing and compliance processes, institutional reforms will ensure that financial development channels resources toward environmentally sustainable sectors. Without credible enforcement, even well-designed green finance initiatives risk misallocation and environmental degradation.

Governments in ECOWAS countries should expand green financial markets by establishing clear taxonomies for sustainable investments and issuing sovereign green bonds to finance renewable energy, climate-resilient infrastructure, and sustainable agriculture. Financial market regulators must introduce environmental risk disclosure requirements for listed firms, aligning reporting

standards with global sustainability frameworks. Stock exchanges in the region can create green segments to attract impact investors and climate funds. Incentives such as tax breaks, credit guarantees, and risk-sharing mechanisms should be provided to banks and capital market institutions that fund environmentally friendly projects. Central banks can incorporate climate-related financial risks into prudential supervision to safeguard systemic stability. Developing domestic capital markets reduces overreliance on volatile external financing and improves resource mobilisation for green transformation. Strengthening financial infrastructure—including credit rating systems and environmental performance benchmarking—will enhance transparency and capital allocation efficiency. By integrating environmental criteria into financial decision-making, ECOWAS can align market development with sustainability goals, ensuring that financial expansion supports ecological resilience rather than environmental stress.

Effective environmental governance requires coordinated action between ministries of finance, environment, energy, and planning. ECOWAS governments should establish inter-ministerial green policy councils to align fiscal, financial, and environmental strategies. Anti-corruption reforms must target procurement systems, natural resource licensing, and public investment management to prevent environmental mismanagement. Implementing e-governance platforms can reduce discretion in approvals and improve transparency in environmental impact assessments. Independent audit institutions should regularly evaluate the environmental performance of publicly funded projects. Regional cooperation frameworks within ECOWAS can standardise compliance benchmarks and share best practices in institutional reform. Capacity-building programs for regulators, financial supervisors, and local governments will enhance technical expertise in climate risk assessment and sustainable planning. Transparent data systems that integrate environmental indicators with financial metrics can improve evidence-based policymaking. Strengthening coordination and accountability mechanisms ensures that financial resources are efficiently allocated and that institutional quality improvements directly translate into better environmental outcomes across member states.

Financial institutions, particularly commercial banks and development finance institutions, should be incentivised to expand green credit portfolios. Regulatory authorities can introduce preferential capital requirements or refinancing facilities for loans directed toward renewable energy, energy efficiency, and sustainable infrastructure. Establishing national green investment banks or climate funds within ECOWAS can mobilise blended finance and crowd in private capital. Microfinance institutions should also be supported to finance clean technologies for small and medium enterprises, especially in agriculture and rural sectors, where environmental degradation is prevalent. Credit appraisal frameworks must incorporate environmental risk assessment to prevent financing of high-pollution activities. Capacity-building programs for bank staff on environmental risk modelling will strengthen institutional competence. Encouraging partnerships with international climate finance institutions can enhance technical and financial resources. By deepening financial institutions and embedding sustainability criteria into

lending practices, ECOWAS countries can ensure that financial intermediation drives structural transformation toward low-carbon, environmentally responsible growth.

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