GLOBALIZATION, FINANCIAL DEVELOPMENT, AND ENVIRONMENTAL DEGRADATION: EVIDENCE FROM WEST AFRICAN COUNTRIES USING ECOLOGICAL FOOTPRINT

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1. Introduction

Over the last five decades, the rising global warming and climate change have become a global challenge for governments because of their deleterious consequences on various aspects of human health and economic development. Environmental degradation is recognized as one of the causes of climate change. It is caused by an increase in the exploitation of natural resources in the production and consumption of goods and services. It is widely acknowledged that our current economic development model is leading to the significant depletion of natural resources and forest reserves, and Sub-Saharan Africa (SSA) is no exception. African countries heavily depend on a broad range of natural resources for their development. For instance, according to a World Forest, Society and Environment (WFSE) report,

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approximately 20% of the income for landless and poor households is derived from forests, and 85% of the wood removed from forests and woodlands is used as fuel by African households.[1] Today, the region faces serious environmental challenges, including soil erosion, desertification, deforestation, and air and water pollution. Forests, which play a crucial role in environmental protection by storing carbon dioxide, are unfortunately disappearing at an alarming rate due to urbanization and the lack of enforcement of environmental protection standards. Simultaneously, both rural and urban areas are contributing significant amounts of pollutants to the atmosphere.

Kifle (2008) argues that African countries are particularly vulnerable to the impacts of global warming, as they rely heavily on climate-sensitive sectors such as forestry, agriculture, water resources, non-renewable energy, fisheries, and tourism for their survival and economic development.[2] Recent models further highlight the severe effects of climate change on African economies, estimating losses of between 5% and 15% of gross domestic product (GDP) per capita due to climate change and extreme weather events.[3] *The African Economic Outlook 2022* report projects that losses and damages from climate change will range between $289.2 billion and $440.5 billion from 2022 to 2030.[4] If African countries continue with their current climate policies, they could lose up to 64% of their GDP by 2100 due to climate change.

Globally, the over-extraction and depletion of natural resources, combined with the emission of waste and pollutants, exceed the biosphere's capacity to cope, exacerbating climate conditions. Numerous scientific studies have documented the negative impacts of climate change on various aspects of economic development (e.g., Araújo and Rahbek 2006; Schlenker and Lobell 2010; Calzadilla et al. 2013; Lalthapersad-Pillay and Udjo 2014; and Du et al. 2017).[5]

These environmental concerns have drawn global attention from policymakers, who are increasingly focused on mitigating the impact of human activities on the environment. Protecting the planet has become a widely accepted priority. The establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, followed by the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1997, demonstrates a collective commitment to addressing climate change. These pioneering agreements have paved the way for significant international progress, with developed and developing countries alike committing to the 2030 Agenda for Sustainable Development, adopted in September 2015, the Paris Agreement on Climate Change (COP15) in December 2015, and more recently, the Sharm El-Sheikh Climate Change Conference (COP27) in November 2022. Meeting these commitments will require substantial financial resources to transform the current economic development model and promote environmentally sustainable practices. According to the African Economic Outlook 2022, African countries will need between $1.3 trillion and $1.6 trillion over the period 2020-2030 to adequately address climate change.[6]

However, the report highlights a significant shortfall in climate finance, with an annual funding gap of $99.9 to $127.2 billion, which could hinder Africa's efforts to build climate resilience. In light of this challenge, African nations must seek new funding sources or implement more efficient measures to mitigate environmental issues. These actions should be guided by strong evidence from empirical research, with a focus on factors that significantly impact environmental quality.

The quest to identify the factors driving environmental degradation has led to an expanding body of research. One prominent line of inquiry explores the relationship between economic growth and environmental pollution, with a particular focus on the Environmental Kuznets Curve (EKC). The EKC suggests that economic growth initially results in environmental degradation in the early stages of development, but as countries grow wealthier, environmental quality tends to improve. Another area of research examines the environmental impact of variables such as energy consumption, trade, population growth, and urbanization. More recently, attention has turned to the roles of financial development and globalization in influencing environmental degradation. Financial development can impact environmental quality by funding environmentally friendly activities, but it can also support resource-intensive industries that generate significant pollution and waste.[7] Globalization, which refers to the growing interconnectedness of economies through the removal of cross-border barriers, facilitates technology transfer, trade, capital flows, and the spread of information. When globalization is accompanied by advanced technology through foreign direct investment and imports of cleaner equipment, it can benefit the environment by reducing ecological footprints and pollution. However, globalization can also harm environmental quality in developing countries with lax environmental regulations.[8] In this context, it is hypothesized that African countries may be particularly vulnerable to the negative environmental impacts of globalization due to their weak institutional frameworks and low environmental standards.

The evidence regarding the environmental impacts of financial development and globalization is conflicting. Some studies have found that financial development enhances environmental quality (e.g., Adjei et al. 2022 and Qudrat-Ullah and Nevo 2022),[9] while others have reported its harmful effects (e.g., Acheampong 2019; Ehigiamusoe and Lean 2019; Ganda 2021; and Usman et al. 2022).[10] A similar pattern emerges in the literature on globalization. While many studies suggest that globalization benefits the environment (e.g., Amuakwa-Mensah and Adom 2017; Erdogan et al. 2021; Aladejare 2022; and Usman et al. 2022),[11] other research highlights its negative environmental impacts (e.g., Bataka 2021; Yameogo 2021; and Talpur et al. 2022).[12] These conflicting findings can be attributed to variations in study periods, the proxies used for financial development, globalization, and environmental quality, as well as the estimation techniques employed.

Despite the extensive empirical literature on this topic, very few studies have specifically analyzed the environmental effects of financial development and globalization in the context of Sub-Saharan Africa (SSA), highlighting the need for more research in this area. Furthermore, most existing studies rely on carbon dioxide emissions as the primary indicator of environmental degradation. While carbon emissions are a major contributor to environmental damage, this metric overlooks other crucial aspects such as water, forest, and land degradation. As a result, using carbon emissions alone may provide incomplete insights into the impact of economic growth, financial development, and globalization on the environment.

In light of this, the current study seeks to examine the evidence from West African countries using the ecological footprint as a more comprehensive measure of environmental sustainability. The ecological footprint captures the use of various ecological resources in production and consumption processes. The selected countries are open, dynamic economies that have undergone financial reforms and rapid globalization through trade and foreign direct investment to accelerate their economic development. At the same time, they face numerous adverse effects of climate change, including rising temperatures, droughts, unstable precipitation patterns, desertification, biodiversity loss, forest fires, tropical diseases, food insecurity, and flooding. Therefore, addressing environmental degradation is crucial for the economic sustainability of African countries.

The main objective of this research is to investigate the role of financial development and globalization in shaping the ecological footprint of eight West African countries from 1990 to 2018, based on available data. Specifically, the study seeks to answer the following questions: Do financial development and globalization significantly impact the ecological footprint of West African countries? Are these effects homogeneous across different countries? Can globalization help improve environmental quality in West African nations? By answering these questions, the study will assess the extent to which financial sector development and globalization contribute to environmental sustainability in SSA countries.

From an econometric perspective, many existing studies have employed standard panel estimation techniques, which come with certain limitations. First, these methods often assume slope homogeneity across countries, an assumption that is unlikely to hold due to differences in institutional and economic structures among nations. Second, they frequently overlook the issue of cross-sectional dependence, where events in one country may influence others. Ignoring cross-sectional dependence can undermine the reliability of empirical results.

This study addresses these shortcomings by employing second-generation panel estimation techniques that account for both cross-sectional dependence and heterogeneity. Specifically, we use the Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) estimators to analyze the relationship between financial development, globalization, and ecological footprint. Additionally, the variables were tested for unit root and cointegration in the presence of cross-sectional dependence and heterogeneous slopes. By addressing these econometric issues, the study aims to provide unbiased, efficient, and consistent estimates of the slope coefficients in the estimated models. The findings from this research will contribute to the ongoing debate on the determinants of environmental quality in SSA. The policy recommendations derived from this study are expected to assist the selected countries in improving their environmental quality.

The remainder of this study is structured as follows: Section 2 provides a review of the existing literature on the environmental effects of financial development and globalization. Section 3 introduces the data and the econometric methodology used in the analysis. Section 4 discusses the findings. Finally, Section 5 concludes the study and offers policy recommendations based on the empirical results.

2. *Literature Review*

Numerous studies have scrutinized the causes of environmental degradation using different methodologies and indicators. Most of them focused on the economic growth and carbon emissions nexus with the view of testing the famous Environmental Kuznets Curve (EKC). Shahbaz and Sinha (2019) and Naveed et al. (2022) provide a recent systematic literature review of academic research on the EKC.[13] In addition to energy consumption and economic growth, researchers have tested the role of other determinants such as globalization and financial development.

According to Rennen and Martens (2003), globalization is a phenomenon that links economies, and that spreads cultural, social, and political values.[14] From this definition, we see that globalization is a multidimensional concept that can affect various socio-economic aspects of economic development. Globalization can affect the environment through three channels, namely, scale effect, technique effect, and composition effect.[15] The scale effect occurs when globalization enhances economic growth through trade and foreign direct investment. The expansion of economic growth increases the consumption of natural resources, thus escalating environmental degradation.[16] The technique effect is associated with the transfer of environmentally friendly technology from home countries to host countries.[17] Increased access to new technology enables domestic firms to improve their production processes, which, in turn, will mitigate environmental degradation. Concerning the composition effect, it results in the production of more natural resource-intensive goods, thus causing environmental degradation. However, globalization can change the mix of production from natural resource-intensive activities to environmental-friendly ones, thus improving the quality of the environment.[18] The net effect of globalization on the environment will depend on which of these three effects dominates.

With respect to the development of the financial sector, it may affect the environment through several channels. On the one hand, financial development facilitates the access to credit, which may increase investment in new projects as well as boost consumption of new items. This will stimulate the demand for energy and ecological resources thereby worsening the quality of the environment.[19] On the other hand, by efficiently channeling savings towards investments that promote clean and efficient technology, financial development may help mitigate the negative consequences of economic growth on the environment.[20]

On the empirical front, a growing literature has scrutinized the effects of financial development and globalization on the environmental quality using both times series and panel data analysis techniques. No conclusive findings have been reached in this regard as the literature documented both favorable and detrimental effects associated with financial development and globalization. There are studies that have failed to find any significant effect of financial development and globalization on the environment. For instance, Shahbaz et al. (2013) investigate the effects of financial development, economic growth, coal consumption, and trade openness on CO_2 emissions in South Africa over the period 1965–2008.[21] The application of the ARDL bounds testing approach to cointegration reveals that economic growth and coal consumption aggravate environmental degradation, whereas financial development and trade openness improve it. Al-Mulali et al. (2015) probe the effect of financial development on carbon emissions in 129 countries for the period 1980-2011, controlling for economic growth, urbanization, trade openness, and energy consumption.[22] The DOLS results show financial development improving environmental quality. Farhani and Ozturk (2015) examine the connection between CO_2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization for Tunisia during the period of 1971–2012.[23] The results from the ARDL approach reveal economic growth and financial development contributing to environmental pollution. M. Shahbaz et al. (2015) examine the effect of globalization on CO_2 emissions in India over the period 1970-2012, including energy use, financial development, and economic growth as control variables.[24] Employing the ARDL approach, they find that globalization, energy consumption, financial development and economic growth deteriorate the environmental quality by raising carbon emissions. Dogan and Seker (2016a) investigate the impacts of real income, energy consumption, financial development, and trade openness on CO_2 emissions for the OECD countries using second-generation panel econometric approaches that consider issues of heterogeneity and cross-sectional dependence.[25] The results find that energy consumption contributes to increased carbon emissions whereas openness and financial development mitigate them. In another article by E. Dogan and F. Seker (2016b) the authors gauge the response of CO_2 emissions to income, renewable energy consumption, non-renewable energy consumption, trade openness, and financial development for the top renewable energy countries.[26] They employ heterogeneous panel estimation techniques that allow for cross-section dependence. The results from the FMOLS and the DOLS reveal that renewable energy consumption, trade openness, and financial development contribute to lower carbon emissions while non-renewable energy consumption increase air pollution. M. Shahbaz et al. (2016) examine the impact of globalization on carbon emissions in 19 African countries for the period of 1971–2012.[27] The study relies on the ARDL approach and the study finds that globalization mitigates carbon emissions at the panel level, and in eight countries (i.e., Angola, Cameroon, Congo Republic, Egypt, Kenya, Libya, Tunisia, and Zambia) but increases carbon emissions in five countries (i.e., Ghana, Morocco, South Africa, Sudan, and Tanzania). Amuakwa-Mensah and Adom (2017) analyze the impacts of institutions and globalization (trade and FDI) on the environment for a panel of 43 Sub-Saharan African countries during the period 1990-2011.[28] They apply the panel two-step system GMM method to deal with the simultaneity problem. The results find that both FDI and trade liberalization generate positive environmental outcomes in the region. Shahbaz et al. (2017) report evidence of globalization negatively impacting CO_2 emissions both in the short and long run in China.[29] Solarin et al. (2017) investigate the determinants of CO_2 emissions in Ghana for the period of 1980–2012, by means of the ARDL approach.[30] They find that economic growth, foreign direct investment, urban population, financial development, and trade contribute to increases in CO_2 emissions. Twerefou et al. (2017) scrutinize the impact of economic growth and globalization on CO_2 emissions for 36 Sub-Saharan African countries over the period 1990-2013.[31] Employing the system GMM technique, they find globalization worsening environmental degradation by increasing carbon emissions. Uddin et al. (2017) test the effects of real income, financial development, and trade openness on the ecological footprint of 27 leading emitting countries during the period 1991–2012.[32] Results from DOLS indicate that real income increases the ecological footprint while trade openness and financial development reduce it. Haseeb et al. (2018) assess the impact of energy consumption, financial development, globalization, economic growth, and urbanization on CO_2 emissions for BRICS economies.[33] Results from the Dynamic Seemingly Unrelated Regression (DSUR) show that energy consumption and financial development increase CO_2 emissions whereas the effect of globalization and urbanization is negative but insignificant.

Acheampong (2019) analyzes the effect of financial development on carbon emissions for 46 Sub-Saharan Africa countries over the period 2000–2015 utilizing the system-GMM.[34] The results find that financial development worsens the environmental quality by increasing carbon emission levels. Additionally, financial development mitigates the negative effects of GDP and energy consumption on the environment. The results do not confirm the EKC hypothesis. The findings demonstrate heterogeneity across regional and income groups. In a follow up article, Acheampong et al. (2019) examine the impact of globalization measured in terms of foreign direct investment and trade openness, and renewable energy on carbon emissions in 46 Sub-Saharan African countries over the period 1980–2015.[35] Using fixed and random effect estimation methods, they report that renewable energy and foreign direct investment contribute to the mitigation of carbon emissions whereas trade openness deteriorates the environment. Additionally, population growth and financial development also lead to increased carbon emissions in the region. Ahmed et al. (2019) investigate the impact of globalization on the ecological footprint in Malaysia from 1971 to 2014.[36] The results from the ARDL modelling reveal that globalization does not significantly affect the ecological footprint, but it does significantly increase the ecological carbon footprint. Baloch et al. (2019) test the impact of financial development on the ecological footprint in a panel of 59 belt and road countries during the period 1990-2016.[37] The findings suggest that financial development worsens environmental degradation by increasing the ecological footprint. Further, economic growth, energy consumption, foreign direct investment (FDI), and urbanization were found to contribute to the degradation of the environment. Ehigiamusoe and Lean (2019) analyze the experience of 122 countries within the time span of 1990–2014.[38] Second-generation cointegration and estimation methods were employed to address heterogeneity, endogeneity, and cross-sectional dependence. The results show that energy consumption, economic growth, and financial development have detrimental effects on carbon emissions in the full panel. When the panel is split into different income groups, economic growth and financial development decrease carbon emissions in the high-income group but increase them in the low-income and middle-income groups. Phong (2019) studies the case of selected ASEAN-5 countries (i.e., Myanmar, Malaysia, Philippines, Singapore, and Thailand) over the 1971-2014 period by utilizing the fixed and random effects regression models.[39] The results show that financial development, energy consumption, urbanization, and globalization increase CO_2 emissions. Moreover, the findings favor the EKC hypothesis. Salahuddin et al. (2019a) employ second-generation panel regression techniques to examine the impacts of globalization on CO_2 emissions for a panel of 44 SSA countries over the period 1984–2016.[40] The results unveil that globalization has no significant effect on carbon emission levels. Salahuddin et al. (2019b) set out to investigate the effects of globalization on CO_2 emissions for South Africa over the period 1980–2017.[41] The results from the ARDL technique reveal that globalization triggers CO_2 emissions in South Africa in the long run. Wang et al. (2019) assess the impact of globalization and financial development on carbon dioxide for OECD countries from 1990 to 2015, using the Pool Mean Group (PMG) method.[42] The results show that both human development and financial development improve environmental quality in the long run, while globalization, energy consumption, and economic growth increase carbon dioxide emissions. Zafar et al. (2019) study the effects of globalization and financial development on carbon emissions in selected OECD countries over the 1990–2014.[43] They find globalization and financial development improving environmental quality by mitigating carbon emissions. Zaidi et al. (2019) also document that globalization and financial development significantly reduce carbon emissions in Asia Pacific Economic Cooperation (APEC) countries from 1990 to 2016.[44]

Awan et al. (2020) gauge the impact of globalization and financial development on carbon emissions in the six Middle East and North Africa (MENA) countries from 1971 to 2015.[45] The results from the feasible generalized least squares (FGLS) show that globalization and financial development have adverse effects on the environment. Godil et al. (2020) gauge the impact of tourism, financial development, and globalization on the ecological footprint in Turkey during the period of 1986 to 2018, using quantile ARDL.[46] The results show that tourism, globalization, and financial development are detrimental to the environment by increasing the ecological footprint of the country. Langnel and Amegavi (2020) study the impact of globalization and electricity consumption on the ecological footprint for Ghana from 1971 to 2016.[47] Applying the ARDL approach, the results indicate that globalization and electricity consumption significantly increase the ecological footprint. Moreover, economic growth and urbanization contribute to environmental degradation. Le and Ozturk (2020) study the impact of globalization and financial development on CO_2 emissions for 47 emerging markets and developing countries over the period 1990–2014.[48] They employ CCEMG, AMG, and DCCE estimators to assess cross-sectional dependence and slope heterogeneity in the panel data. The findings support the idea that globalization, financial development, and energy consumption trigger CO_2 emissions. Odhiambo (2020) explores the relationship between financial development, income inequality, and CO_2 emissions in 39 SSA countries during the period 2004–2014.[49] The findings of the study conclude that financial development reduces the carbon emissions footprint in SSA countries. The results further show that there is a threshold level of income inequality above which financial development worsens rather than mitigates air pollution. Rahman (2020) depicts the effects of electricity consumption, economic growth, and globalization on the CO_2 emissions of the top 10 electricity consuming countries over the period from 1971 to 2013.[50] Using the FMOLS and DOLS methods, the results of the study suggest that electricity consumption and economic growth deteriorate environmental quality while globalization improves it. The findings also support the EKC hypothesis. Saud et al. (2020) analyze the role of financial development and globalization on the ecological footprint for 49 one-belt-one-road initiative countries from 1990 to 2014.[51] The results based on the PMG estimation conclude that financial development triggers the ecological footprint whereas globalization reduces it. The country-specific results show that the ecological footprint increases with financial development in 30 countries and with globalization in 29 countries. However, the ecological footprint decreases with financial development in 14 countries and with globalization in 4 countries. In a case study of India over the period 1980–2015, Sethi et al. (2020) find that globalization and financial development are detrimental to the environment through the economic growth channel.[52] Ulucak et al. (2020) gauge the impact of financial globalization on the ecological footprint of the emerging economies for the period 1974–2016.[53] The results reveal that financial globalization improves environmental quality while urbanization causes environmental degradation. Usman et al. (2020) identify the effects of renewable energy and globalization on the ecological footprint in the United States from 1985 to 2014.[54] Using the ARDL approach, renewable energy and real output were found to reduce the ecological footprint while financial development and globalization lead to environmental degradation.

More recently, Ahmed et al. (2021) utilize the ARDL approach to depict the relationship of economic globalization, economic growth, and financial development with the ecological footprint in Japan over the period 1971 to 2016.[55] The results indicate that economic globalization and financial development increase the ecological footprint in Japan. However, the findings from the asymmetric ARDL approach indicate that positive and negative changes in economic globalization reduce the footprint. Financial development and energy consumption were found to deteriorate the environment by increasing the ecological footprint. Bataka (2021) depicts the nexus between globalization and environmental pollution in a panel of 38 Sub-Saharan African countries for the period from 1980 to 2017.[56] Using the second-generation panel methodological approach, the study reveals that globalization worsens environmental pollution in Sub-Saharan African countries by increasing CO_2 emissions. In a study of 23 Sub-Saharan African countries from 1960 to 2016, Erdogan et al. (2021) adopt the CUP-FM and CUP-BC approaches and conclude that globalization and human capital improve environmental quality by reducing the ecological footprint.[57] Ganda (2021) investigates the determinants of carbon emissions of 44 countries in Sub-Saharan Africa for the period 1990–2014.[58] According to the findings, financial development and economic growth increase air pollution, whereas industrial practices and renewable energy consumption mitigate it. Khan et al. (2021) investigate the relationship between globalization, economic growth, energy consumption, and carbon emission in South Asian countries during the period 1972-2017.[59] The results using the FMOLS method reveal that globalization, economic growth, and energy consumption exert positive impacts on environmental quality. Nathaniel et al. (2021) depict the link between natural resources, globalization, urbanization, and environmental degradation in Latin American and Caribbean countries from 1990 to 2017.[60] The study employs the Augmented Mean Group (AMG) and the Common Correlated Effects Mean Group (CCEMG) estimators to account for cross-sectional dependence and heterogeneity. The results reveal that globalization and urbanization increase CO_2 emissions. Additionally, human capital is found to have a moderating role in promoting urbanization sustainability. Nurgazina et al. (2021) investigate the impact of globalization and economic growth on carbon emissions in Malaysia over the period 1978-2018.[61] The results of ARDL modeling reveal that globalization, energy consumption, trade openness, and urbanization deteriorate the environment. Pata and Caglar (2021) examine the environmental externalities of income, human capital, globalization, renewable energy consumption, and trade openness in China during the period 1980–2016.[62] The findings from ARDL modeling highlight that globalization, trade openness, and income increase air pollution while human capital mitigates the ecological footprint. Renewable energy consumption was found to exert no significant effect on CO_2 emissions and the ecological footprint. Tahir et al. (2021) analyze the impact of financial development, globalization, and energy use on CO_2 emissions of South Asian economies over the period 1990–2014.[63] Using FMOLS, DOLS, and PMG estimators, the results suggest that financial development deteriorates environmental quality, whereas globalization improves it. Yameogo (2021) analyzes the effect of globalization and urbanization on deforestation in Burkina Faso.[64] The study employs the ARDL model and data covering the period 1980-2017. The results find that globalization, urbanization, and agricultural land have a positive and significant effect on deforestation. Yameogo et al. (2021) apply the GMM approach to examine the effects of economic globalization on environmental pollution in Sub-Saharan Africa for the period 2002-2017.[65] The results suggest that economic globalization, control of corruption, and economic growth negatively affect environmental quality. Yang et al. (2021) find evidence of globalization, financial development, and energy consumption deteriorating environmental quality in the Gulf Cooperation Council (GCC) countries.[66]

Adjei et al. (2022) gauge the nexus of globalization and CO_2 emissions in the ten largest economies in Africa, over the period 1990-2018.[67] Applying FMOLS, DOLS, and Fixed Effect models, the study reports that economic growth increases CO_2 emissions, whereas financial development, globalization, population, and renewable energy consumption reduce them. Ahmad et al. (2022) analyze the dynamics of the ecological footprint in emerging countries over the period 1984-2017.[68] Using the cross-sectional ARDL technique, the results prove that financial development deteriorates the environmental quality by increasing the ecological footprint. On the other hand, human capital and institutional quality promote environmental quality by reducing the ecological footprint. The results further reveal that institutional quality moderates the negative environmental effect of financial development. Aladejare (2022) analyzes the contributions of natural resource rents and globalization to environmental degradation in the five richest African economies (i.e., Algeria, Egypt, Morocco, Nigeria, and South Africa) from 1990 to 2019.[69] The study uses three measures of environmental degradation, namely, CO_2 emissions, methane emissions, and ecological footprint. Results from the feasible generalized least squares and the augmented mean group show that natural resource rent escalates environmental degradation while globalization mitigates it. Alvarado et al. (2022) examine the impact of the informal economy, urban concentration, and globalization on the ecological footprint of 95 countries during the period 1990–2018.[70] Employing the AMG, CCEMG, and DCCE, the study finds a detrimental effect of the informal economy on the ecological footprint in the long run. Additionally, urban population and the globalization index have limited causal relationships with the ecological footprint. Ashraf et al. (2022) analyze the effects of financial development on the ecological footprints in a global sample of 124 economies.[71] The results from the two-step system GMM prove that financial development exhibits an inverted U-shaped relationship with ecological footprints. According to the authors, this relationship stems from the declining scale effect of financial development and its rising technological and composition effects on the economy. Jahanger et al. (2022) assess the determinants of the ecological footprint figures in 73 developing countries over the period from 1990 to 2016.[72] The findings of the study spotlight that globalization decreases the ecological footprint of African and Latin American countries. Furthermore, financial development decreases ecological footprints for the whole panel, and for the Asian countries but not for the African and Latin American and Caribbean countries. Talpur et al. (2022) gauge the impact of globalization, renewable energy consumption, and economic growth on CO_2 emissions in five South Asian developing economies for the period 1990 to 2014.[73] Using FMOLS and DOLS, they find that globalization and economic growth increase pollution whereas renewable energy consumption significantly mitigates it. Qudrat-Ullah and Nevo (2022) investigate the relationships among renewable energy consumption, economic growth, and financial development in five Sub-Saharan African countries (Nigeria, South Africa, Kenya, Ethiopia, and Ghana) over the period from 2000 to 2020.[74] The findings from PMG and DOLS estimations show that economic growth worsens CO_2 emissions, whereas financial development and renewable energy consumption mitigate them in the long run. Usman et al. (2022) explore the influence of financial development, natural resources, globalization, and energy consumption on the ecological footprint in financially resource-rich countries from 1990 to 2018.[75] Applying the second-generation panel data approach, the results show that financial development, natural resources, and non-renewable energy increase the ecological footprint, while globalization and renewable energy reduce it. In a study for 67 countries over the period 1971–2018, Xia et al. (2022) report a significant and positive connection between globalization and carbon emissions.[76] Xu et al. (2022) apply the FMOLS and DOLS methods to a panel of big five economies of the world including the United States, China, United Kingdom, Germany, and Japan.[77] They find that financial development, capital formation, natural resources, and globalization have detrimental effects on the environmental quality. Zhang et al. (2022) rely on quantile regression to investigate the effects of financial globalization, economic expansion, urbanization, renewable energy, and technological innovation on the ecological footprint of BRICS countries for the period from 1990 to 2018.[78] Financial globalization was found to increase the ecological footprint across all quantiles. Finally, Aladejare (2022b) studies the case of 29 African countries from 1970 to 2019 using panel regression methods accounting for cross-sectional dependency and heterogeneity.[79] The study spotlights that globalization, life expectancy, and human capital development improve environmental quality while income growth and urbanization degrade it in the long term.

In summary, the review of literature demonstrates that the empirical literature has used various econometric techniques to examine the factors driving environmental degradation. The evidence on the impact of financial development and globalization is unclear. While many studies exist for Asian developing and developed countries, there are few studies for Sub-Saharan African countries. Moreover, carbon emissions are the most commonly used proxy for measuring environmental degradation. However, this indicator has been criticized for providing only partial information on environmental degradation (Dogan et al., 2020),[80] as it fails to account for other crucial aspects of environmental sustainability, such as water, forest, and land degradation. To enhance the relevance of this study, we employ the ecological footprint as a more comprehensive indicator of environmental degradation in analyzing the case of West African countries. The following section presents the study's methodological framework.

3. *Data, Model, and Methodology*

Data Description: This study uses annual data covering the period from 1990 to 2018 for eight West African countries selected on the basis of data availability, namely, Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali, Nigeria, Senegal, and Togo. The choice of the countries and the time period were based on the availability of information. Various indicators are used as proxies for environmental degradation. Carbon emissions are the most often used proxy for environmental deterioration as they are the most significant source of air pollution. However, this metric does not consider all dimensions of environmental degradation such as deforestation, water pollution, and land degradation. In this research, we follow some recent works and rely on ecological footprint as a proxy for environmental degradation.[81] Ecological footprint quantifies the use of multiple categories of natural resources by humans in the environment through their activities. These natural resources include cropland, forest products, carbon space, built-up land, fishing grounds, and grazing land.[82] Ecological footprint is a more holistic indicator to assess the environmental damages caused by human actions.

The explanatory variables of this study include real GDP per capita, renewable energy consumption, financial development, and globalization. We use domestic credit to private sector granted to the private sector as percentage of GDP as a proxy for financial development. Globalization is measured by the KOF globalization index, which varies on a scale from 0 to 100. The greater the value of the KOF globalization indicates a higher level of globalization. The description, unit of measurement and sources of the variables are shown in Table 1. Furthermore, ecological footprint and real GDP per capita are transformed into their natural logarithms.

Table 1
DESCRIPTION OF VARIABLES[a]

Variable	Description	Units	Sources
EFP	Ecological footprint	Global hectare per person	Global Footprint Network
GDP	Economic growth	GDP per capita (constant 2015 U.S.$)	WDI*
REN	Renewable energy consumption	Renewable energy use as a % of total final energy consumption	WDI
FD	Financial development	Domestic credit to the private sector as % of GDP	WDI
GLO	KOF globalization index	Index	KOF index**

[a]*WDI—World Development Indicators from the World Bank (2022), ** KOF Index—its revised KOF globalization index (Gygli et al., 2019).

The descriptive statistics presented in Table 2 indicate that, for the representative country, the mean value of the ecological footprint is 0.232. The ecological footprint ranges from -0.077 to 0.723. Real GDP per capita has an average value of 6.859, with a range from 5.844 to 7.896. The globalization index shows a mean value of 46.585, reaching a maximum of 61.633 and a minimum of 28.719. The coefficient of variation, calculated as the ratio of the standard deviation to the mean, indicates substantial variability across countries. Specifically, the coefficient of variation for the ecological footprint is 71.3%. The Jarque-Bera test for normality rejects the null hypothesis, indicating that not all of the variables follow a normal distribution.

Table 2
DESCRIPTIVE STATISTICS[a]

Variables	lnEFP	lnGDP	REN	FD	GLO
Mean	0.232	6.859	72.005	15.193	46.585
Median	0.215	6.888	76.560	13.817	46.653
Maximum	0.723	7.896	94.988	40.163	61.633
Minimum	−0.077	5.844	36.150	3.657	28.719
Std. Deviation	0.165	0.521	15.512	6.958	7.376
Cof. variation	0.713	0.076	0.215	0.458	0.158
Jarque-Bera	26.472	9.816	22.844	51.642	2.911
n	232	232	232	232	232

[a]lnEFP = log of ecological footprint as global hectare per person; lnGDP = log of real GDP per capita; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; and GLO=KOF globalization index.

Several insights emerge from the analysis of the correlation matrix (Table 3). First, real GDP and globalization exhibit a positive and significant relationship with both the ecological footprint and carbon emissions, indicating that economic growth and globalization contribute to environmental degradation. Second, although the relationship between the ecological footprint and financial development is positive, it is statistically insignificant. Third, renewable energy demonstrates a negative and significant relationship with both the ecological footprint and carbon emissions, suggesting that the use of renewable energy sources may help improve environmental quality. Finally, there is no evidence of a strong relationship between the explanatory variables, as the correlations among them are weak (<0.7). To further assess multicollinearity among the regressors, the tolerance value and variance inflation factor (VIF) were employed.[83] These statistics measure the extent to which the variances of the estimated coefficients are inflated by the presence of strong relationships among variables. The VIF and tolerance values indicate that the regressors in this study are free from multicollinearity.

Model Specification: To empirically analyze the impacts of financial development and globalization on environmental degradation, we use the following model in equation (1):

$$lnED_{it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 REN_{it} + \beta_3 FD_{it} + \beta_4 GLO_{it} + \mu_{it} \quad (1)$$

where ED_{it} denotes environmental degradation in country i and year t; GDP_{it} is real GDP per capita; REN_{it} represents renewable energy consumption; FD_{it} is financial development; and GLO_{it} stands for globalization index. Also, μ_{it} is an error term normally distributed. The parameter β_0 refers to the intercept to be estimated while the parameters β_1, β_2, β_3, and β_4 are the elasticities of environmental

Table 3

CORRELATION MATRIX AND COLLINEARITY TEST RESULTS[a]

	Correlation coefficients					Collinearity results	
Variables	**lnEFP**	**lnGDP**	**REN**	**FD**	**GLO**	**VIF**	**Tolerance**
lnEFP	1.000	0.179*	−0.435*	0.018	0.344*	–	–
lnGDP		1.000	−0.329*	−0.120**	0.562*	1.749	0.572
REN			1.000	−0.252*	−0.606*	1.587	0.630
FD				1.000	0.342*	1.358	0.736
GLO					1.000	2.494	0.401

[a]lnEFP = log of ecological footprint as global hectare per person; lnGDP = log of real GDP per capita; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. The general rule is Tol>0.2 and VIF<5. The asterisks * and ** indicate significance at the 5% and 10% levels, respectively.

degradation associated with income, renewable energy consumption, financial development, and globalization. We can modify equation (1) to test the validity of the EKC hypothesis by including the squared term of the real GDP per capita.

In regard to the expected signs, economic growth increases the consumption of energy, foods, water, and other natural resources, which, in turn, harms the environment. Therefore, the sign of the parameter β_1 is hypothesized to be positive (i.e., $\beta_1 = \delta lnED/\delta lnGDP > 0$). On the other hand, renewable energy consumption is acknowledged in the literature on energy economics to have a mitigating effect on environmental degradation. Thus, the sign of the coefficient β_2 is expected to be negative (i.e., $\beta_2 = \delta lnED/\delta REN > 0$). Financial development is expected to have a harmful effect on the environment through economic growth and demand for energy-consuming materials. Accordingly, the coefficient β_3 should be positively signed (i.e., $\beta_3 = \delta lnED/\delta FD > 0$). The coefficient may be negative if loans from banks are primarily given to firms that invest in projects that are mostly environmentally friendly. Lastly, many Sub-Saharan African countries have persistently globalized their economies and at the same time experienced environmental concerns. Globalization may stimulate economic growth, which increases ecological resources consumption and, hence, increases environmental degradation. Therefore, the coefficient on globalization is hypothesized to be positively signed as well (i.e., $\beta_4 = \delta lnED/\delta GLO > 0$). However, globalization can also introduce eco-friendly technologies that promote economic growth with minimal environmental damage. In such a case, the coefficient β_4 would have a negative sign.

Methodology: This study relies on panel data framework combining the cross-sectional and time-series dimensions of the data to analyze the impact of financial development and globalization on the ecological footprint. It is a well-known fact that panel data methods increase the power of the tests. However, cross-sectional dependence and slope heterogeneity may arise as two important issues to be addressed in econometric analysis of country panel data. We must check these issues before selecting the appropriate estimation methods. Therefore, the econometric methodology of this study is implemented through five steps. First, we start by checking cross-sectional dependence for each variable by mean of the Lagrange Multiplier (LM) statistic test proposed by Breusch and Pagan (1980) and its adjusted version developed by Pesaran (2004) and Baltagi et al. (2012).[84] Second, we test for slope homogeneity in the relationship among the variables following Swamy (1970) and Pesaran and Yamagata (2008).[85] Third, we determine the order of integration of the series using panel unit root tests. It is well-known that the presence of cross-sectional dependence undermines the power of first-generation panel unit root tests, based on independence between the panel units. To test for unit root, we employ the Cross-sectional Augmented Dickey-Fuller (CADF) test proposed by Pesaran (2007) that addresses the issue of cross-sectional dependence and heterogeneity through common factors.[86] Fourth, we test whether there is a meaningful relationship between the variables using the cointegration test suggested by Pedroni (2004).[87] As a cross-check, we also carry out the cointegration test developed by Westerlund (2007).[88] Fifth, if there is evidence of cointegration between the variables, we estimate the associated long-run coefficients. In this regard, several estimators for cointegrated panel data have been developed in econometric literature. Standard estimation techniques such as FE, RE, OLS, DOLS, and FMOLS do not account for cross-section dependence and slope heterogeneity. To provide valid and reliable estimates, we consider panel data estimators that are robust against cross-sectional dependence, slope heterogeneity, unit roots, and co-integration in the data. More precisely, this study employs the Common Correlated Effects Mean Group (CCEMG) and the Augmented Mean Group (AMG) estimators.

The CCEMG estimator designed by Pesaran (2006)[89] assumes the following multifactor error structure in equation (2):

$$lnED_{it} = \beta_{0i} + \beta_{1i}lnGDP_{it} + \beta_{2i}REN_{it} + \beta_{3i}FD_{it} + \beta_{4i}GLO_{it} + \mu_{it}$$
$$\mu_{it} = \lambda_i f_t + e_{it} \tag{2}$$

where f_t is a $r \times 1$ vector of unobserved common factors with country-specific factor loading λ_i, such that $\lambda_i f_t = \lambda_{1i} f_{1t} + \lambda_{2i} f_{2t} + \cdots + \lambda_{ri} f_{rt}$, where r is the number of common factors; and e_{it} is individual country-specific idiosyncratic error term assumed to be independently distributed across i and t.

Since the common factors are unobserved, they must be estimated. The CCEMG approach suggested by Pesaran (2006) approximates them by including cross-sectional averages of dependent and independent variables.[90] Therefore, the CCEMG estimator is constructed by transforming equation (2) into the following model in equation (3):

$$lnED_{it} = \beta_{0i} + \beta_{1i}lnGDP_{it} + \beta_{2i}REN_{it} + \beta_{3i}FD_{it} + \beta_{4i}GLO_{it} + d_i\overline{Z}_t + e_{it} \tag{3}$$

where $\overline{Z}_t = (\overline{lnED}_t, \overline{lnGDP}_t, \overline{REN}_t, \overline{FD}_t, \overline{GLO}_t)$ is the vector of the cross-sectional averages of the variables.

The augmented model given by equation (3) is estimated with OLS technique for each panel unit. The consistent CCEMG estimator is computed as the simple average of the group-specific estimates. Simulation studies (Pesaran 2006; Coakley et al. 2006; Kapetanios et al. 2011; Pesaran and Tosetti 2011)[91] have shown that this approach is robust to omitted variables bias, structural breaks, and endogeneity of regressors. Furthermore, it performs well even when the cross-section size is small, when variables are nonstationary, and cointegrated or not.

Alternatively, the Augmented Mean Group (AMG) estimator developed by Eberhardt and Teal (2010), controls for cross-sectional dependence by including a common dynamic process in the coefficients of cross-sectional unit regressions.[92]

It follows a two-stage procedure. In the first stage, time dummies variables (d_t) are included into a first-differenced model which is estimated with OLS.

$$\Delta lnED_{it} = \alpha_i + \theta_i \Delta X_{it} + \sum_{t=2}^{T} \gamma_i d_t + e_{it} \tag{4}$$

where X_{it} is the vector of explanatory variables, i.e., $X_{it} = (lnGDP_{it}, REN_{it}, FD_{it}, GLO_{it})$. In the second stage, the unobserved common factor (f_t) is replaced with the coefficients of time dummies as follows:

$$lnED_{it} = \beta_{0i} + \beta_{1i} lnGDP_{it} + \beta_{2i} REN_{it} + \beta_{3i} FD_{it} + \beta_{4i} GLO_{it} + \lambda_i \hat{\gamma}_t + e_{it} \tag{5}$$

To reach the panel estimates, as indicated above, the AMG estimator takes the simple average of estimates for each panel unit.

To complement the empirical analysis, we further investigate the causal interaction between the variables using Granger causality tests. We follow the strategy suggested by Toda and Yamamoto (1995) that allows causal inference to be conducted in a level VAR model.[93] This approach has the advantage of not requiring pre-testing for cointegration among the variables and can be implemented when the variables are integrated of different orders. More precisely, the modified version of Granger causality test suggested by Toda and Yamamoto (1995) artificially augments the right order of the VAR by the maximum integrated order of integration of the variables.[94] Thus, the model to be estimated is written as follows:

$$\begin{cases} ED_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{1j} ED_{it-j} + \sum_{j=1}^{p} \alpha_{2j} GDP_{it-j} + \sum_{j=1}^{p} \alpha_{3j} FD_{it-j} + \sum_{j=1}^{p} \alpha_{4j} GLO_{it-j} + u_{1it} \\ FD_{it} = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} ED_{it-j} + \sum_{j=1}^{p} \gamma_{2j} GDP_{it-j} + \sum_{j=1}^{p} \gamma_{3j} FD_{it-j} + \sum_{j=1}^{p} \gamma_{4j} GLO_{it-j} + u_{2it} \\ GLO_{it} = \varphi_0 + \sum_{j=1}^{p} \varphi_{1j} ED_{it-j} + \sum_{j=1}^{p} \varphi_{2j} GDP_{it-j} + \sum_{j=1}^{p} \varphi_{3j} FD_{it-j} + \sum_{j=1}^{p} \varphi_{4j} GLO_{it-j} + u_{3it} \end{cases} \tag{6}$$

where $p = k + d_{max}$, d_{max} is the maximum order of integration of the series and k is the optimal lag order of the level VAR.

A standard Wald test is applied to the first lagged k explanatory variables to make causal inference. For instance, financial development Granger causes environmental degradation if the null hypothesis $\alpha_{3j} = 0$ is rejected for $j = 1,..., k$. Similarly, causality from globalization to environmental degradation implies the null hypothesis $\alpha_{4j} = 0$ is rejected for $j = 1, \ldots, k$. The inclusion of d_{max} extra lags is to ensure that the computed Wald-statistic follows a chi-square distribution with k degrees of freedom.

4. Empirical Results and Discussion

As a first step, we apply cross-sectional dependence tests to the variables. The results presented in Table 4 indicate that they are subject to cross-sectional dependency. Next, we test for cross-sectional dependency in the residuals and slope homogeneity. Results displayed in Table 5 show that the residuals of the model are plagued by cross-sectional dependence. This outcome implies that there are strong connections among the countries of concern. This revelation also indicates that a shock in one country is likely to transmit to the others. Furthermore, the results suggest that there is slope heterogeneity in the relationship between ecological footprint, globalization, and financial development. This means that inconsistent estimates will be obtained if cross-section dependence and slope heterogeneity are ignored.

To make sure that we do not run spurious regression, we check the order of integration of the series by means of unit root tests. We apply the well-known IPS test developed by Im et al. (2003), which is less restrictive and more powerful compared to the other first generation panel unit root tests.[95] To account for cross-sectional dependence in the data, we further perform the Cross-sectional Augmented Dickey-Fuller (CADF) test proposed by Pesaran (2007).[96] Table 6 depicts the outcomes of these tests, indicating that the null hypothesis of unit root cannot be rejected for all variables. However, when variables are considered in the first difference, they are stationary. Thus, we can regard the variables as being integrated of order one, which suggests that there might be a long-run relationship among them.

We test for cointegration using the residual-based test of Pedroni (2004) and the test of Westerlund (2007).[97] The overall results presented in Table 7 point to the existence of a long-run relationship among the variables.

Table 4
RESULTS FOR CROSS-SECTIONAL DEPENDENCE TESTS FOR INDIVIDUAL VARIABLES[a]

Series	LM Test (Breusch and Pagan, 1980)	Scaled LM Test (Pesaran, 2004)	CD Test (Pesaran, 2004)	LM_{BC} Test (Baltagi *et al.*, 2012)
lnEFP	113.183* [0.000]	11.383* [0.000]	3.090* [0.000]	11.240* [0.000]
lnGDP	444.535* [0.000]	55.661* [0.000]	19.073* [0.000]	55.519* [0.000]
REN	317.275* [0.000]	38.656* [0.000]	15.583* [0.000]	38.513* [0.000]
FD	297.513* [0.000]	36.015* [0.000]	14.022* [0.000]	35.872* [0.000]
GLO	714.903* [0.000]	91.791* [0.000]	26.722* [0.000]	91.648* [0.000]

[a]lnEFP = log of ecological footprint as global hectare per person; lnGDP = log of real GDP per capita; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. p-values are given in brackets. The asterisk * denotes rejection of the null hypothesis of unit root at the 5% significant level.

Table 5
RESULTS FOR CROSS-SECTIONAL DEPENDENCE AND HOMOGENEITY TESTS FOR MODEL[a]

Tests	**Statistic**	***p-value***
Cross-sectional dependence test		
Breusch-Pagan LM	117.470*	0.000
Pesaran CD	3.418*	0.000
Pesaran scaled LM	11.955*	0.000
Homogeneity test		
Delta	194.302*	0.000
Delta adjusted	206.876*	0.000
Swamy test	2791.41*	0.000

[a]The asterisk * indicates the rejection of the null hypothesis at 5% significance level.

The finding of cointegration does not give the nature of the relationship between environmental quality and the explanatory variables. We estimate the long-run coefficients employing the CCEMG and AMG estimators. For comparison purposes, we first apply the Mean Group (MG) estimator proposed by Pesaran and Smith (1995),[98] and the Group Mean estimators – the Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) – developed by Pedroni (2000, 2001).[99] The results are reported in Table 8. As expected, income is significantly positively related to the ecological footprint in

Table 6
PANEL UNIT ROOT TEST RESULTS[a]

	Level		**First difference**	
Variable	**IPS test**	**CADF test**	**IPS test**	**CADF test**
lnEFP	−1.129 [0.129]	1.678 [0.953]	−14.550* [0.000]	−5.084* [0.000]
lnGDP	3.290 [0.999]	2.445 [0.993]	−7.433* [0.000]	−2.441* [0.007]
REN	0.834 [0.798]	0.009 [0.504]	−8.624* [0.000]	−2.907* [0.002]
FD	1.642 [0.949]	−1.011 [0.156]	−9.220* [0.000]	−2.306* [0.011]
GLO	−0.489 [0.312]	−0.054 [0.478]	−9.309* [0.000]	−3.032* [0.001]

[a]lnEFP = log of ecological footprint as global hectare per person; lnGDP = log of real GDP per capita; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. The IPS test provides W-t-bar statistic, whereas the CADF test provides z-t-bar statistic of Pesaran (2007) test. Tests are conducted with intercept and *p-values* are given in brackets. Optimal lag length was determined using AIC with a maximum of 5. The asterisk * denotes rejection of the null hypothesis of unit root at the 5% significant level.

Table 7
RESULTS OF PANEL COINTEGRATION TESTS[a]

Tests/Statistic	Statistic	Prob.
Pedroni (1999) tests		
Panel v	0.870	0.192
Panel rho	−1.335**	0.090
Panel PP	−5.877*	0.000
Panel ADF	−5.862*	0.000
Group rho	−0.672	0.250
Group PP	−7.966*	0.000
Group ADF	−6.855*	0.000
Westerlund (2007) tests		
Group-τ	−3.181*	0.001
Group-α	−0.140	0.444
Panel-τ	−3.688*	0.000
Panel-α	−1.747*	0.040

[a]The asterisks * and ** denote rejection of the null hypothesis of no cointegration at the 5% and 10% levels, respectively.

two out of the three estimators. Renewable energy consumption is significant only in the FMOLS model. Financial development enters significantly and positively in two regressions. Concerning globalization, it enters significantly only into the FMOLS model. The diagnostic tests reported in the bottom rows of the table divulge that in most cases the residuals exhibit cross-sectional dependence and unit root. Therefore, an estimator that tackles slope heterogeneity and cross-sectional dependence is required so as to provide a more adequate analysis of the effects of financial development and globalization on the ecological footprints of the selected countries.

Table 9 contrasts the results from the CCEMG and AMG estimators. The results reveal a positive monotonic relationship between real GDP and the ecological footprint, in line with our expectation. A one percentage rise in real GDP per capita brings about 0.4-0.7 percentage increase in ecological footprint, other things remaining constant. This outcome indicates that economic growth in selected countries takes place at the expense of environmental degradation through energy use and land, forest and water degradation. Further, renewable energy is not significantly related to the ecological footprint in the selected African countries. This finding may be attributable to the low level of renewable energy consumption in SSA. Financial development demonstrates a significant and positive influence on the ecological footprint, indicating that the financial sector significantly contributes to worsening the environmental quality. Our finding confirms those of Solarin et al. (2017), Acheampong et al. (2019), Usman et al. (2020), Ganda (2021), and Ahmad et al. (2022), but contradicts Adjei et al. (2022) and Qudrat-Ullah and Nevo (2022).[100] This result suggests that financial

Table 8
ESTIMATION RESULTS FROM DOLS, FMOLS, AND MG[a]

	(1)			(2)		
	DOLS	**FMOLS**	**MG**	**DOLS**	**FMOLS**	**MG**
lnGDP	0.210	0.397*	0.466*	0.087	0.207*	0.296*
	[0.125]	[0.000]	[0.006]	[0.565]	[0.016]	[0.006]
REN	0.001	0.003*	0.002	–	–	–
	[0.453]	[0.017]	[0.295]			
FD	0.004*	0.004*	0.002	0.004*	0.004*	0.003
	[0.005]	[0.000]	[0.202]	[0.026]	[0.000]	[0.133]
GLO	0.004	0.005*	0.004	0.005	0.005*	0.004
	[0.230]	[0.005]	[0.252]	[0.276]	[0.026]	[0.239]
Obs.	213	224	232	214	224	232
IPS	−0.016	−0.884	−10.351*	0.156	−0.738	−8.560*
	[0.493]	[0.188]	[0.000]	[0.562]	[0.230]	[0.000]
CADF	−0.752	0.411	0.091	2.084	2.166	−0.261
	[0.226]	[0.659]	[0.536]	[0.981]	[0.985]	[0.397]
CD test	−1.905**	−0.759	2.970*	−1.739**	−1.243	3.090*
	[0.056]	[0.448]	[0.003]	[0.081]	[0.213]	[0.002]

[a]lnEFP = log of ecological footprint as global hectare per person; lnGDP = log of real GDP per capita; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. The dependent variable is lnEFP. CADF test provides z-t-bar statistic of Pesaran (2007) unit root test and CD is Pesaran (2004) cross-sectional dependency test statistic performed on the residuals of the given estimations. Intercepts are not reported for simplicity. Figures in brackets are *p*-values. The asterisks * and ** denote statistical significance at the 5% and 10% levels, respectively.

development probably promotes the development of projects and activities that increase ecological resource consumption, hence deteriorating the environment. Accordingly, West African countries should discourage credits to inefficient energy-consuming activities that potentially worsen the environmental quality.

Regarding globalization, it has a positive and significant coefficient, signifying that the human pressure on the environment rises with the increasing level of globalization. Intuitively, it means that globalization causes environmental degradation in West African countries by increasing the ecological footprint. Other things remain the same, an increase of one unit in the overall globalization index causes around 0.9 percent rise in the ecological footprint. The possible explanation is that globalization in African countries attracts foreign direct investment, technologies, and high production, which increase land degradation and air pollution. The fact that globalization causes environmental degradation also provides support to the pollution haven hypothesis. Our empirical finding is in tandem with studies by Bataka (2021), Yameogo (2021), and Zhang et al. (2022).[101] However, it contradicts the findings by Amuakwa-Mensah and Adom (2017), Erdogan et al. (2021),

Table 9
CCEMG AND AMG RESULTS[a]

	(1)				(2)			
	CCEMG		AMG		CCEMG		AMG	
	Coef.	**Prob.**	**Coef.**	**Prob.**	**Coef.**	**Prob.**	**Coef.**	**Prob.**
lnGDP	0.742*	0.000	0.540*	0.008	0.529*	0.001	0.401*	0.006
REN	−0.001	0.625	0.001	0.812	–	–	–	–
FD	0.001	0.582	0.005*	0.040	0.001	0.506	0.005*	0.034
GLO	−0.001	0.836	0.008*	0.011	0.003	0.250	0.009*	0.003

[a]lnEFP = ecological footprint as global hectare per person in log; lnGDP = real GDP per capita in log; REN = renewable energy consumption as % of total final energy consumption; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. The asterisks * indicate significance at the 5% level.

and Aladejare (2022), who found that globalization improves the environmental quality by reducing the ecological footprint.[102] Our finding also opposes the conclusion of Salahuddin et al. (2019a) who discovered no significant effect of globalization on the environment in African countries.[103] According to our finding, the major challenge facing West African countries is how to strike the balance between the adverse effects of globalization and the improvement of environmental quality.

We report the country-level results in Table 10. As expected, the results show considerable heterogeneity across countries. A significant detrimental effect of domestic income is found for six countries (Cote d'Ivoire, Ghana, Mali, Nigeria, Senegal, and Togo). The elasticity with respect to income ranges between 0.308 and 1.513 percent. This suggests that an increase in domestic income in each of these countries boosts the demand for natural resources, leading to a deterioration of the environment. Similarly, the effect of financial development is statistically significant and positive in five countries (Benin, Burkina Faso, Cote d'Ivoire, Ghana, and Mali). Financial development contributes to worsening the environmental quality in these countries. Regarding the effect of globalization, the results prove that it deteriorates the environment in four countries (i.e., Benin, Cote d'Ivoire, Ghana, and Nigeria) whereas it is neutral for the remaining countries (i.e., Burkina Faso, Mali, Senegal, and Togo). This outcome suggests that globalization involves foreign investment and foreign trade that transfer energy-intensive dirty technologies towards countries with weak environmental regulations. Globalization also attracts investment flows in sectors consuming ecological resources.

Finally, the paper explores the causal relationship between the variables using Granger causality tests. The results presented in Table 11 reveal that real GDP and globalization cause the ecological footprint. On the other hand, real GDP and globalization cause financial development.

Table 10
COUNTRY-SPECIFIC RESULTS OF ECOLOGICAL FOOTPRINT[a]

	CCEMG			AMG		
Country	**lnGDP**	**FD**	**GLO**	**lnGDP**	**FD**	**GLO**
Benin	0.473	−0.001	0.014*	0.581	0.012*	0.009
	[0.414]	[0.961]	[0.049]	[0.146]	[0.000]	[0.144]
Burkina Faso	0.156	0.001	0.007	−0.236	0.014*	0.013
	[0.807]	[0.905]	[0.704]	[0.518]	[0.000]	[0.254]
Cote d'Ivoire	0.447*	0.004	0.008	0.535*	0.005*	0.015*
	[0.002]	[0.365]	[0.306]	[0.000]	[0.000]	[0.000]
Ghana	0.003	0.006**	0.005	0.308*	0.010*	0.017*
	[0.989]	[0.091]	[0.259]	[0.000]	[0.003]	[0.000]
Mali	0.524*	0.002	−0.010	0.676*	0.005**	−0.002
	[0.002]	[0.596]	[0.224]	[0.000]	[0.098]	[0.592]
Nigeria	0.506*	−0.003	0.005	−0.112	−0.005	0.018*
	[0.000]	[0.342]	[0.455]	[0.421]	[0.324]	[0.002]
Senegal	1.513*	−0.003	−0.006	1.036*	0.001	−0.003
	[0.000]	[0.725]	[0.686]	[0.000]	[0.811]	[0.359]
Togo	0.612*	−0.001	0.002	0.422*	−0.001	0.003
	[0.008]	[0.928]	[0.715]	[0.000]	[0.638]	[0.140]

[a]lnEFP = ecological footprint as global hectare per person in log; lnGDP = real GDP per capita in log; FD = financial development based on domestic credit to the private sector as % of GDP; GLO=KOF globalization index. The asterisks * and ** indicate significance at the 5% and 10% levels, respectively.

Table 11
TODA-YAMAMOTO CAUSALITY TEST[a]

Causality	Chi-sq	Prob.	Causality	Chi-sq	Prob.
GDP → EFP	10.431*	0.015	EFP → FD	0.266	0.966
FD → EFP	1.926	0.587	GDP → FD	8.067*	0.044
GLO → EFP	8.721*	0.033	GLO → FD	11.446*	0.009
EFP → GDP	1.315	0.725	EFP → GLO	0.206	0.976
FD → GDP	1.662	0.645	GDP → GLO	1.377	0.710
GLO → GDP	2.637	0.451	FD → GLO	0.874	0.831

[a]lnEFP = ecological footprint as global hectare per person in log; lnGDP = real GDP per capita in log; FD = financial development based on domestic credit to the private sector as % of GDP; GLO = KOF globalization index. The asterisks * and ** indicate significance at the 5% and 10% levels, respectively.

5. *Conclusion*

The aim of this study was to examine the environmental effects of financial development and globalization in eight West African countries from 1990 to 2018. Previous research in this area has predominantly used carbon dioxide emissions as an indicator, which fails to capture the full complexity of environmental degradation, such as land and water degradation. To address this gap, the present study utilized the ecological footprint as a more comprehensive measure of environmental quality. Given the presence of cross-sectional dependence and slope heterogeneity in the data, appropriate unit root tests were conducted to assess the stationarity of the variables, and cointegration tests were used to determine the existence of cointegration among the variables. For the estimation strategy, the study employed the Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) estimators to address issues related to cross-sectional dependence and heterogeneity. The results of the study indicate that economic growth, financial development, and globalization are significantly and positively associated with the ecological footprint. Additionally, the findings do not support the validity of the Environmental Kuznets Curve (EKC) hypothesis for the selected countries as a whole. The study also explored the causal relationships between the variables using Granger causality tests, concluding that economic growth and globalization play a significant predictive role in shaping the ecological footprint of these countries. The country-level results reveal considerable heterogeneity, showing that financial development worsens environmental quality in five countries, while it remains neutral in the others. Similarly, globalization negatively impacts the environment in four countries but has a neutral effect in the remaining countries.

From a policy standpoint, the findings of this study indicate that financial development, economic growth, and globalization in West Africa are occurring at the cost of environmental degradation. Therefore, if economic growth, financial deepening, and globalization continue unchecked, they will further exacerbate environmental damage unless environmentally friendly technologies and knowledge are integrated across all sectors of the economy. The financial sector, in particular, often overlooks environmental sustainability when providing credit to the private sector. We recommend that the financial sector in these countries consider the environmental sustainability of investment projects more carefully. Policymakers should also develop and implement strategies that encourage the adoption of clean energy sources. In this regard, substantial investment in solar energy, which is abundant across the continent, should be prioritized. Such initiatives could be executed at a regional level in selected countries, under the guidance of sub-regional organizations such as ECOWAS, the African Development Bank, WAEMU, and the African Union. This approach would help African economies meet energy demands while advancing towards sustainable development goals. Given the critical role forests play in livelihoods and carbon mitigation, forest landscape restoration campaigns should be actively promoted. Additionally, environmental standards need to be strengthened to protect natural resources. Introducing a carbon tax and restricting the importation of high-energy-consuming machinery and equipment are strategies that should be explored to support these objectives.

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