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Banking sector development and environmental degradation in the Economic Community of West African States: do technology effects matter?

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Abstract

This paper contributes to the discussion on environmental degradation by exploring the connection between banking sector development and environmental degradation in the ECOWAS. In addition, we investigate the direction of causation between environmental degradation and its drivers and the technological effect of banking sector development on environmental degradation. We rely on a balanced panel dataset of 11 ECOWAS nations from 1990 to 2019. We present the following conclusions using the AMG estimator and the Driscoll–Kraay panel regression model. First, banking sector development reduces environmental degradation. Second, banking sector development has a deleterious technological effect on environmental quality. Thirdly, population and affluence were found to significantly promote environmental degradation, while the impact of technology was inconclusive. We further demonstrate a unidirectional causation association between the development of the banking sector and environmental degradation using the Dumitrescu and Hurlin causality analysis. Based on the study conclusions, numerous policy ramifications have been suggested for the ECOWAS nations to mitigate environmental degradation.

Keywords Banking sector development, Environmental degradation, ECOWAS, STIRPAT model

Introduction

Environmental quality (EQ) issues have gained worldwide attention over the past decade. Many academics and decision-makers in developed and developing nations have reiterated the importance of reducing greenhouse gas emissions (GHGs), major contributors to climate change and global warming [1, 2]. These stated hazards are mostly linked to population growth, economic growth, technological advancements, and other economic activities linked to an increase in fossil fuel utilisation, of which banking sector development (*BSD*) is no exception. In this paper, we review issues concerning the association between *BSD* and environmental degradation, perform an empirical exercise concentrating on long-run impacts utilising information from ECOWAS, and elaborate on the findings' policy ramifications. Financial sector development (*FSD*) happens when the costs that financial market players incur for information, transactions, and enforcement relating to the operation and monitoring of the financial system are lowered [3]. *FSD* can but does not invariably, have a favourable impact on economic growth [4]. Unsurprisingly, *FSD* is most frequently investigated regarding how it impacts economic

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growth, given the proven favourable social well-being consequences linked to economic growth.

Climate change issues in the ECOWAS region have gone unaddressed until recently, while policies promoting economic growth have received much attention. Owing to that, environmental degradation in ECOWAS has worsened due to rising CO_2 emissions. Figure 1 shows that CO_2 emissions have surged from 1990 to 2019 with few instances of decline. The increases in non-renewable energy consumption might explain this trend, as increases in non-renewable energy consumption dampen *EQ* by releasing greenhouse gases into the atmosphere [5]. Many studies have examined how *FSD* affects *EQ* and energy consumption. Considering the underdeveloped nature of the banking sector in the ECOWAS subregion, supporting the adoption and implementation of green technologies would be herculean. This is because research and development (R&D) efforts vital for adopting and implementing eco-friendly technologies get inadequate funding in economies with underdeveloped banking sectors. Even after embarking on several reforms to accelerate banking sector development, ECOWAS still lags behind other regions in this aspect.

The paper concentrates on the causal impacts of *BSD* on environmental degradation (*ED*), which is vital for at least three reasons. First, since these impacts are ambiguous from a theoretical standpoint, it is important to research to identify the empirical causal links between *BSD* and *ED*. Prior studies have shown that the impact of *FSD* on *EQ* has varied by the dimension of *FSD* examined, the country or region, and the period studied. As noted, these impacts can be positive [6–8], negative [9–11], and neutral [12, 13]. Second, some studies have established a bidirectional causality between *FSD* and economic growth [14, 15]. Thus, comprehending the observed causal association between *ED* and *FSD* sheds new light for better appreciating the nexus between economic growth and *ED*. Third, as relevant social and economic policies are more impacted by environmental factors, which are receiving larger community attention, this understanding is becoming even more crucial.

Despite much research on the connection between *FSD* and *EQ*, this paper expands the corpus of knowledge in three areas. Firstly, a few studies try to determine how the *BSD* has impacted *EQ*, for example, Samour et al. [1] for South Africa, Radulescu et al. [10] for OECD countries, and Mehmood [16] for a panel of N-11 economies. It is crucial to highlight that none of these studies examined how *BSD* affected *EQ* in the ECOWAS region. As a consequence, the novelty of this paper is to examine how *BSD* influences *ED* in ECOWAS. Secondly, this study departs from prior studies by exploring the technological effects of *BSD* on *ED*. *BSD* may have a technological impact because credit provided by the banking sector often facilitates technological advancements. These technological improvements may lead to adopting and implementing ecologically friendly technologies [11] or drive energy utilisation [17]. Finally, most existing empirical literature fails to account for cross-sectional dependence (CSD) and slope heterogeneity, which may invalidate empirical findings if present in the data. This study addresses this gap by utilising the second-generation stationarity test, the Westerlund cointegration test, the augmented mean group (AMG) estimator, and the Driscoll–Kraay panel regression technique, which offer reliable estimations when slope and CSD heterogeneity are present.

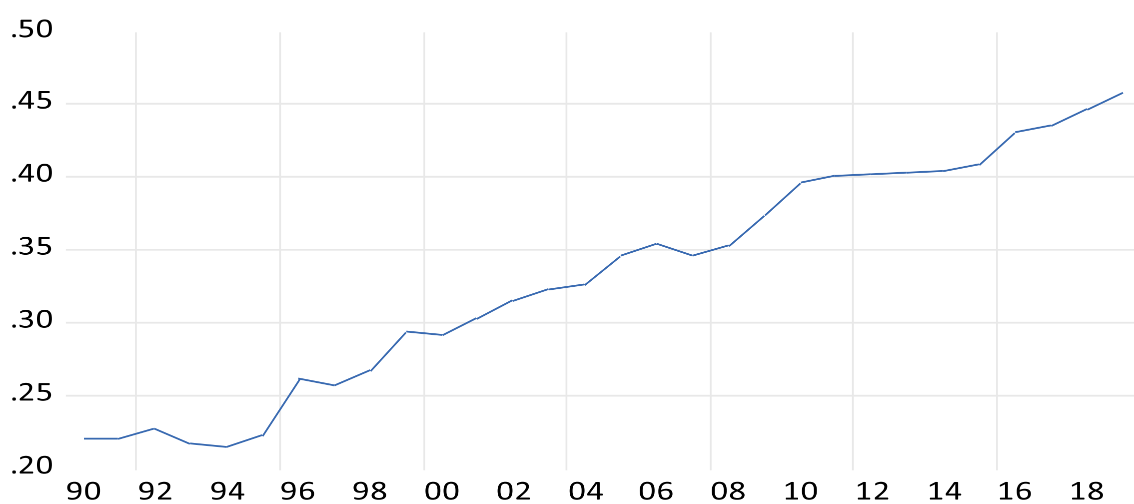

Fig. 1 The trend of CO_2 emissions in ECOWAS from 1990 to 2019

Following this introduction, the remainder of the paper comprises the following sections: A succinct summary of the pertinent literature is provided in "Literature review" section. The data and econometric techniques are covered in "Methodology" section. The empirical findings are presented and discussed in "Results and discussion" section. "Conclusion and policy ramifications" section presents the conclusion and policy ramifications.

Literature review

During the last decades, many scholars have explored the factors influencing *EQ*, CO_2 emissions in particular. The seminal work of Grossman and Krueger [18] demonstrated an inverted U-shaped association between economic growth (income) and *ED*. Environmental Kuznets curve (EKC) is the term given to this connection [19–21]. It contends that income is positively associated with *ED* at the early phases until a certain threshold, beyond which the association becomes negative. Also, A plethora of studies have explored the factors influencing *ED* on different dimensions like the impact of income (affluence) on *EQ* [21–23], the effect of population on *EQ* [24–28] and the interaction between technology and *EQ* [29–31] using a variety of time series and panel models with a range of sample sizes. For instance, on the affluence-*ED* nexus, Phadkantha and Tansuchat [32] using the Markov switching model indicate that rises in income increase *ED* in Thailand. Similarly, Chen et al. [33] found that affluence boosts *ED* while technology mitigates *ED* in Bangladesh from 1972 to 2020. In the case of Egypt, Raihan et al. [34] validate the harmful impact of affluence on *EQ* from 1990 to 2019. Similar findings were established by Raihan and Tuspekova [35] for Kazakhstan, Malik et al. [36] for Pakistan, Udeagha and Breitenbach [37] for South Africa, Patel and Mehta [38] for India, and Liu et al. [39] for China.

Turning to the population-*ED* nexus, Yang et al. [40] and Li et al. [41] demonstrate that low *EQ* is associated with increasing population size in China. On the contrary, employing the ARDL technique, Ali et al. [42] found that increasing population size significantly improved *EQ* in China from 1990 to 2019. Using the log-polynomial estimating approach, Yeh and Liao [43] established a positive association between population and *ED* in Taiwan from 1990 to 2014. Between 1999 and 2014, Hashmi and Alam [26] examine the nexus between population and *ED* in OECD nations and found that population growth harms *EQ*. Studies conducted by Kwakwa and Alhassan [44], Anser et al. [45] and Liu et al. [46] further reinforced the harmful effect of increasing population size on *EQ*. However, Begum et al. [47] document that population growth does not affect *EQ* in the Malaysian context.

Regarding the impact of technology on ED, Hussain and Dogan [48] conducted a panel study of BRICS nations using data from 1992 to 2016. Using the cross-section augmented ARDL approach, their findings suggest that technology negatively influences ecological footprints. The implication is that technology drives *EQ*. A recent study by Chu [49] establishes that technology and renewable energy usage are critical in attaining sustainable development as they reduce environmental degradation. Huo et al. [50] explored the nexus for China using data covering 1991–2017 and the ARDL technique. Technology was found to harm *EQ*. Employing the quantile QARDL model and data from Pakistan from 1980 to 2019, Chien et al. [51] found a negative association between technological innovations and *ED*. The inhibiting effect of technology on ED is supported [31, 52–54].

Theoretically, the association between *FSD* and *ED* is contentious among scholars with conflicting viewpoints. Indeed, a relevant issue that has received much empirical attention over the past few decades is how banking sector development (i.e., *FSD*) affects *ED*. For instance, Samour et al. [1] using the ARDL approach, conclude that *BSD* significantly dampens *EQ* in South Africa for the period covering 1986–2017. Therefore, an increase in credit from the banking sector will result in investments in projects and expansions and an enhancement of risk mitigation mechanisms, which would influence economic growth and energy demand, increasing CO_2 emissions. Mehmood [16] using data from N-11 countries and the cross-sectional ARDL approach, established that *BSD* has a significant positive association with CO_2 emissions. Regarding OECD economies, Radulescu et al. [10] demonstrated that *BSD* has a deleterious impact on environmental sustainability. Employing the Methods of Moments—Quantile Regression, Chien et al. [55] found that *FSD* and economic growth significantly harmed *EQ* in BRICS from 1995 to 2018. This finding is validated by Yang et al. [17] for the period 1990–2016. Similarly, Baloch et al. [56] established that *FSD* increases ecological footprint using the Driscoll–Kraay panel regression model for 59 Belt and Road countries (BRIC). Similar outcomes of the adverse influence of *FSD* on *EQ* were established by Ibrahiem [57] for Egypt, Avom et al. [11] for Sub-Saharan Africa (SSA), Charfeddine et al. [58] for the MENA region, Zakaria and Bibi [59] for South Asia and Musah et al. [9] for West Africa.

On the contrary, Shahbaz et al. [60] showed that *FSD* lessens CO_2 emissions, reducing environmental deterioration in France. Aluko and Obalade [8] highlight that *FSD* contributes to an environmental decline in Sub-Saharan Africa (SSA). However, *FSD* has a dampening technological effect on *EQ*. Park et al. [61] suggested that FSD reduces *ED* by hindering CO_2 emissions in European

Union (EU) economies. Regarding Asia Pacific Economic Cooperation (APEC) countries, Usman and Hammar [6] demonstrated that *FSD* and renewable energy usage positively impact *EQ*. Saidi and Mbarek [62] found that *FSD* mitigates *ED* in emerging economies. Applying the ARDL model, Salahuddin et al. [63] found an inverse association between *FSD* and *ED*. Dogan and Seker [64] discovered that *FSD* had a dampening influence on CO_2 emissions in top renewable energy countries. Focusing on G-7 and N-11 nations, Zafar et al. [7] found evidence that *BSD* promoted *EQ*. Using data from 54 developing economies, Yang et al. [65] demonstrate that financial instability enhances *EQ* by reducing CO_2 emissions.

Some studies also established the neutral impact of *FSD* on *ED*. For example, Adams and Klobodu [66] using a panel of 26 African nations, concluded that *FSD* is an insignificant determinant of *EQ*. Studies like Omri et al. [67] for MENA countries, Jamel and Maktouf [13] for European countries, and Maji et al. [12] for Malaysia confirm the neutral effect of *FSD* on *EQ*. The empirical works of Acheampong et al. [68] and Acheampong [69] demonstrate that the impact of *FSD* on *EQ* is contingent on the measure of *FSD*, the sampled period, and the countries under study. Fakher and Ahmed [70] observed that *FSD* magnifies the positive impact of technology on EQ using a sample of 25 OECD nations.

Thus, there is no unanimity among the findings of different studies worldwide. Furthermore, there is a paucity of studies that address this critical connection between *BSD* and *EQ*, as well as the technological impact of *BSD* on *EQ* generally and in the ECOWAS region specifically. The authors are aware of no empirical work in ECOWAS that examines these nexuses. Additionally, most of these studies fail to consider critical panel data issues like CSD and slope homogeneity, which might generate biased conclusions. This study, therefore, examines the case of ECOWAS while accounting for cross-sectional dependence and slope homogeneity by using appropriate second-generation and long-run estimators such as the augmented mean group estimator and the Driscoll–Kraay panel regression model.

Methodology

Empirical model

The study adheres to the conceptual framework of the STIRPAT model [71]. The STIRPAT argues that environmental degradation results from affluence, technological changes, and population. The STIRPAT model is an improvement on the IPAT model [72] by transforming it into a stochastic model. The IPAT model is a mathematical identity that presupposes proportionality among these determinants in the functional association and does not permit hypothesis testing [73]. This limitation was overcome by the STIRPAT model, which also offered a theoretical foundation for understanding how population growth, technological advancements, and affluence affect *EQ*. The STIRPAT model has been modified in several studies to include additional critical determinants of environmental degradation [8, 11, 29, 74–77]. The following equation gives the basic STIRPAT:

$$I_{it} = \alpha P_{it}^{\partial} A_{it}^{\varphi} T_{it}^{\omega} \varepsilon_{it} \tag{1}$$

In model 1, I is environmental degradation, α is the constant, while ∂, φ and ω denote elasticities of population (P), affluence (A), and technology (T), respectively. ε is the residual term, and subscripts i and t are the cross-sectional unit (i.e., country) and time period, respectively. The STIRPAT model is linearised by taking the natural logarithm (ln) form, which is written as:

$$\ln I_{it} = \ln \alpha + \partial \ln P_{it} + \varphi \ln A_{it} + \omega \ln T_{it} + \varepsilon_{it} \tag{2}$$

We modify the STIRPAT model by integrating lnBSD to reflect the impact of BSD on ED. The modified STIRPAT model is stated as follows:

$$\ln \mathrm{ED}_{it} = \ln \alpha + \partial \ln P_{it} + \varphi \ln A_{it} + \omega \ln T_{it} + \rho \ln \mathrm{BSD}_{it} + \varepsilon_{it} \tag{3}$$

To explore the technological effect of lnBSD on lnED, we examine if ln$T$ moderates the lnBSD—lnED nexus. Model 3 was thus modified by incorporating an interactive term of lnBSD and ln$T$ ($\ln \mathrm{BSD} \times \ln T$):

$$\begin{aligned} \ln \mathrm{ED}_{it} = & \ln \alpha + \partial \ln P_{it} + \varphi \ln A_{it} + \omega \ln T_{it} \\ & + \rho \ln \mathrm{BD}_{it} + \vartheta (\ln \mathrm{BSD} \times \ln T)_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

In this study, the impacts of banking sector development (lnBSD), population (ln$P$), affluence (ln$A$), technology (ln$T$), and technology effect of *BSD* (lnBSD×ln$T$) on environmental degradation (lnED) are empirically examined with the aid of AMG estimator [78, 79] which accommodates a common dynamic mechanism and takes into account CSD $\hat{\mu}_t^*$ in the country regression. Additionally, the AMG estimator exhibits acceptable bias and RMSE performance and is resilient to CSD and nonstationary data. The AMG estimate goes through two phases:

$$\text{Phase 1}: \ \Delta Y_{it} = \beta' \Delta X_{it} + \sum_{t=2}^{T} c_t \Delta D_t + \varepsilon_{it} \rightarrow \hat{c}_t = \hat{\mu}_t^* \tag{5}$$

$$\text{Phase 2}: \ Y_{it} = \emptyset_i + \beta' X_{it} + d_i \hat{\mu}_t^* + \varepsilon_{it}; \hat{\beta}_{AMG} = N^{-1} \sum_i \hat{\beta}_i \tag{6}$$

where Δ is the first difference operator, $\emptyset_i$ is the intercept, ε_{it} is the residual term and $\hat{\beta}_{\mathrm{AMG}}$ denotes the AMG estimation. $\hat{\mu}_t^*$ is the time dummy parameter. Lastly, the path of causality was examined using the Dumitrescu and Hurlin [80] panel causality test, which produces unbiased outcomes in small and large heterogeneous panels and is robust to CSD.

Data and variables

In this study, panel data are employed because they can be used to analyse outcomes that are difficult to identify in time series or cross-section data [81]. We used a balanced dataset for eleven Economic Community of West African States (Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, Ghana, Guinea, Niger, Nigeria, Senegal, Sierra Leone, and Togo) covering the period 1990–2019. Only ECOWAS nations with data for the chosen variables were captured in this paper. The WDI database is the source of all data. Environmental degradation was measured using CO_2 (emissions per capita) [24, 57, 82–84], banking sector development is proxied by domestic credit to the private sector by banks (% of GDP), GDP per capita (constant 2015 US$) measures affluence [8, 29, 85, 86]. The technological effect (T) is the industry sector value added (% of GDP). Modern technologies are introduced during industrialisation to produce new and old goods. As a result, industrialisation has frequently been employed as a technology indicator [8, 73, 82, 87]. The technological effects of BSD ($\ln BSD \times \ln T$) are the interaction between lnBSD and $\ln T$. In sync with most empirical papers, the aggregate population of a nation is used as a proxy for population. ED is more pronounced in economies with high populations [88]. All variables were transformed into their natural logarithmic forms for easy analysis and interpretation of results.

Table 1 presents the descriptive statistics of the variables. lnA and lnBSD are the only variables that are not negatively skewed. All variables, except population, which has a leptokurtic distribution, can be seen to have a platykurtic distribution. The correlations among the study variables are highlighted in Table 2. All the regressors are positively correlated with lnED. However, an insignificant correlation was established between lnP and lnED. A strong correlation coefficient of 0.832 was observed between lnA and lnED, indicating a strong correlation between these variables. A moderate correlation was established between lnBSD and lnED. The explanatory variables have modest correlation coefficients, with the maximum correlation coefficient being 0.505. This indicates the absence of multicollinearity issues among the variables. According to Gujarati [89], the problem of collinearity is present if the correlation coefficient exceeds 0.8. Figure 2 illustrates the associations between the variables in a graphical format.

Table 1 Descriptive statistics

	lnED	ln*A*	ln*P*	ln*T*	lnBSD
Mean	−1.420	6.795	16.119	3.043	2.411
Maximum	0.119	8.107	19.119	3.659	4.179
Minimum	−3.108	5.809	12.731	1.516	0.420
SD	0.845	0.599	1.316	0.343	0.764
Skewness	−0.300	0.303	−0.454	−0.013	0.283
Kurtosis	2.095	1.964	4.418	2.695	2.825
Observations	330	330	330	330	330

Table 2 Pairwise correlations

	lnED	ln*A*	ln*P*	ln*T*	lnBSD
lnED	1.000				
ln*A*	0.832***	1.000			
ln*P*	0.077	0.108**	1.000		
ln*T*	0.216***	0.129**	0.203***	1.000	
lnBSD	0.564***	0.505***	−0.248***	−0.034	1.000

*** and ** indicate significance at 1% and 5% levels, respectively

Results and discussion

Preliminary analysis

CSD may arise from globalisation which has brought dependence on economies in one region. Regression estimations could be biased and inconsistent if this problem is not resolved. This study begins its empirical analysis by conducting a CSD test for all three functional forms. Three different CSD approaches, Pesaran et al. [90] LM test, Breusch and Pagan [91] LM test, and Pesaran [92] CSD test were applied in this study. The outcomes of the CSD tests are reported in Table 3. All three tests reveal no cross-sectional independence in the panel models. The outcomes suggest that CSD exists; hence, employing an estimating approach that considers CSD is imperative. It is, therefore, appropriate for us to apply the AMG estimator.

The presence of CSD rules out the use of first-generation panel stationarity tests owing to its stringent requirement of cross-section independence. Hence, using the first-generation stationarity tests might generate biased outcomes. Thus, we utilise a second-generation panel unit root test known as the cross-sectionally augmented IPS (CIPS) proposed by Pesaran [93], which checks the unit root properties of variables under the assumption of CSD. As displayed in Table 4, we failed to confirm the H_0 of nonstationary for all the variables except $\ln A$, which

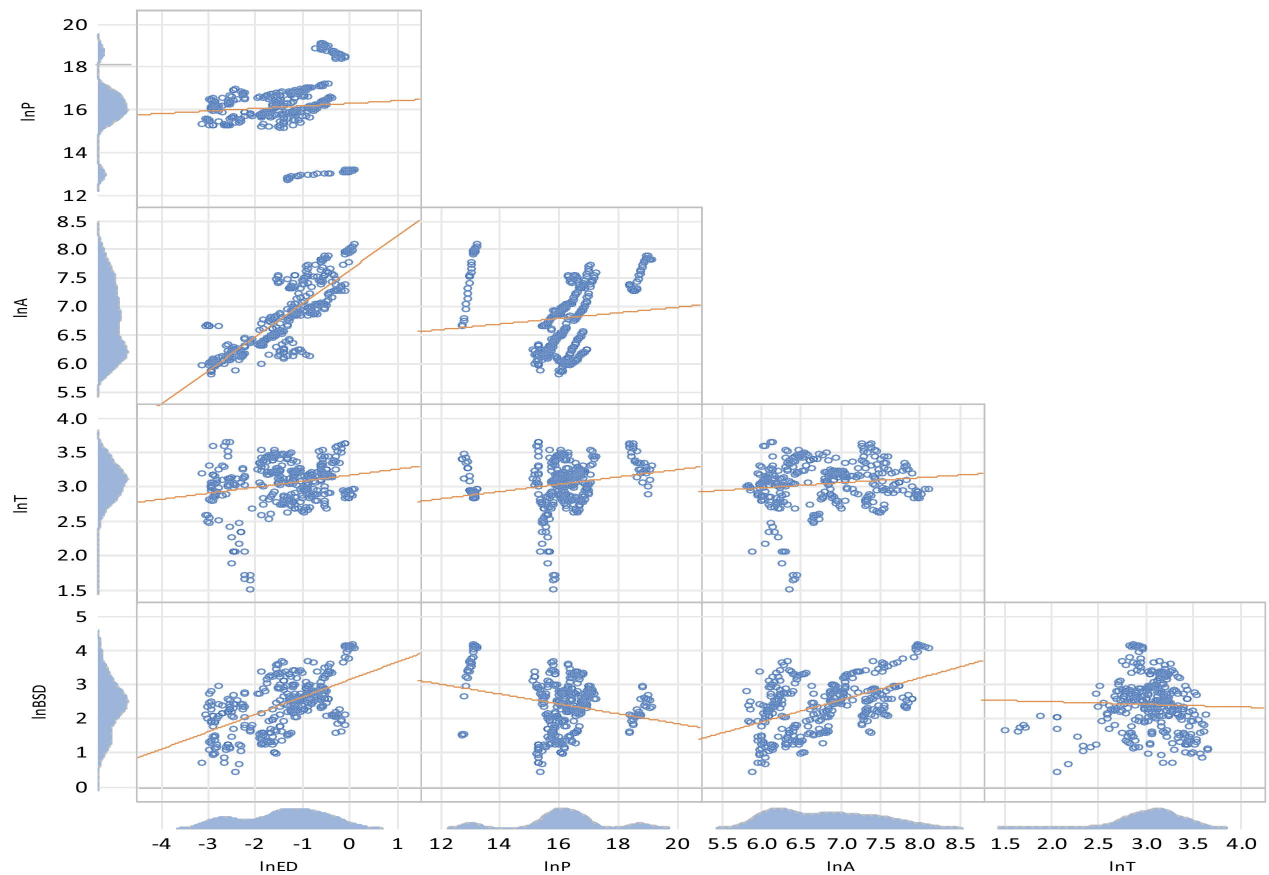

Fig. 2 Scatter plot of the lower triangular matrix, kernel density of regression line variables

Table 3 Outcomes of CSD tests

Test	lnED = *f* (ln*P*, ln*A*, ln*T*)		lnED = *f* (ln*P*, ln*A*, ln*T*, lnBSD)		lnED = *f* (ln*P*, ln*A*, ln*T*, lnBSD, lnBSD x ln*T*)	
	Statistic	***p* value**	**Statistic**	***p* value**	**Statistic**	***p* value**
Breusch–Pagan LM	442.098***	0.000	312.297***	0.000	311.782***	0.000
Pesaran scaled LM	36.908***	0.000	24.532***	0.000	24.483***	0.000
Pesaran CD	9.975***	0.000	4.345***	0.000	4.232***	0.000

***Indicates significance at 1%

Table 4 CIPS stationarity test

	lnED	lnBSD	ln*P*	ln*A*	ln*T*	lnBSD × ln*T*
Levels	− 2.480***	− 2.696***	− 3.568***	− 1.300	− 2.289**	− 2.584***
1st difference				− 4.016***		

*** and ** indicate CIPS statistic > critical value at 1%, 5%, and 10% levels, respectively. H_0 (homogeneous non-stationary): bi = 0 for all i

Table 5 Westerlund test for cointegration

Test	lnED = *f* (ln*P*, ln*A*, ln*T*)			lnED = *f* (ln*P*, ln*A*, ln*T*, lnBSD)			lnED = *f* (ln*P*, ln*A*, ln*T*, lnBSD, lnBSD × ln*T*)		
	Value	z-value	*p* value	Value	z-value	*p* value	Value	z-value	*p* value
G_t	−3.644	−4.962	0.000	−3.709	−3.091	0.001	−3.513	−3.017	0.001
G_a	−7.239	1.677	0.953	−0.884	6.322	1.000	−2.422	0.779	0.782
P_t	−9.831	−3.275	0.001	−6.945	−8.875	0.000	−3.969	−6.271	0.000
P_a	−2.637	2.440	0.993	−6.945	1.771	0.962	−2.392	0.883	0.811

H_0 No cointegration

Table 6 AMG test results

	1	2	3
Constant	−19.511*** (5.337))	−21.204*** (5.116)	−17.112*** (4.154)
ln*P*	0.736*** (0.279)	0.833*** (0.262)	0.586*** (0.152)
ln*A*	0.852*** (0.257)	0.887*** (0.255)	1.246** (0.564)
ln*T*	0.154 (0.128)	0.221* (0.118)	−0.671 (0.529)
lnBSD		−0.120** (0.052)	−1.327** (0.586)
lnBSD × ln*T*			0.415** (0.207)
Wald x^2	14.51***	30.15***	38.08***
Root MSE	0.110	0.102	0.093
Residual order of integration	*I*(0)	*I*(0)	*I*(0)
CSD test statistic [*p* values]	0.69 [0.489]	0.64 [0.524]	1.20 [0.229]
Number of observations	330	330	330

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

became stationary after the first differencing. This shows that none of the variables are $I(2)$. The AMG estimator may produce spurious results in the presence of $I(2)$ variables.

After establishing the presence of an $I(1)$ variable in the panel series, the next logical step is to test for cointegration among the models. The Westerlund [94] cointegration test is based on four different types of statistics: group statistics (G_t and G_a) and Panel Statistics (P_t and P_a). From Table 5, the Westerlund panel cointegration test results are mixed in all panels and groups for the three models. The results of G_a and P_a confirmed the H_0 of no cointegration. At the same time, G_t and P_t failed to confirm the $H_{0,}$ indicating the existence of cointegration in the STIRPAT and modified STIRPAT models. This shows that the regression results are valid and that there are long-term interactions among the variables. However, It is worth noting that the lack of cointegration does not impose restrictions on the AMG estimator [78, 95].

Table 6 summarises the results of the AMG estimator. The findings suggest that ln*P* significantly positively affects lnED, as shown in columns 1–3. A 1% rise in ln*P* increases lnED by 0.586–0.833%. Thus, a surge in ln*P* promotes lnED because a rise in ln*P* drives the demand for non-renewable energy consumption, increasing the volume of GHGs emitted into the atmosphere [5]. This outcome of the study confirms those of Ghazali and Ghulam [25], Hashmi and Alam [26], Acheampong et al. [96], Opoku and Aluko [29], Aluko and Obalade [8], and Li and Lin [73] which shows a rise in population lower *EQ*. Franklin and Ruth [97] argued that ln*P* and other socioeconomic factors exert massive pressure on natural resources leading to *ED*. ln*A* is positively associated with lnED at least at the 5% significance level. This supposes that a rise in lnA harms *EQ*. From the analysis, a percentage rise in ln*A* will result in a 0.852–1.246% increase in lnED. The harmful effect of affluence suggests that a rise in the income levels of citizens increases the demand for goods and services, driving energy consumption which consequently drives the degradation of the environment in ECOWAS. This evidence corroborates the findings of Mohsin et al. [98], Pham et al. [99], Wang and Dong [100], and Anwar et al. [101], which also found an unfavourable impact of ln*A* on lnED. Adams and Klobodu [66] attributed the harmful impact of ln*A* on lnED to the prevalence of less effective production methods and procedures on the African continent.

We found a neutral effect of ln*T* on lnED in columns 1 and 3. However, in Column 2, we established a positive but marginally significant (p value < 0.1) association between ln*T* and lnED. The outcome indicates that lnED will likely increase by 0.221% should ln*T* increase by 1%. This finding corroborates the findings of Usman and Hammar [6], Gu and Wang [102], Kivyiro and Arminen [103] and Yongping [104], which claimed that technology might promote *ED* due to inadequate funds allocated to research and development (R&D) for the desired level of technology to be attained. This finding also supports Jevon's Paradox [105] which posits that technological advancements lead to a rise in energy consumption, thereby increasing CO_2 emissions. Also, this finding resonates with the rebound effect theory, a scenario in which technological advancements result in lower energy prices for energy-related products and services—thereby stimulating demand.

lnBSD significantly hinders lnED in both Columns 1 and 2. A percentage rise in lnBSD will significantly reduce lnED by 0.120–1.327%. Thus, we discover evidence that *BSD* amplifies *EQ* in ECOWAS nations. This finding agrees with Aluko and Obalade [8] for SSA countries and Usman and Hammar [6] for APEC nations. However, it contradicts the findings of Mehmood [16] and Samour et al. [1] which found a deleterious impact of *FSD* on *EQ* for South Africa and N-11 economies, respectively. As posited by Jiang and Ma [106], developments in the financial sector increase lnED by making funds/loans available to individuals and households that promote the acquisition of energy-consuming appliances such as automobiles and equipment. Mehmood [16] contends that increased bank lending to the private sector will boost economic activity and increase energy usage. The outcome of this paper, however, suggests that lnBSD can enhance *EQ* in ECOWAS by channelling funds toward investments in environmentally friendly technologies.

Focusing on the interactive term of *BSD* and technology (lnBSD × ln*T*), we establish a significant positive association between lnBSD×ln*T* and lnED. The finding demonstrates an adverse technological effect of lnBSD and shows that ln*T* complements lnBSD to raise lnED. Financial sector developments may promote technological advancements driving energy demand [5, 70, 107]. lnBSD may channel its dampening effect on lnED through lnT by increasing firms' ability to access low-cost financing to expand their operations, acquire more machines and plants and create more jobs leading to a rise in energy consumption [108]. This may have dire consequences on *EQ*. This empirical outcome is similar to the work of Aluko and Obalade (2020), which reflects the harmful technological effect of *FSD* on *EQ*. Regarding the diagnostic tests, the Wald x^2 for all the estimations are significant at 1%, indicating that the results are valid for making predictions. The residuals are also free from strong CSD. Strong CSD in residuals may render statistical conclusions invalid.

To ascertain the robustness of the AMG estimates, we have applied the Driscoll and Kraay [109] standard error test, which is resilient to cross-sectional dependence and heteroscedasticity [21] and Table 7 presents the findings. As is evident, the outcomes corroborate the AMG estimates.

The AMG estimator only estimates the magnitude of the long-run association among the variables. Knowing the path of causality of these associations (+ or –) is critical to suggest some practical policy ramifications.

Table 7 Driscoll–Kraay standard errors test results

	1	2	3
Constant	–20.175*** (1.976)	–21.133*** (2.133)	–20.636*** (2.031)
ln*P*	0.831*** (0.102)	0.856*** (0.093)	0.846*** (0.093)
ln*A*	0.687*** (0.060)	0.802*** (0.133)	0.814*** (0.148)
ln*T*	0.085 (0.059)	0.225** (0.092)	0.083 (0.197)
lnBSD		–0.223** (0.088)	–0.322*** (0.039)
lnBSD × ln*T*			0.770*** (0.109)
F-statistic	109.45***	107.70***	212.12***
within R-squared	0.56	0.56	0.57
Number of observations	330	330	330
Number of Groups	11	11	11

*** and **indicate significance at 1% and 5%, respectively

Table 8 Dumitrescu and Hurlin Granger non-causality test outcomes

Null hypothesis	W-Stat	Zbar-Stat	Prob	Causality
ln*P* ≠> lnED	9.008	9.382	0.000	Yes
lnED ≠> ln*P*	23.004	28.643	0.000	Yes
ln*A* ≠> lnED	6.213	5.535	0.000	Yes
lnED ≠> ln*A*	7.959	8.058	0.000	Yes
ln*T* ≠> lnED	2.568	0.519	0.604	No
lnED ≠> ln*T*	4.535	3.227	0.001	Yes
lnBSD ≠> lnED	7.569	7.401	0.000	Yes
lnED ≠> lnBSD	1.761	–0.591	0.555	No

The sign ≠> indicates no causality between the specified variables

In the presence of CSD, we applied the Dumitrescu and Hurlin [80] Granger non-causality test which accounts for CSD. The results of the D-H panel causality test of lnED and determining factors (ln*P*, ln*A*, lnT and lnBSD) are reported in Table 8. The findings indicate a two-way causality between lnP and lnED and lnA to lnED. The directional relationship between lnA and lnED is in sync with Ibrahiem [57] which supports the interdependence between ln*A* and lnED. ln*A* causes lnED, and lnED causes lnA in ECOWAS, and this is consistent with the literature because ECOWAS member states are developing nations with low-income levels. The unidirectional causality from lnBSD to lnED was anticipated. Advancement in the banking sector enables industries to access cheaper sources of funds for expansion and purchase of machinery which promotes economic growth but drives energy usage, consequently releasing harmful emissions. Furthermore, the analysis discovered a one-way causality from lnED to ln*T*. lnED causes ln*T*, and technology encourages using clean energy sources, promoting *EQ* by mitigating CO_2 emissions.

Conclusion and policy ramifications

The globe has seen increased attempts to stem the rising tide of environmental degradation in an effort to attain the Sustainable Development Goals (SDGs). As scholars are finding ways to improve environmental quality, we explored the modified STIRPAT model by incorporating banking sector development and the interactive term of technology and banking sector development using a balanced panel of 11 ECOWAS member states for the period 1990–2019 using the AMG Estimator and Kraay standard error test. In addition, we explored the path of causality between environmental degradation and its determinants.

After considering cross-sectional dependence, the empirical findings demonstrate cointegration in all STIRPAT and modified STIRPAT models. The findings suggest that population and affluence are positively associated with environmental degradation. Thus, ECOWAS countries with larger populations and greater affluence are associated with higher rates of environmental degradation. However, we discovered that the model determined how technology affected environmental deterioration. Technology is, therefore, not a robust determinant of environmental degradation in ECOWAS. Banking sector development is negatively associated with environmental degradation, and this indicates that banking sector development improves environmental quality in ECOWAS. The results further suggest that technology moderates banking sector development to increase the intensity of environmental degradation. The technological effect of banking sector development is, therefore, harmful to environmental quality. Additionally, the findings of the Dumitrescu Hurlin panel Granger non-causality tests showed that population, affluence, and banking sector development could all be used to predict future environmental quality in the sub-region.

In view of policy ramifications, ECOWAS nations must promote banking sector development by implementing policies intended to enhance their banking institutions and the financial sector as a whole since this has the potential to lessen environmental degradation. Considering the harmful technological effect of banking sector development on environmental quality, it would be crucial for banking institutions to ensure that funds are made available for firms at a cheaper rate to encourage them to adopt energy-efficient technologies. Governments can also support innovative ideas to install ecologically friendly technologies. This will undoubtedly boost the use of contemporary clean energy instead of non-renewable sources. Future environmental regulations should also mandate that businesses and industries reveal their environmental performance. The study also suggests that firms in the nations, especially large multinational firms, integrate sustainable development practices into their reporting cycle per SDG 12. Environmental regulators could also employ other tools to mitigate environmental degradation including emissions trading, caps, and taxes. Also, it is necessary to control population growth to keep it from exceeding the ecosystem's carrying capacity. This can be done by creating a demographic policy. Finally, ensuring that country-specific heterogeneous effects are considered when executing an environmental quality strategy is essential. The ramifications of policy extend beyond the ECOWAS nations to other developing regions. If considered, the abovementioned policy ramifications will assist ECOWAS in addressing SDG 13, which addresses climate change and its dire effects.

Notwithstanding the considerable methodological and policy ramifications, this study has shortcomings worth addressing. ECOWAS countries were the primary focus of the paper. However, as some other countries are also dealing with high population growth, rising levels of wealth, and advanced technology, the underlying analytical framework and line of inquiry may be extended to other countries, particularly emerging economies and regions. The study only focused on how bank-based financial development influenced environmental degradation in ECOWAS. It would be interesting to comprehend how market-based development and the overall development of the financial sector also influence environmental quality in ECOWAS.

Abbreviations

ED Environmental degradation
EQ Environmental quality
FSD Financial sector development
BSD Banking sector development
AMG Augmented mean group
CSD Cross-sectional dependence

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Author contributions

KBP and FKD contributed to conceptualisation and original write-up. JMF and KBP helped in literature review, methodology, proofreading, and editing. SAY and KBP done model estimation, discussion, and conclusion. The paper has been reviewed and accepted by all authors.

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Availability of data and materials
The sources of data used in the study are mentioned in the manuscript. However, we declare that if needed, data used in the study and other related materials can be provided by the corresponding author.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflict of interest.

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