Econometric Research in Finance • Vol. 8 • No. 1

On Interaction of the Green Growth and Environmental Quality in ECOWAS: Environmental Regulation

Rahman Olanrewaju Raji[*][♣]

[♣]Canterbury International High School, Nigeria

Submitted: November 2, 2023 • Accepted: December 31, 2023

ABSTRACT: This paper explores the impact of environmental regulations on environmental quality and green growth, utilizing panel data from six ECOWAS economies. The study employs the CSD-PLS framework, incorporating the Dumitrescu-Hurlin's panel test, covering the period from 2000 to 2020 with quarterly data. The regression model applied to panel data reveals an inverted U-shaped interaction between environmental regulation and environmental destruction in selected ECOWAS economies, indicating the presence of innovation compensation. Additionally, a U-shaped relationship is identified between environmental regulations and green growth, aligning with the Porter hypothesis. The findings suggest that effective environmental protection policies reduce environmental destruction and promote green growth in ECOWAS economies. Supportive environmental protection policies encourage enterprises to develop environmentally friendly technological and business innovations, which mitigates environmental pollutant emissions and energy consumption, fostering environmental sustainability and green growth.

JEL classification: O31, O44, O55.

Keywords: Environmental Regulation, Environment Quality, Green Growth, Technological Innovations.

---

[*] Corresponding Author. E-mail: rahmandole@gmail.com

DOI: 10.33119/ERFIN.2023.8.1.2

© 2023 The Author(s). Licensed under the Creative Commons Attribution 4.0 International License.

1 Introduction

It is believed that interconnectivity and interdependence between the economy and the environment have impacted both economic and social development of every society. The more economic activities expand, the greater their impact on the environment and vice versa. Sustainable development is in joint action with the economic growth and environmental quality along with social progress. What follows is the fact that the joint economy-equity-environment system tends to satisfy the demands of current generations without undermining the ability of next generations to accomplish their own necessities as a result of unthreatened processes. A threat to the processes of the joint economy-equity-environment system leads to inability to satisfy the demands of current generations and undermining the ability of next generations to accomplish their own necessities. This is a result of unsustainable processes leading to market failure. Qi et al. (2016) suggests that environmental regulations have a tendency to contribute to emission reduction effect resulting in conducive economic development while a strong institutional environment tends to amplify positive effect and ensure slow down distortion effect of monitoring policies which could yield environment-economy balance.

Market failures potentially have devastating consequences and might establish situations that are not socially optimal. This might be the result of economic agents making decision to exploit the environment on the basis of their own benefit without considering the negative impact of their actions on the environment, since there is no monetary punishment or sufficient discouragement from generating negative externality. Consequently, markets produce too much of the negative externality, thereby exacerbating the negative external effect as could be seen in the GHG emissions. Carbon dioxide is a greenhouse gas, and the rise in its levels is most closely associated with human activity. Pollution, extreme weather conditions and food production are the main contributors to greenhouse gas emissions, due to industrial activities. Since economies tend to specialize in those industries which result to comparative advantages, they strengthen the volume of productive activities and heighten the level of CO2 emissions. This leads to the conclusion that as economic globalization widens the volume of CO2 emission becomes larger as long as non-renewable energy technologies are still in use. It implies that there is a high probability of environmental degradation in the societies and the economies at large. Lobato et al. (2021) opines that strict regulatory policy raises the level of polluting behavior by enterprises in order to boost production as a means of compensating for the emission reduction cost. This, in turn, results in environmental degradation and inhibits high-quality economic growth. Yang et al. (2012) reiterates that environmental regulation promotes technological innovation which improves the production cost of enterprises and could form a competitive advantage. Zhao et al. (2022) argues that the influence of environmental regulations on carbon emission reduction promotes positive improvement in the efficiency of power plants and drastic reduction of carbon emission in Chinese economy. Similarly, Bel and Joseph (2018) argue that mounting pressure of environmental stringency policy in EU economies enhances green growth, which, in turn, improves environmental quality. Castellacci and Lie (2017) further report that technological innovations and pollution emission reduction of industries in China, driven by environmental innovation and environment stringency policies, claim viable green growth in the economy. Since CO2 emissions are a major factor influencing environmental quality and have adverse implications for the health of society, failure to detect or develop efficient environmental policies and energy technologies which could mitigate the wastage of energy resource or the escalation of CO2, might pose a real threat to human life. As CO2 density raises, it tends to migrate to lower altitude in the atmosphere and build up at ground level. This might lead to negative impacts on human health and adverse effect on labour productivity. An unhealthy population tends to be more susceptible to disease, dizziness, headaches, visual and hearing impairments and finally unconsciousness. Additionally, they may experience reduced energy levels, leading to lower productivity. This tends to impede economic growth and earnings. Moreover, a population suffering from poor health is likely to undergo a significant decline in mental capacity, cognitive abilities, and academic performance. This ultimately results in diminished work productivity, particularly for tasks that demand higher-level thinking.

Environmentalists, policy makers and researchers are concerned about the rate at which environmental degradation is escalating driven by CO2 emission as well as energy consumption in global economies. To transform the existing trade off relationship between economic growth and environmental quality, it has become a must to establish political will necessary to institute stringent environmental policies which could overcome environmental challenges and threats. Through the implementation of such policies and environmental innovation, there is tendency to achieve sustainable growth. However, failure to promote stringent environmental policies alongside innovation will result in continued environmental challenges and threats adversely impacting the long-term health status of people, and exerting negative effects on the cognitive functioning, productivity and efficiency of the working population. Consequently, this might generate further loss of economic growth and development. The existing studies on the effect of environmental regulation on the environmental quality have produced conflicting outcomes making it difficult to precisely infer the influence of environmental regulations on green growth. Previous research on this debate has been conducted for developed and developing countries across Europe, Latin America, and Asia. However, Sub-Saharan Africa including ECOWAS states (Benin Republic, Burkina Faso, Cabo Verde, Cote D'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger Republic, Nigeria, Senegal, Sierra Leone and Togo) has received much less attention in studies. This study distinguishes itself from existing research by adopting ecological footprint as a reasonable proxy for environmental quality, while green growth replaces common economic growth captured by pollution-adjusted GDP. Unlike previous studies, which measure environmental quality and economic growth using CO2 emissions and GDP growth, respectively. This study assesses the impact of environmental regulation on environmental quality and green growth with econometric models in order to comprehend strategies and policy directions for the improvement of sustainability in the ECOWAS economies. In view of the reality, our research hypothesis/research questions include; there is no significant relationship between environmental regulation and environmental quality in ECOWAS economies/what are the impacts of environmental regulations on environmental quality in ECOWAS economies? Secondly, there is no significant connection between environmental regulations and green growth in ECOWAS economies/How have environmental regulations affected green growth in ECOWAS economies? Finally, there is no significant relationship towards a balance between green growth and environment in ECOWAS economies/provided effective environmental regulations, could there be a balance between the economy and the environment in ECOWAS economies?

2 Literature review

2.1 Theoretical issues

Theoretical studies attribute the existence of market failure to the unregulated activities of economic agents in production, resulting in negative externalities. Chen (2009) explains that when polluting behavior is left unregulated, it tends to affect economic progress. If pollution emissions grow at a level lower than the natural environmental carrying capacity, there is a tendency for achieving a positive impact of economic progress, as the natural environment can dissipate the waste through self-cleaning processes. If the natural environment's carrying capacity is lower than the pollutant emission level, it implies that firms and industries achieve economic progress through high energy consumption resulting in high pollution with high emissions. Continuous pollutant emission threaten environmental quality, triggering negative externalities and eventually inhibiting economic development. Due to environmental destruction and the desire for long-term sustainable development, society initiates environmental regulation or protection mechanisms to prevent and check pollutant emission levels. This is done in order to sustain resources, the environment and the economy. With regard to environmental regulation, environmental quality and economic growth (green growth), there is a scholastic argument that environmental regulations tend to weaken economic growth, termed as the cost of compliance theory or the "constraint hypothesis". It argues that strict environmental regulation increases production cost, which in turn negatively affects firms or industries' profitability. This may lead some enterprises to be forced out of business or to relocate to areas with less stringent regulation, often referred to as pollution havens. This, in turn, threatens environmental quality and damages economic progress (Greenstone et al., 2012; Barbera and McConnell, 1990). On the other hand, these regulations can strengthen economic growth and promote environmental progress, a theory known as the innovation compensation hypothesis or the Porter hypothesis. It claims that environmental regulations stimulate business innovation and technological innovation. The theory argues that with appropriate and effective environmental regulations, firms and industries are compelled to design technological innovations aimed at reducing environmental pollutant emission and energy use. This could stimulate business innovation, leading to economic progress, improved economic development, and enhanced environmental quality (Zhu et al., 2014; De Santis and Jona-Lasinio, 2015; Li and Li, 2021; Cohen and Tubb, 2018).

2.2 Empirical evidence

Chen et al. (2022) examined the interaction of strict regulations and related environmental policies on the ecological footprint for the Organization for Economic Cooperation and Development (OECD) and non-OECD (non-members of OECD) economies from 1990 to 2015. The CS-ARDL and the augmented mean group (AMG) techniques confirmed that environmental taxes, stringent environmental policies, and ecological innovation significantly improved environmental quality in OECD compared to the non-OECD countries. In similar findings, Wolde-Rufael and Weldemeskel (2020) explored the impact of stringent environmental policies on CO2 emissions in the BRICS countries, plus Indonesia, and Turkey, between 1993 and 2014. Their study depicted an inverted U-shaped interaction between policy regulations and CO2 emissions, indicating an inverse and significant interaction between stringent environmental policies and CO2 emissions.

Demiral et al. (2021) searched for the determinants of CO2 emissions in the 15 emerging countries with the largest greenhouse gas emissions between 1995 and 2015. Their findings discovered that excessive stringent environmental policies had not yielded a drastic decrease in CO2 emissions. This study contradicted Wolde-Rufael and Mulat-Weldemeskel (2022), who revealed the role of environmental policy effectiveness in ensuring drastic reduction in environmental destruction of few emerging economies from 1994 to 2015.

Lin and Li (2011) investigated and found a negative interaction existing between environment-related regulations and CO2 emissions in Finland, while Morley (2012) examined the environmental-related policies and CO2 emissions nexus in EU member nations, showing the inverse relationship between environmental taxes and CO2 emissions. The findings of Lin and Li (2011) and Morley (2012) were in consonance with Shapiro and Walker (2018), who studied the impact of environmental protection on environmental degradation in the USA between 1990 and 2008, and concluded that a reduction in CO2 emissions occurred as a result of effective protection policies. Additionally, Greenstone (2004) studied the effect of environmental protection on SO2 emission in the US in 70s. The findings suggested that environmental regulations did not significantly reduce SO2 emissions, with a series of robust analyses confirming the conclusions.

Ma and Xu (2022) conducted research on the impact of environmental regulation on high-quality economic development using panel data from 30 provinces (cities and regions) in China from 2005 to 2019. They found support for the cost compliance hypothesis, indicating that strict environmental regulation measures inhibited high-quality economic development. Ma and Xu (2022) diverged slightly from Li et al. (2021), who conducted panel findings on 216 prefecture-level cities in China from 2003 to 2016. He emphasized the intensity of environmental regulation on both environmental quality and economic quality (green total factor productivity). Their outcomes indicated that appropriate environmental regulations were conducive to promoting environmental quality and improving urban green growth. This research aligns with Zhu et al. (2019) whose investigation focused on the impact of changes in the stringency of environmental policies on productivity growth in OECD countries. They found that a tightened environmental policy was associated with a short-term increase in industry-level productivity growth, and at the firm level, there was a positive effect on productivity growth from stringent environmental policies.

In conclusion, most existing findings concur that with appropriate and effective environmental regulation, there is a high probability that environmental degradation would be minimized and economic quality or green growth tends to be drastically improved. However, most studies have traditionally adopted CO2 as measure of environmental degradation. Our study replaces it with the ecological footprint, which determines natural resources consumption and production, while green growth replaces common economic growth with pollution adjusted GDP, termed as green growth. Finally, this kind of study is very scanty in Sub-Sahara Africa, specifically ECOWAS economies, indicating a significant gap in research in this region regarding the interplay between environmental regulation, economic growth, and environmental quality.

3 Model estimation

3.1 Panel data regression model

Following the basic structure of the environmental Kuznets curve (EKC) theorized by Grossman and Krueger (1995), which determines the trade-off between the environment and growth, our study assesses the impact of environment regulation on environmental quality and green growth. The aim is to test the possibility of achieving an environment-economy balance. To reveal the accurate quantified effect of environmental regulation on the environment and economy, we analyze relevant data from six countries in ECOWAS economies from 2000 to 2020.

$$EQ_{it} = \beta_0 + \beta_1 log(ER)_{it} + \beta_3 control_{it} + \varphi_i + \emptyset_t + \mu_{it} \tag{1}$$

$$EQ_{it} = \beta_0 + \beta_1 log(ER)_{it} + \beta_2 log(RE)^2_{it} + \beta_3 control_{it} + \varphi_i + \emptyset_t + \mu_{it} \tag{2}$$

$$GG_{Rit} = \beta_0 + \beta_1 log(ER)_{it} + \beta_3 control_{it} + \varphi_i + \emptyset_t + \mu_{it} \tag{3}$$

$$GG_{Rit} = \beta_0 + \beta_1 log(ER)_{it} + \beta_2 log(RE)^2_{it} + \beta_3 control_{it} + \varphi_i + \emptyset_t + \mu_{it} \tag{4}$$

Using the above models, Equation 1 and 2 were formulated to capture the linear and non-linear effects of environmental regulation on environmental quality, where EQ denotes environmental quality. Then, Equation 3 and 4 were designed to capture the linear and non-linear effects of environmental regulation EP on quality of green growth, where GG denotes green growth. Additionally, control it represents control variables related to both environmental quality and green economic growth, which include education ED, renewable energy RE, and non-renewable energy NRE while φ_i, $\emptyset_t$, and μ_{it} represent individual fixed effects, time fixed effects, and the error term, respectively. Our models were estimated using the panel least squares technique along with the cross-section dependence (CSD) test.

CSD is an econometric tool used in panel data empirical research by assess the induction of similar impacts of a particular macroeconomic shock on multiple cross-sectional nations. CSD examines the effects of macroeconomic shocks when representative nations share similar economic features, such as emerging countries and transition economies, due to trade internationalization, financial integration, and globalization. In panel data analysis, cross-sectional dependency poses a significant challenge in empirical studies to avoid biased and inconsistent estimation of stationarity and cointegrating properties of data. Stationarity is critical for all econometric forecasts to obtain accurate estimators, which in turn produce clear and reliable results for appropriate policy recommendations.

Therefore, our study employs the CSD test to determine whether dataset exhibits cross-sectional dependence, as ECOWAS economies are interconnected through globalization. Common stocks tend to predict a simultaneous effect as they induce dependency among countries in the cross-sectional units (Pesaran et al., 2008; Chudik and Pesaran, 2015).

To assess CSD among variables, including residual error, the study employs various CSD test to detect the CSD in the analysis of panel data. These tests include the Breusch-Pagan LM, Pesaran scaled LM test, bias-corrected scaled LM test, and Pesaran CD test. Furthermore, the study checks the robustness of the panel least squares technique with the aid of the panel modified OLS technique. Additionally, Dumitrescu-Hurlin's panel test is used to examine the existence of causal relationships between the variables of interest.

3.2 Data definition and sources

The study has been conducted using interpolated quarterly data spanning from 2000Q1 to 2020Q4 for six ECOWAS countries (Benin Republic, Burkina Faso, Cote d'Ivoire, Ghana, Nigeria and Togo). These periods were chosen because some data were reported in 2000. The data, which are reported annually, include environmental regulation (environmental performance index obtained from Global Metrics for the Environment), environmental quality (ecological footprint sourced from the Global Footprint Network), green growth (pollution-adjusted GDP), renewable energy, non-renewable energy (sourced from World Development Indicators), and education (primary school enrollment sourced from Our World in Data). Since the required data for this study were reported annually, quarterly observations were interpolated from annual data using the method proposed by Lisman and Sandee (1964) with the aid of the Eviews program. This method allows for a more detailed and granular analysis of the data, enabling the study to capture potential variations and trends over time with higher resolution.

4 Empirical analysis of results

4.1 Descriptive statistics of data series

Table 1: Descriptive statistics of data series

	$\log(EQ)$	GG	$\log(EP)$	$\log(RE)$	$\log(ED)$	$\log(NRE)$
Mean	−0.33	8.69	3.84	0.63	4.61	9.73
Median	−0.46	3.07	3.81	0.57	4.61	9.28
Maximum	0.19	1.11	4.09	1.45	4.89	11.82
Minimum	−0.65	−5.77	3.16	−0.06	4.21	7.20
Std. dev.	0.25	1.38	0.19	0.28	0.18	1.47
Skewness	0.80	3.50	−0.57	0.49	−0.08	0.30
Kurtosis	2.04	20.23	3.12	3.10	1.90	1.60

Table 1 presents the summary statistics of the sample data and the variables used for the analysis. The descriptive statistics reveal that the mean values of environmental regulations, education and non-renewable energy over the given period are 3.84, 4.61 and 9.73 respectively, with their median values at 3.81, 4.61 and 9.28 respectively. The maximum values for environmental regulations, education and non-renewable energy are 4.09, 4.89 and 11.82 respectively, while the minimum values for environmental policy, education and non-renewable energy are 3.16, 4.21 and 7.20 respectively. As for dispersion, the three variables recorded low values of standard deviation. The means and medians of all of the variables (environmental regulation, education and non-renewable energy) lie between the maximum and minimum values, implying that the variables have a high tendency to be normally distributed.

The mean values of environmental quality, green growth and renewable energy over the given period are -0.33, 8.69 and 0.63 respectively, with median values of 3.07, -0.46 and 0.57 respectively. The maximum values for environmental quality, green growth and renewable energy are 0.19, 1.11 and 1.45 respectively, whereas the minimum values for environmental quality, green growth, and renewable energy are -0.65, -5.77 and -0.06 respectively. The values indicate that two variables, green growth and non-renewable energy over the given period, have witnessed disparity, which implies that they were high in some years and abysmally lower than the observed average in others. This dispersion is confirmed by the relatively high standard deviation values for green growth and non-renewable energy at 1.38 and 1.46 respectively.

With respect to skewness of the variables, since all of the variables except green growth lie within the range of -1.0 and 1.0, the distributions of the variables are considered symmetrical because the skewness is not substantial. As for the Kurtosis statistic, which measures the peakedness or flatness of the distribution of the series, a Gaussian distribution is expected to have a kurtosis of 3.0. Since all of the variables lie within the range of 3, the implication is that most variables have a high tendency to be normally distributed.

4.2 Results of pre-estimation analyses

In this section, the study presents the results of the cross-section dependency (CSD) tests, which examine the reliance between ECOWAS countries regarding the variables under study. The results are provided in Table 2. The analysis indicates that CSD is present among the variables, as indicated by the array of techniques (Breusch-Pagan LM, Pesaran scaled LM, bias-corrected scaled LM and Pesaran CD) employed for the test. The outcomes of the CSD tests show that there is no CSD among ECOWAS countries for all variables. Therefore the hypothesis is severely rejected by the CSD test findings. This suggests that a change in the factors studied in any of the six ECOWAS countries has an effect on the other. To validate the CSD outcomes, the study further conducts stationary test through panel data unit root test.

Table 2: Cross-sectional dependence test outcomes

	NRE	ED	RE	EP	EQ	GG
Breusch-Pagan LM	370.1080	241.0243	158.2543	480.6094	73.73544	595.8417
	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*
Pesaran scaled LM	63.73811	40.17077	25.05910	83.91281	9.628131	104.9512
	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*
Bias-corrected scaled LM	63.68357	40.11307	25.0045	83.85826	9.573585	104.8967
	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.00000)*
Pesaran CD	18.38334	10.83561	3.085848	19.32775	1.615437	24.26068
	(0.0000)*	(0.0000)*	(0.0020)*	(0.0000)*	(0.1062)*	(0.0000)*

Note: * signifies 1% significance level.

The Im, Pesaran and Shin W-stat panel unit root test is conducted in order to assess the stationarity of the study variables, and the results are presented in Table 3. According to the test results, the null hypothesis stating that the series includes a panel unit root for the level values of all the study variables is not rejected. However, in the first difference form of all study variables, the null hypothesis is rejected, indicating that the series is stationary.

Table 3: Im, Pesaran and Shin W-stat panel unit root test outcomes

	NRE	ED	RE	EP	EQ	GG
Level	0.62812	−4.04025	0.59334	4.49533	2.35934	5.33797
	(0.7350)	(0.0000)*	(0.7235)	(1.0000)	(0.0092)*	(0.0000)*
First difference	1.86529	−2.56624	−6.02052	9.41282	5.20739	3.85178
	(0.0311)***	(0.0051)**	(0.0000)*	(0.0000)*	(0.0000)*	(0.0001)*

Note: *, **, and *** signify 1%, 5% and 10% significance levels respectively.

4.3 Estimation result: impact of environmental regulation on environmental quality

Table 4 presents the impact of environmental regulation on environmental quality, including control variables. Control variables are included to mitigate issues of endogeneity in our study, often caused by variable omission in the model. The inclusion of control variables aims to render the test results more consistent with objective facts. The analysis of the model results is as follows.

A one percent significant relationship exists between the quadratic coefficient and the primary coefficient of environmental regulation and environmental quality. It implies that, the quadratic coefficient of environmental regulation is -0.070, while the primary coefficient is 0.171. This indicates an inverted U-shaped relationship between environmental regulation and environmental quality, where the latter initially increases and then decreases. When the level of environmental regulation is less than 1.2, the critical value $(1.2214 = (0.171/2 * 0.070)$, it verifies an *innovation compensation* effect between environmental regulation and environmental quality. In this scenario the level of environmental quality tends to improve with the intensity of environmental regulation. According to the Porter hypothesis, appropriate environmental regulation can stimulate enterprises to explore technological innovation, which could reduce environmental pollution, thus accompanying green economic growth in ECOWAS economies. However, when the environmental regulation level is greater than 1.2, the critical value, the level of environmental begins to decline due to ineffective and inhibiting environmental regulation instituted by the environmental authorities. As strict environmental regulation increases, it escalates the cost of pollution control and depresses the investment in research and development by business firms and industries, thus inhibiting green growth.

Regarding the co-efficient of control variables, there is a one percentage negative and significant relationship exhibited between green growth and environmental quality, including between renewable energy and environmental quality. A one percent increase in green growth and renewable energy cushions the effect of environmental degradation by 1.2 percent and 0.04 percent respectively, whereas a one percent rise in education and non-renewable energy leads to a decline in environmental quality by 0.20 percent and 0.23 percent respectively. The coefficient of education suggests that the education levels in these economies have not contributed significantly towards green environment and environmental sustainability.

The outcomes of the fully modified OLS technique are reported in Table 5, showing the estimated t-statistics and p-values of the explanatory variables, complementing the conclusion drawn from the ordinary least squares technique adopted in the study.

Table 4: Impact environmental regulations on environmental quality

Variable	Coefficient	t-statistic	p-value
GG	-1.200	-3.61	0.000*
$log(EP)$	0.171	4.83	0.000*
$log(EP)^2$	-0.070	-4.62	0.000*
$log(RNE)$	-0.040	-2.31	0.022***
$log(ED)$	0.203	3.34	0.001*
$log(NRE)$	0.232	8.34	0.000*
C	-8.79	-8.00	0.000*
$R-squared$		0.97	

Note: *, ** and *** signify 1%, 5% and 10% significance levels respectively.

In summary, the quadratic coefficient of environmental regulation is -0.148 at a 1% significance level, while the primary coefficient is 0.358. These findings indicate an inverted U-shaped relationship between environmental regulation and environmental quality, where environmental quality initially rises and then falls. When the level of environmental regulation is below 1.209, there is an *innovation compensation* effect between environmental regulation and environmental quality, and the level of environmental quality tends to increase with the intensity of environmental regulation.

Table 5: Robustness test of environmental regulations-environmental quality

Variable	Coefficient	t-statistic	p-value
$log(GG)$	-2.47	-9.84	0.000*
$log(EP)$	0.35	10.79	0.000*
$log(EP)^2$	-0.14	-12.17	0.000*
$log(RNE)$	-0.52	-7.64	0.000*
$log(ED)$	0.34	6.18	0.000*
$log(NRE)$	0.10	8.12	0.000*

Note: * signifies 1% significance level.

4.4 Residual cross sectional dependence (CSD) test results

The empirical findings of the CSD test are presented in Table 6. The presence of CSD is identified in the panel data analysis as this study adopted the Pesaran LM normal, Friedman chi-square, Pesaran CD normal, and Breusch-Pagan chi-square tests, respectively. The results show that the null hypothesis indicating the absence of existence of CSD, is rejected. Instead, the alternative hypothesis, indicating the presence of CSD, is confirmed.

Table 6: Residual cross sectional dependence (CSD) test results

Test	Statistic	p-value
Chi-square	1015.194 791	0.0000*
Pesaran scaled LM	15.136 21	0.0000*
Bias-corrected scaled LM	15.077 39	0.0000*
Pesaran CD	−5.217 589	0.0000*

Note: * signifies 1% significance level.

4.5 Estimation result: impact of environmental regulation on green growth

Table 7 presents the impact of environmental regulation on green growth, including control variables. The analysis of the outcome is as follows. A ten percent significant relationship exists between the quadratic coefficient and the primary coefficient of environmental regulation and green growth. The quadratic coefficient of environmental regulation is -7.50, while the primary coefficient is 3.44. These findings indicate a U-shaped relationship between environmental regulation and green growth in ECOWAS economies, where green growth initially rises and then falls. The critical value is calculated as 1.090 (7.50/2 * 3.44). When the level of environmental regulation is greater than 1.090, it verifies an *innovation compensation* effect between environmental regulation and green growth. This signifies that green growth tends to be heightened with the intensity of environmental regulation. Based on the coefficient of control variables, a one percentage negative and significant relationship exhibited in environmental degradation, renewable energy and non-renewable energy against green growth in ECOWAS economies. A one percent increase in environmental degradation, renewable energy and non-renewable energy depressed green growth by 4.43 percent, 1.16 percent, and 5.04 percent respectively, whereas a one percent rise in education contributes to green growth by 1.79 percent. The coefficient of education exhibits a stimulant indicator towards the success of green growth in this region, unlike the reserved situation when environmental quality and regulation were previously analyzed in our study. The outcomes of fully modified OLS technique are displayed in Table 8 below, depicting the estimated t-statistics and p-values of the explanatory variables, complementing the conclusion drawn from the ordinary least squares technique adopted in the study.

To summarize, the robustness outcomes reveal that the quadratic coefficient of environmental regulation is 3.36 at 1% significance level, while the primary coefficient is -8.69. These findings indicate a U-shaped relationship between environmental regulation and green growth, where green growth initially rises and then falls. When the level of environmental regulation is above 1.29, there is an *innovation compensation* effect between environmental regulation and green growth, and the level of green growth tends to intensify with effective environmental regulation.

Table 7: Impact of environmental regulations on green growth

Variable	Coefficient	t-statistic	p-value
C	1.93	1.24	0.214
$log(EQ)$	−4.43	−3.83	0.000*
$log(EP)$	−7.50	−1.70	0.088***
$log(EP)^2$	3.44	1.79	0.073**
$log(RNE)$	−1.16	−4.07	0.000*
$log(ED)$	1.79	1.84	0.065**
$log(NRE)$	−5.04	−1.025	0.306

Note: *, **, and *** signify 1%, 5% and 10% significance levels respectively.

Table 8: Robustness test of environmental regulations-green growth

Variable	Coefficient	t-statistic	p-value
$log(EQ)$	−3.21	−2.28	0.000*
$log(EP)$	−8.69	−6.14	0.000*
$log(EP)^2$	3.36	1.75	0.000*
$log(RNE)$	−9.86	−5.66	0.000*
$log(ED)$	3.33	6.56	0.000*
$log(NRE)$	−1.08	−2.01	0.000*

Note: * signifies 1% significance level.

4.6 Residual cross sectional dependence (CSD) test results

The empirical findings of the residual CSD test for green growth are presented in Table 9. The presence of CSD is indicated in the panel data analysis. The Pesaran LM normal test, Friedman chi-square test, Pesaran CD normal test, and Breusch-Pagan chi-square test, respectively, displayed rejection of the null hypothesis, confirming the absence of CSD the tests, or verifying the alternative hypothesis indicating the presence of CSD.

Table 9: Residual cross sectional dependence (CSD) test results

Test	Statistic	p-value
Breusch-Pagan LM	272.8265	0.0000*
Pesaran scaled LM	45.977 01	0.0000*
Bias-corrected scaled LM	45.918 19	0.0000*
Pesaran CD	−2.962 350	0.0031**
Chi-square	345.709 082	0.0000*

Note: * and ** signify 1% and 5% significance level respectively.

To conclude our estimation, we examined whether our variables exhibit bidirectional or unidirectional relationships using Dumitrescu and Hurlin (2012). D-H panel causality technique has been acclaimed as superior to the Granger non-causality test for panel data, providing two simultaneous statistics, i.e., the average Wald statistic ($\bar{W}$) and the standardized statistic $\bar{Z}$ (Chudik and Pesaran, 2015; Dumitrescu and Hurlin, 2012).

Understanding the direction of causality is crucial for authorities of ECOWAS nations, including policymakers and environmental management, to derive lessons in regulating appropriate economic and environmental policies. Table 10 reveals the outcomes of the D-H panel causality test. This findings indicate that unidirectional causality runs from environmental quality to non-renewable energy education has unidirectional cause with green growth. There is a unidirectional causality from non-renewable energy to green growth. Bidirectional causality relationships are observed between environmental quality and linear environmental policy, as well as between environmental quality and the square of environmental policy, and between environmental quality and education. Overall, incorporating the D-H panel causality test results with long-term parameter estimation in our findings verifies that adopting good environmental policies tends to significantly reduce environmental degradation in this region. The causal relation from environmental degradation to non-renewable energy confirms that the more damage to the environment, the more non-renewable energy escalates in the region. Moreover, the education-green growth nexus a causal relationship, suggesting that significant improvements in the education sector with effective enlightenment could strengthen environmental quality. The discovery of the non-renewable energy-green growth nexus also confirms a causal relationship; continuous use of non-renewable energy reduces the level of green growth in economies which threatens the green environment and impedes environmental sustainability in the ECOWAS region.

4.7 Discussion of results

The evidence presented in this study indicates the existence of a causal relationship between candidate variables of interest, using both CSD-panel least squares and fully modified least squares techniques. The estimates of environmental regulation and the square of environmental regulation suggest a strong evidence in support of the existence of an EKC-type relationship in ECOWAS economies between 2000 and 2020. The outcome of our findings aligns with the Porter hypothesis, which states that effective environmental regulation stimulates enterprises towards technological innovations, thereby strengthening the level of output while mitigating the effects of environmental degradation through compensation mechanisms, thus accompanying economic growth. This study confirms the work conducted by Rubashkina et al. (2015) and Franco and Marin (2017). It implies that appropriate and effective environmental regulations tend to be conducive, prompting enterprises including pollution-related industries engage in environmental governance and technological innovation, thereby reducing environmental degradation in ECOWAS economies.

Additionally, the study revealed a U-shaped relationship between environmental regulations and green growth, supporting the idea that appropriate and effective environmental regulations play a conducive role in stimulating economic growth, which is in line with the Porter hypothesis. This hypothesis suggests that alongside economic develop-

Table 10: Statistical findings of the Dumitrescu-Hurlin panel test

Null Hypothesis	$\bar{W}$-stat.	$\bar{Z}$-stat.	p-value
GG does not homogeneously cause $log(EQ)$	0.960	-1.264	0.205
$log(EQ)$ does not homogeneously cause GG	3.196	1.235	0.216
$log(EP)$ does not homogeneously cause $log(EQ)$	3.753	1.861	0.062*
$log(EQ)$ does not homogeneously cause $log(EP)$	11.80	10.88	0.000***
$log(EP)^2$ does not homogeneously cause $log(EQ)$	3.750	1.858	0.063*
$log(EQ)$ does not homogeneously cause $log(EP)^2$	10.59	9.52	0.000***
$log(RNE)$ does not homogeneously cause $log(EQ)$	8.058	6.650	3.000
$log(EQ)$ does not homogeneously cause $log(RNE)$	7.84	6.41	1.000
$log(EDU)$ does not homogeneously cause $log(EQ)$	13.54	12.80	0.000***
$log(EQ)$ does not homogeneously cause $log(EDU)$	4.79	3.02	0.002**
$log(NRE)$ does not homogeneously cause $log(EQ)$	6.87	5.36	8.000
$log(EQ)$ does not homogeneously cause $log(NRE)$	9.51	8.31	0.000***
$log(EP)$ does not homogeneously cause GG	1.49	-0.66	0.505
GG does not homogeneously cause $log(EP)$	2.04	-0.05	0.955
$log(EP)^2$ does not homogeneously cause GG	1.601	-0.5487	0.583
GG does not homogeneously cause $log(EP)^2$	2.213	0.135	0.892
$log(RNE)$ does not homogeneously cause GG	1.88	-0.23	0.812
GG does not homogeneously cause $log(RNE)$	2.95	0.96	0.336
$log(EDU)$ does not homogeneously cause GG	3.49	1.56	0.117*
GG does not homogeneously cause $log(EDU)$	6.81	5.28	1.000
$log(NRE)$ does not homogeneously cause GG	3.37	1.44	0.149*
GG does not homogeneously cause $log(NRE)$	1.43	-0.73	0.465
$log(EP)^2$ does not homogeneously cause $log(EP)$	4.45	2.64	0.008**
$log(EP)$ does not homogeneously cause $log(EP)^2$	4.05	2.20	0.027*
$log(RNE)$ does not homogeneously cause $log(EP)$	7.01	5.48	4.000
$log(EP)$ does not homogeneously cause $log(RNE)$	7.16	5.65	2.000
$log(EDU)$ does not homogeneously cause $log(EP)$	13.87	13.17	0.000***
$log(EP)$ does not homogeneously cause $log(EDU)$	12.8	11.9	0.000***
$log(NRE)$ does not homogeneously cause $log(EP)$	15.20	14.6	0.000***
$log(EP)$ does not homogeneously cause $log(NRE)$	7.27	5.79	7.009
$log(RNE)$ does not homogeneously cause $log(EP)^2$	7.11	5.59	2.008
$log(EPI)^2$ does not homogeneously cause $log(RNE)$	7.19	5.68	1.008
$log(EDU)$ does not homogeneously cause $log(EP)^2$	11.8	10.8	0.000***
$log(EP)^2$ does not homogeneously cause $log(EDU)$	14.0	13.3	0.000***
$log(NRE)$ does not homogeneously cause $log(EP)^2$	13.6	12.93	0.000***
$log(EP)^2$ does not homogeneously cause $log(NRE)$	7.08	5.58	2.000
$log(EDU)$ does not homogeneously cause $log(RNE)$	12.7	11.8	0.000***
$log(RNE)$ does not homogeneously cause $log(EDU)$	6.06	4.42	1.000
$log(NRE)$ does not homogeneously cause $log(RNE)$	12.9	12.06	0.000***
$log(RNE)$ does not homogeneously cause $log(NRE)$	4.33	2.49	0.012*
$log(NRE)$ does not homogeneously cause $log(EDU)$	21.2	21.4	0.000***
$log(EDU)$ does not homogeneously cause $log(NRE)$	15.2	14.6	0.000***

Note: ***, **, and * signify 1%, 5% and 10% significance levels respectively.

ment, establishing appropriate and effective environmental regulations not only safeguards firms and industries in the economy but also encourages them to explore technological innovations, thereby mitigating environmental pollution or deterioration. However, the study warns against excessive environmental regulations that could escalate the cost of pollution control and depress research and development investment in business firms and industries, thus inhibiting green growth. This finding is consistent with Li et al. (2021) and Greenstone et al. (2012), who advocate for appropriate environmental regulations conducive to strengthening environmental quality and enhancing economic development, thereby improving green growth. Conversely, excessive environmental regulations may threaten environmental quality, thereby impeding economic growth and green growth in the long-run.

From the control factors, non-renewable energy consumption is shown to escalate, leading to a decline in environmental quality. There is a positive and significant correlation between non-renewable energy consumption and ecological footprint destruction, coupled with a confirmed inverse relationship between non-renewable energy consumption and economic growth in the region. Continuous use of non-renewable energy exacerbates ecological footprint destruction, which negatively impacts human health, plant growth, any economic development. This finding is supported by studies such as Sharif et al. (2019), Saleem et al. (2020), Bekun et al. (2019) and Inglesi-Lotz (2016), which have reported a positive relationship between non-renewable energy consumption and environmental degradation, leading to a decline in investment in land rehabilitation and diversification of domestic energy supply as non-renewable energy consumption intensifies.

Conversely, renewable energy improves environmental quality by reducing the level of ecological footprint destruction, while also decreasing the level of green growth in ECOWAS economies. This outcome aligns with the views of Poruschi and Ambrey (2019), who suggest that economic growth may be hindered by a transition to renewable energy, as more firms and industries switch to solar panels for their energy needs. Similarly, Song et al. (2020) argue that low-renewable energy strategies may initially have an inverse relationship with economic growth, while Suo et al. (2021) suggest that energy transition in the initial stages may slow down or halt economic progress.

In summary, this investigation confirms the presence of relationship between environmental regulation-green growth nexus and environmental regulation-environmental quality nexus. This underscores the importance of implementing appropriate and effective environmental regulations, alongside promoting technological innovation and clean energy intensity, to achieve sustainable growth and mitigate environmental degradation (Bilal et al., 2022; Bashir, 2022).

5 Concluding remarks

This paper investigates the impact of environmental regulation on environmental quality and green growth in ECOWAS economies utilizing quarterly time series data from 2000Q1 to 2020Q4. The study employs the CS-PLS (cross-sectional panel least squares) method and incorporates control factors under the framework of the environmental Kuznets curve (EKC). The findings reveal the presence of an inverted U-shaped EKC relationship between environmental regulation and environmental quality. This suggests that initially, environmental regulation may lead to deterioration in environmental quality, but after a certain threshold level, the quality begins to improve. Additionally, a U-shaped relationship is identified between environmental regulation and green growth, indicating that environmental regulation can initially hinder green growth but may later promote it.

To validate the empirical outcomes, the study employs the panel fully modified least squares approach to test the robustness of our estimated values. Moreover, using the Dumitrescu-Hurlin panel causality technique, the study explores the interactions between environmental regulation, environmental quality, and green growth, considering variables such as renewable energy, non-renewable energy and education.

The findings highlight the interdependence and interconnectivity of a long-term relationship between the candidate variables. The causality analysis reveals the existence of both unidirectional and bidirectional causal relationships between the main variables of interest, indicating the complex dynamics at play in the relationship between environmental regulation, environmental quality, and green growth in ECOWAS economies.

Based on our findings, it can be concluded that strict environmental policies and regulations have the potential to foster environmental progress and facilitate green growth in ECOWAS economies. This can be achieved through the implementation of appropriate and effective environmental protection policies that encourage the adoption of eco-friendly technologies over environmentally harmful ones. These initiatives may contribute to environmental sustainability and promote green growth in the short term. Furthermore, in the long run, the implementation of such policies and regulations might strengthen high-quality economic development (HGED) in ECOWAS economies. To achieve these objectives, it is essential to establish responsible and credible institutions that oversee environmental preservation efforts and promote the adoption of environmentally friendly innovations. Effective coordination among stakeholders is crucial for realizing the goals of environmental sustainability and improving high-quality economic growth across the ECOWAS region over time.

References

Barbera, A. J. and McConnell, V. D. (1990). The Impact Of Environmental Regulations On Industry Productivity: Direct And Indirect Effects. *Journal of Environmental Economics and Management*, 18(1):50–65.

Bashir, M. F. (2022). Discovering the Evolution of Pollution Haven Hypothesis: A Literature Review and Future Research Agenda. *Environmental Science and Pollution Research*, 29:48210–48232.

Bekun, F. V., Alola, A. A., and Sarkodie, S. A. (2019). Toward a Sustainable Environment: Nexus Between CO2 Emissions, Resource Rent, Renewable and Nonrenewable Energy in 16-EU Countries. *Science of The Total Environment*, 657:1023–1029.

Bel, G. and Joseph, S. (2018). Policy Stringency Under the European Union Emission Trading System and Its Impact on Technological Change in the Energy Sector. *Energy Policy*, 117:434–444.

Bilal, Khan, I., Tan, D., Azam, W., and Tauseef Hassan, S. (2022). Alternate Energy Sources and Environmental Quality: The Impact of Inflation Dynamics. *Gondwana Research*, 106:51–63.

Castellacci, F. and Lie, C. M. (2017). A Taxonomy of Green Innovators: Empirical Evidence From South Korea. *Journal of Cleaner Production*, 143:1036–1047.

Chen, M., Jiandong, W., and Saleem, H. (2022). The Role of Environmental Taxes and Stringent Environmental Policies in Attaining the Environmental Quality: Evidence From OECD and Non-OECD Countries. *Frontiers in Environmental Science*, 10.

Chen, S. (2009). Energy Consumption, CO2 Emission and Sustainable Development in Chinese Industry. *Economic Research Journal*, 4:41–55.

Chudik, A. and Pesaran, H. (2015). Large Panel Data Models with Cross-Sectional Dependence: A Survey. In *The Oxford Handbook of Panel Data*, pages 3–45. Oxford University Press.

Cohen, M. A. and Tubb, A. (2018). The Impact of Environmental Regulation on Firm and Country Competitiveness: A Meta-analysis of the Porter Hypothesis. *Journal of the Association of Environmental and Resource Economists*, 5(2):371–399.

De Santis, R. and Jona-Lasinio, C. (2015). Environmental Policies, Innovation and Productivity in the EU. In *LSE 'Europe in Question' Discussion Paper Series.*

Demiral, M., Akça, E. E., and Tekin, I. (2021). Predictors of Global Carbon Dioxide Emissions: Do Stringent Environmental Policies Matter? *Environment, Development and Sustainability*, 23:18337–18361.

Dumitrescu, E.-I. and Hurlin, C. (2012). Testing for Granger Non-causality in Heterogeneous Panels. *Economic Modelling*, 29(4):1450–1460.

Franco, C. and Marin, G. (2017). The Effect of Within-Sector, Upstream and Downstream Environmental Taxes on Innovation and Productivity. *Environmental and Resource Economics*, 66:261–291.

Greenstone, M. (2004). Did the Clean Air Act Cause the Remarkable Decline in Sulfur Dioxide Concentrations? *Journal of Environmental Economics and Management*, 47(3):585–611.

Greenstone, M., List, J. A., and Syverson, C. (2012). *The Effects of Environmental Regulation on the Competitiveness of U.S. Manufacturing.* Working Paper No. 18392, National Bureau of Economic Research.

Grossman, G. M. and Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, 110(2):353–377.

Inglesi-Lotz, R. (2016). The Impact of Renewable Energy Consumption to Economic Growth: A Panel Data Application. *Energy Economics*, 53:58–63.

Li, X., Cheng, B., Hong, Q., and Xu, C. (2021). Can a Win–Win Situation of Economy and Environment Be Achieved in Cities by the Government's Environmental Regulations? *Sustainability*, 13(11).

Li, Y. and Li, S. (2021). The Influence Study on Environmental Regulation and Green Total Factor Productivity of China's Manufacturing Industry. *Discrete Dynamics in Nature and Society.*

Lin, B. and Li, X. (2011). The Effect of Carbon Tax on Per Capita CO2 Emissions. *Energy Policy*, 39(9):5137–5146.

Lisman, J. H. C. and Sandee, J. (1964). Derivation of Quarterly Figures from Annual Data. *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, 13(2):87–90.

Lobato, M., Rodríguez, J., and Romero, H. (2021). A Volatility-match Approach to Measure Performance: the Case of Socially Responsible Exchange Traded Funds (ETFs). *Journal of Risk Finance*, 22(1):34–43.

Ma, X. and Xu, J. (2022). Impact of Environmental Regulation on High-Quality Economic Development. *Frontiers in Environmental Science*, 10.

Morley, B. (2012). Empirical Evidence on the Effectiveness of Environmental Taxes. *Applied Economics Letters*, 19(18):1817–1820.

Pesaran, M. H., Ullah, A., and Yamagata, T. (2008). A Bias-adjusted LM Test of Error Cross-section Independence. *The Econometrics Journal*, 11(1):105–127.

Poruschi, L. and Ambrey, C. L. (2019). Energy Justice, the Built Environment, and Solar Photovoltaic (PV) Energy Transitions in Urban Australia: A Dynamic Panel Data Analysis. *Energy Research and Social Science*, 48:22–32.

Qi, Y., Lu, H. Y., and Zhang, N. C. (2016). Can Environmental Regulation Achieve Win-Win of 'Reducing Pollution' and 'Increasing Performance'? Evidence From Key Environmental Protection Cities With 'Compliance' and 'Non-compliance' Quasi-experimental. *Finance and Trade Economics*, 37:126–143.

Rubashkina, Y., Galeotti, M., and Verdolini, E. (2015). Environmental Regulation and Competitiveness: Empirical Evidence on the Porter Hypothesis From European Manufacturing Sectors. *Energy Policy*, 83:288–300.

Saleem, H., Khan, M. B., and Shabbir, M. S. (2020). The Role of Financial Development, Energy Demand, and Technological Change in Environmental Sustainability Agenda: Evidence From Selected Asian Countries. *Environmental Science and Pollution Research*, 27:5266–5280.

Shapiro, J. S. and Walker, R. (2018). Why Is Pollution from US Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade. *American Economic Review*, 108(12):3814–3854.

Sharif, A., Raza, S. A., Ozturk, I., and Afshan, S. (2019). The Dynamic Relationship of Renewable and Nonrenewable Energy Consumption With Carbon Emission: A Global Study With the Application of Heterogeneous Panel Estimations. *Renewable Energy*, 133:685–691.

Song, Y., Yang, T., Li, Z., Zhang, X., and Zhang, M. (2020). Research on the Direct and Indirect Effects of Environmental Regulation on Environmental Pollution: Empirical Evidence From 253 Prefecture-level Cities in China. *Journal of Cleaner Production*, 269:122425.

Suo, C., Li, Y., Nie, S., Lv, J., Mei, H., and Ma, Y. (2021). Analyzing the Effects of Economic Development on the Transition to Cleaner Production of China's Energy System Under Uncertainty. *Journal of Cleaner Production*, 279:123725.

Wolde-Rufael, Y. and Mulat-Weldemeskel, E. (2022). The Moderating Role of Environmental Tax and Renewable Energy in CO2 Emissions in Latin America and Caribbean Countries: Evidence From Method of Moments Quantile Regression. *Environmental Challenges*, 6:100412.

Wolde-Rufael, Y. and Weldemeskel, E. M. (2020). Environmental Policy Stringency, Renewable Energy Consumption and CO2 Emissions: Panel Cointegration Analysis for BRIICTS Countries. *International Journal of Green Energy*, 17(10):568–582.

Yang, C.-H., Tseng, Y.-H., and Chen, C.-P. (2012). Environmental Regulations, Induced R&D, and Productivity: Evidence From Taiwan's Manufacturing Industries. *Resource and Energy Economics*, 34(4):514–532.

Zhao, X., Ma, X., Shang, Y., Yang, Z., and Shahzad, U. (2022). Green Economic Growth and Its Inherent Driving Factors in Chinese Cities: Based on the Metafrontier-global-SBM Super-efficiency DEA Model. *Gondwana Research*, 106:315–328.

Zhu, S., He, C., and Liu, Y. (2014). Going Green or Going Away: Environmental Regulation, Economic Geography and Firms' Strategies in China's Pollution-intensive Industries. *Geoforum*, 55:53–65.

Zhu, X., Zeng, A., Zhong, M., Huang, J., and Qu, H. (2019). Multiple Impacts of Environmental Regulation on the Steel Industry in China: A Recursive Dynamic Steel Industry Chain CGE Analysis. *Journal of Cleaner Production*, 210:490–504.