Renewable Energy Demand, Financial Reforms and Environmental Quality in West Africa

Bright Obuobi (✉ obuobibright@gmail.com)

Nanjing Forestry University <https://orcid.org/0000-0002-5271-7420>

Yifeng Zhang

Nanjing Forestry University

Emmanuel Nketiah

Nanjing University of Science and Technology

Gibbson Adu-Gyamfi

Nanjing University of Science and Technology School of Economics and Management

Dan Cudjoe

Nanjing University of Information Science and Technology

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Renewable Energy Demand, Financial Reforms and Environmental Quality in West Africa

Bright **Obuobi**^{a*}, Yifeng **Zhang**^b, Emmanuel **Nketiah**^c, Gibbson **Adu-Gyamfi**^c, Dan **Cudjoe**^d

^aCollege of Economics and Management, Nanjing Forestry University, Nanjing, Jiangsu, 210037, China

^bCentre for Ecological Civilization and Rural Revitalization, Nanjing Forestry University, Nanjing Jiangsu, 210037

^cSchool of Economics and Management, Nanjing University of Science and Technology, Xuanwu District, Nanjing, Jiangsu, 210094, China

^dSchool of Business, Nanjing University of Information Science & Technology, Pukou District, Nanjing, Jiangsu, 210044, China

Corresponding author; Bright **Obuobi**, College of Economics and Management, Nanjing Forestry University, Nanjing, Jiangsu, 210037, China; obuobibright@gmail.com*

Abstract

Sustainable Development Goal (SDG-7) stipulates the need for clean energy, reduced carbon emissions, prevention of environmental degradation, promotion of biodiversity, and ecosystem preservation. Towards achieving these goals, this study provides new evidence on the causal link between renewable energy demand, financial reforms, economic growth, foreign direct investment, and environmental quality among emerging West African economies. The study adopted the Fully Modified Ordinary Least Squares, Dynamic Ordinary Least Squares, Pooled Mean group estimation and Granger causality test for its analysis. It was found that renewable energy demand has been favorable to the environmental health of West African economies. Also, financial reforms made within the region contributed to increasing the ecological footprints of the region. Direct investments from foreign companies showed encouraging results as it improves the environment quality. We also found a unidirectional causality from ecological footprints to renewable energy demand and financial reforms but a bidirectional relationship with economic growth and foreign

direct investment. Moreover, it was evident that ecological footprints granger causes financial reforms and economic growth but not vice versa. Policy recommendations outlined encourages governments and policy-makers to embark on intensive clean energy technologies and effective green financial reforms to help achieve Sustainable Development Goals.

Keywords: Renewable Energy Demand, Financial Reforms, Economic Growth, Environmental Quality; West Africa

1. Introduction

The significant share of fossil energy in our current energy structure has skyrocketed greenhouse gas emissions (Zhang et al. 2020). Carbon dioxide (CO₂) emissions from fossil fuels and other gases are a key contributor to greenhouse gas emissions and their consequences (Xu et al., 2020; Yang, et al., 2015). CO₂ emissions pose a significant risk to biodiversity as well as long-term sustainability (Nathaniel and Iheonu 2019). It is unfortunate that human activities are still the dominant source of global greenhouse gasses (Li et al. 2019). It has been a never-ending debate about CO₂ emissions and global warming ever since the turn of the century (Liu and Xiao 2018) prompting coordinated worldwide action from a variety of sources.

Energy demand is constantly increasing in production and consumption due to increasing population density and industrialization. Most of the world's energy resources are fossil fuels including natural gas, coal and oil (Khan et al., 2020; Shahbaz et al., 2021). Evidently, increasing fossil fuel consumption proportionately increases CO₂ emissions in the atmosphere, which eventually promotes environmental pollution (Khan et al., 2020). Pollution resulting from CO₂ emissions from diverse sources has impacted on human health adversely and contributes to mortality (Nathaniel and Adeleye 2021). In Africa, the high mortality rate makes it even more

49 alarming (WHO 2015). In view of this, low-carbon and green energy production has become a
50 prevalent trend due to these global challenges (Bauer et al. 2016; Fang et al. 2020). With the
51 public's knowledge on global CO₂ emissions, new technical ways to lowering pollution, fossil fuel
52 usage, and improving efficacy in energy demand have become critical (Shahbaz et al. 2021). To
53 ensure a green future environment, we must move from traditional fossil fuel energy to renewable
54 energy (Zhang et al. 2021) and the greatest fundamental hurdle to overcome in solving this feasible
55 task is the cost of production and other financial restrictions (Shahbaz et al. 2021).

56 Fortunately, some studies have found that financial development is critical in addressing
57 environmental pollution through renewable energy generation (Destek and Sarkodie, 2019;
58 Katircioğlu and Taşpınar, 2017; Sarkodie and Strezov, 2019; Xu et al., 2020). By improving the
59 environment and promoting environmentally friendly activities through research, good financial
60 systems can help to reduce environmental deterioration and facilitate clean technology investments
61 in renewable energy projects (Zhang 2011). Therefore, it becomes important for countries with
62 long-term visions to have a well-developed financial system, which prioritizes a green economy.

63 To combat this threat, literature on this subject recommend that African economies focus on clean,
64 renewable energy sources, reduce emissions, and improve environmental quality (Nathaniel and
65 Iheonu 2019; Zhang et al. 2019). Oil, natural gas, and other natural resources with high emissions
66 are often produced by developing countries, including those in Africa (Khan et al. 2020a). Africa
67 is known for its abundance of clean energy sources, but its substantial reliance on non-renewable
68 energy sources, which deteriorate the environment is concerning (Aliyu et al. 2018; da Silva et al.
69 2018). With Africa exploring a free trade agreement, research has become extremely important as
70 this agreement is expected to create \$3.4 trillion in combined GDP and reduce red tape and
71 streamline customs for a total of \$292 billion in potential revenue benefits (WorldBank 2021).

This calls for financial reforms in various sectors, renewable energy investments and foreign direct investments. Also, a call for studies that consider such a prominent course and sustainability, especially in this era is much needed as it is rarely available. Narrowing this problem, West African economies share many things in common as the countries in the region embark on a journey to create a common currency (Eco). This will have a greater impact on their investment trend, trade, financial reforms and energy usage. As a result, this study is narrowed to some selected countries in the West of Africa to enhance a deeper analysis.

Despite the numerous studies on this subject, a variation of research methods is necessary to generate new insights and to avoid distorted findings, especially in the African perspective. As a result, this study provides three significant contributions to the subject. First, the study looks into the influence of renewable energy demand (RED), financial reforms (FR) and economic growth (EG) on West Africa's environmental health. Second, some researches have been conducted on RED, EG together with other common elements but unfortunately, the causal relationship between RED, FR, EG and environmental quality have not been examined. This is extremely significant, particularly in the West African context, and this study aims to address that gap. Lastly, unlike earlier research in the field, which utilized only carbon emissions (negative measure) to estimate environmental health, this study used ecological footprint (EF) (positive measure) to assess West-African countries' environmental health. EF has a more comprehensive, broader, and better measure of environmental health compared to CO₂ emissions (Rudolph and Figge 2017; Destek and Sinha 2020). Fig. 1 below shows West Africa's ecological footprints.

Fig. 1. West Africa's ecological footprints

2. Literature Review

Concerning reducing climate change and improving environmental quality, many scholars have attached importance to it and focused on identifying and assessing the possible factors that are likely to influence carbon emission and eventually decrease the environments' quality in general. Table 2 below summarizes some major studies conducted in recent years as far as environmental quality, renewable energy, financial developments, and economic growth are concerned.

Table 2: Some major studies on environmental quality, renewable energy, financial developments and economic growth (*I think you can put your study's information in the last part of this Table to inform readers about the difference between your study and existing ones*)

Author (s)	Country/Area	Methodology used	Major/Related Findings
(Chiu and Chang 2009)	OECD	Panel Threshold	RE has a negative impact on (CO ₂)
(Zhang 2011)	China	Cointegration theory, Granger causality test, variance decomposition	FD increases CO ₂
(Acaravci and Ozturk 2012)	Turkey	Granger causality models	FD has no effect on CO ₂
(Mahesh and Shoba Jasmin 2013)	India	Review	RE has unidirectional effects on CO ₂
(Dong et al. 2017)	BRICS	AMG	RE has a negative effect on CO ₂

(Balsalobre-Lorente et al. 2018)	EU-5 countries	Least square Models	EG has a negative impact on CO ₂ , RE has positive effect on CO ₂
(Acheampong 2018)	116 countries	GMM	EG negatively impact CO ₂ , EC has negative effect on EF
(Liu and Xiao 2018)	69 Countries	VECM, FMOLS, DOLS	EG increases EF
(Shahbaz et al. 2018)	Japan	ARDL	EC and EG drives CO ₂
(Nguyen and Kakinaka 2019)	107 countries	Panel Cointegration	RE has a negative effect on EF
(Khan et al. 2019)	192 countries	Panel Quantile regression	FD increases CO ₂
(Sarkodie and Strezov 2019)	5 developing countries	Driscoll-Kraay standard errors, <i>U</i> test estimation approach and panel quantile regression with non-additive fixed-effects.	EC increase CO ₂ , FD degrades the environment
(Acheampong et al. 2019)	46 Sub-Saharan countries	Fixed and Random effect estimation technologies	RE has unidirectional effect on CO ₂ , FDI has negative effects on CO ₂
(Arshad Ansari et al. 2020)	37 Asian countries	GMM	EG has negative effect on EF, EC has negative effect on EF
(Khan et al. 2020b)	G7 countries	2 nd G Panel cointegration	EG has a positive effect on CO ₂ , Financial developments has a negative effect on CO ₂
(Aziz et al. 2020)	Pakistan	Quantile ARDL	RE decreases EF
(Baz et al. 2020)	China, India, Pakistan	DOLS, FMOLS	EG increases EF
(Shen et al. 2021)	China	CARDL	FD has a unidirectional relationship with CO ₂
(Destek and Sinha 2020)	24 OECD	FMOLS, DOLS, and CCEMG	RE abates environmental degradation
(Nathaniel and Adeleye 2021)	44 African countries	Static and dynamic econometric techniques	FD accelerates environmental degradation

103 *Note: RE is renewable energy, FD is financial developments, CO₂ is carbon emissions, EG is economic growth, EC*
104 *is energy consumption, EF is ecological footprints,*

105
106 Considering the objectives of this research, various research has been done, analyzing factors that
107 affect environmental quality from the international level decentralized through to the industrial
108 level. This topic has gotten much attention in the last decade or two, which provides enough of a
109 foundation for more studies to enhance the environment's quality. Given this, it is no surprise that
110 the impact of many variables on the environment has piqued economists' and environmentalists'
111 interest. Furthermore, scholars use a variety of methodologies and techniques to address the

environmental problem at different levels. EG has been the biggest impact among the different parameters employed in recent studies on CO₂ and environmental degradation (Ma et al. 2019; Khan et al. 2020a; Nathaniel and Adeleye 2021). The next section reviews various literature on renewable energy demand and financial reforms on environmental quality which forms the core part of this study.

2.1 Environmental quality measurement

Some studies are directed to the relationship among EG, energy use, as well as environmental deterioration for more than four decades, using models developed within the EKC structure (Destek and Sinha 2020). Numerous indicators of environmental health is adopted, including (Jayanthakumaran and Liu 2012) with sulfur dioxide, (Khan et al. 2018, 2019; Abokyi, E., Appiah-Konadu, P., Abokyi, F., Oteng-Abayie 2019; Sarkodie and Ozturk 2020) with CO₂ emissions, and (Aydin et al. 2019; Destek and Sinha 2020; Nathaniel and Adeleye 2021) with EF. EF is a favorable indicator, while the first two are negative indicators. Due to the criticism leveled against CO₂ emissions, recent research have focused on EF as an indicator of environmental quality (Altıntaş and Kassouri 2020; Arshad Ansari et al. 2020; Baz et al. 2020; Destek and Sinha 2020; Sharif et al. 2020; Nathaniel and Adeleye 2021)

2.2 Renewable energy Demand (RED) and Environmental quality

The function of RED has been explored since it significantly impacts carbon emissions. CO₂ emissions and EF are the two most frequent indicators used by academics to represent environmental quality. In terms of renewable energy demands, (Shafiei and Salim 2014) discovered that as OECD countries' demand for renewable energy grows, carbon emissions decrease. In (Işık et al. 2019) study, a positive effect of renewable energy demand on carbon emission was found in the United States. A similar study in Sub-Saharan Africa by (Hanif 2018)

examined the relationship between carbon dioxide emissions caused by fossil fuels, renewable energy use, solid fuel consumption, and urban expansion. It was revealed that renewable energy greatly diminishes CO₂ emissions in the countries studied. According to (Zoundi 2017), the extortion of renewable energy consumption has some constraints regarding reduced economic growth and conditioned countries. Also, (Jebli and Youssef, 2015) demonstrated that, renewable energy consumption increases EG and eventually affects the environment's quality. Similarly, (Apergis and Payne 2014) discovered a long-run link between CO₂ emissions and renewable energy demand. With the increasing impact of renewable energy consumption on the environment, (Sinha et al. 2018) assert that the initial cost of renewable energy investment to fulfill demand inhibits developing nations from focusing entirely on renewable energy sources. Using data from five developing nations, (Sarkodie and Strezov 2019) examined the energy-CO₂ emissions nexus and found that energy use increases CO₂. (He et al. 2019) looked at the effect of energy demand and EG on EF in Malaysia and discovered that the former contributed significantly to the latter. Energy demand, population, and EG are the main causes of environmental degradation in OPEC countries, according to (Fakher 2019)

2.3 Financial reforms and Environmental quality

Several prior research have adopted proxies of financial reforms in different regions and established its relationship with environmental quality. It was determined by (Al-Mulali and Binti Che Sab 2012) that increased CO₂ emissions result from financial development. According to (Zhang, 2011), financial institutions have a vital role in lowering environmental pollution. Similarly, (Tamazian and Bhaskara Rao 2010) argues that financial development impact on CO₂ emissions adversely, although (Zhang 2011) claims a positive impact in China. (Acaravci and Ozturk 2012), on the other hand, assert that there is no effect of financial developments on CO₂ in

Turkey. According to (Sarkodie and Strezov 2019), a well-functioning financial system encourages FDI inflows, which deteriorate environmental quality. (Majeed and Mazhar 2019) studies on 131 countries reveal that, financial development enhances environmental quality by decreasing EF and energy demand. However, they found that FDI and GDP accelerate EF. There has been a heated debate in the literature on FDI and its effects on environmental quality, renewable energy usage, and other aspects. According to (Stretesky and Lynch 2009), FDI in the form of technology commodities can assist the reduction of air pollution. Similarly, different scholars opine that, FDI reduces air pollution and increases economic growth by raising an economy's productivity, resulting in high energy usage. Furthermore, polluting firms invest in developing nations to minimize production costs since these economies lack proper environmental rules that allow them consume more energy, resulting in higher CO₂ emissions (Acharyya, 2009; Lau et al., 2014). Therefore, these deficiencies in environmental rules attract such FDIs and raise CO₂ emissions. In view of this, the relevance of FDI is examined in the study.

Based on the literatures reviewed, we identify a methodology gap and also discrepancies between findings in the global setting and the African context. As a result, we develop a conceptual framework for the study involving other relevant control variables used in similar studies as seen in Fig. 2.

Fig. 2: Conceptual framework

3. Data and Methodology

3.1 Data collection and variables used

The study adopts panel data on 11 West African economies from 1990 to 2017. Countries selected were based on data available to meet the objectives of this research. Table 2 below provides the data used and their variable explanation and their measurement unit and source.

Table 2: Variables used and their data sources

Abbreviation	Name of variable	Unit of measurement	Data Source
EF	Ecological footprints	Ecological footprints (gha)	Global Footprints Network (2021)
RED	Renewable energy demand	Renewable energy consumption (% of total final energy consumption)	Worldbank 2021)
FR	Financial reforms	Domestic credit to private sector (% of EG)	Worldbank 2021)
FDI	Foreign direct investment	Foreign direct investment, net inflows (% of EG)	Worldbank 2021)
EG	Economic growth	EG (current US\$)	Worldbank 2021)
NRR	Natural resource rent	Total natural resources rents (% of EG)	Worldbank 2021)
POP	Population	Total Population	Worldbank 2021)

184

185 3.2 Empirical model

186 The study's theoretical structure was centered on an endogenous model with renewable energy
187 demand, financial reforms, foreign direct investment, natural resource rent, economic growth,
188 and population. Thus, this equation is formulated below (1).

$$189 \quad EF_{it} = \alpha_0 + \beta_1 RED_{it} + \beta_2 FR_{it} + \beta_3 FDI_{it} + \beta_4 NRR_{it} + \beta_5 EG_{it} + \beta_6 POPN_{it} + u_{it} \dots \dots \dots (1)$$

190 Where EF is ecological footprints, RED is renewable energy demand, FR is financial reforms, FDI
191 represents foreign direct investment, NRR denotes natural resource rent, EG stands for economic
192 growth and POPN represents population. ($\beta_1 - \beta_6$) are the parameter estimates, α is the intercept, t
193 is the period, and u represents the error term.

194 In achieving efficient, dependable, and consistent outcomes, and examine the long-term link
195 between variables, we express Eq. (1), to their natural logarithm in Eq. (2).

$$196 \quad \log_e (EF) = \alpha + \sum a \log_e (RED, FR, FDI, NRR, EG, POPN) \dots \dots \dots (2)$$

197 Hence, the functional model can be written as:

$$198 \quad \ln EF_{it} = \alpha_0 + \beta_1 \ln RED_{it} + \beta_2 \ln FR_{it} + \beta_3 \ln FDI_{it} + \beta_4 \ln NRR_{it} + \beta_5 \ln EG_{it} + \beta_6 \ln POPN_{it} + u_{it} \dots (3)$$

199

200

201 3.3 Methodology

202 The general expectation is that the panel data model disturbances are cross-sectional, especially
203 when the (N) dimension is vast. Ignoring cross-sectional independence could greatly impact
204 unaccounted residual dependence which can lead to inefficiency and a statistically invalid test.
205 Due to the above issues, the study first examined the cross-sectional dependence using Pesaran
206 CD (Pesaran, 2004). Pesaran CD employs rigorous ways to resolve any unnoticed causes or
207 disruptive effects in countries because of economic growth, similar economic indicators, and other
208 common characteristics.

$$209 \quad CD = \sqrt{\frac{2T}{N(N-1)}} (\sum_{i=1}^{N-1} \sum_{j=i+1}^N P'ij) \equiv N(0,1) \dots \dots \dots (4)$$

210 T means time period, N refers to sample size, and P'ij is the country's sample estimate of cross-
 211 sectional correlation errors i and j given as

$$212 \quad P'_{ij} = \frac{\sum_{t=1}^T u_{it}u_{jt}}{(\sum_{t=1}^T u_{it}^2)^{1/2}(\sum_{t=1}^T u_{jt}^2)^{1/2}} \dots\dots\dots (5)$$

213 Where, H₀: p_{ij} = p_{ji} = cor(u_{it}, u_{jt}) = 0 for i ≠ j, and the alternative hypothesis as, H₁ : p_{ij} = p_{ji} ≠ 0
 214 for some i ≠ j

215 **3.4 Unit root test**

216 We used the augmented Dicker-Fuller (ADF) to analyze variables' stationarity. It is expressed as

$$217 \quad \Delta y = a_i + p_i y_{i,t-j} + \gamma_1 \bar{y}_{t-1} + \sum_j^k \gamma_{ij} \Delta \bar{y}_{i,t-j} + \sum_{j=0}^k \Delta \bar{y}_{i,t-j} + \varepsilon_{it} \dots\dots\dots (6)$$

218 Where $\bar{y}_{t-1} = \left(\frac{1}{N}\right) \sum_{i=1}^N y_{i,t-1}$, $\Delta \bar{y}_t = \left(\frac{1}{N}\right) \sum_{i=1}^N y_{it}$ and t_i (N, T) is the t-statistics of the estimates
 219 and P' is the individual ADF statistics

220

221 **3.5 Cointegration analysis**

222 To establish the cointegration among the variables used, the Kao and Pedroni cointegration test
 223 was adopted. To achieve the objective stated in Eqn. 1, we first apply the Kao cointegrating test.
 224 The ADF t-statistics is mathematically expressed as,

$$225 \quad ADF = \frac{t_{ADF} + \left(\frac{\sqrt{6N\vartheta_q}}{2\vartheta_{0q}} \right)}{\sqrt{\left(\frac{\vartheta_{0q}^2}{2\vartheta_q^2} \right) + (10\vartheta_{0q}^2)}} \dots\dots\dots (7)$$

226 Where $\vartheta_a^2 = \sum_{u\varepsilon} - \sum_{u\varepsilon} \sum_{\varepsilon}^{-1}$, $\vartheta_{0a}^2 = \Omega_u - \Omega_{u\varepsilon} \Omega_{\varepsilon}^{-1}$, Ω denotes the long-run covariance matrix and
 227 'ADF refers to t-statistic in ADF regression for cointegration.

228 Moving further, the study used confirms the results achieved by the Kao cointegration test through
 229 the application of Pedroni, (2004) cointegrating technique. The Pedroni cointegration test is based
 230 on intra- and inter-dimensional cointegration with parenthesis lag lengths. It can be expressed
 231 mathematically as,

$$232 \quad EF = \alpha_i + \delta_{1i} X_{it} + \delta_{2i} X_{2it} + \dots \delta_{pi} X_{pit} + \varepsilon_{it} \dots\dots\dots (8)$$

α_i and δ_i are the intercepts and gradient coefficients and can differ across cross-sections, $t=1, T, i=1, N, p=1$, EF, x, and p are considered to be similar and orderly integrated (I(1)). Under the null hypothesis of no cointegration, the residuals ε_{it} will be I (1).

3.6 Long-run estimates

To generate our variables' long-run estimates, the Dynamic Ordinary Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) for elasticity were prioritized over the traditional Ordinary Least Square (OLS) because the FMOLS is the modification of the OLS. They cater for serial correlation problems as well as the endogeneity bias predominance. Getting rid of Endogeneity issues using a non-parametric method, the regressors and error term are sequentially correlated (Dogan and Seker 2016). As a result, the FMOLS is quite effective. A parametric approach, lags, and leads are also used by the DOLS estimator. The FMOLS approach to measuring the long-run relationship between the variables proposed by (Pedroni 2000) can be expressed as;

$$EF = \omega_0 + \beta X_{it} - i + \sum_{j=i}^j \gamma_j \gamma X_{it-j} + \mu_{it} \dots\dots\dots (9)$$

Where EF refers to the dependent variable Ecological footprints. The X_{it} denotes the independent variables used for the study. The long-run variance is given by

$$\Omega_i = \lim_{T \rightarrow \infty} F \left[\left(\frac{1}{T} \right) (\sum_t^T = 1^{u_{it}})' \right] \dots\dots\dots (10)$$

FMOLS estimator is subsequently extended to Eqn. 11, as indicated below.

$$\beta = \frac{1}{n} \sum_{i=1}^n [\sum_{t=1}^T ((X_{it} - \bar{X}_{it})^2)^{-1} (\sum_{t=1}^T (X_{it} - \bar{X}_{it})) (EF_{it} - \tau_\gamma)] \dots\dots\dots (11)$$

Where $EF = EF_{it} - \overline{EF_{eq}} - \left(\frac{\hat{\Omega}_{1,0}}{\hat{\Omega}_{1,1}} \right) \Delta X_{it}$; and

$$\hat{\gamma} = \hat{\tau}_{1,0} + \hat{\Omega}_{1,0} - \left(\frac{\hat{\Omega}_{1,0}}{\hat{\Omega}_{1,1}} \right) (\hat{\tau}_{1,1} + \hat{\Omega}_{1,1})$$

Finally, we establish the directional causality among the variables by applying the Pool Mean Group (PMG) estimator and the Granger causality.

4. Results and Discussion

4.1 Descriptive statistics

259 In Table 3, we display the results of the descriptive statistics conducted for all variables used. The
 260 mean, maximum, minimum, volatility, skewness, kurtosis, and distribution normality. The kurtosis
 261 indicates that all variables show a platykurtic distribution in determining whether the distribution
 262 is too peaked since they are all greater than one (1). Also, RED, FR, FDI and NRR indicate a left-
 263 skewed distribution. However, EG, EF and population also show a right-skewed distribution. Also,
 264 all of the variables are generally distributed, according to the Jarque-Bera test statistic. All other
 265 statistics of the respective variables can be found in Table 3.

	EF	RED	FR	FDI	NRR	EG	POP
Mean	16.2712	4.3211	2.2437	0.2775	2.1804	22.3855	16.0525
Median	16.3638	4.3766	2.4064	0.4991	2.3158	22.1628	16.0996
Maximum	19.1058	4.5535	3.6929	3.4751	3.4592	27.0271	19.0671
Minimum	13.8303	3.7236	-0.9099	-6.0888	0.6938	19.1456	13.7701
Std. Dev.	1.2819	0.1845	0.7037	1.4142	0.6237	1.6476	1.2703
Skewness	0.2643	-1.1645	-0.7703	-1.2994	-0.4331	0.5718	0.2903
Kurtosis	2.8063	3.5963	4.1258	5.7302	2.2767	3.3349	3.1030
Jarque-Bera	3.7377	68.1495	42.9277	167.5323	15.0164	16.7468	4.1011

266

267 4.2 Cross section Dependency test

268 Table 4 displays the results of the cross-section dependency test (CD test). The test was conducted
 269 in the various panels option; OLS, fixed effects and random effects. The Table shows the t-
 270 statistics with their respective p-values. The null hypothesis indicated no cross-section dependency,
 271 and at a significance level of 5%, the null hypothesis couldn't be rejected. We then conclude that,
 272 there is no cross-section dependence among the variables used for the study.

Residual Cross-Section Dependence Test

Null hypothesis: No cross-section dependence in residuals

Test	OLS		Fixed Effects		Random effects	
	t- value	p-value	t-value	p-value	t- value	p-value
Pesaran CD	0.8415	0.4000	-0.1655	0.8686	-0.5718	0.5674

*Statistical significance: 1%***, 5%** and 10%* Reject null at 5% significance*

4.3 Panel Unit root test

In table 5, the Augmented Dickey-Fuller test results can be seen. This was to test the stationarity of the variables for further analysis. At level, FDI was significant at 1% level, NRR at 5% level and POP at 10% level. All other variables were insignificant at level which we can't reject null hypothesis. The variables were then assessed in their 1st difference under the same test method, and they all became stationary at 1% level. We can then conclude that, the variables are integrated simultaneously and can be used for econometric modeling.

Table 5: Augmented Dicker-Fuller (ADF) Results

Test	Level statistic	Prob.	Ist Diff. statistic	Prob.
EF	8.7622	0.9945	156.518	0.0000***
RED	11.7565	0.9622	107.458	0.0000***
FR	31.7810	0.0812	97.0939	0.0000***
FDI	62.6479	0.0000***	111.948	0.0000***
NRR	37.5822	0.0204**	123.255	0.0000***
EG	2.2159	1.0000	110.043	0.0000***
POP	31.2557	0.0910*	141.584	0.0000***

*Statistical significance: 1%***, 5%** and 10%* Reject null at 5% significance*

4.4 Cointegration Test results

4.4.1 Kao Residual Cointegration

One of the fundamentals of this study was to determine the existence of long-run relationship among constructs. In Table 6, we used the Kao cointegration test to confirm a long-run association among the variables and are cointegrated. With a p-value of 0.0000, we accept the alternative hypothesis indicating a long-run association among the variables.

Table 6: Kao Residual Cointegration Test results

Null Hypothesis: No cointegration

	t-Statistic	Prob.
ADF	-5.640799	0.0000***

*Statistical significance: 1%***, 5%** and 10%* Reject null at 5% significance*

292

293 **4.4.2 Pedroni Residual Cointegration Test results**

294 In testing for the cointegration among the variables, the Pedroni cointegration test was also adopted
 295 after the Kao, and the results are displayed in Table 8 shows the results obtained when the Pedroni
 296 cointegration test was conducted. In the Table, 11 results are displayed from the test. With all 11
 297 results obtained, panel PP-statistic (0.0000, 0.0000) and panel ADF-statistic (0.0000, 0.0000),
 298 Group PP-statistic (0.0000) and Group ADF-statistic (0.0000) were found significant at 1% level.
 299 Overall, 6 out of the 11 were significant, which means we can reject null hypothesis of
 300 cointegration. This confirms the Kao cointegration test results as the Pedroni panel cointegration
 301 test results have a majority of the Pedroni panel cointegration test results rejected the null
 302 hypothesis.

Table 7: Pedroni Residual Cointegration Test results

Null Hypothesis: No cointegration

Alternative hypothesis: common AR coefs. (Within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-1.7054	0.9559	-2.0807	0.9813
Panel rho-Statistic	0.7428	0.7712	1.0642	0.8564
Panel PP-Statistic	-6.2833	0.0000***	-5.7752	0.0000***
Panel ADF-Statistic	-4.6935	0.0000***	-4.5177	0.0000***

Alternative hypothesis: individual AR coefs. (Between-dimension)

	Statistic	Prob.
Group rho-Statistic	1.9849	0.9764
Group PP-Statistic	-10.8724	0.0000***
Group ADF-Statistic	-5.5993	0.0000***

303 *Statistical significance: 1%***, 5%** and 10%* Reject null at 5% significance*

304

305 From Table 8, the results of DOLS and FMOLS have an explanatory power of 99.97% and 63.5%
 306 respectively. The left-hand side reveals the results from the FMOLS with coefficient, t-statistics
 307 and p-values. Likewise, the right-hand side displays the results from the DOLS.

Table 8: DOLS and FMOLS results**Dependent Variable: EF**

	FMOLS			DOLS		
Variable	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
RED	-0.0428	-63.1797	0.0000***	-0.4290	-5.6300	0.0000***

FR	0.0390	17.6490	0.0000***	-0.0279	-0.7727	0.4450
FDI	-0.1952	-59.8566	0.0000***	-0.0751	-10.8537	0.0000***
NRR	0.1146	74.7870	0.0000***	0.1146	4.8448	0.0000***
EG	0.0747	145.0681	0.0000***	0.0713	2.9669	0.0055***
POP	0.8600	71071.4400	0.0000***	1.0164	22.0693	0.0000***

R-squared 0.635638

0.999743

*Statistical significance: 1%***, 5%** and 10%* Reject null at 5% significance*

Regarding RED and environmental quality measured in EF, we found a negative (-0.0428) significant (0.0000) relationship. This is confirmed by the DOLS results which also reveals a negative significant relationship between the variables. This means that a 1% increase in the demand for renewable energy in West Africa improves the region's environmental quality by 0.0428% (FMOLS) and 0.429% (DOLS). From this, we could deduce that West African economies demand and for renewable energy has been favorable to their EF. This is consistent with the works of (Apergis and Payne 2014; Zhou and Li 2019; Khan et al. 2020a) who found renewable energy usage to declines CO₂ emissions and (Nguyen and Kakinaka 2019; Aziz et al. 2020) who found renewable energy consumption to decrease EF.

On FR and developments in the region, our FMOLS results revealed a significant positive impact on environmental quality. This means that 1% increment in FR increases their EF by 0.039%, which declines environmental quality. This results align with (Zhang 2011) and (Nathaniel and Adeleye 2021) who concluded that financial developments degrades the environment. The DOLS couldn't confirm as it indicated an insignificant impact just like (Acaravci and Ozturk 2012) who found no impact between FR and environmental quality in Turkey. FDI, which forms an integral part of any developing country, was found to negatively affect environmental quality among West African economies. This indicates that any 1% increment in direct investment from foreign companies improved the environmental quality by 0.1952% (FMOLS) and 0.0751% (FMOLS). This may be attributed to the fact that, as the world goes towards sustainability, these economies

are getting interested in green investments that develop the country and promote the quality of the environment. (Khan et al. 2020a) found similar results. NRR, a very important variable among West African economies, was identified to have impacted EF positively. This is confirmed from the table by FMOLS and DOLS with 0.1146 coefficients. This indicates that the compensation (rents) from the natural resources keeps causing harm to the environment. As the rents increase, environmental quality decreases by EF. Economic growth measured by GDP in US\$ shows a positive significant (FMOLS=0.0747, DOLS=0.0713) relationship with environmental quality. A 1% increase in the growth of West African economies increases their environmental degradation. As a result of deforestation and mining, the majority of Africa's economies rely on these industries, which could have an impact on their environment. This finding conforms to (Liu and Hao 2018), who found economic growth to increase EF among 69 countries. However, it is inconsistent with (Dong et al. 2017) and (Balsalobre-Lorente et al. 2018), who also found economic growth to decrease environmental quality measured by CO₂ among BRICS and EU-5 countries, respectively. The population and its growth in West Africa are found to positively affect the quality of the environment by FMOLS (0.8600) and DOLS (1.0164). As the population of the region increases, so does their EF.

The results for the Pooled Mean group estimates are displayed in Table 9. The study adopted it to determine the short and long-run directional causality among some key variables used for the study. The PMG estimator allows short-term dynamics to differ between countries while limiting the long-term coefficients for all cross-sections data.

Table 9: Results of Pooled Mean Group (PMG)

Causality Test		
Estimator	Short-Run	Long-Run
PMG	EF → FR	EF ↔ FR
	EF → RED	EF ↔ RED
	EF ↔ EG	EF ↔ EG

EF ↔ FDI	EF FDI
RED → FR	RED → FR
FDI ↔ FR	FDI → FR
EG → RED	EG ↔ RED
EF → NRR	NRR → EF
POP → EF	POP ↔ EF

|| means no directional causality, → means unidirectional causality, ↔ means bidirectional causality

From Table 9, the short-run causalities can be found on the left side and the long-run on the other side. On the short-run, we found a unidirectional causality from EF to FR, RED and NRR. Also, a unidirectional causality was found from RED to FR, EG to RED and population to EF. However, EF and EG, EF and FDI, FDI and FR were all bidirectional causalities. This means they influence each other.

On the long-run, we noticed similar and different results. Only RED to FR, FDI to FR and NRR to EF had a unidirectional causal relationship. EF has a bidirectional relationship with RED, FR, EG and population. Also, a bidirectional relationship was found between EG and RED. Our study found no causal relationship between EF and FDI in the long run.

We adopted the Granger causality test to enhance further our study and its findings (Granger 1969). Granger Causality is widely used because of its computational simplicity. Also, as other tests determine what causes what, Granger causality determines whether or not one variable is useful to forecast another variable. We used this to test if the variables used can be useful when forecasting the other variables, and the results are seen in Table 10.

Table 10: Pairwise Granger Causality Tests Results

Null Hypothesis: does not granger cause	F-Statistic	Prob.	
FDI to EF	0.2454	0.6208	
EF to FDI	0.1383	0.7103	
FR to EF	0.0037	0.9513	
EF to FR	5.8313	0.0164	***
EG to EF	0.0441	0.8339	
EF to EG	4.6357	0.0321	**
NRR to EF	0.1161	0.7335	
EF to NRR	0.2624	0.6088	
POP to EF	5.6998	0.0176	***
EF to POP	4.6480	0.0319	**
RED to EF	0.1430	0.7056	
EF to RED	0.3792	0.5385	

FR to FDI	0.4075	0.5238	
FDI to FR	7.2455	0.0076	**
EG to FDI	0.7046	0.4020	
FDI to EG	6.3790	0.0121	***
NRR to FDI	2.0998	0.1485	
FDI to NRR	0.0164	0.8983	
RED to FDI	8.1704	0.0046	***
FDI to RED	5.3986	0.0209	**
EG to FR	10.3026	0.0015	***
FR to EG	0.0494	0.8243	
POP to FR	6.1327	0.0138	***
FR to POP	18.0060	0.0000	***
RED to FR	2.3429	0.1269	
FR to RED	0.0099	0.9208	
POP to EG	3.2515	0.0724	*
EG to POP	13.9836	0.0002	***
RED to EG	0.7176	0.3976	
EG to RED	0.2136	0.6443	

*Statistical significance: 1%***, 5%** and 10%**

With the null hypothesis developed, the granger causality test rejected some of the hypotheses and revealed that EFs granger causes FR, EG and POP in West Africa. Also, POP granger causes EFs, FDI granger causes FR, FDI granger causes EG, RED granger causes FDI and vice versa, EG granger causes FR, POP also granger causes FR and vice versa, and POPN granger causes EG at 10% significance and vice versa at 5% significant level. Other results found can be seen on Table 10.

6. Conclusion and Policy implication

This study evaluated the relationship between environmental quality and renewable energy demand, financial reforms, foreign direct investment, Economic growth Natural resource rent and population. After a series of tests, we found that RED in West Africa has been favorable to their environmental quality, reducing their EF. Also, FR adopted by the region was found to have affected the quality environment as EF was found to increase accordingly. One major finding identified was the negative impact of FDI on EF. This shows that countries in the region have been

378 focusing on attracting green investments for sustainability purposes. Also, the growth of these
379 economies in the region tends to decline their environmental quality as EG affects EF positively.
380 Using the PMG estimator, the study had some major findings, including EF having a bidirectional
381 relationship with RED, FR, EG and population. Finally, in determining which variables forecast
382 the other, the Granger causality test revealed that EF granger causes FR, EG and Population in
383 West Africa. These findings confirm and go contrary to some researches mentioned in the literature.
384 Based on these revelations, we make the following policy recommendations;

385 In light of the positive impact of RED on environmental quality in West Africa, we advise
386 policymakers to adopt clean technology by expanding renewable energy consumption as a tool to
387 improving environmental quality. Due to the importance of energy in poverty reduction and
388 development, these countries should establish energy development programs, shift to clean and
389 renewable energy consumption to significantly improve environmental quality in these countries.
390 As a result, unless West African governments and related stakeholders exploit the continent's
391 wealth of "clean energy" sources such as solar and geothermal energy and biomass and biogas,
392 tidal and wind power in earnest, the prospect of biodiversity becoming grossly uninhabitable
393 abounds.

394 In addition, our findings suggest that FR has been detrimental to the quality of the environment.
395 Therefore, countries should focus on improving their financial systems, providing more incentives
396 for sustainable and clean energy production projects. They should also support research and
397 development efforts that focus on helping achieve United Nation Sustainable Development Goal
398 7 (UN *SDG-7*). Aside from that, governments should promote financial institutions because they
399 may assist in providing funding for environmentally friendly projects that benefit the countries'
400 surroundings. Limited financial resources hinder renewable energy consumption and sustainability;

however, growth in financial services can assist firms to have access to more funds to embrace sustainable initiatives and investments.

Regarding FDIs, the study showed a favorable impact on the environment. However, its sustenance IS key to the long-term development of the region. Therefore, host nations among these regions should be aware of the environmental implications of FDI before introducing foreign investors to their country, especially countries with high EF or biocapacity deficits. To that effect, green investments that enhance recycling and promote a circular economy and sustainability must be attracted and invited into the countries whilst limiting investments that degrade the environment.

The Western section of Africa, in particular, is heavily resource dependent. Resources are a major factor in the region's economy. Activities (mining, natural resource exploration, agriculture) and some resources (petroleum, coal, natural gas, among others) stimulate deforestation, depletion of biocapacity, and an increase in EF. Consequently, another strategy to decrease the EF for sustainability is to boost sustainable activities in the natural resource industry and increase the consumption of less polluting sources. The rents generated from the sector must be invested in recyclable projects that offset the resources lost. To will help balance biocapacity or keep it within positive figures.

Finally, economic growth has been found to affect environmental quality negatively. These findings have been found in this region and in advanced countries who are now trying their best to reduce CO₂ emissions and its associated effects. As these emerging economies aspire to be like the advanced countries, governments should not only focus on just growing their economy but growing it sustainably and familiarizing with the UN SDGs so that their economies can be kept green as they grow.

Authors' contribution

B. Obuobi: Conceptualization, Methodology, Software, Writing-Original draft preparation, Validation, Investigation

Y. Zhang: Writing-Reviewing and Editing, Supervision

E. Nketiah: Data curation, Writing-Reviewing and Editing

G. Adu-Gyamfi: Data curation, Writing-Reviewing and Editing

D. Cudjoe: Writing-Reviewing and Editing, Supervision

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