Environment, Development and Sustainability (2022) 24:10183–10207
https://doi.org/10.1007/s10668-021-01860-9

The nexus amid foreign direct investment, urbanization, and CO_2 emissions: Evidence from energy grouping along the ECOWAS community

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Received: 4 April 2020 / Accepted: 23 September 2021 / Published online: 22 October 2021

Abstract
The vision of every country or subregions is to achieve economic growth and sustainable economic growth. Thus, the Economic Community of West African States (ECOWAS) as an economic cooperation renders interaction among 16 relevant countries to increase economic development. However, CO_2 emissions as a result of economic growth are of great concern. Thus, this study delves into the determinants of CO_2 emissions along the ECOWAS community, taking into consideration if countries are energy exporters or energy importers. The analytical procedure applied indicated the presence of heterogeneity in the slope coefficient and cross-sectional dependencies across the various panels. Applying the Westerlund bootstrap co-integration unveiled, the employed variables have a long-run equilibrium association. The results from the augmented mean group (AMG) revealed that the contribution weight (order of importance) to CO_2 emissions varies across panel clusters. Finally, the causality results unveil a bidirectional causation in all panels between urbanization and CO_2 emissions, whereas foreign direct investment and CO_2 emissions have a bidirectional effect in energy importers and the main panel. These results obtained indicate that foreign direct investment, urbanization, energy consumption, trade openness, and gross domestic product are the determinants of CO_2 emissions along the community. Based on the outcome, the suggested policy implications indicate that (a) the need for a paradigm shift from fossil fuel sources to renewables be encouraged in the community and (b) again, the awareness of spillover of economic growth and energy transition on CO_2 emissions from foreign companies to local businesses must be promoted.

Keywords ECOWAS countries · Energy consumption · Urbanization · Energy importers · Energy exporters · AMG estimation

Abbreviations

GDP	Gross domestic product
CO_2	Carbon dioxide emissions
ENR	Energy consumption

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FDI	Foreign direct investment
URB	Urbanization
TR	Trade openness
ARDL	Autoregressive distributed lag
AMG	Augmented mean group
CCEMG	Common correlated effects mean group
D–H test	Dumitrescu and Hurlin
VIF	Variance inflation factor
PMG	Pooled mean group
BRI	Belt and road initiative
MINT	Mexico, Indonesia, Nigeria, and Turkey
SAARC	South Asian Regional Cooperation Council
ECOWAS	Economic Community of West African States
RMSE	Root mean square error
WDI	World Bank Development Indicators
UNCTAD	United Nations Conference on Trade and Development

1 Introduction

Climate change has gained a great deal of attention among environmental economists around the world as a result of its impact on sustainable growth (He et al., 2020). Rafique et al. (2020) posit that investment is debated as key to a country's development, particularly foreign direct investment (FDI) inflows. Consequently, Abdouli and Omri (2021) posit that the drastic environmental changes in recent decades have been triggered by excess FDI, economic growth, and its associated energy use. Hongxing et al. (2021b) articulated that FDI inflows provide direct financing resources to promote economic growth through technology transfer and the development of new processes and management skills. However, with FDI inflows' positive impact on economic growth, theoretically, there are two competing schools of thought about the relationship between the FDI inflows and environmental pollution. Scholars such as (Mukhtarov et al., 2020; Wu et al., 2020) regard FDI inflows as one of the key factors that contribute to environmental degradation, whereas others, such as (Munir & Ameer, 2020; Sabir et al., 2020), argue that FDI inflows increase the quality of the environment. A closely linked variable with environmental degradation is urbanization with its associated industrialization and agricultural modernization (Odugbesan & Rjoub, 2020). The United Nations Urbanization Statistics (2019) revealed that cities like Tokyo have become the world's largest city with an agglomeration of 37 million inhabitants, followed by New Delhi with 29 million, Shanghai with 26 million, and Mexico City and São Paulo, each with about 22 million inhabitants. According to Ahmad et al. (2021), URB results in the use of more energy due to the diversification of operations from low to high energy demand sources. The resultant upsurge in energy consumption results in high CO_2 emissions. A contrasting finding was obtained by Mahmood et al. (2020), who unveiled evidence that showed URB has an inverse predictor of CO_2 emissions in Saudi Arabia.

This relationship between FDI inflows, urbanization, and environmental quality is puzzling. It is still unclear for developing countries, especially the Economic Community of West African States (ECOWAS), whether the effect of FDI and URB is positive or negative on the environment. The net inflows FDI in ECOWAS grew from US $1.91 billion in 2000 to US $13.5 billion in 2009 with a net inflow reaching an all-time high of US $18.8

billion in 2011. In 2016, ECOWAS share of total inflows to Africa's FDI amounted to US $10.1 billion (19.14%), whereas in 2017 it grew to US $12.69 billion (30.39%) (UNCTAD, 2018). The World urbanization prospects (2016), revealed that the number of urban dwellers within ECOWAS rose from 4 million in 1950 to 165 million urban dwellers in 2015. The increase in urban dwellers may have led to an increase in energy consumption, although its effect on CO_2 emissions is a dilemma. Whereas studies such as (Gbatu et al., 2019; OMOJOLAIBI et al., 2020) revealed that URB is a determinant of CO_2 emissions in ECOWAS, studies such as (Ameyaw et al., 2020; Omotor, 2017) posit that URB is not a key determinant of CO_2 emissions in ECOWAS. ECOWAS experienced remarkable economic growth which is evident from their GDP's reaching a promising level of US$ 6.36 trillion in 2017, at an increasing rate of 3.7% from previous years. Economic growth in the community was peaked at 3.9% in 2019 before the outbreak of coronavirus (UNCTAD, 2018). ECOWAS's total regional greenhouse gas emissions as in 2014 were 994.70 million metric tons equivalent (MtCO2e) and rose in 2019 to 1.043 billion metric tons. Thus, the question of the sustainability of growth in ECOWAS has become an issue of interest since many academic discourses have shown evidence of conflicting effect of FDI and URB on CO_2 emissions.

Literature regarding CO_2 emissions–FDI–growth can be grouped into three hypotheses; the unidirectional hypothesis, the feedback hypothesis, and the hypothesis of neutrality. In regards to the unidirectional hypothesis, Odugbesan and Rjoub (2020) examined the nexus between economic growth and CO_2 emissions in MINT countries within the period 1990–2017 ARDL Bounds test approach. The empirical findings support the unidirectional causal effect from economic growth to CO_2 emissions. Rahman et al. (2020) similarly but different variables and methodological focus investigated the relationship between trade openness and CO_2 emissions using the Granger causality from 1990 to 2017. Their empirical finding supports the unidirectional causation from trade openness to CO_2 emissions. Other studies revealed a bidirectional Hypothesis contrary to the unidirectional causation effect. Thus, some studies obtained a two-way causation relationship. Abban and Hongxing (2021a) delved into the determinants of economic growth in Africa from 1990 to 2018. They grouped the main panel into sub-groups of economic classification and employed the D–H causality test. They discovered that a bidirectional affiliation exists between FDI and CO2 in the main panel and lower-middle-income panel. Wu et al. (2020) explored the relationship between CO_2 emissions and urbanization from 1990 to 2018 using the D–H causality, taking into account income grouping along the BRI. Empirical evidence showed that a bidirectional association was found between urbanization and CO_2 emissions in low- and lower-middle-income countries. Yet again other studies reported the neutrality hypothesis, these studies obtained no causal effect on the employed variable and CO_2 emissions, which validates the neutrality hypothesis. Saidi and Omri (2020) also investigated the impact of economic growth and CO_2 emissions in 15 major renewable energy-consuming countries. They employ a panel data set from 1990 to 2014 and the vector error correction model (VECM) to unveil the effect of energy consumption on CO_2 emissions. They revealed that no causation effect exists between energy consumption and CO_2 emissions. In a similar vein, Zeren and Akkuş (2020) investigated the relationship between energy consumption and CO_2 emissions in emerging countries from 1980 to 2015. The empirical result from the D–H causality test revealed that no causal effect between energy consumption and CO_2 emissions exists. The diversity reports by researchers on CO_2 and its determinants are indicative of the need for further study of the relationship of CO_2 and its determinants.

A handful of studies on CO_2 emissions and other variables have been conducted in the ECOWAS community, nevertheless, there are limitations to these previous ECOWAS studies relating to CO_2 emissions and its determinants. This study resolves and to the extant literature in two ways. First, as a priority made on determining the epitope of CO_2 emissions in the ECOWAS community, most studies only considered the lump sum of countries without considering sub-panels. This study, however, clustered the countries into energy exporters and energy importers. Theoretically, there is a differential impact between energy exporters and energy importers and warrant an empirical study to test this assumption. Lastly, in addition to the few studies that exist based on our knowledge of CO_2 emissions and their initiators in the ECOWAS community, they pre-arrogate the existence of slope heterogeneity and cross-sectional independence residual, which to some extent is likely to produce inaccurate estimation results. This research probed into cross-sectional dependency and heterogeneity, thus, the analysis in this study used recently established econometric methods that take the above problems into account.

2 Methodology

This section constitutes the model formulation and econometric processes employed during the study. The section also describes the Source of Data and Descriptive Statistics.

2.1 Model formulation

Examining the causal relationship among CO_2, ENR, FDI, GDP, TRD, and URB, the study employed (Abban & Hongxing, 2021b; Gao & Zhang, 2021) and others' model, therefore the CO_2 emissions estimate function was written as:

$$CO_2 = (\text{ENR},\ \text{FDI},\ \text{GDP},\ \text{TRD},\ \text{URB}). \tag{1}$$

To address the problem of absence of homoscedasticity, hence, the transformed multivariate CO_2 model was written as;

$$\text{LnCO}_{2,\text{ it}} = \beta_0 + \beta_1\text{LnENR}_{\text{it}} + \beta_2\text{LnFDI}_{\text{it}} + \beta_3\text{LnGDP}_{\text{it}} + \beta_4\ \text{LnTRD}_{\text{it}} + \beta_5\text{LnURB}_{\text{it}} + \varepsilon_{\text{it}} \tag{2}$$

where β_0 is the coefficient of the slope, i represents each selected countries in the study (1, 2… N), t for the period of study and error term giving by ε_{it}. $\beta_1 - \beta_5$ are the coefficients for ENR, FDI, GDP, TRD, and URB, respectively.

2.2 CCEMG and AMG estimators

The augmented mean group (AMG) and common correlated effects mean group (CCEMG) were used to obtain the effects of the independent variables on the dependent variable. The method framework is as follows;

Taking a model such as;

$$y_{\text{it}} = \beta_{\text{i}} x_{\text{it}} + \varepsilon_{\text{it}} \tag{3}$$

$$\text{where} \quad \varepsilon_{\text{it}} = \theta_{1\text{i}} + \delta_{\text{i}} f_{\text{t}} + u_{\text{it}} \tag{4}$$

$$x_{it} = \theta_{2i} + \delta_i f_t + \vartheta_i g_t + e_{it}. \quad (5)$$

In the CCEMG as proposed by Pesaran (2006), y_{it} is the response variable, x_{it} is the explanatory variables where as β_i is each specific country slope coefficient on the observed independent variable, while ε_{it} is made up of the unobserved independent and the error terms u_{it}. Time invariant heterogeneity across groups is captured by θ_{1i}, the group fixed effects, f_t is an observed common factor, while δ_i captures time-variant cross-sectional correlation and heterogeneity. e_{it} and u_{it} are the error terms.

The Eberhardt and Teal (2010)' AMG, was used along with the CCEMG estimator. Unlike the CCEMG estimation which considers f_t as a nuisance, and its accountability was not of interest, the AMG accounts for f_t. The AMG follows three steps: (1) is the ordinary least square in Eq. 6 with T-1 year dummy (q_t) in the first difference (ΔD_t). (2) ω_t was then included in Eq. 7. It is included to compensate for any special processes that may develop over time. The subtraction of ω_t from the response variable (Eq. 8), signifying that a mutual process has been inflicted on each set of unit coefficients. (3) Lastly, AMG estimates are obtained as averages from each country's estimates. The group-specific regression model is adjusted with variables of β_t first, and then the average group-specific parameters are calculated. In regards to Eq. (2), the model is written as;

$$\mathrm{LnCO}_{2,\,\mathrm{it}} = \beta_0 + \beta_1 \mathrm{LnENR}_{\mathrm{it}} + \beta_2 \mathrm{LnFDI}_{\mathrm{it}} + \beta_3 \mathrm{LnGDP}_{\mathrm{it}} + \beta_4 \mathrm{LnTRD}_{\mathrm{it}} + \beta_5 \mathrm{LnURB}_{\mathrm{it}} + \sum_{t=2}^{T} q_{\mathrm{t}} \left(\Delta D_{\mathrm{t}}\right) + \mu_{\mathrm{it}} \quad (6)$$

$$\mathrm{LnCO}_{2,\mathrm{it}} = \beta_0 + \beta_1 \mathrm{LnENR}_{\mathrm{it}} + \beta_2 \mathrm{LnFDI}_{\mathrm{it}} + \beta_3 \mathrm{LnGDP}_{\mathrm{it}} + \beta_4 \mathrm{LnTRD}_{\mathrm{it}} + \beta_5 \mathrm{LnURB}_{\mathrm{it}} + d_1 \left(\omega_{\mathrm{t}}\right) + \mu_{\mathrm{it}} \quad (7)$$

$$\mathrm{LnCO}_{2,\mathrm{it}} - \omega_{\mathrm{t}} = \beta_0 + \beta_1 \mathrm{LnENR}_{\mathrm{it}} + \beta_2 \mathrm{LnFDI}_{\mathrm{it}} + \beta_3 \mathrm{LnGDP}_{\mathrm{it}} + \beta_4 \mathrm{LnTRD}_{\mathrm{it}} + \beta_5 \mathrm{LnURB}_{\mathrm{it}} + \varepsilon_{\mathrm{it}}. \quad (8)$$

2.3 Analytical processes

In order to specify the impact of the exploratory variables on the dependent variables, the following process was undertaken: (1) Various cross-sectional-dependency tests (Breusch–Pagan LM, bias-corrected scaled LM, Pesaran scaled LM, Pesaran CD, and Friedman) together with the Pesaran and Yamagata (2008) homogeneity test were performed to substantiate the existence of cross-sectional dependency and heterogeneous slopes in the panels. (2) The confirmation of cross-sectional reliance and slope heterogeneity led to the usage of the CIPS and CADF unit roots test proposed by Pesaran (2007) to determine the stationarity of the employed variables. (3) In order to determine the long-term connection among the variables, the Westerlund and Edgerton (2007) and the Pedroni (2004) test was carried out. (4) The long-term effects of the exploratory variables on the dependent variable were obtained with the AMG and the CCEMG estimators. (5) Lastly, the Dumitrescu and Hurlin (2012) were employed to ascertain the causal affiliation among the employed variables. The econometric processes are illustrated pictorially in Fig. 1.

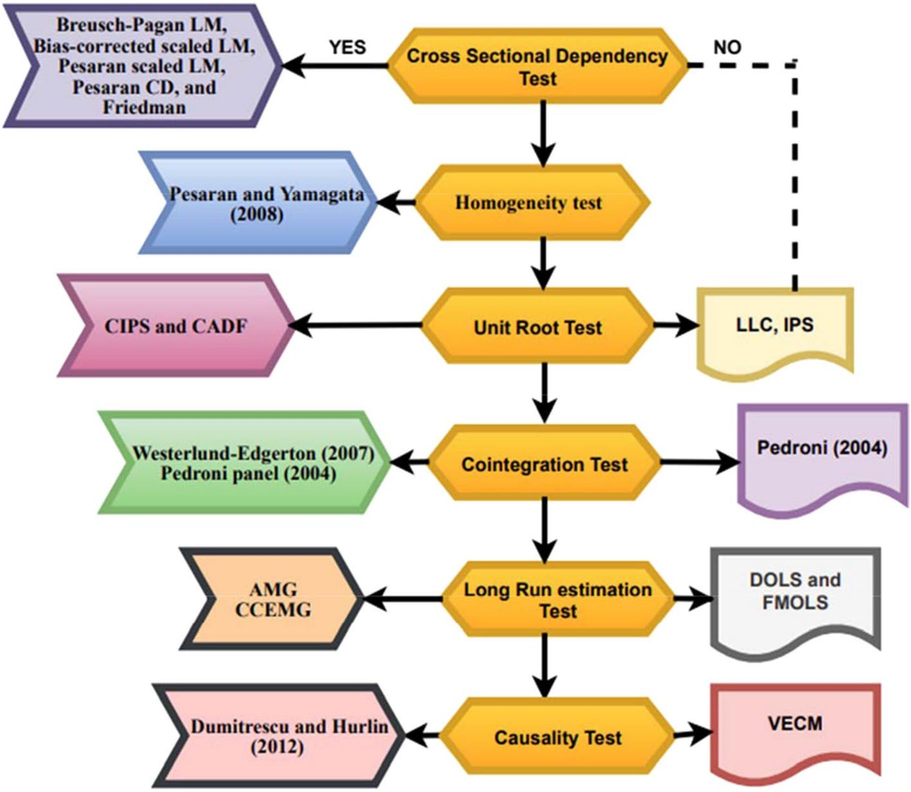

Fig. 1 Econometric processes employed during the study

2.4 Data source and descriptive statistics

It was necessary to divide these countries into energy importers and exporters because of the scarcity of conventional energy reserves and the rising reliance on energy imports. This provides a way of diversifying energy supply sources and maintaining energy protection for the ECOWAS group. These 14 countries obtained from the World Bank Development Indicators were divided into energy exporters and energy importers, according to the International Energy Agency (Table 1). The study span from 1990 to 2018 and this was due to data availability. The grouping is determined based on the ratio between net energy imports and energy usage, where energy imports are estimated to be energy use minus oil equivalent output. Net exporters are countries with negative net energy imports (Liu & Hao, 2018). Net energy imports are estimated as energy use less production, both measured in oil equivalents. A negative value indicates that the country is a net energy exporter. Using natural logarithms, the data were transformed to describe the estimates obtained as the elasticity of the response variable (CO_2 emissions). The variables selected, their explanations, measurement units, and references are outlined in Table 2.

In order to understand the coefficients of the employed variables as elasticities, the data in this analysis was transformed using the natural logarithm. The descriptive statistics of the study are displayed in Table 3. For the ECOWAS panel, CO_2 ($M = 9.741$, $SD = 1.904$),

Table 1 List of selected countries

Panel Groupings		
ECOWAS panel	Energy importers	Energy exporters
Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Guinea-Bissau, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo	Benin, Cote d'Ivoire, Gambia, Guinea-Bissau, Guinea, Mali, Senegal, Sierra Leone, Togo	Burkina Faso, Ghana, Mauritania, Niger, Nigeria

Table 2 Variable's description and data source

Variables Definitions	Abbreviation	Period	Source
Carbon dioxide emissions (kt)	CO_2	1990–2018	WDI
Energy consumption per capital (kg of oil equivalent)	ENR	1990–2018	WDI
Economic growth (per capita current US $)	GDP	1990–2018	WDI
Foreign direct investment inflows	FDI	1990–2018	WDI
Trade openness	TRD	1990–2018	WDI
Urbanization, urban population as the share of the total	URB	1990–2018	WDI

Table 3 Descriptive statistics

Panel	Variable	Mean	Std. dev	Skewness	kurtosis	JB test
ECOWAS panel	CO_2	9.741	1.904	0.731	3.419	37.906[a]
	ENR	8.317	1.175	-0.321	4.501	44.773[a]
	GDP	9.883	1.204	-0.273	3.114	6.877[c]
	FDI	13.254	0.965	0.177	2.383	8.749[b]
	TRD	16.403	1.308	-0.278	5.114	75.358[a]
	URB	8.634	1.041	0.634	2.107	35.088[a]
Energy exporters	CO_2	10.723	2.135	0.791	2.328	17.239[a]
	ENR	8.615	0.751	-0.190	4.304	10.780[a]
	GDP	10.117	1.386	-0.401	2.377	5.867[c]
	FDI	13.401	1.371	-0.154	1.766	9.681[a]
	TRD	16.789	1.142	1.032	3.164	24.653[a]
	URB	8.566	0.987	0.175	1.651	11.454[a]
Energy importers	CO_2	9.201	1.577	0.057	1.902	12.769[a]
	ENR	7.976	1.289	-0.176	3.987	11.231[a]
	GDP	9.713	1.120	-0.751	3.576	25.512[a]
	FDI	13.432	0.801	0.167	2.761	4.829[b]
	TRD	16.154	1.314	-0.779	5.103	68.324[a]
	URB	8.442	1.106	0.864	2.631	30.753[a]

The usage of the Jarque–Bera was to find out if the variables conform to the normal distribution. The rejection of null hypothesis was at "a, b, and c" that is 1%, 5%, and 10% significant level

ENR $(M = 8.317,\ SD = 1.175)$, GDP $(M = 9.883,\ SD = 1.204)$, FDI $(M = 13.254,\ SD = 0.965)$, TRD $(M = 16.403,\ SD = 1.308)$ and URB $(M = 8.634,\ SD = 1.041)$. Comparing the descriptive statistics for the two energy groups, Table 4 reveals that CO_2 in energy exporters $(M = 10.653,\ SD = 2.105)$ to importers countries $(M = 9.201,\ SD = 1.577)$. For ENR, energy exporters $(M = 8.615,\ SD = 0.751)$ to energy importers $(M = 7.976,\ SD = 1.289)$. FDI has $(M = 13.401,\ SD = 1.371)$ in energy exporters compared to energy importers $(M = 13.432,\ SD = 0.801)$. In regards to GDP, energy importers $(M = 10.117,\ SD = 1.386)$ compared to energy exporters

Table 4 Multicolinearity test results

	CO_2	ENR	FDI	GDP	TRD	URB	Collinearity Statistics	
CO_2	1						VIF	Tolerance
ENR	0.420	1					1.543	0.671
FDI	0.246	0.254	1				2.023	0.469
GDP	0.133	0.178	0.501	1			1.823	0.543
TRD	0.304	0.379	0.584	0.611	1		2.267	0.474
URB	0.585	0.307	0.401	0.349	0.438	1	1.612	0.654

CO_2 being the dependent variable while the value of the tolerance being greater than 0.2 and that of VIF being not more 5. Per the Pearson product correlation, the coefficient of correlation can be calculated by the formula

$$r = \frac{\sum_{i=1}^{n}(x_{1i}-\hat{x}_1)(x_{2i}-\hat{x}_2)}{\sqrt{\sum_{i=1}^{n}(x_{1i}-\hat{x}_1)^2}\sqrt{\sum_{i=1}^{n}(x_{2i}-\hat{x}_2)^2}}$$

(M = 9.713, SD = 1.120). For TRD, energy exporters have (M = 16.789, SD = 1.142) to (M = 16.154, SD = 1.314) in energy importers. Lastly for URB energy exporters (M = 8.566, SD = 0.987) compared to (M = 8.442, SD = 1.106) in energy importers countries. The correlation effects among the variables employed are shown in Table 4. As shown below by the Pearson product correlation, a correlation coefficient less than 0.7 among all the variables was observed. Hence, no evidence of a strong relationship among the explanatory variables. Again the variance inflation factor (VIF) and tolerance values are employed to ascertain the multicollinearity between explanatory variables. Inferentially, since the value of VIF (< 5) and the value of tolerance (> 0.2), it can be reasoned that each explanatory variable has a unique effect on the response variable.

3 Empirical results

The empirical results obtained from the various econometrics approaches follow as; cross-sectional dependence results, slope heterogeneity results, unit root test results, panel co-integration test results, panel model estimation results, and causality test results.

Table 5 Cross-sectional dependence results

Test statistics	ECOWAS panel		Energy exporters		Energy importers	
	Value	Prob	Value	Prob	Value	Prob
Breusch–Pagan LM	121.16[b]	0.000	103.78[a]	0.000	89.71[a]	0.000
Bias-corrected scaled LM	201.37[a]	0.000	164.23[a]	0.000	75.06[a]	0.000
Pesaran scaled LM	101.65[a]	0.000	132.11[a]	0.000	65.87[a]	0.000
Pesaran CD	42.17[a]	0.000	34.65[a]	0.000	39.47[a]	0.000
Friedman	36.81[a]	0.000	27.90[a]	0.000	17.94[a]	0.000

1%, 5%, 10% level of statistical significance is represented by "a, b, and c," respectively

Table 6 Pesaran and Yamagata homogeneity test results

	ECOWAS panel		Energy exporters		Energy importers	
	Value	Prob	Value	Prob	Value	Prob
Delta tilde ($\tilde{\Delta}$)	41.34[a]	0.000	57.09[a]	0.000	28.509[a]	0.000
Adjusted delta tilde ($\tilde{\Delta}_{adj}$)	23.75[a]	0.000	32.82[b]	0.000	9.037[a]	0.000

Note: "a, b and c" imply significance at the 1%, 5%, and the 10% levels, respectively

3.1 Cross-sectional dependence and slope heterogeneity test results

The findings of the cross-section dependence test are shown in Table 5. The results from the various tests indicated that the null hypothesis of cross-sectional independence is dismissed. The inference was there are enough grounds of cross-section correlation in the error terms among the panels. Hence econometric estimations that consider cross-sectional dependence was employed. Again, ignoring heterogeneity of slope coefficients may lead to imprecise estimates and skewed inferences (Breitung & Das, 2005). Hence, the Pesaran and Yamagata (2008) test was utilized in making that accession. As revealed in Table 6, the alternative hypothesis of heterogeneity in the slope coefficient is accepted. On this basis, estimators which are robust to heterogeneous problems and cross-sectional reliance were employed.

3.2 Unit root test results

Table 7 gives the results obtained from the panel unit root tests. From the results, it was inferred that the null hypothesis of the unit root at the variable level, regardless of whether the time trend is included or not should be accepted. However, after the first difference, the six variables were stable at significant levels of 1%, 5%, and 10%. Therefore, all variables in this study are of order 0, I (0) and then became of order 1, that is, I (1). This allows for further research on the long-term equilibrium association between CO_2, GDP, ENR, URB, FDI, and TRD variables.

3.3 Panel co-integration test results

In using the Westerlund and Edgerton (2007)' co-integration to determine the long-run association, the null hypothesis of non-existence of co-integration is rejected at the various significance levels with respect to the statistics G_τ, G_α, P_τ, and P_α. As a comparative analysis, Pedroni (2004) co-integration test was also employed. Tables 8 and 9 present the two co-integration test results. The robust p values, which provide robust evidence of co-integration as shown in Table 8, were the basis for decision. Table 9 presents a total of seven statistics to confirm the Pedroni's panel co-integration test. Four test statistics rejected the null hypothesis of non-existence of co-integration. Therefore, there was much proof of co-integration among variables in the dataset.

Table 7 Panel unit root test results

	CIPS						CADF					
	Levels			First difference			Levels			First difference		
Variables	Constant	Constant &Trend	Inf	Constant	Constant &Trend	Inf	Constant	Constant &Trend	Inf	Constant	Constant &Trend	Inf
ECOWAS panel												
CO_2	– 1.032	– 1.319	I (0)	– 3.562[a]	– 5.212[a]	I (1)	– 1.035	– 1.541	I (0)	– 4.781[a]	– 4.823[a]	I (1)
ENR	– 1.124	– 1.465	I (0)	– 4743[a]	– 5.337[a]	I (1)	– 1.712	– 1.472	I (0)	– 3.956[a]	– 5.134[a]	I (1)
FDI	– 1.305	– 1.217	I (0)	– 5.416[a]	– 5.487[a]	I (1)	– 2.001	– 1.203	I (0)	– 4.987[a]	– 4.924[a]	I (1)
GDP	– 1.322	– 1.212	I (0)	– 5.308[a]	– 5.207[a]	I (1)	– 1.343	– 1.305	I (0)	– 5.434[a]	– 4.715[a]	I (1)
TRD	– 1.214	– 1.374	I (0)	– 4.767[a]	– 5.492[a]	I (1)	– 2.015	– 1.436	I (0)	– 3.976[a]	– 5.205[a]	I (1)
URB	– 1.156	– 1.422	I (0)	– 5.420[a]	– 4.746[a]	I (1)	– 1.380	– 1.671	I (0)	– 4.121[a]	– 4.734[a]	I (1)
Energy exporters panel												
CO_2	– 1.342	– 1.402	I (0)	– 4.757[a]	– 5.034[a]	I (1)	– 1.476	– 1.954	I (0)	– 5.176[a]	– 5.376[a]	I (1)
ENR	– 1.140	– 1.301	I (0)	– 5.298[a]	– 5.269[a]	I (1)	– 1.145	– 1.478	I (0)	– 4.588[a]	– 4.908[a]	I (1)
FDI	– 1.432	– 1.245	I (0)	– 4.378[a]	– 5.343[a]	I (1)	– 2.017	– 1.522	I (0)	– 4.775[a]	– 4.798[a]	I (1)
GDP	– 1.351	– 1.034	I (0)	– 5.197[a]	– 5.431[a]	I (1)	– 2.105	– 1.740	I (0)	– 4.649[a]	– 5.396[a]	I (1)
TRD	– 1.133	– 1.378	I (0)	– 4.756[a]	– 5.478[a]	I (1)	– 2.138	– 1.412	I (0)	– 5.502[a]	– 4.798[a]	I (1)
URB	– 1.451	– 1.452	I (0)	– 4.920[a]	– 4.998[a]	I (1)	– 1.943	– 1.305	I (0)	– 5.208[a]	– 4.654[a]	I (1)
Energy importers panel												
CO_2	– 1.152	– 1.233	I (0)	– 5.014[a]	– 5.253[a]	I (1)	– 1.469	– 1.358	I (0)	– 5.145[a]	– 4.392[a]	I (1)
ENR	– 1.124	– 1.423	I (0)	– 4.532[a]	– 4.755[a]	I (1)	– 1.553	– 1.575	I (0)	– 4.776[a]	– 3.497[a]	I (1)
FDI	– 1.306	– 1.205	I (0)	– 4.764[a]	– 4.809[a]	I (1)	– 1.634	– 1.108	I (0)	– 4.909[a]	– 4.566[a]	I (1)
GDP	– 1.123	– 1.298	I (0)	– 4.898[a]	– 4.976[a]	I (1)	– 1.524	– 1.327	I (0)	– 5.278[a]	– 4.767[a]	I (1)
TRD	– 1.381	– 1.334	I (0)	– 5.765[a]	– 5.523[a]	I (1)	– 1.732	– 1.445	I (0)	– 4.672[a]	– 4.457[a]	I (1)
URB	– 1.334	– 1.408	I (0)	– 4.987[a]	– 5.540[a]	I (1)	– 1.424	– 1.339	I (0)	– 5.782[a]	– 5.178[a]	I (1)

Both the CADF and CIPS test the null hypothesis that the variables have unit root for each panel. “a, b, c” represent the level significance at 1%, 5%, 10%, respectively

Table 8 Westerlund bootstrap co-integration test

Country groups	G_τ		G_α		P_τ		P_α	
	Value	Robust p value	Value	Robust p value	Value	Robust p value	Value	Robust p value
ECOWAS panel	-5.542[a]	(0.000)	-6.323[a]	(0.000)	-7.513[a]	(0.000)	-7.763[a]	(0.000)
Energy exporters	-4.511[a]	(0.000)	-4.774[a]	(0.000)	-5.912[a]	(0.000)	-6.322[a]	(0.000)
Energy importers	-4.576[a]	(0.000)	-4.612[a]	(0.000)	-5.943[a]	(0.000)	-5.141[a]	(0.000)

a, b and c indicate 1%, 5% and 10% level of significance, respectively. Probability of rejection of H_0 is provided in (). Calculation of the P values is based on one side of the normal distribution test

Table 9 Pedroni co-integration test

Country groups	Panel statistics				Group statistics		
	V-statistic	Rho-statistic	PP-statistic	ADF-statistic	Rho-statistic	PP-statistic	ADF-statistic
ECOWAS panel	0.285	− 3.231[a]	− 7.832[a]	− 4.591[a]	1.954	− 10.371[a]	− 3.755[a]
Energy exporters	− 0.032	0.335	− 6.788[a]	− 4.364[a]	1.687	− 11.743[a]	− 4.329[a]
Energy importers	− 3.376[a]	− 0.310	− 5.498[a]	− 2.684[a]	1.156	− 4.188[a]	− 3.643[a]

Note: "a, b, c" denote the acceptance of the alternative hypothesis at 1%, 5% and 10% level of significance. The test adopts the null hypothesis of no co-integration

Table 10 AMG and CCEMG test results

Variables	Estimation method: Long-Run Coefficient					
	ECOWAS Panel		Energy Exporters		Energy importers	
	AMG	CCEMG	AMG	CCEMG	AMG	CCEMG
ENR	0.405[b]	0.414[a]	0.311[a]	0.337[c]	0.186[b]	0.354[a]
FDI	0.376[a]	0.403[c]	0.258[c]	0.314[b]	0.302[a]	0.413[a]
GDP	0.311[a]	0.337[b]	0.271[a]	0.306[a]	0.407[b]	0.521[a]
TRD	0.503[a]	0.527[c]	0.413[a]	0.522[a]	0.363[a]	0.437[a]
URB	0.365[a]	0.408[a]	0.244[b]	0.510[a]	0.411[c]	0.532[a]
(c.d.p)	1.073[a]		1.375[a]		0.964[a]	
RMSE	0.020	0.031	0.011	0.034	0.042	0.025
Observations	392	392	140	140	252	252

a, b, c represent level of Significance at 1%, 5% and 10%. The additional regressors "Common dynamic process" (cdp) was included

3.4 Panel model estimation and validity test results

Estimations of the independent variables on CO_2 emissions from the AMG and CCEMG estimations are depicted in Table 10. A percentage increase in ENR increases CO_2 by 0.545%, 0.438%, and 0.186% in the main ECOWAS panel, energy exporters, and energy importers, respectively. A percentage increase in FDI heightens CO_2 by 0.376%, 0.388%, and 0.452% in ECOWAS panel, energy exporters, and energy importers, whereas an increase in GDP rises the level of CO_2 by 0.747%, 0.671%, and 0.477% and in energy importers, energy exporters, and ECOWAS panel, respectively. With regard to TRD, its one percentage increase is likewise associated with a 0.593%, 0.723%, and 0.463% increase in ECOWAS panel, energy exporters, and energy importers. Lastly, an increase in URB caused a rise of 0.662%, 0.442%, and 0.405% in the ECOWAS panel, energy exporters, and energy importers. The CCEMG was used as a robust check to the AMG. A closed look at the Common dynamic process (c.d.p) showed that they were all significant. Figure 2 depicts the elastic impacts of explanatory variables on CO_2 in all three Panel groupings.

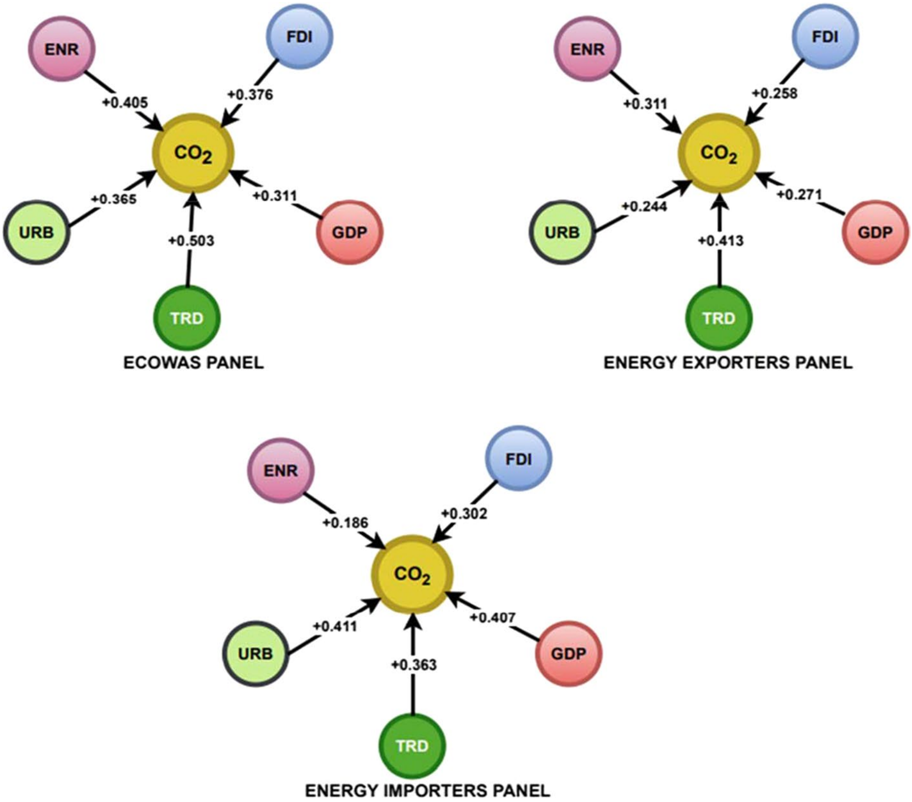

Fig. 2 The elastic impacts of explanatory variables on CO_2 in all three Panel groupings

The values of RMSE indicate the goodness of the response variables predicted by the model. Therefore, inferring from the RMSE value, we concluded that each model in the panel groups (ECOWAS panel, energy exporters, and energy exporters) are appropriate models in predicting the CO_2 emissions. The elastic impacts (weights) of explanatory variables are illustrated pictorially in Fig. 2.

While the contribution weight (order of importance) varied across panel groupings, the employed variables ENR, FDI, GDP, TRD, and URB were found to have a statistically significant and positive impact on CO_2 emissions across all panels. This means that the increase in each of the above variables rises the CO_2 emissions in all three clusters and is

Table 11 Diagnostics test results

Statistics test	ECOWAS Panel		Energy Exporters		Energy importers	
	Value	Prob	Value	Prob	Value	Prob
Wooldridge Serial Correlation test	34.233	0.412	42.324	0.511	37.451	0.158
White Heteroscedasticity test	14.411	0.356	10.543	0.361	12.124	0.506

Note: WSC test—Wooldridge serial correlation test, WH test—White heteroscedasticity test thus considered to be a possible contributor to CO_2 emissions. After the estimation of the parameters, the validity of the model is carefully checked. The White heteroskedasticity test and the Wooldridge serial correlation test were used to assess the efficacy of the model. The results shown in Table 11 do not show any definite heteroscedasticity and serial correlation between the model residuals.

3.5 Causality test results

The Dumitrescu and Hurlin (2012) were used to specify the direction of the causalities among the variables. The significance of the causality in the D–H test is determined by two types of test statistics: w-bar statistics (mean statistics for testing) and z-bar information (using standard normal distribution). The D–H causality test results are shown in Appendix Tables A, B, and C for the different income levels with Table 12 providing the summary of the test. For the ECOWAS panel, the results depicted in Table 12 revealed for CO_2 emissions, a bidirectional causal affiliation amid (CO_2 and URB), (CO_2 and ENR), (CO_2 and GDP), (CO_2 and TRD), and (CO_2 and FDI). With respect to energy exporters, a unidirectional causal affiliation was depicted from ENR to CO_2, from FDI and CO_2, from TRD to CO_2, whereas a two-way causal affiliation was depicted among (CO_2 and URB) and (CO_2 and GDP). With respect to energy importers, a two-way causal association existed among (CO_2 and ENR), (FDI and CO_2), and (CO_2 and URB), whereas a unidirectional causal effect from GDP to CO_2, from TRD to CO_2. Figure 3 illustrates the results obtained from the D–H granger causality.

4 Discussion of results

A disparate panel of 14 ECOWAS countries was grouped into energy importers and exporters for the period 1990 to 2018 to investigate the relationship amid foreign direct investment, urbanization, and CO_2 emissions. Given the empirical findings in the primary step of the cross-sectional dependence test, all panel groupings firmly confirmed the existence of cross-sectional independence. Thus, this suggests that a shock that occurs in any country within any of the panels employed appears to be transmitted or, in other words, may spill over to other countries within the same area due to strong economic relations between countries within each panel. The homogeneity test also showed all country groups give strong evidence of the rejection of the null hypothesis of homogeneity. Thus, revealing that country-specific heterogeneity occurs across the different country groupings within the individual coefficients. Consequently, from an econometric perspective,

Table 12 Summary results from D–H granger causality test

ECOWAS panel	Energy exporters	Energy importers
$CO_2 \Longleftrightarrow$ ENR	$CO_2 \Rightarrow$ ENR	$CO_2 \Longleftrightarrow$ ENR
$CO_2 \Longleftrightarrow$ FDI	FDI $\Rightarrow CO_2$	$CO_2 \Longleftrightarrow$ FDI
$CO_2 \Longleftrightarrow$ GDP	$CO_2 \Longleftrightarrow$ GDP	GDP $\Rightarrow CO_2$
$CO_2 \Longleftrightarrow$ TRD	TRD $\Rightarrow CO_2$	TRD $\Rightarrow CO_2$
$CO_2 \Longleftrightarrow$ URB	$CO_2 \Longleftrightarrow$ URB	$CO_2 \Longleftrightarrow$ URB

Note: $\not\Leftrightarrow$, $\Rightarrow$, and $\Longleftrightarrow$ indicate no causality, one-way, and two-way causality

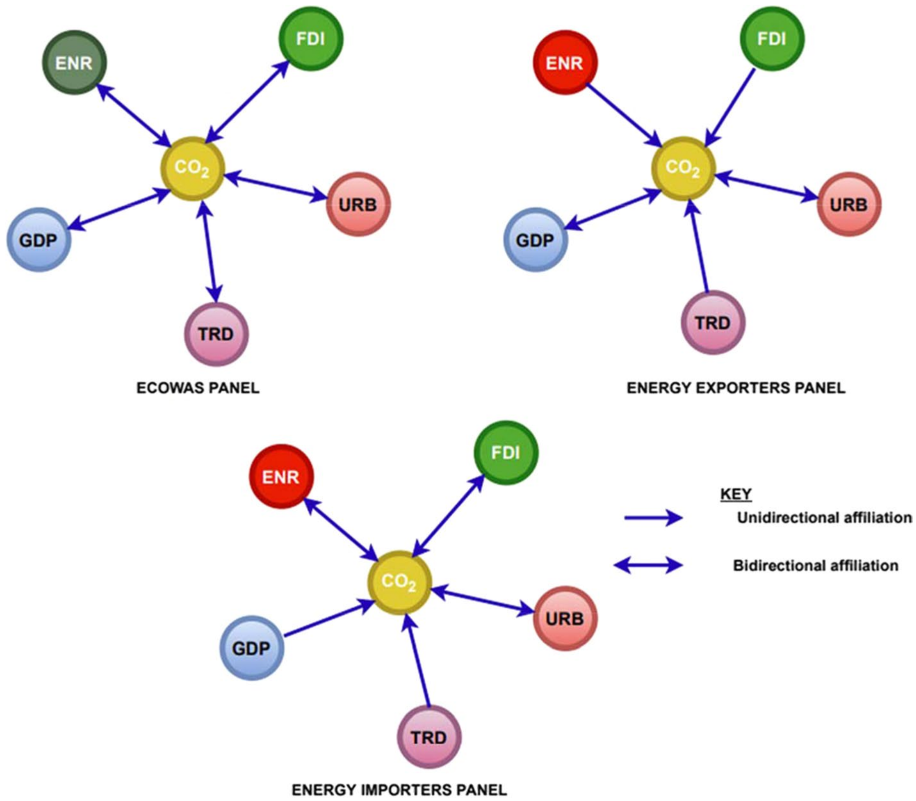

Fig. 3 Causalities among variables across panel groupings

the second-generation econometric techniques were employed to ascertain accurate and consistent results as a result of the confirmed cross-sectional reliability and heterogeneity residual across all panel groups. This is in accordance with the study done by Ibrahim and Ajide (2021) who ensure that cross-sectional dependency and heterogeneity exist among the variables when exploring the linkage between non-renewable and renewable energy consumption, trade openness, and environmental quality in G-7 countries. However, this contradicts the study done by Zhang et al. (2019) who showed no evidence of cross-sectional dependency and heterogeneity between economic growth, CO_2 emissions, and energy consumption in developing countries. Once more working with time-series panel models, the stationarity of the employed variables is vital. Thus, this study ensured that the stationarity of the employed variables was obtained. In accordance with Le and Bao (2020), who ensured no unit roots among variables so prevent the transmission of erroneous results in Latin America and the Caribbean Emerging market. The CADF and CIPS panel unit root test results showed that all employed variables were I (0), thus became I (1) after the first difference. Consequently, this gives the assurance that the variables used would be able to produce efficacious results. Regarding the long-run association, the Westerlund–Edgerton bootstrap co-integration employed revealed that there exists a long-run association among the employed variables. This result is inconsonant with Wu et al. (2020)'s work in assessing the nexus between CO_2 emissions, energy consumption, urbanization, economic structure, and economic growth in Belt and Road economies. On the contrary, these results differ from the work of Ozturk and Acaravci (2010). They did not find a long-term relationship between economic growth and electricity consumption in the 15 emerging countries.

The results obtained for the long-run estimates from the AMG showed that FDI and URB in all panel groupings have a significant incremental effect on CO_2 emissions. However, the incremental effect of URB in energy exporters is much higher than that of energy importers, whereas the incremental effects of FDI in energy importers are higher than that of energy- exporters. One of the explanations for the incremental effect of URB on CO_2 emissions in energy-exporters countries is that, at the economic growth stage, these countries ignore other factors' effects on environmental pollution but concentrate only on economic growth. Again, due to economic expansion, citizens turn to increase their income, so does the energy demand increased, which then worsening the quality of the environment. The positive effect of URB on CO_2 in all panel groups harmonized with the studies done by Musa et al. (2021) in Nigeria, where they stated that URB has a significant positive impact on CO_2 emissions. Their empirical findings suggested that URB has a positive effect on CO_2 emissions. However, the study done by Nuţă et al. (2021) contradicts the positive effect of URB on CO_2 emissions in EU countries. In their study, URB has a negative effect on CO_2 emissions, thus indicating that URB increases CO_2 emissions. The incremental effect of FDI inflows in energy importers can be associated with multinational company who flew extremely difficult environmental policies in developed countries to these countries where there are no or less environmental regulations. Thus, the results point that building of more foreign and local companies in this economic group has contributed to the creation of more jobs for the local residents which has led to the movement of individuals from the rural areas to the urban areas. The positive impact of FDI on CO_2 emissions in all panel clusters is in accordance with the output obtained by Halliru et al. (2021) for the same ECOWAS community. Their empirical findings unveiled that FDI increases CO_2 emissions within the ECOWAS community. Likewise, Awodumi (2021) also encountered a positive significant effect of FDI on CO_2 emissions in his time-series analysis on ECOWAS countries. Again, GDP in all panel groups indicated a positive significant effect on CO_2 emissions. This output is in line with the work done by Hdom and Fuinhas (2020). They posit that GDP has a positive significant effect on CO_2 emissions when they investigated the relationship between energy production, economic growth, and CO_2 emissions in Brazil. Lastly, it was evidenced that ENR also has a positive significant impact on C_{O2} emissions in all panel groups. This positive impact is in accordance with the study done by Wu et al. (2020), who obtained a positive impact of ENR in all panels in their study along the BRI economies.

Regarding the causal association among the variables, the two-way of the causality's affiliation between CO_2 and FDI in the ECOWAS community and energy importers. This depicts that more FDI and emissions of CO_2 are interrelated, such that a fall or rise in FDI turns to decrease or increase CO_2 and the other way around. Thus, this points to policymakers in these groupings to allow more investment that will turn to reduce the emissions of CO_2. These results are similar to the work done by Abban et al. (2020) along the BRI countries where they obtained a bidirectional affiliation between CO_2 and FDI. With regard to the nexus between CO_2–URB, the two-way causal affiliation evidenced in all panel groupings indicates that the two variables are closely related such that a rise in one variable turns to increase the other. These results agree with work done in Anser et al. (2020) in SAARC countries. Their findings stated that a bidirectional affiliation exists between CO_2–URB. Considering the CO_2–GDP nexus, a two-way causality was evidenced in the main panel and energy exporters but a one-way causal effect was seen in energy importers. The two-way causality indicates that a decrease or increase in GDP turns to decrease or increase CO_2 in the main panel and energy exporters. The two-causal affiliation obtained in the main panel and energy exporters is similar to the work done by Hongxing et al. (2021a) in 81 BRI countries, where they confirmed the presence of a bidirectional causation between CO_2–GDP, whereas the unidirectional from GDP to CO_2 in energy importers is in line with the study done by Ummalla and Goyari (2021) in BRICS countries. In their study, they posit that a one-way causal effect exists from GDP to CO_2 emissions. Regarding the nexus between CO_2–TRD, a one-way affiliation from TRD to CO_2 was observed in both energies grouping but a bidirectional effect in the main panel. The results obtained in the main are in line with studies done by Chen et al. (2021) in top BRI countries, where they also observed a bidirectional causal effect between CO_2–TRD, whereas the one-way affiliation observed in energy groups is consistent with work done by Rahman et al. (2020) in South Asia, where they also confirmed the way directional causal effect from TRD to CO_2 emissions. Lastly, the two-way causation effects between CO_2 and ENR in the ECOWAS community and energy importers showed that CO_2 and ENR are interrelated. The interconnection points that an increment in ENR leads to a corresponding step-up in CO_2 emissions. This effect is in line to the studies done by Onuoha et al. (2021) in West Africa community, respectively. Therefore, the ECOWAS community must consider the changeover of ENR (fossil fuel) to clean energy and in other to achieve zero emissions growth. Thus, increasing economic growth with the increased use of clean energy while leading to zero emissions of CO_2 along ECOWAS.

5 Conclusion and policy recommendations

The study investigates the dynamic nexus between CO_2 emissions, FDI, GDP, ENR, TRD, and URB in the ECOWAS community from 1990 to 2018. The study applied a number of analytical procedures including panel unit root tests, panel co-integration test, panel long-run elasticity, and panel D–H causality approach to ensure more reliable and reasonable results among the variables. A variety of conclusions was drawn accordingly. Estimates from the AMG affirmed that FDI accelerates CO_2 emissions in all panel groups, likewise

URB stimulates an increase in CO_2 emissions in the ECOWAS panel and two-panel groups. A percentage rise in GDP corresponds to different significant weights in all panel groupings, whereas trade openness in all panel grouping indicated a significant weight on CO_2 emissions. The white heteroscedasticity test and the Wooldridge serial correlation test employed to validate the model indicated that the model is statistically fit in predicting CO_2 emissions. To grasp the causal relationship among the employed variables, it was discovered that a quick distinct relationship exists, as FDI has a unidirectional liaison to CO_2 in energy exporters, whereas a bidirectional liaison between FDI and CO_2 in ECOWAS and energy importers panels. URB exhibited a bilateral causal effect with CO_2 in all panel groups. ENR exhibited a bilateral causal effect with CO_2 in energy importers and ECOWAS panels.

In ripple effect out the finding obtained, the following implications were deduced for this study;

1. Because an increase in FDI correspondingly raises CO_2 emissions through an increase in energy consumption, stringent environmental legislation needs to be extended to both international and local companies to curtail CO_2 emissions. Since multimillionaire's companies turn to flee from developing countries where stringent environmental policies have been established to reduce pollution. Again, the awareness of spillover from FDI companies to local businesses must be promoted.
2. In the long run, an increase in energy usage would also lead to high emissions of CO_2 in the economy. Although energy resources are essential for higher economic growth, it as well contributes to environmental degradation. Therefore, the government should increase the share of renewable energy sources in the economy's overall energy mix to increase energy availability.
3. The bidirectional causality affiliation between energy consumption and CO_2 emissions asserts that ensuring energy availability is necessary for achieving long-run economic growth. Since ECOWAS and that matter, Africa is already suffering from extreme energy/electricity shortages, the government of various energy groups in ECOWAS should concentrate on building resources to ensure that the economy has sufficient energy supplies. Thence, in the presence of bidirectional causality, energy shortages have clear consequences for economic growth in the economy.
4. Economic growth and the CO_2 emissions in the long-run feedback in the ECOWAS panel. This suggests that higher economic growth could occur at the cost of a cleaner environment, which will undermine the quality of economic growth. Thus, to address this feedback, it is recommended that the abatement of CO_2 emissions activities be included in ECOWAS's central energy and environmental policy to abridge impairments related to CO_2 emissions.

Appendix

See Tables 13, 14 and 15

Table 13 D–H causal affiliations in ECOWAS panel

Hypothesis	$W_{N,T}^{stat}$	$\overline{Z}_{N,T}^{stat}$	Prob	Inference
CO2 → ENR	8.868[a]	17.589[a]	0.000	Bidirectional causal affiliation between CO2 and ENR
ENR → CO2	3.764[a]	6.047[a]	0.000	
CO2 → FDI	1.893c	1.816[c]	0.069	Bidirectional causal affiliation between CO_2 and FDI
FDI → CO2	2.934[a]	4.169[a]	0.000	
CO2 → GDP	3.403[a]	5.229[a]	0.000	Bidirectional causal affiliation between CO2 and GDP
GDP → CO2	5.233[a]	9.369[a]	0.000	
CO2 → TRD	2.363[a]	2.878[a]	0.004	Bidirectional causal affiliation between CO_2 and TRD
TRD → CO2	2.613[a]	3.443[a]	0.000	
CO2 → URB	6.797[a]	12.905[a]	0.000	Bidirectional causal affiliation between CO2 and URB
URB → CO2	6.702[a]	12.691[a]	0.000	
FDI → ENR	2.142[a]	2.378[a]	0.017	Unidirectional causal affiliation from FDI to ENR
ENR → FDI	0.730	-0.815	0.414	
GDP → ENR	2.109[b]	2.302[b]	0.021	Unidirectional causal affiliation from GDP to ENR
ENR → GDP	1.187	0.218	0.827	
TRD → ENR	1.837[c]	1.689[c]	0.091	Unidirectional causal affiliation from TRD to ENR
ENR → TRD	1.263	0.390	0.696	
ENR → URB	2.684[a]	3.604[a]	0.000	Bidirectional causal affiliation between ENR and URB
URB → ENR	3.175[a]	4.713[a]	0.000	
FDI → GDP	3.829[a]	6.192[a]	0.000	Bidirectional causal affiliation between FDI and GDP
GDP → FDI	2.408[a]	2.979[a]	0.002	
FDI → TRD	1.948[c]	1.939[c]	0.052	Bidirectional causal affiliation between FDI and TRD
TRD → FDI	4.309[a]	7.277[a]	0.000	
FDI → URB	2.479[a]	3.139[a]	0.001	Bidirectional causal affiliation between FDI and URB
URB → FDI	5.666[a]	10.347[a]	0.000	
GDP → TRD	1.651	1.267	0.205	Unidirectional causal affiliation from TRD to GDP
TRD → GDP	6.987[a]	13.335[a]	0.000	
URB → GDP	4.303[a]	7.266[a]	0.000	Bidirectional causal affiliation between GDP and URB
GDP → URB	6.193[a]	11.538[a]	0.000	
URB → TRD	3.154[a]	4.667[a]	0.000	Bidirectional causal affiliation between TRD and URB
TRD → URB	12.764[a]	26.400[a]	0.000	

Table 14 D–H causal affiliation among energy exporters

Hypothesis	$W_{N,T}^{stat}$	$\overline{Z}_{N,T}^{stat}$	Prob	Inference
CO2 → ENR	0.719	-0.501	0.615	Unidirectional causal affiliation from ENR and CO_2
ENR → CO2	5.608[a]	6.105[a]	0.000	
CO2 → FDI	1.152	0.083	0.933	Unidirectional causal affiliation from FDI to CO_2
FDI → CO2	3.430[a]	3.161[a]	0.001	
CO2 → GDP	7.572[a]	8.759[a]	0.000	Bidirectional causal affiliation between CO2 and GDP
GDP → CO2	7.241[a]	8.313[a]	0.000	
CO2 → TRD	1.378	0.388	0.697	Unidirectional causal affiliation from TRD and CO2
TRD → CO2	5.112[a]	5.434[a]	0.000	
CO2 → URB	11.906[a]	14.618[a]	0.000	Bidirectional causal affiliation between CO2 and URB
URB → CO2	7.608[a]	8.808[a]	0.000	
FDI → ENR	1.907	1.103	0.269	No causal affiliation between FDI and ENR
ENR → FDI	0.863	− 0.307	0.758	
GDP → ENR	2.744[b]	2.234[b]	0.025	Bidirectional causal affiliation between GDP and ENR
ENR → GDP	2.553[b]	1.976[b]	0.048	
TRD → ENR	1.572	0.650	0.515	No causal affiliation between TRD and ENR
ENR → TRD	1.642	0.745	0.455	
ENR → URB	2.123	1.395	0.162	Unidirectional causal affiliation from URB to ENR
URB → ENR	3.879[a]	3.769[a]	0.000	
FDI → GDP	4.447[a]	4.536[a]	0.000	Unidirectional causal affiliation from FDI to GDP
GDP → FDI	1.222	0.177	0.859	
FDI → TRD	1.211	0.163	0.870	Unidirectional causal affiliation from TRD to FDI
TRD → FDI	4.983[a]	5.260[a]	0.000	
FDI → URB	5.037[a]	5.333[a]	0.000	Bidirectional causal affiliation between FDI and URB
URB → FDI	3.295[a]	2.979[a]	0.002	
GDP → TRD	2.652[b]	2.110[b]	0.034	Bidirectional causal affiliation between TRD and GDP
TRD → GDP	14.354[a]	17.925[a]	0.000	
URB → GDP	4.942[a]	5.205[a]	0.000	Bidirectional causal affiliation between GDP and URB
GDP → URB	2.725[b]	2.208[b]	0.027	
URB → TRD	6.616[a]	7.467[a]	0.000	Bidirectional causal affiliation between TRD and URB
TRD → URB	10.520[a]	12.744[a]	0.000	

Table 15 D–H causal affiliations among energy importers

Hypothesis	$W_{N,T}^{stat}$	$\overline{Z}_{N,T}^{stat}$	Prob	Inference
CO2 → ENR	13.395[a]	22.312[a]	0.000	Bidirectional causal affiliation between ENR and CO_2
ENR → CO2	2.740[a]	2.991[a]	0.002	
CO2 → FDI	2.305[b]	2.203[b]	0.027	Bidirectional causal affiliation between FDI and CO_2
FDI → CO2	2.658[a]	2.843[a]	0.004	
CO2 → GDP	1.086	-0.007	0.994	Unidirectional causal affiliation from GDP and CO_2
GDP → CO2	4.118[a]	5.489[a]	0.000	
CO2 → TRD	2.911[a]	3.301[a]	0.001	Unidirectional causal affiliation from CO_2 and TRD
TRD → CO2	1.225	0.243	0.807	
CO2 → URB	3.958[a]	5.200[a]	0.000	Bidirectional causal affiliation between CO2 and URB
URB → CO2	6.199[a]	9.262[a]	0.000	
FDI → ENR	2.272[b]	2.143[b]	0.032	Unidirectional causal affiliation from FDI to ENR
ENR → FDI	0.656	-0.787	0.431	
GDP → ENR	1.756	1.206	0.227	No causal affiliation between GDP and ENR
ENR → GDP	0.428	-1.201	0.229	
TRD → ENR	1.985	1.621	0.104	No causal affiliation between TRD and ENR
ENR → TRD	1.052	-0.068	0.945	
ENR → URB	2.996[a]	3.456[a]	0.000	Bidirectional causal affiliation between URB and ENR
URB → ENR	2.783[a]	3.069[a]	0.002	
FDI → GDP	3.485[a]	4.342[a]	0.000	Bidirectional causal affiliation between FDI and GDP
GDP → FDI	3.067[a]	3.583[a]	0.000	
FDI → TRD	2.357[b]	2.296[b]	0.021	Bidirectional causal affiliation between TRD and FDI
TRD → FDI	3.934[a]	5.156[a]	0.000	
FDI → URB	1.057	-0.059	0.952	Unidirectional causal affiliation from URB and FDI
URB → FDI	6.983[a]	10.684[a]	0.000	
GDP → TRD	1.094	0.006	0.994	Unidirectional causal affiliation from TRD to GDP
TRD → GDP	2.894[a]	3.271[a]	0.001	
URB → GDP	3.949[a]	5.183[a]	0.000	Bidirectional causal affiliation between GDP and URB
GDP → URB	8.119[a]	12.74[a]	0.000	
URB → TRD	1.231	0.2557	0.798	Unidirectional causal affiliation from TRD to URB
TRD → URB	14.011[a]	23.428[a]	0.000	

Funding This study is sponsored by Prof. Wu Jiying who has received a research grant from Humanities and Social Science Research Youth Fund Project of Ministry of Education of China (17YJC910008).

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