MODELLING THE EMISSIONS-INCOME RELATIONSHIP IN EAST AFRICAN COMMUNITY (EAC) COUNTRIES: A PANEL COINTEGRATION APPROACH[1]

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ABSTRACT

This study examines the nexus between economic growth and carbon dioxide (CO_2) emissions in East African Community (EAC) countries, with a focus on the role of renewable energy consumption. As EAC countries undergo rapid industrialisation and urbanisation, understanding the impact of economic growth on emissions is critical for shaping sustainable development policies. Using a panel cointegration approach, the study applies the environmental Kuznets curve (EKC) hypothesis to data from six EAC countries, namely, the Democratic Republic of the Congo, Burundi, Rwanda, Kenya, Uganda and Tanzania, for the period from 1990 to 2022. The panel autoregressive distributed lag (ARDL) model is employed, with the pooled mean group (PMG) estimator used to analyse both long-run and short-run dynamics. The results reveal a U-shaped relationship between economic growth and CO_2 emissions, challenging the traditional inverted U-shaped EKC hypothesis. The findings suggest that while the early stages of economic growth reduce emissions, emissions begin to rise again beyond a certain income threshold, indicating a potential overdevelopment phase. Renewable energy consumption is found to significantly reduce CO_2 emissions; however, its economic benefits are constrained by infrastructural and policy challenges. This study contributes to existing literature by integrating renewable energy into the EKC framework and offers valuable insights for policymakers seeking to balance economic growth with environmental sustainability. The findings emphasise the need for targeted policies to promote clean energy adoption, low-carbon industrialisation and stronger environmental governance across EAC countries.

1. INTRODUCTION

The nexus between economic growth and environmental degradation, particularly carbon dioxide (CO_2) emissions, remains a central concern in global sustainability discussions. As economies expand, greenhouse gas (GHG) emissions have surged, exacerbating climate change and posing significant threats to economic stability, public health and ecosystems. The growing frequency and intensity of extreme weather events, such as floods, droughts and heat waves, reflect the tangible consequences of these emissions. These climate-induced disruptions reduce agricultural productivity, threaten livelihoods and accelerate biodiversity loss. According to the World Economic Forum's Global Risks Report (World Economic Forum, 2024), climate change, extreme weather and ecosystem collapse rank among the most pressing global risks, emphasising the need for coordinated international action. This aligns with the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), which advocates for global collaboration to limit temperature increases and reduce emissions.

These environmental challenges are particularly pronounced in the East African Community (EAC), where rapid urbanisation, industrialisation and increasing energy demands have intensified pollution and environmental degradation. According to Sun et al. (2022), economic growth in EAC countries is largely driven by carbon-intensive sectors such as agriculture, manufacturing and energy production. Unlike many developed economies that have begun to decouple economic expansion from environmental degradation, growth within the EAC remains closely tied to rising CO_2 emissions. This interdependence presents a significant development dilemma: how to pursue sustained economic progress without exacerbating ecological damage. Addressing this challenge requires acknowledging the region's continued reliance on traditional fossil fuels, which underscores the urgent need for a strategic transition toward cleaner, renewable energy sources. Embracing renewables and adopting low-carbon development strategies will be essential to align the region's economic aspirations with environmental sustainability.

Given these regional challenges, it becomes essential to apply robust theoretical frameworks to understand the interaction between economic activity and emissions. One such framework is the environmental Kuznets curve (EKC), which posits an inverted U-shaped relationship between income and environmental degradation. According to this hypothesis, environmental degradation tends to increase in the early stages of economic growth but may decline as income rises and cleaner technologies are adopted. However, its applicability in developing regions, particularly East Africa, remains inconclusive, as early stages of economic growth often coincide with rising emissions before any potential decoupling occurs (Baidoo, 2023). Renewable energy consumption emerges as a promising pathway to reduce CO_2 emissions while sustaining growth. Although the broader role of renewables in addressing climate change is well established, their specific impact on emissions within EAC countries remains underexplored. As investment in clean energy accelerates across the region, understanding its implications for both environmental and economic outcomes has become increasingly vital.

To address these gaps, this study aims to investigate the long-term and short-term relationship between economic growth and CO_2 emissions in East African Community countries, with a focus on the role of renewable energy consumption. The objectives are twofold: first, to assess the validity of the EKC hypothesis in the EAC countries; and second, to evaluate the impact of renewable energy consumption on the emissions-income relationship. The study utilises data from six EAC countries: the Democratic Republic of the Congo, Burundi, Rwanda, Kenya, Uganda and Tanzania, spanning the period from 1990 to 2022, marked by early industrialisation and a surge in clean energy investments. The study applies the EKC framework using the pooled mean group (PMG) estimator within a panel autoregressive distributed lag (ARDL) model to analyse both long-run and short-run dynamics.

By examining the emissions-growth nexus, this study provides key insights into the sustainability challenges facing East African Community countries and highlights the transformative potential of renewable energy. Moreover, it contributes to the broader discourse by shedding light on a region that is often underrepresented in global discussions on environmental sustainability. The rest of the paper is structured as follows: Section 2 reviews the relevant literature; Section 3 details the data and methodology; Section 4 presents the empirical results; Section 5 discusses the key findings; and Section 6 concludes with policy recommendations.

2. EMPIRICAL LITERATURE

The relationship between income and carbon emissions has been widely examined, yielding mixed evidence regarding the validity of the environmental Kuznets curve (EKC) hypothesis. As previously described, the EKC hypothesis suggests that CO_2 emissions initially rise with income but may decline after a certain threshold is reached. However, empirical findings remain inconclusive.

While some studies support the EKC hypothesis, others reveal alternative patterns, including monotonic increases, N-shaped curves, or even no clear relationship. These inconsistencies often stem from differences in a country's economic and structural conditions, income levels, methodological approaches and the specific pollutants or indicators under study.

Recent empirical studies offer robust support for the applicability of the EKC hypothesis, particularly within developing countries. Ganda (2023), employing the autoregressive distributed lag (ARDL) model, confirmed the existence of an inverted U-shaped relationship between income and CO_2 emissions in South Africa, consistent with the EKC framework. Similarly, Boga and Boga (2024) provided evidence that renewable energy consumption and financial development play a critical role in mitigating emissions, thereby reinforcing the EKC hypothesis across leading renewable energy-consuming countries. Complementing these findings, Hlongwane and Daw (2022) applied a vector error correction model (VECM) and found a statistically significant negative long-run relationship between economic growth and carbon emissions in South Africa, further validating the EKC trajectory in Sub-Saharan Africa.

Adeleye, Adedipe, and Okunlola (2021) revealed significant variation in the income-emissions nexus across 28 African countries, emphasising the importance of regional variation in shaping this relationship. Their study found that per capita income moderates the effect of energy consumption on carbon emissions, with marked regional contrasts. Southern Africa exhibited the highest energy-driven emissions, whereas West Africa demonstrated the strongest moderating effect of income. While regional heterogeneity is central to understanding the EKC within Africa, global patterns also provide critical insight into the complex relationship between income and emissions. Almeida, Duarte, and Pinheiro (2024) found that high-income countries are increasingly successful at decoupling economic growth from emissions, while low-income countries continue to experience a positive and often linear relationship between the two.

While the EKC hypothesis offers a valuable lens for examining the relationship between income and emissions, empirical evidence indicates that it is not universally applicable. Emissions outcomes are shaped by a complex interplay of factors, including the energy mix, income inequality and distinct regional dynamics. Shivani (2024) highlights the moderating role of renewable energy, suggesting that its integration into the energy system can significantly reduce the environmental impact of economic growth. Similarly, Boga and Boga (2024) emphasise that income inequality, along with globalisation drivers such as international trade and foreign direct investment, influences emissions patterns, thereby highlighting the need for multidimensional and country-specific policy approaches. While economic expansion tends to drive emissions upward, studies by Teklie and Dogan (2024) affirm that technological innovation and increased adoption of renewable energy can counterbalance these effects. Collectively, these findings reinforce the importance of designing strategic, evidence-based policies that align economic development goals with environmental sustainability.

The diversity of empirical findings on the EKC highlights that a uniform policy approach is unlikely to yield effective results across different regions. Instead, strategies should be tailored to reflect the unique energy structures, socio-economic conditions and institutional capacities of each country. In the case of the EAC countries, examining the income-emissions relationship within a localised framework is essential for uncovering relevant patterns and designing policies that support both economic development and environmental sustainability.

Figure 1 visually represents the EKC hypothesis, describing an inverted U-shaped relationship between income and environmental degradation

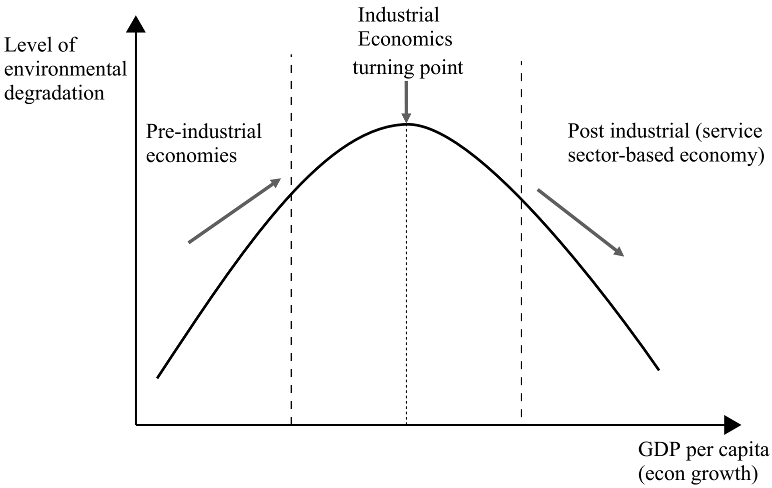

Figure 1: Environmental Kuznets Curve

Source: Pettinger, 2019.

This transition, as shown in the EKC, reflects how countries may shift toward sustainability as incomes grow. In the early stages of economic growth, environmental quality deteriorates. However, as countries grow wealthier, they tend to adopt more sustainable practices. In the early stages of economic development, pollution tends to rise due to industrialisation, urban expansion and increased consumption. During this phase, economic growth is often prioritised over environmental concerns, leading to heavy reliance on fossil fuels, deforestation and resource-intensive manufacturing. However, as income levels increase and economies mature, structural changes begin to take hold. Technological innovations facilitate the adoption of cleaner and more efficient production methods, while stronger regulatory frameworks and rising public awareness drive demand for environmental accountability. Simultaneously, increased investment in sustainable infrastructure, such as renewable energy, waste management and green transportation, further supports this transition. These combined efforts gradually decouple economic growth from environmental degradation, resulting in reduced emissions and improved environmental outcomes.

Wealthier societies are more likely to enforce stringent environmental regulations, such as the European Union's Carbon Border Adjustment Mechanism (CBAM) and Deforestation Regulation (EUDR), which promote sustainable practices across industries and global supply chains. These regulatory efforts are often accompanied by increased investment in sustainable infrastructure and renewable energy, as evidenced by the growing participation of institutional investors in green energy projects and climate finance initiatives (UNCTAD, 2023). In addition, structural economic transformations contribute to environmental improvements, including shifts in the labour market toward green jobs, facilitated by training programmes and the adoption of carbon taxes aimed at discouraging pollution-intensive production. Simultaneously, rising public awareness and enhanced institutional capacity reinforce sustainability efforts. Universities and corporations are progressively integrating green operational models, while development agencies champion coherent environmental, social and governance (ESG) frameworks and innovative financing mechanisms to align international trade with climate objectives (DCED, 2025). As living standards improve, so do public expectations for environmental accountability, generating political momentum for policies such as wealth taxes to fund climate resilience and ensure that high-emission industries are held responsible.

However, while these mechanisms have proven effective in wealthier countries, the extent to which developing countries can replicate such transitions remains uncertain. Despite the EKC's theoretical appeal, its applicability is still debated, particularly across varying country conditions and environmental indicators. According to Wang, Li, and Li (2024), although empirical studies often confirm the EKC in developed economies, many developing countries continue to face persistent environmental degradation even as incomes rise. This divergence is largely attributed to factors such as weak governance structures, limited access to clean technologies, reliance on resource-intensive industries and ineffective environmental regulation, all of which hinder progress toward the EKC's turning point. Moreover, not all pollutants adhere to the EKC trajectory; for example, CO_2 emissions frequently continue to increase with economic growth, reflecting an enduring dependence on fossil fuels for energy and transport.

3. DATA & METHODOLOGY

3.1 Data

To examine the dynamic causal relationship between environmental degradation and economic growth, this study uses carbon dioxide (CO_2) emissions per capita and renewable energy consumption as measures of environmental impact. Gross domestic product (GDP) per capita serves as the primary indicator of economic growth. The variables are denoted as follows: GDP for GDP per capita, CO_2 for carbon dioxide emissions per capita and REN for renewable energy consumption.

The analysis focuses on a panel of six East African Community countries: the Democratic Republic of Congo (DR Congo), Burundi, Rwanda, Kenya, Uganda and Tanzania. Annual data from 1990 to 2022 were obtained from the World Bank Indicators database. The dataset includes GDP per capita (in US dollars), CO_2 emissions per capita (in metric tons) and REN (measured as the percentage of total energy consumption derived from renewable sources).

Table 1 below presents the descriptive statistics for GDP per capita (lnGDP), CO_2 emissions per capita ($lnCO_2$) and renewable energy consumption (lnREN) across six EAC countries from 1990 to 2022.

Table 1: Descriptive statistics

Variable		Mean	Sd	Min	Max	No. of observation
lnGDP	Overall	6.354	0.5139	5.249	7.411	186
	Within group		0.1602	6.128	6.626	31
	Between-group		0.4886	5.766	7.184	6
$lnCO_2$	Overall	-2.5021	0.7626	-3.8263	-0.8902	186
	Within group		0.2011	-2.767	-2.119	31
	Between-group		0.7625	-3.350	-1.257	6
lnREN	Overall	4.493	0.0805	4.263	4.588	186
	Within group		0.0251	4.437	4.519	31
	Between-group		0.0795	4.349	4.569	6

Source: Author's computation

GDP per capita (lnGDP) has the highest mean value of 6.354 among the variables. The between-group standard deviation (0.4886) is significantly larger than the within-group standard deviation (0.1602), indicating that the variation in GDP per capita is primarily driven by differences across countries rather than changes over time within each country.

CO_2 emissions per capita ($\ln CO_2$) have a mean of -2.5021, reflecting the overall low levels of per capita emissions for the countries. This variable exhibits the highest overall standard deviation (0.7626) among the three indicators, suggesting substantial variation in emissions levels across the sample. The between-group standard deviation (0.7625) is much higher than the within-group standard deviation (0.2011), implying that cross-country differences in CO_2 emissions are more pronounced than within-country variations over time. This suggests that some EAC countries have significantly higher per capita emissions than others, but the rate of change within individual countries is relatively small.

Renewable energy consumption (lnREN) has a mean of 4.493 and exhibits the lowest variation among the three variables. The between-group standard deviation (0.0795) is slightly larger than the within-group standard deviation (0.0251), indicating that differences in renewable energy consumption across countries are slightly greater than variations over time. This suggests that EAC countries have relatively stable renewable energy consumption patterns over time, with only minor cross-country differences.

3.2 Methodology

This study adopts a quadratic functional form, allowing for non-linear relationships between income levels and environmental degradation. The baseline specification follows the conventional EKC model (Shafik, 1994; Primer, 2002), where the natural logarithm of CO_2 emissions *i is* regressed on the natural logarithm of GDP per capita and its squared term:

$$\ln\left(CO2_t\right)=\beta_0+\beta_1\ln GDP_t+\beta_2\ln\left(GDP_t\right)^2+\varepsilon_t \quad \text{..(1)}$$

To account for country-specific effects and incorporate the role of renewable energy consumption, the study extends to a panel data model, applying a fixed-effects framework as shown below (Farhani et al., 2014):

$$\ln\left(CO2_{i,t}\right)=\alpha_i+\beta_1\ln GDP_{i,t}+\beta_2\ln\left(GDP_{i,t}\right)^2+\beta_3\ln REN_{i,t}+\varepsilon_{i,t} \quad \text{............................(2)}$$

Here, α_i captures unobserved country-specific heterogeneity, while i and t denote country and time, respectively. The coefficients β_1 and β_2 represent the elasticity of emissions for GDP and GDP squared, and β_3 captures the effect of renewable energy consumption on emissions, $\varepsilon_{i,t}$ is the stochastic disturbance error term.

For the EKC hypothesis to hold, $\beta_1>0$ and $\beta_2<0$, implying an inverted U-shaped relationship between economic growth and environmental degradation. A linear relationship would be indicated by $\beta_2=0$ while a U-shaped curve, reflecting an initial decline in emissions followed by a rise, would be supported if $\beta_1<0$ and $\beta_2>0$.

According to Arshed, Munir and Iqbal (2021), the inverted U-curve is interpreted through two stages: the deterioration stage, where emissions rise with growth, and the maturity stage, where emissions begin to decline. Conversely, the U-shaped path follows a balanced growth phase, characterised by reduced emissions during initial development, followed by an overdevelopment phase where emissions rise again.

3.2.1 Cointegration and Stationary Tests

To determine the stationarity properties of the variables, panel unit root tests were applied under the assumption of a first-order autoregressive process. Each time series for cross-sectional unit i was modelled to assess integration order. Given the presence of a mix of I(0) and I(1) variables, the panel ARDL cointegration framework was selected for its flexibility in handling such series. Upon confirming cointegration, the pooled mean group (PMG) estimator was employed, constraining long-run parameters to be homogeneous across countries while allowing for short-run heterogeneity, thus ensuring consistent and efficient estimates within a panel data framework.

Assuming a first-order autoregressive process for the panel data, the time series for each cross-sectional unit i is represented as:

$$Y_{it}=\left(1-\alpha_i\right)\mu_i+\alpha_i Y_{i,t-1}+\varepsilon_{it} \quad (3)$$

Rewriting in first differences yields:

$$\Delta Y_{it}=-\varphi_i\mu_i+\varphi_i Y_{i,t-1}+\varepsilon_{it} \quad (4)$$

where $\Delta Y_{it}=Y_{it}-Y_{it-1}$ and $\varphi_i=\alpha_i-1$

Incorporating mean deviations, $\hat{Y}_{it} = \alpha_i Y_{i,t-1} + \varepsilon_{it}$ and $\hat{Y}_{it} = Y_{it} + \mu_i$, the panel unit root model becomes:

$$\Delta \hat{Y}_{it} = \phi_i Y_{i,t-1} + \varepsilon_{it} \quad \text{.......(5)}$$

The null hypothesis tests for the presence of a unit root across all panels:

$$H_0:\ \phi_1 = \phi_2 = \cdots = \phi_N = 0$$

The alternative hypothesis has two possible outcomes. The homogeneous alternative, where the stationary panel unit has identical autoregressive coefficients, and the heterogeneous alternative, where there are stationary panels with specific individual autoregressive coefficients.

Homogeneous alternative: $H_{1a}:\ \phi_1 = \phi_2 = \cdots = \phi_N = \phi$

Heterogeneous alternative: $H_{1a}:\ \phi_1 < 0,\ \phi_2 < 0, \ldots \phi_N < 0$

Panel data stationarity testing is often constrained by challenges such as unobserved heterogeneity, cross-sectional dependence, and asymptotic limitations. To address these, both first-generation and second-generation unit root tests are employed. First-generation tests (e.g., Levin-Lin-Chu, Im-Pesaran-Shin) assume cross-sectional independence, whereas second-generation tests account for cross-sectional dependence due to common shocks or spatial effects. In the second-generation framework, a cross-sectional error component is introduced:

$$\Delta \hat{Y}_{it} = \mu_i \phi_i + \phi_i Y_{i,t-1} + \varepsilon_{it} \quad \text{.......(6)}$$

3.2.2 Panel Cointegration

To test for long-run relationships among CO_2 emissions, GDP per capita, and renewable energy consumption, Pedroni's (2001, 2004) residual-based panel cointegration tests were applied. All seven test statistics were computed, including four-panel statistics (v-statistic, rho-statistic, PP-statistic, ADF-statistic) and three group statistics. Emphasis was placed on the panel v-statistic, panel ADF-statistic and group ADF-statistic due to their higher reliability for medium-sized panels. The null hypothesis of no cointegration was rejected, confirming a stable long-run relationship across countries.

Cointegration implies the existence of a stationary linear combination of the variables:

$$\beta_i' X_{it} = \varepsilon_{it}, \ \varepsilon_{it} \sim I(0) \quad (7)$$

Where β_i is a k × r matrix, X_{it} is a k × 1 vector of the observed time series, ε_{it} is an r × 1 vector of the error term, and r ($r \geq 1$) is the number of cointegration relations.

Following the confirmation of cointegration, the study estimates the short-run and long-run dynamics using the pooled mean group (PMG) estimator within a panel ARDL ($p,q_1,q_2,...,q_k$) framework.

$$Y_{it} = \sum_{j=i}^{p} \alpha_{ij} Y_{i,t-j} + \sum_{j=0}^{q} \hat{\delta}_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (8)$$

where μ_i is the fixed effect parameter, δ_{ij} is a k × 1 vector for the explanatory coefficient vector.

Equation (8) is re-parameterised into the error correction model (ECM) form (Pesaran, Shin and Smith, 1999; Njenga, 2024):

$$\Delta Y_{it} = \phi_i Y_{i,t-1} + \beta_i' X_{it} + \sum_{j=1}^{p-1} \eta_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \omega_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (9)$$

Where

$$\phi_i = -\left(1 - \sum_{j=1}^{p} \alpha_{ij}\right), \ \ \beta_i = -\sum_{j=0}^{q} \delta_{ij}, \ \ \eta_{ij} = -\sum_{m=j+1}^{p} \alpha_{im}, \ \ \omega_{ij} = -\sum_{m=j+1}^{q} \delta_{im}$$

Where j=1, 2,…,q-1

Stacking the model across time for country *i* gives the compact short-run form:

$$\Delta Y_i = \phi_i Y_{i,-1} + X_{it} \beta_i + \sum_{j=1}^{p-1} \eta_{ij} \Delta Y_{i,-j} + \sum_{j=0}^{q-1} \Delta X_{i,-j} \omega_{ij}' + \mu_i + \varepsilon_i \quad (10)$$

where l is a T × 1 vector of ones and $-j$ implies the lagged values of the respective variable. The implied long-run relationship is expressed as:

$$Y_{it} = -\left(\frac{\beta_i'}{\phi_i}\right) X_{it} + \xi_{it} \quad (11)$$

Where the term ξ_{it} is a stationary process. This represents the equilibrium linkage between CO_2 emissions, income and renewable energy use in the panel.

The PMG model was estimated using maximum likelihood in R, employing the back-substitution algorithm. The short-run coefficients were allowed to vary across countries, while the long-run coefficients were constrained to be homogeneous. The error correction terms (ECTs) were negative and statistically significant, validating the long-run relationship and confirming convergence toward equilibrium after short-run shocks. These findings align with the earlier cointegration results and confirm the suitability of the panel ARDL-PMG approach for this study.

3.2.3 Granger Causality

To examine directional relationships among variables, the study applied the Dumitrescu-Hurlin (2012) panel Granger causality test, an extension of Granger's (1969) causality framework. The test was implemented based on the following model (Lopez & Weber, 2017):

$$Y_{it} = \pi_i + \sum_{k=1}^{k} \rho_{ik} Y_{i,t-k} + \sum_{k=1}^{k} \tau_{ik} X_{i,t-k} + \varepsilon_{it} \quad (12)$$

The null hypothesis of non-causality is defined as:

$$H_0:\ \tau_{i1} = \tau_{i2} = \cdots = \tau_{ik} = 0 \ \ \forall i$$

The alternative hypothesis allows for causality in at least a subset of the cross-sectional units:

$$H_1:\ \tau_{ik} \neq 0 \ \ \text{for some } i$$

The test statistic follows a standard normal distribution. Granger causality from ($X_{it} \rightarrow Y_{it}$) is inferred when the Wald statistic exceeds the critical value or when the p-value falls below the 5% significance level.

4. RESULTS AND DISCUSSIONS

The environmental Kuznets curve (EKC) model results in Table 2 indicate that the relationship between economic growth and CO_2 emissions in EAC countries follows a U-shaped pattern rather than the traditional inverted U-shaped EKC hypothesis. The model explains approximately 73% of the variation in CO_2 emissions ($R^2 = 0.73383$), suggesting a strong explanatory power. The F-statistic (162.663) and p-value (0.0001) confirm the overall statistical significance of the model at the 5% level.

Table 2: Fixed effect model results

Parameters		
Variable	**Coefficient**	**Pvalue**
$\ln GDP_{i,t}$	-3.3806	0.0200
$\ln(GDP_{i,t})^2$	0.3207	0.0063
$\ln RE_{i,t}$	-3.7071	0.0001
Overall model		
Total Sum of Squares	17.483	
Residual Sum of Squares	4.6534	
R-Squared	0.73383	
Adj. R-Squared	0.7218	
F-statistic	162.663	
Degree of Freedom	(3,177)	
p-value	0.0001	

Source: Author’s computation

Examining the coefficients of GDP and its squared term, the coefficient of lnGDP (β_1) is -3.3806 (negative and statistically significant at p = 0.0200), while the coefficient of $\ln GDP^2$ (β_2) is 0.3207 (positive and highly significant at p = 0.0063). This coefficient structure indicates a U-shaped relationship between economic growth and CO_2 emissions, which deviates from the standard inverted U-shaped EKC hypothesis. In this case, EAC countries initially experience a decline in CO_2 emissions as GDP increases. However, beyond a certain income threshold, further economic growth leads to a reversal, where CO_2 emissions start rising again, implying a shift toward higher environmental degradation. The coefficient of lnRE (renewable energy consumption) is -3.7071 (p = 0.0001), indicating a strong and significant negative effect on CO_2 emissions. This suggests that increased reliance on renewable energy sources effectively reduces environmental pollution, supporting the argument for policy interventions that promote clean energy adoption in EAC countries.

To determine the appropriate panel unit root test, this study first assessed cross-sectional dependence using the Pesaran (2004, 2015) cross-sectional dependence test.

Table 3: Cross-sectional dependency test results

Variable	Statistics	P-value
$\ln GDP_{i,t}$	44.141	0.0001
$\ln CO2_{i,t}$	47.783	0.0001
$\ln REN_{i,t}$	48.756	0.0001

Source: Author's computation

The p-values for all variables are below the critical threshold, as shown in Table 3, indicating the presence of cross-sectional dependence among the observed variables. Given this result, the study applies second-generation panel unit root tests, specifically, the Choi (2001) Z-test and the modified Fisher statistic test, to account for cross-sectional dependence when assessing stationarity in the panel dataset.

The panel unit root tests presented in Table 4 examine the stationarity properties of the variables at levels and after first differencing. The results indicate a mixed order of integration, confirming that the variables are either I(0) (stationary at level) or I(1) (stationary after first differencing), which supports the use of panel ARDL cointegration techniques to analyse long-run relationships.

At level, GDP per capita (lnGDP) is trend stationary at conventional significance levels ($p = 0.0234$ for Choi Z-statistic in the trend model). However, for the intercept model, it is of integrated order one (I(1)), requiring first differencing to achieve stationarity ($p = 0.0001$ after first differencing). CO_2 emissions (lnCO_2) show mixed results; while the trend component model is stationary at the 10% significance level ($p = 0.0769$), the intercept model becomes stationary only after first differencing ($p = 0.0001$ for Choi Z-statistic). This suggests that CO_2 emissions follow a weak stationarity pattern in trend models but require first differencing for robust stationarity.

Renewable energy consumption (lnREN) is found to be non-stationary in both trend and intercept models at level (p-values > 0.05 for all tests), confirming that it is integrated of order one (I (1)). However, after first differencing, lnREN becomes stationary in both trend and intercept models ($p = 0.0001$ for Choi Z-statistic and Fisher tests), indicating that it is an I(1) variable.

Table 4: Panel unit root test results

In level

Variable	Test	Intercept	P-value	Trend	P-value
$\ln GDP_{i,t}$	Choi Z-statistic	1.4886	0.9317	-1.9888	0.0234
	Choi Fisher	-0.5150	0.6967	5.4816	0.0001
$\ln CO2_{i,t}$	Choi Z-statistic	0.8447	0.8009	-1.4262	0.0769
	Choi Fisher	0.8746	0.1909	2.0407	0.0206
$\ln REN_{i,t}$	Choi Z-statistic	2.5987	0.9953	0.3563	0.6392
	Choi Fisher	-0.8411	0.7999	0.67044	0.2513

1st difference

Variable	Test	Intercept	P-value	Trend	P-value
$\ln GDP_{i,t}$	Choi Z-statistic	-5.6523	0.0001	-	-
	Choi Fisher	10.716	0.0001	-	-
$\ln CO2_{i,t}$	Choi Z-statistic	-10.946	0.0001	-9.9371	0.0001
	Choi Fisher	28.415	0.0001	-	-
$\ln REN_{i,t}$	Choi Z-statistic	-7.9048	0.0001	-9.4855	0.0001
	Choi Fisher	19.569	0.0001	27.289	0.0001

Source: Author's computation

The findings confirm that the observed variables exhibit a mixed order of integration, with some variables stationary at level (I(0)) and others requiring first differencing (I(1)). This validates the suitability of panel ARDL cointegration techniques, complemented by the pooled mean group (PMG) estimator, to analyse both long-run and short-run relationships among GDP per capita, CO_2 emissions and renewable energy consumption across the six EAC countries studied. The panel ARDL approach is appropriate for this case, as it accommodates heterogeneous integration orders and allows for dynamic adjustments over time in response to economic and environmental changes.

Table 5 presents the results of Pedroni's panel cointegration test, providing strong statistical evidence of a long-run equilibrium relationship among GDP per capita, CO_2 emissions per capita and renewable energy consumption in the panel of six EAC countries. The test evaluates both panel-based and group-based statistics, determining whether the variables exhibit cointegration across the sample.

Table 5: Pedroni's cointegration test results

Test Statistic	Empirical	Standardised
Panel v-statistic	4.7144×10^{34}	-4.4398
Panel rho-statistic	7.9718	5.8974
Panel PP-statistic	1.8206	11.8280
Panel ADF-statistic	-9.104×10^{33}	-1.0976×10^{34}
Group rho-statistic	10.0867	7.21099
Group PP-statistic	2.4373	14.8222
Group ADF-statistic	-0.2082	11.2321

Source: Author's computation

The panel rho-statistic (7.9718) is significantly positive, suggesting strong evidence of cointegration among the variables in the panel. Additionally, the highly negative panel ADF-statistic (-9.104×10^{33} empirically and -1.0976×10^{34} standardised) further supports this conclusion, indicating that deviations from equilibrium are corrected over time, confirming the presence of a long-run relationship. The group rho-statistic (10.0867) and group ADF-statistic (-0.2082) provide further insights into cointegration within specific subgroups of the panel, supporting the presence of co-movements among the studied variables.

These results confirm that GDP per capita, CO_2 emissions per capita and renewable energy consumption move together over the long run, justifying the application of panel cointegration techniques for further analysis. Given this evidence, the study applies the pooled mean group (PMG) estimator, which is suitable for estimating long-run and short-run relationships while considering cross-country heterogeneity. The PMG approach enables the differentiation between country-specific short-run dynamics and shared long-run equilibrium relationships among economic growth, environmental degradation and renewable energy consumption. This method ensures that the long-run coefficients remain homogeneous across countries, while short-run adjustments can vary, capturing the diverse economic and environmental responses within the EAC countries.

Table 6 presents the pooled mean group (PMG) estimation model diagnostics, examining the overall model, JB normality test, Breusch-Godfrey autocorrelation test and JQ *heteroscedasticity* test in six EAC countries. The log-likelihood statistic (410.310) confirms the model's statistical significance at the 5% level, as it exceeds the critical value of 3.84, validating the model's suitability for analysing the economic-environmental nexus in EAC countries.

Table 6: PMG model diagnostics results

log-likelihood statistic = 410.310

ECM

Country	Breusch-Godfrey test		Breusch-Godfrey test		Goldfeld–Quandt test		Jarque–Bera test	
	Statistics (F)	p-value	Statistics (Chi-Squared)	p-value	statistics	p-value	Statistics	p-value
D.R Congo	0.0117	0.9997	0.0469	0.9997	3.0624	0.0698	1.2674	0.5306
Burundi	0.5856	0.6813	2.3425	0.6730	4.4149	0.0268	21.3564	0.0001
Kenya	0.3237	0.8553	1.2947	0.8623	1.2010	0.3978	1.9772	0.3721
Rwanda	1.1357	0.3990	4.5428	0.3373	3.5020	0.0500	7.4270	0.0244
Uganda	0.4868	0.7458	1.9471	0.7455	1.3049	0.3561	0.8385	0.6575
Tanzania	0.4565	0.7660	1.8259	0.7677	2.0645	0.1776	4.1472	0.1257

Source: Author's computation

Both the Chi-squared and F-statistic results from the Breusch-Godfrey autocorrelation tests indicate no significant autocorrelation in the error terms across the individual country models, as the tests fail to reject the null hypothesis in any case. The Goldfeld–Quandt test reveals evidence of heteroscedasticity in the Burundi model, while the models for Kenya, DR Congo, Uganda and Tanzania exhibit homoscedastic error terms. Rwanda's p-value for heteroscedasticity lies exactly at the 5% significance level, suggesting a borderline result. The Jarque–Bera test indicates that the residuals are normally distributed in DR Congo, Kenya, Uganda and Tanzania, while the data for Burundi and Rwanda show signs of skewness, violating the normality assumption. The PMG regression results are deemed efficient and reliable for DR Congo, Kenya, Uganda and Tanzania. However, the accuracy and performance of the Burundi and Rwanda models may be compromised due to the violation of the normality assumption.

Table 7 presents the pooled mean group (PMG) estimation results, examining long-run and short-run relationships between GDP per capita, CO_2 emissions per capita and renewable energy consumption in six EAC countries.

Table 7: PMG model results

Long-run relationship		
Variable	**Coefficient**	**p-value**
$\ln CO2_t$	0.1833	0.3155
$\ln REN_t$	-13.3273	0.0022

Short-term dynamics						
	DR Congo		**Burundi**		**Kenya**	
Parameter	Estimate	p-value	estimate	p-value	estimate	p-value
Intercept	-1.6571		0.0344		0.0225	
ECT	0.0245	0.6136	-0.0003	0.9875	-0.0004	0.9628
$\Delta\ln GDP_{t-1}$	0.7796	0.0001	0.3996	0.0183	0.2685	0.121
$\Delta\ln CO2_t$	0.0246	0.6671	0.1084	0.3714	-0.1041	0.3795
$\Delta\ln CO2_{t-1}$	0.1236	0.0294	-0.0901	0.4794	0.0709	0.5724
$\Delta\ln REN_t$	-0.8276	0.4864	0.9003	0.654	-0.8543	0.1304
$\Delta\ln REN_{t-1}$	1.8231	0.1966	-1.2953	0.526	-0.0734	0.9062
	Rwanda		**Uganda**		**Tanzania**	
Parameter	**Estimate**	**p-value**	**estimate**	**p-value**	**Estimate**	**p-value**
Intercept	6.9477		10.6866		0.6592	
	-0.1053	0.0022	-0.1588	0.0016	-0.0098	0.2727
	0.0717	0.7831	-0.4602	0.0073	0.8011	0.0001
	0.4156	0.0291	0.1887	0.1665	0.052	0.214
	0.0678	0.7101	0.1423	0.0009	-0.0008	0.9851
	3.4105	0.0008	-0.3611	0.5639	-0.0724	0.8835
	-0.467	0.6136	0.3113	0.6603	-0.2136	0.6787

Source: Author's computation

i. Short-Run Dynamics

The short-run results from the PMG model highlight considerable heterogeneity in the relationship between GDP, CO_2 emissions and renewable energy consumption across the six EAC countries.

Rwanda and Uganda exhibit notable short-term adjustments toward equilibrium, as indicated by the significant error correction terms (ECTs) ($p = 0.0022$ for Rwanda, $p = 0.0016$ for Uganda). This suggests that GDP in these countries responds quickly to deviations from its long-run equilibrium, with CO_2 emissions and renewable energy consumption playing an active role in short-term GDP fluctuations. On the other hand, Kenya, Tanzania and Burundi experience a slow rate (less than 1%) of adjustment to equilibrium status. The rate of adjustment in these countries takes a longer time compared to Rwanda and Uganda. In Kenya, Tanzania and Burundi, changes in renewable energy or CO_2 emissions do not significantly affect GDP in the short run, implying that these factors are not the immediate drivers of economic fluctuations. In DR Congo, there is no convergence to a long-run equilibrium. This scenario is attributed to either a significant change over time in the nexus that exists among the observed variables or errors in the data set for the country. This calls for a need to re-examine the nexus using alternative model for DR Congo.

DR Congo, Burundi and Tanzania demonstrate strong GDP persistence, where past GDP significantly influences current GDP growth at 5% significant level. This implies that historical economic performance strongly determines present economic outcomes, possibly due to structural economic factors, institutional inertia or investment patterns. In Uganda, past GDP performance leads to a significant decline in current GDP in the short term. Kenya and Rwanda past GDPs do not influence current GDP growth.

Kenya and Burundi show limited short-term dynamics, as CO_2 emissions and renewable energy consumption exhibit insignificant effects on GDP growth (p-values > 0.10 for most short-term coefficients). This suggests that other macroeconomic factors, beyond energy and environmental variables, may be more influential in shaping short-run economic performance in these countries.

These results highlight the heterogeneous nature of economic growth determinants in the countries. Countries exhibit varying responses to changes in CO_2 emissions and renewable energy consumption, indicating that a one-size-fits-all policy approach may not be effective.

ii. Long-Run Relationship

The long-run relationship between economic growth (GDP) and CO_2 emissions, while controlling for renewable energy consumption (REN) is expressed as follows:

$$\ln GDP_t = 0.1833 \ln CO2_t - 13.3273 \ln REN_t \quad \text{..(13)}$$

The coefficient of CO_2 emissions (0.1833) is positive but statistically insignificant (p = 0.3155), indicating that although higher CO_2 emissions are associated with higher GDP, the relationship lacks robustness in the long run. This suggests that economic growth in EAC countries is linked to pollution, but the impact is not strong enough to be conclusive.

Conversely, the coefficient of renewable energy consumption (-13.3273) is negative and statistically significant (p = 0.0022). This implies that an increase in the share of renewable energy in the energy mix is associated with a decline in GDP. A possible explanation is that at the current stage of economic development, the reliance on renewable energy may be associated with higher costs, lower efficiency and limited infrastructure, making it less economically competitive compared to traditional fossil fuels. These findings suggest that while renewable energy is crucial for sustainability, its economic benefits may not yet be fully realised in these countries due to structural challenges. This long-run analysis reveals a complex economic-environmental dynamic in EAC countries. While CO_2 emissions exhibit a weak positive relationship with GDP, renewable energy consumption appears to hinder economic growth in the current development phase.

Table 8: Causality test results

Causality directions	Statistic	p-value
$\ln GDP_t \rightarrow \ln CO2_t$	2.3651	0.0180
$\ln CO2_t \rightarrow \ln GDP_t$	2.2282	0.0259
$\ln CO2_t \rightarrow \ln REN_t$	0.7198	0.4716
$\ln REN_t \rightarrow \ln CO2_t$	3.4471	0.0006
$\ln REN_t \rightarrow \ln GDP_t$	5.4232	0.0001
$\ln GDP_t \rightarrow \ln REN_t$	2.2084	0.0272

Source: Author's computation

Table 8 presents the results of the panel causality test, examining the directional relationships between GDP per capita, CO_2 emissions per capita and renewable energy consumption in the panel of six EAC countries. The findings reveal a complex interplay among economic growth, environmental pollution and renewable energy adoption.

The results indicate a significant bidirectional causality between GDP and CO_2 emissions ($p = 0.0180$ for GDP → CO_2 and $p = 0.0259$ for CO_2 → GDP). This suggests that economic growth leads to an increase in CO_2 emissions, likely due to higher industrial activity, energy consumption and fossil fuel reliance. Conversely, higher CO_2 emissions also contribute to GDP growth, implying that pollution-intensive industries, such as manufacturing and energy production, play a substantial role in driving economic activity. This reinforcing relationship highlights the environmental costs of economic expansion, as growth-driven emissions could further accelerate climate-related challenges in these countries.

The causal relationship between CO_2 emissions and renewable energy consumption is insignificant ($p = 0.4716$ for CO_2 → REN). This implies that changes in CO_2 emissions do not significantly influence the adoption or consumption of renewable energy in the short term. However, renewable energy consumption does exhibit a significant causal impact on CO_2 emissions ($p = 0.0006$ for REN → CO_2), suggesting that increasing the share of renewables effectively reduces emissions. This reinforces the importance of transitioning to cleaner energy sources to mitigate environmental degradation.

A strong causal relationship is observed between renewable energy consumption and GDP, where increasing renewable energy usage positively impacts economic growth ($p = 0.0001$ for REN → GDP). This could be attributed to factors such as job creation in the renewable energy sector, infrastructure investments and enhanced energy security, which collectively contribute to economic expansion. In addition, the causality from GDP to renewable energy consumption is also significant ($p = 0.0272$ for GDP → REN), suggesting that economic growth facilitates greater investment in renewable energy technologies. As economies expand, they generate more financial resources, policy incentives and institutional capacity to support the transition to clean energy.

5. DISCUSSIONS

This study reveals a U-shaped relationship between economic growth and CO_2 emissions in EAC countries, deviating from the traditional inverted U-shaped environmental Kuznets curve (EKC) hypothesis. Initially, economic growth leads to a decrease in emissions; however, once a certain income threshold is surpassed, emissions begin to rise again. This U-shaped pattern contrasts with the typical inverted U-shaped curve, where environmental degradation worsens with initial growth but improves as economies advance. These results are consistent with the findings of Simbi et al. (2024), who found that in low-income countries, early stages of economic growth might reduce emissions, but sustained development could eventually lead to greater environmental pressure. This deviation observed in EAC countries can likely be attributed to their early-stage industrialisation, high dependence on carbon-intensive energy sources and challenges in adopting renewable energy.

The findings indicate a mutually reinforcing relationship between economic growth and CO_2 emissions, driven by pollution-intensive industries that fuel expansion. Without targeted interventions, this cycle is positioned to intensify environmental degradation. Although renewable energy positively influences GDP growth and can drive investment in clean energy technologies, the countries' underdeveloped renewable energy infrastructure limits its full economic potential. The findings agree with the United Nations' (2022) Regional Collaborative Platform Report for Africa, which emphasises the need for country-specific policies that align economic growth with environmental sustainability. Prioritising low-carbon industrialisation, renewable energy investments and stronger governance can help EAC countries transition toward a sustainable future while fulfilling developmental and climate commitments.

A critical outcome of the study is the strong negative correlation between renewable energy consumption and CO_2 emissions, which aligns with global evidence suggesting that an increased share of renewable energy sources reduces environmental degradation. However, the results also reveal a counterintuitive finding: renewable energy consumption negatively affects GDP per capita. This suggests that renewable energy adoption in EAC countries may not yield the expected economic benefits yet. Several plausible explanations emerge for this: First, renewable energy technologies may still be in a nascent stage, characterised by high capital costs, low efficiency and limited grid integration. Second, inadequate infrastructure for the storage and distribution of renewable energy may hinder its economic viability, constraining industrial productivity. Third, the current policy landscape may not sufficiently support renewable energy investments, limiting their capacity to drive economic growth.

The study also reveals significant heterogeneity in short-run economic and environmental dynamics across the six countries. Rwanda and Uganda exhibit rapid adjustments to economic and environmental shocks, as indicated by significant error correction terms (ECTs). In contrast, DR Congo and Tanzania demonstrate a high degree of GDP persistence, suggesting that past economic conditions heavily influence current economic trajectories. Kenya and Burundi display weak short-run linkages between CO_2 emissions, renewable energy consumption and GDP, implying that other macroeconomic variables may exert stronger influences on their growth.

The bidirectional Granger causality between economic growth and CO_2 emissions observed in EAC countries mirrors findings from Western and Central Africa, where a 2023 VECM analysis (1970-2020) demonstrated that both variables adjust to restore long-run equilibrium. This interdependence suggests that economic growth drives higher emissions, aligning with the notion that industrialisation, urbanisation and rising energy demand contribute to environmental degradation. Conversely, the reverse causality, where increased CO_2 emissions also fuel GDP growth, reinforces the reliance of these economies on pollution-intensive sectors such as mining, manufacturing and transportation. This cycle presents a challenge, as continued dependence on carbon-intensive industries risks exacerbating environmental degradation and jeopardizing long-term sustainability (Yu et al., 2024). Without proactive interventions, the EAC countries may struggle to transition toward a low-carbon growth trajectory.

The study also finds a positive causal relationship between renewable energy consumption and GDP growth. This suggests that investment in renewable energy can stimulate economic expansion by generating employment, improving energy security, and fostering technological innovation. Moreover, the bidirectional causality between GDP and renewable energy implies that economic growth facilitates greater investment in clean energy technologies, further supporting sustainability transitions. However, as earlier results indicated, the current renewable energy framework in EAC countries has not yet yielded optimal economic benefits. The potential of renewables as an economic driver can only be realized if challenges related to energy infrastructure, policy support, and financial accessibility are addressed.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study examines the relationship between economic growth, CO_2 emissions and renewable energy consumption in six EAC countries from 1990 to 2022. The findings reveal a U-shaped relationship between GDP per capita and CO_2 emissions, which deviates from the conventional environmental Kuznets curve (EKC) hypothesis. This suggests that while economic growth initially improves environmental quality, it eventually leads to increased CO_2 emissions beyond a certain threshold, highlighting the risk of environmental degradation without effective policies. The study confirms the presence of a long-run relationship between economic growth, CO_2 emissions and renewable energy consumption, with significant long-term dynamics observed in Rwanda and Uganda. Granger causality tests show bidirectional causality between GDP and CO_2 emissions, reinforcing a cycle of growth-driven emissions, while renewable energy consumption positively impacts GDP. However, the study also finds that some renewable energy sources may still contribute to CO_2 emissions due to inefficiencies and infrastructure limitations.

To ensure sustainable growth across East African Community (EAC) countries, it is imperative to adopt tailored policy frameworks that reflect each country's unique economic structure, energy profile and responsiveness to environmental and growth-related shocks. The study reveals significant heterogeneity in short-run dynamics; Rwanda and Uganda exhibit faster adjustments to shocks, suggesting a high potential for responsive policy interventions. These could include rapid-response green stimulus programs or pilot renewable projects with measurable outcomes. Conversely, DR Congo and Tanzania show persistent GDP patterns, indicating a need for long-term structural reforms that decouple growth from emissions, such as investing in greener value chains and energy transition infrastructure. Kenya and Burundi, which exhibit weaker short-run linkages between GDP, emissions and renewable energy, need to pursue comprehensive macroeconomic diagnostics to identify alternative drivers of growth and environmental change before designing integrated sustainability policies.

A key policy priority is to disrupt the feedback loop between economic growth and CO_2 emissions, as revealed by the bidirectional Granger causality in the study. This finding suggests that growth is both a cause and a consequence of emissions, largely driven by pollution-intensive sectors such as manufacturing, mining and transport. To address this, EAC countries need to embrace green industrialisation, transforming production processes and value chains toward cleaner technologies. Fiscal instruments such as green tax incentives, technology adoption subsidies and accelerated depreciation allowances for low-emission equipment would create incentives for firms to adopt environmentally friendly practices. These interventions reduce emissions and support industrial competitiveness and technological upgrading, especially in emerging green sectors.

The study highlights that renewable energy consumption causally reduces CO_2 emissions and has a positive effect on GDP, supporting the case for scaling up renewable energy investments. However, the evidence also points to underutilisation of this potential due to infrastructure and integration challenges. Therefore, a focused policy effort is needed to expand energy infrastructure, particularly grid and off-grid renewable systems, which can serve both urban industries and rural communities. This includes investing in storage, smart grids and distribution networks that can handle the intermittency of renewables and integrate them into national energy mixes. Establishing dedicated green infrastructure funds, either nationally or at the EAC level, can help crowd in private investment and leverage concessional finance from international climate funds.

Moreover, the bidirectional causality between GDP and renewable energy consumption found in the study reveals that economic growth and clean energy uptake reinforce each other. As such, policy coherence between growth planning and energy strategies is vital. National development plans need to embed clear renewable energy targets, while energy policies need to be aligned with broader macroeconomic objectives to ensure coherence between environmental sustainability and economic growth. Economic expansion can generate fiscal space and stimulate demand for clean energy, while well-developed renewable energy infrastructure enhances productivity, improves energy security and strengthens long-term economic resilience.

A counterintuitive finding of the study, that renewable energy adoption may negatively affect GDP per capita in the short run, points to important transitional challenges. This suggests that while renewables reduce emissions, current systems may be plagued by high capital costs, low energy output and weak grid connectivity. Policymakers need to focus on improving the quality and efficiency of renewable technologies in the region. This includes supporting local innovation ecosystems around renewables (e.g., solar panel assembly, battery research) and offering capacity-building programs for technicians, engineers and entrepreneurs working in the clean energy space.

Given the study's emphasis on the long-run equilibrium among GDP, emissions and renewable energy, enhancing environmental governance is essential to ensure that growth remains within ecological limits. Governments need to strengthen emission standards, environmental audits and carbon pricing mechanisms such as carbon taxes or emissions trading systems. These tools not only internalise environmental costs but also incentivise firms and households to switch to cleaner alternatives. Revenues from carbon pricing can be reinvested in climate resilience programs and energy access initiatives, creating a virtuous cycle of sustainable development. Additionally, regional collaboration under the EAC framework can amplify these outcomes. The establishment of a regional clean energy investment platform, co-financed by member states and development partners, would facilitate cross-border energy trade, optimise renewable resource distribution (e.g., hydro in Uganda, geothermal in Kenya) and promote policy harmonisation. Such collaboration would help overcome the scale and capital limitations that individual countries face.

To further support effective implementation, EAC countries need to strengthen data systems and policy evaluation mechanisms. The observed variability in country responses to growth and environmental dynamics suggests a need for evidence-based policymaking supported by timely, disaggregated and accurate data. National statistical offices should receive technical and financial support to build robust monitoring, evaluation and learning (MEL) frameworks, enabling adaptive policy adjustments in response to real-world performance.

This study reinforces that EAC countries are managing the trade-off between accelerating economic growth and safeguarding the environment. By adopting country-specific, evidence-based and future-focused policy strategies, the region can shift toward a low-carbon development pathway, one that safeguards livelihoods, strengthens energy resilience and positions the region as a proactive contributor to global climate action.

Conflict of interest

The authors declare there is no conflict of interest

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МОДЕЛОВАЊЕ ОДНОСА ИЗМЕЂУ ЕМИСИЈА И ДОХОДКА У ЗЕМЉАМА ИСТОЧНОАФРИЧКЕ ЗАЈЕДНИЦЕ: ПРИСТУП ПАНЕЛ КОИНТЕГРАЦИЈЕ

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САЖЕТАК

Ова студија испитује везу између економског раста и емисије угљен-диоксида (CO_2) у земљама Источноафричке заједнице (ЕАС), са фокусом на улогу потрошње обновљиве енергије. Како земље ЕАС пролазе кроз брзу индустријализацију и урбанизацију, разумијевање утицаја економског раста на емисије од кључног је значаја за обликовање политика одрживог развоја. Користећи приступ панел коинтеграције, студија примјењује хипотезу еколошке Кузнецове криве (ЕКС) на податке из шест земаља ЕАС, и то: Демократске Републике Конго, Бурундија, Руанде, Кеније, Уганде и

Танзаније, за период од 1990. до 2022. године. Примијењен је панел модел ауторегресивног распоређеног закашњења (ARDL), при чему је коришћен процјењивач комбиноване групне средине (PMG) за анализу дугорочне и краткорочне динамике. Резултати откривају U-обликован однос између економског раста и емисија CO_2, што доводи у питање традиционалну обрнуту U-обликовану ЕКС хипотезу. Налази сугеришу да, иако ране фазе економског раста смањују емисије, оне почињу поново да расту након одређеног прага дохотка, што указује на могућу фазу „преразвијености“. Утврђено је да потрошња обновљиве енергије значајно смањује емисију CO_2; међутим, њене економске користи су ограничене инфраструктурним и политичким изазовима. Ова студија доприноси постојећој литератури интегрисањем обновљиве енергије у оквир ЕКС и нуди вриједне увиде доносиоцима политика који настоје да уравнотеже економски раст и еколошку одрживост. Налази наглашавају потребу за циљаним политикама ради подстицања усвајања чисте енергије, нискоугљеничне индустријализације и јачања еколошког управљања у земљама ЕАС.

Кључне ријечи: *еколошка Кузнецова крива (ЕКС), панел коинтеграција, комбинована групна средина (PMG), економски раст, емисије гасова са ефектом стаклене баште, климатске промјене.*