Asian Development Policy Review
ISSN(e): 2313-8343
ISSN(p): 2518-2544
DOI: 10.55493/5008.v14i1.5877
Vol. 14, No. 1, 139-155

URL: www.aessweb.com

Trade openness, renewable energy and environmental performance: Evidence from Africa

Nil Sirel Ozturk

Department of Customs Management, Kesan Yusuf Capraz School of Applied Sciences, Trakya University, Edirne, Turkey.
Email: nilsirelozturk@trakya.edu.tr

Article History
Received: 10 December 2025
Revised: 21 January 2026
Accepted: 27 January 2026
Published: 4 February 2026

Keywords
Carbon intensity
Developing African countries
Economic growth
Green growth
Panel data analysis
Renewable energy
Sustainable development
Trade openness.

ABSTRACT

This study analyzes the determinants of economic growth and environmental performance in developing African economies using panel data from 2000 to 2021. The sample includes eight emerging African countries selected based on data availability and regional diversity. Real GDP per capita serves as a proxy for economic growth, while environmental performance is measured by the carbon intensity of GDP. Explanatory variables include trade openness, foreign direct investment inflows, renewable energy use, and urbanization. To address cross-sectional dependence and slope heterogeneity, the analysis employs second-generation panel estimators, specifically the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG). Robustness is tested through System GMM estimations and Dumitrescu–Hurlin panel Granger causality tests. The results indicate that higher carbon intensity correlates with lower per capita income, implying that carbon-intensive production structures hinder long-term growth. Additionally, renewable energy use has a negative short-term effect on growth, reflecting adjustment costs in economies with limited institutional capacity. Overall, the findings highlight a trade-off between growth and environmental performance in Africa.

Contribution/ Originality: This study contributes to existing literature by modeling environmental performance through carbon intensity rather than emission levels. It employs a new estimation methodology by jointly applying AMG, CCEMG, and System GMM. The primary contribution is providing new causal insights into growth–environment trade-offs in developing African economies.

1. INTRODUCTION

Sustainability, which has become central to the global development agenda, extends beyond environmental concerns and increasingly encompasses inclusive economic growth, the reduction of social inequalities, and the efficient use of resources. The African continent, in particular, stands out due to its abundant natural resources, young population, and significant growth potential. However, this potential is often overshadowed by environmental degradation, structural vulnerabilities, and financial dependence. In this context, restructuring Africa's development trajectory around the principles of sustainable and inclusive growth has become strategically important at both regional and global levels.

Sustainable growth refers not only to increases in economic indicators but also to the preservation of environmental limits, improvements in social welfare, and a balanced use of natural resources. Inclusive growth, on the other hand, emphasizes the equitable distribution of the economic benefits of growth across all segments of society.

Considering these two concepts jointly is particularly important in the African context, as it highlights the need for a more holistic approach to development policies across the continent.

This study empirically examines the structural factors affecting per capita income in emerging and developing African economies and explores which instruments can effectively support sustainable and inclusive growth objectives. The effects of carbon-related environmental indicators, renewable energy use, trade openness, foreign direct investment inflows, and urbanization on economic growth are tested using comparative econometric methods. The selected variables capture both environmental and economic dimensions, providing a framework for assessing growth dynamics within a green growth perspective.

The theoretical foundation of the study is shaped by the linkages between classical growth models and environmental economics. Solow-type growth models prioritize factor accumulation as the main driver of growth while typically treating environmental costs as externalities. In contrast, the Environmental Kuznets Curve (EKC) hypothesis attempts to address this limitation by suggesting that environmental pressure may decline as income levels increase. However, in countries with limited structural transformation capacity, this hypothesis may fail to hold, leading to the persistence of carbon-intensive production structures.

An important environmental dimension incorporated in this study is carbon intensity, defined as carbon dioxide emissions per unit of economic output. Unlike aggregate emission levels, carbon intensity reflects the environmental efficiency of production processes and captures the extent to which economic growth is associated with carbon-dependent structures. In developing economies, growth may be achieved through carbon-intensive production in the absence of technological upgrading and institutional capacity, leading to short-term income gains at the expense of environmental sustainability. Therefore, carbon intensity serves as a key indicator for assessing the trade-off between economic growth and environmental performance, particularly in contexts where structural transformation remains incomplete.

The growth-enhancing potential of renewable energy investments is commonly discussed within the framework of the Porter Hypothesis. According to this hypothesis, environmentally friendly investments and regulations may initially impose costs but can improve productivity and competitiveness over time. Nevertheless, the realization of this mechanism depends on the simultaneous presence of technical capacity, institutional quality, and access to finance. In many African economies, shortcomings in these areas constrain the effectiveness of green growth strategies.

The study also evaluates the role of trade openness and foreign direct investment inflows in shaping per capita income dynamics. While trade openness is generally expected to promote growth, the direction and magnitude of this relationship often vary across developing countries depending on structural and institutional conditions. Mechanisms such as financial liberalization, technology transfer, and capital inflows may stimulate growth, but they can also generate risks related to resource dependence, income inequality, and exposure to external shocks.

Urbanization is a key structural variable in analysis. According to structuralist growth theories, urbanization can foster productivity gains by expanding productive sectors and improving labor efficiency. However, the growth impact of urbanization is closely linked to factors such as infrastructure investment, the quality of social services, and labor market efficiency. Consequently, while urbanization can support economic growth, unplanned urban expansion may worsen social and environmental challenges.

The panel data set used in this study covers the period 2000–2021 and includes eight African countries: Kenya, Tanzania, South Africa, Egypt, Morocco, Senegal, Uganda, and Angola. These countries display considerable diversity in terms of growth performance and environmental indicators, allowing for more generalizable conclusions at the continental level.

The empirical methodology is tailored to the specific characteristics of panel data. Given the presence of cross-sectional dependence and slope heterogeneity, second-generation panel data techniques, namely the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators, are employed. To assess robustness and account for potential endogeneity, System GMM estimations are conducted, while Dumitrescu–Hurlin panel Granger causality tests are used to examine the relationships among variables.

Within this theoretical context, Solow-type growth models provide the foundation for examining income dynamics through factor accumulation, trade openness, and capital inflows, as reflected in GDP per capita. The Environmental Kuznets Curve (EKC) hypothesis informs the inclusion of carbon intensity as an indicator of environmental efficiency, capturing whether economic growth is associated with carbon-dependent production structures. Additionally, the Porter Hypothesis motivates the incorporation of renewable energy use, reflecting the potential growth effects of environmental upgrading, particularly in the presence of institutional and technological constraints. Together, these frameworks guide the specification of the empirical model and the hypotheses tested in the analysis.

Overall, this comprehensive framework aims not only to identify the determinants of economic growth but also to emphasize the necessity of balancing economic and environmental considerations. The primary objective of the study is to empirically test the theoretical foundations of sustainable and inclusive growth in Africa and to provide a coherent evaluation framework for policymakers.

2. LITERATURE REVIEW

2.1. Inclusive Growth and Measurement Challenges

The concept of inclusive growth has been analyzed through various indicators across both developed and developing countries. Grömling and Klös (2019) argue that the measurement of inclusive growth should move beyond output-based indicators and instead adopt a production function-based approach emphasizing institutional structures, labor, education, and capital. Similarly, Nolan (2020) critiques traditional metrics such as per capita income and Gross National Income (GNI) suggest that median income and distribution-sensitive measures provide a more accurate reflection of societal welfare. Focusing on coastal regions of China, Sun, Liu, & Tang (2018) developed an inclusive growth index based on Bossel's orientor indicators, survival, capability, development, freedom, and opportunity, and found persistent regional disparities. van Krevel (2023) contends that long-term income convergence is unsustainable, particularly in resource-based economies lacking adequate human capital, which results in weak inclusive wealth creation. At the urban level, Waite, Whyte, and Muirie (2020) stress the importance of concrete evaluation frameworks, such as the capability approach, to prevent the abstraction of inclusive growth in policy documents. Research by Cichowicz and Rollnik-Sadowska (2018) highlights the role of socio-economic history in shaping inclusive growth trajectories across Eastern European nations. Prada and Sánchez-Fernández (2019) argue for the use of synthetic indicators to better capture development outcomes beyond conventional GDP metrics. In the Asia-Pacific context, Li, Zhang, Fan, and Chen (2021) stress the strong link between inclusive green growth and development levels, advocating for regional cooperation. Finally, Birdsall and Meyer (2015) demonstrate that in developing countries, average income metrics fail to adequately capture material well-being, and they recommend using median income for more distribution-sensitive development analysis. These studies highlight the multidimensionality of inclusive growth, emphasizing the importance of income distribution, institutional capacity, regional disparities, and measurement tools.

2.2. Environmental Kuznets Curve Hypothesis in Developing Countries

The Environmental Kuznets Curve (EKC) hypothesis, which explores the relationship between economic growth and environmental degradation, has been widely tested across various countries and time periods. Although not the central focus of this study, the EKC framework provides important insights for developing economies. Özokcu and Özdemir (2017) tested the hypothesis for both developed and emerging countries and found complex outcomes, N-shaped and inverted N-shaped relationships, challenging the universal validity of the EKC. Halkos and Gkampoura (2021) confirm the EKC in middle- and high-income countries shows bidirectional causality between GDP and CO_2

emissions. Zaman and Abd-el Moemen (2017), in a study covering 90 countries, demonstrate that population growth and energy demand significantly increase emissions, emphasizing the importance of regional environmental policies. Hunjra, Bouri, Azam, Azam, and Dai (2024) emphasize the need to balance growth with sustainability in developing countries, noting that FDI and natural resource dependence can influence this trade-off. Zhang et al. (2020) examine energy efficiency and find that the EKC holds in developing countries, stressing the importance of renewable energy policies. These studies suggest that EKC is not universally applicable and that policy approaches must be sensitive to income levels, energy structures, and institutional dynamics. More recent studies emphasize carbon intensity, emissions per unit of output, as a more informative indicator of environmental efficiency, especially in developing economies where growth may coexist with persistent carbon-dependent production structures.

2.3. Green Growth Determinants in Africa

In Africa-specific literature, renewable energy, institutional quality, and financial development are key drivers of green growth. Teklie and Yağmur (2024) show that renewable energy consumption, green innovation, and institutional quality positively influence long-term green growth across 49 African countries, while resource rents have a negative impact. Konyeaso, Eregha, and Vo (2023) find that renewable energy generation contributes to per capita growth across all African regions, although financial development is effective only in non-oil-producing countries. Gershon, Asafo, Sowah, and Tanko (2025) argue that energy transition helps reduce emissions while supporting economic growth. Osman et al. (2025) find that while natural resource abundance and financial development may negatively affect renewable energy use individually, their interaction can yield positive outcomes. Yuni, Ezenwa, Urama, Tingum, and Mohlori-Sepamo (2023) show that renewable electricity production contributes to growth, though its share in total energy consumption remains limited. Focusing on MENA countries, Kahia, Ben Jebli, and Belloumi (2019) find that while growth increases environmental degradation, renewable energy, trade, and FDI are effective in reducing emissions. Namahoro, Wu, Xiao, and Zhou (2021) highlight that energy intensity drives emissions upward, while renewables help reduce them in the long run. In East Africa, Yang, Namahoro, Wu, and Su (2022) show that renewables promote growth, while fossil fuels are detrimental. Namahoro, Wu, Zhou, and Xue (2021) further argue that the determinants of CO_2 emissions vary across countries, calling for region-specific policies. Qudrat-Ullah and Nevo (2022) examine Sub-Saharan Africa's five largest economies and find that while financial development may reduce emissions in the long term, economic growth increases them. Collectively, these findings suggest that green growth strategies in Africa must be built on renewable energy deployment, institutional capacity, and regionally tailored policies. Although the literature frequently refers to "green growth," many empirical studies operationalize this concept through indicators related to economic growth, energy structure, and environmental performance rather than direct policy measures.

2.4. Trade Openness and Economic Growth

The relationship between trade openness and economic growth varies depending on a country's level of development and economic structure, and the empirical literature reports mixed and context-dependent findings. Nam and Ryu (2024) argue that trade openness can promote economic growth in developing countries; however, they caution that excessively low trade barriers may reverse this relationship and generate adverse effects. Monyela and Saba (2024) show that increased trade openness following BRICS membership has contributed positively to economic growth and development. Brueckner and Lederman (2015) find that a 1% increase in the trade ratio in Sub-Saharan Africa leads to a 0.5% rise in economic growth in the short run, with even stronger effects observed over the long term. Overall, these studies indicate that the growth effects of trade openness are neither uniform nor universal; rather, they depend on factors such as financial development, income levels, export structure, and the broader policy context.

2.5. FDI and Development in Africa

The impact of foreign direct investment (FDI) on economic growth remains a contested issue, particularly in developing contexts. Arthur, Saha, Sarpong, and Dutta (2024) demonstrate that FDI may hinder sustainable development in low-income African countries, while yielding positive outcomes in wealthier nations. Scalamonti (2024) emphasizes that the effectiveness of FDI is contingent upon institutional quality and the business environment. Nupehewa et al. (2022) find global bidirectional causality between FDI and growth but note significant regional variation. These findings highlight that FDI's developmental impact is mediated by structural and institutional conditions, and region-specific assessments are essential.

3. METHODOLOGY

This study examines the determinants of economic growth and environmental performance in developing African economies using panel data analysis from 2000 to 2021. The analysis focuses on inclusive growth dynamics, proxied by real GDP per capita, and environmental efficiency of production, captured through carbon intensity. The sample includes eight emerging African economies: Kenya, Tanzania, South Africa, Egypt, Morocco, Senegal, Uganda, and Angola. Country selection was based on data availability, regional diversity, and the representativeness of policy frameworks. All data were retrieved from the World Bank's World Development Indicators (WDI) database, and monetary variables are expressed in constant 2015 US dollars.

The dependent variable is real GDP per capita, used as a proxy for inclusive growth. The independent variables include trade openness, foreign direct investment (FDI) inflows, carbon intensity, the share of renewable energy in total energy consumption, and the urban population ratio. Trade openness is calculated as the sum of exports and imports of goods and services as a percentage of GDP. Renewable energy use is measured as its share of total energy consumption. Carbon intensity is defined as CO_2 emissions per unit of GDP and serves as an indicator of environmental efficiency. FDI inflows are expressed as the net amount of foreign direct investment relative to GDP. The urbanization rate is included as a control variable to reflect the demographic and spatial dimensions of development. A summary of the variables is provided in Table 1.

The dataset has an annual frequency. As a preliminary step, cross-sectional dependence was tested using the Pesaran CD test, followed by the slope heterogeneity test. The presence of both cross-sectional dependence and heterogeneity necessitated the application of second-generation unit root tests. Accordingly, the CADF (Cross-sectionally Augmented Dickey-Fuller) unit root test was employed, and the results indicated that the variables were stationary at levels [I(0)] and at first differences [I(1)]. These findings confirmed that the data structure includes both cross-sectional dependence and heterogeneous slopes.

Given these characteristics, the analysis adopted the Augmented Mean Group (AMG) estimator, one of the second-generation panel estimation techniques. This method accounts for unobserved common factors and country-specific heterogeneity, making it suitable for heterogeneous panel datasets. The estimation incorporates country-specific trends and uses robust standard errors.

Although the AMG estimator forms the core of the empirical analysis, robustness checks were performed using additional estimation techniques such as the Common Correlated Effects Mean Group (CCEMG) estimator, Durbin-Wu-Hausman endogeneity test, and the System Generalized Method of Moments (System GMM). This multi-method approach ensures the reliability of results and addresses potential endogeneity concerns.

Table 1 presents the variable definitions, units of measurement, and data sources used to construct the panel dataset.

Table 1. Variables Used in the Analysis: Definitions, Units, and Data Sources.

Variable Name	Definition	Unit	Source
GDP per Capita	Real gross domestic product per capita	Constant 2015 US$	World Bank (WDI)
Trade Open	Sum of exports and imports of goods and services as a percentage of GDP.	% of GDP	Calculated by the author using World Bank (WDI) data
FDI NET INFLOWS	Net inflows of foreign direct investment as a percentage of GDP	% of GDP	World Bank (WDI)
Carbon Intensity	CO_2 emissions per unit of GDP	kg CO_2 / 2015 US$ GDP	World Bank (WDI)
Renew	Share of renewable energy in total energy consumption	%	World Bank (WDI)
Urban	Urban population as a percentage of total population	%	World Bank (WDI)

4. ANALYSIS AND FINDINGS

The following section presents the results of diagnostic tests and model estimations, as explained in the methodology section, in a systematic manner.

4.1. Cross-Sectional Dependence Test

The cross-sectional dependence test assesses whether countries in a panel data set act independently. In macro-level studies, countries may be influenced by common factors such as global shocks, regional policies, or trade linkages, leading to contemporaneous effects across units. Ignoring this dependence can produce unreliable coefficient estimates. Therefore, testing for cross-sectional dependence is essential before the main analysis. In this study, the CD test developed by Pesaran (2004) is used to examine cross-sectional dependence within the panel structure.

H_0: Cross-sectional independence exists.

H_1: Cross-sectional dependence exists.

Table 2 reports cross-sectional dependence test results, providing strong evidence of cross-country interdependence and justifying the use of second-generation panel estimators.

Table 2. Cross-Sectional Dependence Test.

Variable	CD (Pesaran)	p-value	CDw (Juodis-Reese)	p-value	CDw+ (Fan et al.)	p-value	*CD (Pesaran-Xie)*	p-value
GDP per Capita	19.76	0.000***	8.76	0.000***	113.30	0.000***	-16.10	0.000***
Carbon Intensity	-2.37	0.018**	-0.23	0.821	73.07	0.000***	0.46	0.643
Trade Open	5.24	0.000***	1.42	0.156	60.08	0.000***	3.01	0.003***
FDI NET INFLOWS	0.23	0.818	-1.11	0.268	21.63	0.000***	-0.66	0.507
Renew	16.13	0.000***	8.54	0.000***	93.88	0.000***	-2.74	0.006***
Urban	15.20	0.000***	5.60	0.000***	121.40	0.000***	3.36	0.001***

Note: **, and *** indicate statistical significance at the 5% and 1% levels, respectively.

The results of the cross-sectional dependence test indicate significant interdependence or common shocks among countries for most variables used in the analysis. The power-enhanced CDw+ test developed by Fan, Liao, and Yao (2015) reveals p-values of 0.000 for all variables. This suggests that indicators such as trade openness, renewable energy use, carbon intensity, and urbanization are influenced by similar dynamics or shared global effects across countries. Accordingly, strong cross-sectional dependence is observed in the panel data set. Given this structure, the use of first-generation panel data methods may lead to invalid results; therefore, second-generation panel estimation techniques are preferred.

4.2. Slope Homogeneity Test

In panel data analysis, the assumption of slope homogeneity, that all units (countries) share the same structural relationship, is often unrealistic. Differences in levels of development, institutional structures, or policy priorities may lead to significant variations in how explanatory variables affect individual countries. Slope homogeneity tests help determine whether these differences are statistically significant. If the assumption of homogeneous slopes is rejected, traditional panel estimation methods may yield biased results. Therefore, this study employs the test developed by Pesaran and Yamagata (2008) to assess the presence of slope heterogeneity.

H_0: The slope coefficients are homogeneous.

H_1: The slope coefficients are heterogeneous.

Table 3 presents the slope homogeneity test results, indicating statistically significant slope heterogeneity across countries in the panel.

Table 3. Slope homogeneity test results.

Test type	Test statistic (Δ)	p-value
Delta (Δ)	7.168	0.000***
Adj. Delta ($\tilde{\Delta}$)	8.681	0.000***

Note: *** indicates statistical significance at the 1% level, respectively.

The results of the slope homogeneity test indicate that the effects of the explanatory variables in the model vary across countries. The slope heterogeneity test developed by Pesaran and Yamagata (2008) is statistically significant for both the delta and adjusted delta statistics ($p < 0.01$). This suggests that each country responds differently to factors such as trade openness, foreign direct investment inflows, carbon intensity, and renewable energy use. Therefore, it is methodologically essential to employ heterogeneous panel data methods that account for country-specific structural differences in the analysis.

4.3. Unit Root Test

Determining whether the series in a panel dataset are stationary is critically important for making robust econometric inferences. However, when cross-sectional dependence is present in the panel, classical unit root tests (such as Levin-Lin-Chu or Im-Pesaran-Shin) may produce misleading results. Therefore, second-generation unit root tests are preferred in such cases. In this context, the Cross-sectionally Augmented Dickey-Fuller (CADF) test developed by Pesaran (2007) is employed. The CADF test accounts for common shocks and cross-sectional dependence within the panel, thereby providing a more accurate assessment of the stationarity properties of the variables.

H_0: The variable is non-stationary (Has a unit root).

H_1: The variable is stationary.

Table 4 presents the Pesaran CADF panel unit root test results, which show that most variables are stationary after first differencing, while renewable energy use and urbanization are stationary in levels.

Table 4. Pesaran CADF Panel Unit Root Test Results.

Variable	t-bar	Critical Value (5%)	Z[t-bar]	p-value	Stationarity Status
GDP per Capita (1st diff.)	-2.484	-2.330	-2.112	0.017**	Stationary (I(1))
Carbon Intensity (1st diff.)	-2.912	-2.330	-3.359	0.000***	Stationary (I(1))
Trade Open (1st diff.)	-2.613	-2.330	-2.487	0.006***	Stationary (I(1))
FDI NET INFLOWS (1st diff.)	-2.565	-2.330	-2.347	0.009***	Stationary (I(1))
Renew (level)	-2.329	-2.330	-1.661	0.048**	Stationary (I(0))
Urban (level)	-2.341	-2.330	-1.695	0.045**	Stationary (I(0))

Note: ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

According to the CADF test developed by Pesaran (2007), the level values of GDP per capita, carbon intensity, trade openness, and foreign direct investment are non-stationary; however, they become stationary after first differencing. Conversely, the variables of renewable energy use and urbanization rate are stationary at their level forms. These results indicate that the panel dataset contains a mix of I(0) and I(1) variables, reflecting a mixed order of integration. Therefore, estimation techniques such as the Augmented Mean Group (AMG) method, which can accommodate variables of different integration orders, are methodologically appropriate for the analysis.

4.4. Augmented Mean Group (AMG) Estimation

When both cross-sectional dependence and heterogeneity are detected in a panel dataset, traditional panel regression methods may produce biased and inconsistent results. In such cases, second-generation estimation techniques are preferred. The primary method used in this study is the Augmented Mean Group (AMG) estimator, developed by Eberhardt and Bond (2009). This method stands out in the literature for its ability to account for unobserved common factors and heterogeneous dynamics across panel units.

The AMG estimator follows a two-step procedure: in the first step, it captures the dynamic structures and shocks common to all cross-sections in the panel. In the second step, these common components are included in individual country regressions to estimate group-specific coefficients. This approach controls for both cross-country differences and shared panel structures within the model.

This approach is particularly suitable for analyzing long-run relationships and is known for producing robust results by simultaneously addressing slope heterogeneity and cross-sectional dependence. Using the variables described above, the following baseline panel regression model is constructed.

$$GDPpcit = \alpha i + \beta 1 \cdot CarbonIntensityit + \beta 2 \cdot TradeOpenit + \beta 3 \cdot FDIit + \beta 4 \cdot Renewit + \beta 5 \cdot Urbanit + \varepsilon it \quad (1)$$

The panel regression model employed in this study considers real GDP per capita $GDPpcit$ as the dependent variable. The explanatory variables include: carbon intensity $CarbonIntensityit$, representing the environmental cost of economic growth, trade openness $TradeOpenit$, indicating the level of external economic engagement; foreign direct investment inflows $FDIit$, measuring the capital inflow from abroad, and renewable energy consumption $Renewit$ reflecting the implementation of green growth policies, and the urbanization rate $Urbanit$ capturing the spatial-demographic dimension of development. The model also includes a country-specific fixed effect αi to account for unobserved heterogeneity and an error term εit representing idiosyncratic shocks.

Table 5 presents the Augmented Mean Group (AMG) estimation results for the growth model, controlling for country-specific linear trends.

Table 5. AMG Estimation Results (Model Including Trend).

Method: Augmented Mean Group (AMG); country-specific linear trends are controlled					
Variable	**Coefficient**	**Std. Error**	**z-stat.**	**p-value**	**95% Confidence Interval**
Carbon Intensity	-835.56	316.10	-2.64	0.008***	[-1455.11 ; -216.02]
Trade Open	2.65	1.27	2.09	0.037**	[0.16 ; 5.15]
FDI NET INFLOWS	2.85	2.12	1.34	0.179	[-1.31 ; 7.00]
Renew	-19.41	12.13	-1.60	0.110	[-43.77 ; 0.90]
Urban	103.65	62.96	1.65	0.100*	[-19.76 ; 227.05]
Common Dynamic (R_t)	0.999	0.455	2.19	0.028**	[0.11 ; 1.89]
Linear Trend (t)	-29.38	21.99	-1.34	0.182	[-72.48 ; 13.73]
Constant	-648.40	2328.46	-0.28	0.781	[-5212.11 ; 3915.30]

Note: *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The estimation results from the AMG method indicate that carbon intensity and trade openness significantly affect real GDP per capita. Notably, the coefficient of carbon intensity is negative and statistically significant (coefficient = -835.56; p = 0.008). This suggests that environmental inefficiency, producing more emissions per unit of output, hinders economic growth, implying that development processes in African countries are adversely affected by carbon dependence. The result emphasizes the importance of environmental sustainability and supports the green growth perspective.

Trade openness has a positive and statistically significant coefficient (coefficient = 2.65; p = 0.037), as expected. This result indicates that openness to international trade promotes economic growth in African countries. The positive effect of openness is especially important for growth models dependent on external resources and highlights trade integration's potential to contribute to development.

Although the coefficient of foreign direct investment (FDI) inflows is positive (coefficient = 2.85), it is not statistically significant (p = 0.179). This suggests that the impact of FDI on growth was limited or varied across countries during the period under review. Similarly, the share of renewable energy consumption has a negative coefficient (coefficient = -19.41; p = 0.110), but the effect is not statistically significant. This outcome may indicate that the renewable energy transition in African economies has not yet matured into a productive infrastructure that enhances growth or that the costs of transition are dampening growth in the short term.

Another noteworthy variable in the model is the urbanization rate. Urbanization shows a positive coefficient that approaches the 10% level of statistical significance (coefficient = 103.65; p = 0.100). This suggests that urbanization may positively influence growth, potentially through factors such as labor mobility, infrastructure investment, and the efficiency of urban economies. However, the effect likely varies across countries and requires deeper structural analysis.

The coefficient of the common dynamic process (R_t) is statistically significant (coefficient = 0.999; p = 0.028), indicating that growth trajectories across panel countries are influenced by shared external shocks (e.g., global crises, commodity prices, pandemics). Furthermore, the group-specific linear trend variable, although not statistically significant (coefficient = -29.38; p = 0.182), reveals a downward structural trend in income per capita in some countries, and its inclusion improves the model's robustness.

In conclusion, the model outputs support both the theoretical and empirical dimensions of green growth and inclusive development. The negative effect of carbon intensity and the positive contribution of trade openness suggest that sustainable development policies in African economies must be designed more balanced, with greater attention to environmental concerns.

4.5. Common Correlated Effects Mean Group (CCEMG) Estimator

In the presence of unobserved common stocks that are correlated with the explanatory variables, traditional panel regression methods may produce biased estimates. To address this issue, the Common Correlated Effects Mean Group (CCEMG) estimator, developed by Pesaran (2006), is used as a second-generation technique that accounts for both cross-sectional dependence and contemporaneous interactions among variables. The CCEMG method incorporates the cross-sectional averages of all variables and their lags as control variables in the regression model for each cross-sectional unit. This approach controls for distortions caused by common factors, resulting in more consistent and reliable coefficient estimates. The CCEMG estimator not only accommodates heterogeneous panel structures but also allows for the assessment of policy variables' effects at the individual country level. This flexibility is especially valuable in diverse regional settings such as Africa, where countries differ in institutional quality, policy frameworks, and exposure to global dynamics. In this study, the CCEMG approach is used as a complementary method to validate results from the AMG estimator and to enhance the robustness of the empirical findings.

Table 6 presents the Common Correlated Effects Mean Group (CCEMG) estimation results for the growth model.

Table 6. CCEMG estimation results.

Method: Common Correlated Effects Mean Group (CCEMG)					
Variable	**Coefficient**	**Std. Error**	**z-stat.**	**p-value**	**95% Confidence Interval**
Carbon Intensity	-1255.04	530.77	-2.36	0.018**	[-2295.32 ; -214.76]
Trade Open	5.66	3.15	1.79	0.073*	[-0.52 ; 11.84]
FDI NET INFLOWS	5.24	3.73	1.40	0.160	[-2.07 ; 12.54]
Renew	-23.78	12.15	-1.96	0.050**	[-47.59 ; 0.02]
Urban	117.83	80.00	1.47	0.141	[-38.97 ; 274.64]
Common Dynamic (GDPpc avg)	0.89	0.38	2.34	0.019**	[0.14 ; 1.63]

Note: * and ** denote statistical significance at the 10% and 5% levels, respectively.

The results obtained through the Common Correlated Effects Mean Group (CCEMG) estimator developed by Pesaran (2006) allow the model to capture broader structural heterogeneity by accounting for both observed and unobserved common shocks across panel countries. The model is statistically significant (Wald $\chi^2 = 12.62$; $p = 0.027$), indicating that the explanatory variables collectively have a statistically meaningful effect on per capita income.

The most notable finding is the negative and statistically significant effect of the carbon intensity variable (coefficient = -1255.04; p = 0.018). This result aligns with the AMG model's findings and shows that low environmental efficiency (i.e., higher emissions per unit of GDP) consistently suppresses economic growth. The findings are strongly supported by both theoretical literature and policy discussions.

Trade openness shows a positive coefficient close to statistical significance (coefficient = 5.66; p = 0.073). Compared to the AMG model, the effect's magnitude is larger, indicating that while trade openness supports growth, its strength may vary across countries. This aligns with earlier findings and reinforces the argument that trade integration can promote inclusive development.

The foreign direct investment (FDI) variable also appears to have a positive coefficient (5.24), although it is statistically insignificant (p = 0.160). This suggests that the impact of FDI on growth may operate through more complex mechanisms or involve time-lagged effects.

Renewable energy use yields a negative coefficient that is on the edge of statistical significance (coefficient = -23.78; p = 0.050). This supports the AMG model's result, where the coefficient was also negative but not statistically significant. It indicates that the renewable energy transition in African countries may currently impose cost pressures rather than support growth in the short term.

Urbanization shows a positive coefficient (117.83), but the effect is statistically insignificant (p = 0.141). While the urbanization variable was marginally significant at the 10% level in the AMG model, the CCEMG model fails to confirm this. This suggests that the impact of urbanization on growth may vary significantly across countries, depending on the structural features of the urbanization process.

The coefficient for the common dynamic component based on the panel average is statistically significant (coefficient = 0.89; p = 0.019), confirming that the growth trajectories of these countries are influenced by shared external factors, supporting the AMG model's findings.

Overall, the findings from the AMG and CCEMG estimators reveal general trends at the panel level. Although the AMG method generates country-specific coefficients, these are not presented in this paper. While such group-specific coefficients are valuable for revealing structural heterogeneity across countries, the primary focus of this study is to identify overarching panel-level trends. Evaluating country-level heterogeneity is considered beyond the scope of this paper and is left for future comparative and context-sensitive research.

4.6. Reliability Test

Since the presence of endogeneity can bias the estimated coefficients, diagnostic reliability tests are performed to support the robustness of the model results.

4.6.1. Durbin-WU-Hausman Endogeneity Test

In panel data analysis, it is crucial for the explanatory variables to be exogenous to make valid causal inferences. However, some policy variables included in the model may be associated with the dependent variable due to reasons such as simultaneity or reverse causality. In such cases, the estimation results may become biased and inconsistent. To test this possibility, the Durbin-Wu-Hausman (DWH) endogeneity test (Durbin, 1954; Hausman, 1978; Wu, 1973) is employed. This test helps determine whether the effect of explanatory variables on the dependent variable is causal or simultaneous. It compares the results of a fixed effects model and an instrumental variables (IV) model to assess the consistency of the estimators. If the DWH test yields statistically significant results, the variable is considered endogenous. Consequently, traditional estimation techniques become invalid, and the use of instrumental variable methods or dynamic models such as System GMM is recommended. In this study, the DWH test was applied particularly to variables that may influence and be influenced by economic growth, and the model was adjusted accordingly.

H_0: The variable is exogenous (Not endogenous);

H_1: The variable is endogenous.

Table 7 presents the Durbin–Wu–Hausman endogeneity test results for trade openness and foreign direct investment.

Table 7. Durbin-Wu-Hausman endogeneity test results.

Tested variable	Residual term (resid)	Coefficient	Std. error	t-stat	p-value	Result
FDI NET INFLOWS	resid_fdi	-1761.96	119.45	-14.75	0.000***	Endogenous
Trade Open	resid_trade	194.32	13.17	14.75	0.000***	Endogenous

Note: *** denotes statistical significance at the 1% level, respectively.

According to the Durbin-Wu-Hausman test, both Foreign Direct Investment inflows (FDINETINFLOWS) and Trade Openness (TradeOpen) exhibit statistically significant residual term coefficients ($p < 0.001$ for both variables). These findings indicate that both variables are endogenous within the model, suggesting that estimates obtained through classical estimation methods may be biased. In particular, the large negative coefficient of the resid_fdi variable (-1761.96) and the positive coefficient of the resid_trade variable (194.32) highlight the need for careful consideration of these variables' roles within the model.

Therefore, to enhance the model's reliability, it is necessary to employ estimation methods based on instrumental variable approaches, such as the System GMM estimator. This allows for controlling endogenous structures and enables more robust estimation of the structural factors affecting economic growth.

4.6.2. System GMM Estimator

To address potential endogeneity problems in the model and accurately capture its dynamic structure, the System Generalized Method of Moments (System GMM) estimator developed by Arellano and Bond (1991) and Arellano and Bover (1995) was employed. This method aims to minimize issues of autocorrelation and endogeneity that may arise when the lagged dependent variable is included as an explanatory variable in panel data models. System GMM jointly estimates both level and first-difference equations, producing stronger and more consistent instrumental variables. This approach is particularly well-suited for panels with a short time dimension and many cross-sectional units (countries). It uses the lagged values of the explanatory variables as instruments for potentially endogenous regressors, thereby preserving the model's dynamic structure while avoiding biased estimates. In this study, System GMM was not used as the primary estimation tool but rather as a robustness check to validate the results obtained from the AMG and CCEMG estimators and to test the model's dynamic properties. This approach allows for a more reliable assessment of the direction and statistical consistency of the relationships identified in the analysis.

Tables 8 and 9 present the System GMM estimation results for the growth model, and the corresponding diagnostic test statistics, including autocorrelation and instrument validity tests.

Table 8. System GMM estimation results.

Dependent variable: Real GDP per capita (GDPpc)				
Variable	**Coefficient**	**Std. Error**	**p-value**	**95% confidence interval**
L.GDP per Capita	0.392	0.608	0.540	[-1.047, 1.830]
Carbon Intensity	1270.176	836.337	0.173	[-707.447, 3247.799]
Trade Open	6.997	7.813	0.400	[-11.478, 25.473]
FDI NET INFLOWS	3.569	5.510	0.538	[-9.461, 16.599]
Renew	-59.805	31.147	0.096*	[-133.456, 13.846]
Urban	-4.622	50.868	0.930	[-124.907, 115.662]
Constant	4575.949	2777.357	0.143	[-1991.458, 11143.360]

Note: * denotes statistical significance at the 10% level, respectively.

Table 9. Diagnostic test results for the system GMM estimation.

Test	Test statistic	*p*-value	Interpretation
Arellano-Bond AR(1)	$z = -1.89$	0.059*	First-order autocorrelation is statistically significant.
Arellano-Bond AR(2)	$z = -1.84$	0.066*	No evidence of second-order autocorrelation.
Sargan Overidentification Test	$\chi^2(156) = 179.92$	0.092*	Instrument variables are valid in terms of overidentification restrictions.
Hansen Overidentification Test	$\chi^2(156) = 0.25$	1.000	Strong support for the validity of the instrument variables.

Note: * denotes statistical significance at the 10% level, respectively.

The results of the System GMM estimation analyze the dynamic structure of the key determinants of GDP per capita. Although the lagged GDP variable in the model has the expected positive sign, it is not statistically significant. This suggests that the influence of past growth on the current period is limited. The carbon intensity variable exhibits a positive but statistically insignificant coefficient, indicating that its short-run dynamic effect on growth is inconclusive within the System GMM framework (Dumitrescu & Hurlin, 2012). Trade openness and foreign direct investment (FDI) also display positive signs but fail to attain statistical significance. The lack of significance for these two variables implies that their effects on growth in the sampled countries may be weak, indirect, or subject to time lags. The renewable energy consumption variable shows a negative impact and lies on the borderline of 10% significance. This finding aligns with the literature suggesting that the transition to renewable energy may impose short-term costs on economic growth. The urbanization variable, on the other hand, has a very small coefficient and is completely insignificant, indicating that urbanization alone may not be a sufficient driver of growth.

The validity of the model is assessed using the Arellano-Bond and Hansen diagnostic tests. The AR(1) test indicates mild first-order autocorrelation, while the AR(2) test, with a p-value slightly above the 10% threshold, suggests no second-order autocorrelation.

The Hansen test strongly supports the validity of the instrumental variables and confirms that the model is not over-identified. However, the potential weakening of the test due to a high number of instruments should be acknowledged. Overall, the reliability of the model is established. The results suggest that environmental and energy-related variables are at the threshold of significance in explaining growth, whereas traditional economic factors such as trade and investment appear to contribute less strongly. In this context, it can be inferred that while designing energy transition policies, the short-term growth pressures arising from such shifts should also be carefully considered.

4.7. Granger Causality Test

To determine the direction of relationships between variables in the model, the panel Granger causality test developed by Dumitrescu and Hurlin (2012) was applied. This test is sensitive to issues such as heterogeneity and cross-sectional dependence in panel data structures, offering a more flexible framework by accounting for inter-individual differences. The primary aim of the test is to assess whether the past values of one variable significantly explain the current values of another variable. In this context, the analysis examined whether each explanatory variable Granger-causes economic growth, testing potential causal relationships separately for each variable. Bidirectional causality relationships were evaluated. The test results were interpreted based on the calculated average W-bar, Z-bar, and Z-bar tilde statistics for the panel, along with the corresponding p-values. This approach allowed for an empirical investigation of potential feedback mechanisms among the variables, considering the directionality of the relationships.

Table 10 presents the Dumitrescu and Hurlin (2012) panel Granger causality test results for the variables included in the analysis.

Table 10. Dumitrescu and Hurlin (2012) panel Granger causality test results (Lag = 2).

Causality Direction	Z-bar	p-value	Causality Decision
Trade Open → GDP per Capita	0.1681	0.8665	No causality
GDP per Ca → Trade Open	1.8023	0.0715*	Weak causality
Carbon Intensity → GDP per Capita	0.9084	0.3637	No causality
GDP per Ca → Carbon Intensity	1.8106	0.0702*	Weak causality
Renew → GDP per Capita	0.4331	0.6650	No causality
GDP per Ca → Renew	6.2584	0.0000***	Strong causality
Urban → GDP per Capita	4.9858	0.0000***	Strong causality
GDP per Ca → Urban	1.5072	0.1317	No causality
FDI NET INFLOWS → GDP per Capita	0.2932	0.7693	No causality
GDP per Ca → FDI NET INFLOWS	1.5958	0.1105	No causality

Note: * and *** denote statistical significance at the 10% and 1% levels, respectively.

The panel Granger causality analyses reveal that while some directional causal relationships exist among the variables, others are not statistically significant. Accordingly, trade openness does not Granger-cause per capita income. However, per capita income appears to exert a weak Granger causal effect on trade openness. Similarly, carbon intensity does not Granger-cause income per capita, but income per capita weakly influences carbon intensity.

No Granger causality is detected from renewable energy use to per capita income. In contrast, per capita income exhibits a statistically significant Granger causal effect on renewable energy use. This finding suggests that economic growth may stimulate demand for renewable energy. Urbanization, on the other hand, is a strong Granger cause of per capita income, while the reverse is not statistically significant. This supports literature suggesting that urbanization, rather than growth itself, may more directly influence economic outcomes.

Regarding foreign direct investment (FDI), no bidirectional Granger causality is found between FDI inflows and per capita income. The p-values for both directions (FDINETINFLOWS → GDPperCa and GDPperCa → FDI_NETINFLOWS) exceed the threshold of statistical significance, indicating no strong short-term causal link between FDI and economic growth.

In summary, the presence of weak or strong Granger causality from per capita income to environmental indicators, specifically renewable energy use and carbon intensity, suggests that economic growth may influence environmental outcomes. However, most of the explanatory variables do not significantly Granger-cause income per capita, implying that growth is primarily driven by internal dynamics rather than external policy variables considered in this model.

5. DISCUSSION AND CONCLUSION

This study examines the determinants of inclusive growth by analyzing the drivers of per capita income in emerging and developing African economies from 2000 to 2021. Using panel data for eight countries, Kenya, Tanzania, South Africa, Egypt, Morocco, Senegal, Uganda, and Angola, the empirical model incorporates carbon intensity, trade openness, foreign direct investment (FDI), renewable energy use, and urbanization as explanatory variables. To address cross-sectional dependence and slope heterogeneity, the analysis employs second-generation panel estimators, namely the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG), supported by System GMM estimations and Dumitrescu–Hurlin Granger causality tests.

The results from both AMG and CCEMG estimations indicate that carbon intensity has a negative and statistically significant effect on per capita income. This finding suggests that carbon-intensive production structures constrain long-term economic growth, reflecting inefficiencies associated with energy- and resource-dependent development patterns. Rather than supporting income expansion, higher carbon intensity appears to undermine growth performance in the sampled African economies, pointing to structural limitations in carbon-dependent growth trajectories.

Trade openness shows a positive and statistically significant effect on per capita income in AMG estimations and remains positive with marginal significance in CCEMG results. This suggests that trade integration can promote growth, although its effectiveness depends on country-specific factors such as export structure, diversification, and domestic absorptive capacity.

Renewable energy use displays a negative association with per capita income, reaching statistical significance in the CCEMG estimations. This result suggests that, in the short run, renewable energy investments may impose adjustment costs on growth in economies with limited technological readiness, weak institutional frameworks, and constrained access to finance. While renewable energy remains essential for long-term sustainability, its growth-enhancing effects may not materialize immediately without supportive structural conditions.

Foreign direct investment inflows do not show a statistically significant effect on per capita income in either estimation method, indicating that capital inflows alone are insufficient for sustained growth without domestic capabilities. Urbanization has a positive but model-sensitive impact on income, with weak significance only in the AMG framework, suggesting its growth effects depend on infrastructure quality and labor market efficiency.

Overall, the findings reveal that inclusive growth in Africa is hindered by carbon-intensive production structures, while trade openness offers limited growth support, and renewable energy transitions involve short-term economic trade-offs. These results highlight the importance of structural transformation, institutional strengthening, and productivity-enhancing reforms to reconcile economic growth objectives with environmental performance in the African context.

Granger causality results provide further insights into the direction of relationships among variables. The findings indicate strong unidirectional causality from per capita income to renewable energy use, suggesting that higher income levels enable economies to adopt cleaner energy technologies rather than renewable energy driving income growth. Similarly, urbanization Granger-causes per capita income, highlighting its role as a structural driver of economic growth in the sampled African economies.

In contrast, no causal relationship is found from renewable energy use, trade openness, carbon intensity, or foreign direct investment inflows to per capita income. Weak causality is observed from per capita income to trade openness and carbon intensity, implying that income growth may influence trade integration and environmental performance, but not vice versa. These results reinforce the view that growth dynamics in Africa are primarily shaped by domestic structural factors rather than external capital inflows or environmental variables in the short run.

Taken together, the findings reveal a nuanced relationship between economic growth and environmental performance in Africa. While higher carbon intensity is associated with lower per capita income in long-term estimations, the absence of causality from carbon intensity to income suggests that environmental inefficiencies act as structural constraints rather than immediate growth drivers. Renewable energy transitions, although essential for sustainability, appear to be largely income-driven and subject to short-term adjustment costs.

From a policy perspective, the results emphasize that sustained income growth is a prerequisite for a successful energy transition, while reducing carbon intensity requires productivity-enhancing structural reforms rather than reliance on growth alone. Trade and investment strategies should prioritize domestic absorptive capacity, urban productivity, and institutional quality to support inclusive growth alongside improvements in environmental performance.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by Nil Sirel Ozturk.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.
Disclosure of AI Use: The author used OpenAI's ChatGPT (GPT-4) to edit and refine the wording of the Introduction and Literature Review. All outputs were thoroughly reviewed and verified by the author.

REFERENCES

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277-297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29-51. https://doi.org/10.1016/0304-4076(94)01642-D

Arthur, B., Saha, M., Sarpong, F. A., & Dutta, K. D. (2024). Unlocking Africa's potential: The transformative power of foreign direct investment for sustainable development. *Heliyon*, *10*(5), e26507. https://doi.org/10.1016/j.heliyon.2024.e26507

Birdsall, N., & Meyer, C. J. (2015). The median is the message: A good enough measure of material wellbeing and shared development progress. *Global Policy*, *6*(4), 343-357. https://doi.org/10.1111/1758-5899.12239

Brueckner, M., & Lederman, D. (2015). Trade openness and economic growth: Panel data evidence from Sub-Saharan Africa. *Economica*, *82*, 1302-1323. https://doi.org/10.1111/ecca.12160

Cichowicz, E., & Rollnik-Sadowska, E. (2018). Inclusive growth in CEE countries as a determinant of sustainable development. *Sustainability*, *10*(11), 3973. https://doi.org/10.3390/su10113973

Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, *29*(4), 1450-1460. https://doi.org/10.1016/j.econmod.2012.02.014

Durbin, J. (1954). Errors in variables. In (pp. 23-32). Netherlands: Review of the International Statistical Institute.

Eberhardt, M., & Bond, S. (2009). *Cross-section dependence in nonstationary panel models: A novel estimator*. Retrieved from https://mpra.ub.uni-muenchen.de/17870/

Fan, J., Liao, Y., & Yao, J. (2015). Power enhancement in high-dimensional cross-sectional tests. *Econometrica*, *83*(4), 1497-1541. https://doi.org/10.3982/ECTA12749

Gershon, O., Asafo, J. K., Sowah, J. N., & Tanko, F. (2025). Persistence of emissions in selected African countries: Energy consumption and population growth dynamics. *Energy Strategy Reviews*, *57*, 101628. https://doi.org/10.1016/j.esr.2024.101628

Grömling, M., & Klös, H.-P. (2019). Inclusive growth—institutions matter! *Intereconomics*, *54*(3), 184-192. https://doi.org/10.1007/s10272-019-0819-y

Halkos, G. E., & Gkampoura, E.-C. (2021). Examining the linkages among carbon dioxide emissions, electricity production and economic growth in different income levels. *Energies*, *14*(6), 1682. https://doi.org/10.3390/en14061682

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the Econometric Society*, *46*(6), 1251–1271.

Hunjra, A. I., Bouri, E., Azam, M., Azam, R. I., & Dai, J. (2024). Economic growth and environmental sustainability in developing economies. *Research in International Business and Finance*, *70*, 102341. https://doi.org/10.1016/j.ribaf.2024.102341

Kahia, M., Ben Jebli, M., & Belloumi, M. (2019). Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries. *Clean Technologies and Environmental Policy*, *21*(4), 871-885. https://doi.org/10.1007/s10098-019-01676-2

Konyeaso, A. W., Eregha, P. B., & Vo, X. V. (2023). Unbundling the dynamic impact of renewable energy and financial development on real per capita growth in African countries. *Environmental Science and Pollution Research*, *30*(1), 899-916. https://doi.org/10.1007/s11356-022-22109-6

Li, M., Zhang, Y., Fan, Z., & Chen, H. (2021). Evaluation and research on the level of inclusive green growth in Asia-Pacific region. *Sustainability*, *13*(13), 7482. https://doi.org/10.3390/su13137482

Monyela, M. N., & Saba, C. S. (2024). Trade openness, economic growth and economic development nexus in South Africa: A pre- and post-BRICS analysis. *Humanities and Social Sciences Communications*, *11*(1), 1-18. https://doi.org/10.1057/s41599-024-03604-2

Nam, H.-J., & Ryu, D. (2024). Does trade openness promote economic growth in developing countries? *Journal of International Financial Markets, Institutions and Money*, *93*, 101985. https://doi.org/10.1016/j.intfin.2024.101985

Namahoro, J., Wu, Q., Zhou, N., & Xue, S. (2021). Impact of energy intensity, renewable energy, and economic growth on CO2 emissions: Evidence from Africa across regions and income levels. *Renewable and Sustainable Energy Reviews*, *147*, 111233. https://doi.org/10.1016/j.rser.2021.111233

Namahoro, J. P., Wu, Q., Xiao, H., & Zhou, N. (2021). The impact of renewable energy, economic and population growth on CO2 emissions in the East African region: Evidence from common correlated effect means group and asymmetric analysis. *Energies*, *14*(2), 312. https://doi.org/10.3390/en14020312

Nolan, B. (2020). The median versus inequality-adjusted GNI as core indicator of 'ordinary' household living standards in rich countries. *Social Indicators Research*, *150*(2), 569-585. https://doi.org/10.1007/s11205-020-02311-0

Nupehewa, S., Liyanage, S., Polkotuwa, D., Thiyagarajah, M., Jayathilaka, R., & Lokeshwara, A. (2022). More than just investment: Causality analysis between foreign direct investment and economic growth. *PLoS One*, *17*(11), e0276621. https://doi.org/10.1371/journal.pone.0276621

Osman, A., Afjal, M., Alharthi, M., Elheddad, M., Djellouli, N., & He, Z. (2025). Green growth dynamics: Unraveling the complex role of financial development and natural resources in shaping renewable energy in Sub-Saharan Africa. *Humanities and Social Sciences Communications*, *12*, 64. https://doi.org/10.1057/s41599-025-04364-3

Özokcu, S., & Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. *Renewable and Sustainable Energy Reviews*, *72*, 639-647. https://doi.org/10.1016/j.rser.2017.01.059

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels*. Cambridge Working Papers in Economics No. 0435, University of Cambridge.

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*, *74*(4), 967-1012. https://doi.org/10.1111/j.1468-0262.2006.00692.x

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265-312. https://doi.org/10.1002/jae.951

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010

Prada, A., & Sánchez-Fernández, P. (2019). Transforming economic growth into inclusive development: An international analysis. *Social Indicators Research*, *145*(1), 437-457. https://doi.org/10.1007/s11205-019-02096-x

Qudrat-Ullah, H., & Nevo, C. M. (2022). Analysis of the dynamic relationships among renewable energy consumption, economic growth, financial development, and carbon dioxide emission in five Sub-Saharan African countries. *Energies*, *15*(16), 5953. https://doi.org/10.3390/en15165953

Scalamonti, F. (2024). The foreign investments-growth nexus in underdeveloped countries: The state-of-art of research analysing a selected and recent empirical literature (2020-2022). *Technological Forecasting and Social Change, 198*, 122933. https://doi.org/10.1016/j.techfore.2023.122933

Sun, C., Liu, L., & Tang, Y. (2018). Measuring the inclusive growth of China's coastal regions. *Sustainability, 10*(8), 2863. https://doi.org/10.3390/su10082863

Teklie, D. K., & Yağmur, M. H. (2024). The role of green innovation, renewable energy, and institutional quality in promoting green growth: Evidence from African countries. *Sustainability, 16*(14), 6166. https://doi.org/10.3390/su16146166

van Krevel, C. (2023). Why cross-country convergence of income is unsustainable: Evidence from inclusive wealth in 140 countries. *Social Indicators Research, 170*(3), 847-875. https://doi.org/10.1007/s11205-023-03218-2

Waite, D., Whyte, B., & Muirie, J. (2020). From an agreeable policy label to a practical policy framework: Inclusive growth in city-regions. *European Planning Studies, 28*(9), 1812-1835. https://doi.org/10.1080/09654313.2019.1691507

Wu, D.-M. (1973). Alternative tests of independence between stochastic regressors and disturbances. *Econometrica, 41*(4), 733-750. https://doi.org/10.2307/1914093

Yang, C., Namahoro, J. P., Wu, Q., & Su, H. (2022). Renewable and non-renewable energy consumption on economic growth: Evidence from asymmetric analysis across countries connected to Eastern Africa Power Pool. *Sustainability, 14*(24), 16735. https://doi.org/10.3390/su142416735

Yuni, D. N., Ezenwa, N., Urama, N. E., Tingum, E. N., & Mohlori-Sepamo, K. (2023). Renewable energy and inclusive economic development: An African case study. *International Journal of Sustainable Energy Planning and Management, 39*, 23-35. https://doi.org/10.54337/ijsepm.7413

Zaman, K., & Abd-el Moemen, M. (2017). Energy consumption, carbon dioxide emissions and economic development: Evaluating alternative and plausible environmental hypothesis for sustainable growth. *Renewable and Sustainable Energy Reviews, 74*, 1119-1130. https://doi.org/10.1016/j.rser.2017.02.072

Zhang, J., Alharthi, M., Abbas, Q., Li, W., Mohsin, M., Jamal, K., & Taghizadeh-Hesary, F. (2020). Reassessing the environmental kuznets curve in relation to energy efficiency and economic growth. *Sustainability, 12*(20), 8346. https://doi.org/10.3390/su12208346