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Foreign Direct Investment in the Energy Sector: A Catalyst for Economic Growth in Emerging Economies (1975-2024): Evidence from the Pre- and Post-COVID-19 Periods

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Abstract

This comparative study examines the evolving relationship between foreign direct investment (FDI) in the energy sector and economic growth in emerging economies, distinguishing between the pre-COVID-19 period (1975-2019) and post-COVID-19 period (2020-2024). Employing a comprehensive panel data framework with advanced econometric techniques including CS-ARDL, AMG, Westerlund cointegration, and Granger causality tests, the analysis reveals fundamental structural changes in the FDI-growth nexus. Most notably, FDI transitions from having no significant effect on growth in the pre-COVID period to demonstrating statistically significant positive effects in both the short-run (0.037, p=0.031) and long-run (0.042, p=0.041) in the post-COVID era. The analysis also reveals the emergence of cointegration, enhanced error-correction dynamics, and bidirectional FDI-GDP causality post-COVID. The energy sector consistently drives growth across both periods, though with evolving characteristics. These findings have profound implications for policy formulation in emerging economies seeking to harness FDI for sustainable development in the post-pandemic world.

Keywords: Foreign Direct Investment, Energy Sector, Economic Growth, COVID-19, Emerging Economies, Structural Break, Panel Data Analysis

1. Introduction

The global energy landscape is undergoing a profound transformation, with Foreign Direct Investment serving as a critical engine for capital accumulation and technological diffusion in emerging economies (Aluko et al., 2023; Raihan et al., 2024). According to the International Energy Agency, global investment in clean energy technologies has reached unprecedented levels, necessitating a deeper examination of how these capital flows impact macroeconomic resilience in the face of structural shifts. However, the macroeconomic disruptions triggered by the COVID-19 pandemic have introduced significant volatility into these capital flows, casting doubt on the long-term stability of traditional growth models in developing regions.

This unprecedented volatility highlights a significant research gap concerning the efficacy of energy-sector FDI as a stable catalyst for sustainable development across divergent economic regimes (Ngoc, 2025; Yadav et al., 2024). Consequently, this study aims to disentangle the nuanced relationship between energy-related FDI and output growth by employing an extensive longitudinal analysis spanning 1975 to 2024. By contrasting the pre- and post-pandemic periods, this research contributes to the literature by evaluating whether structural changes in global capital markets have weakened the capacity of foreign investment to drive inclusive green growth and socioeconomic stability (Acheampong, 2023), (Raihan et al., 2025). Furthermore, by addressing the regional and sectoral heterogeneities identified in recent literature (Carmen & Ilidio, 2025; Chaula et al., 2026), this investigation provides policymakers with a refined framework to leverage international capital for industrialization and sustainability in an increasingly fragmented global landscape (Ofori et al., 2023). By rigorously assessing these dynamics, this research clarifies the conditions under which energy infrastructure investment can effectively mitigate carbon dependence while fostering robust economic advancement (Azimi et al., 2024; Imran et al., 2025). This investigation further addresses critical voids in current empirical evidence regarding the long-term effectiveness of capital inflows in promoting sustainable, low-carbon development within emerging market architectures (Estêvão & Lopes, 2023; Hoa et al., 2023). Ultimately, this study offers critical insights into whether international capital flows foster genuine technology transfer and environmental productivity, or if they merely perpetuate historical reliance on resource-intensive consumption patterns (Alola & Rahko, 2023; Sarkodie et al., 2023). By bridging these analytical gaps, the findings seek to inform strategic policy interventions that align capital deployment with the imperatives of both economic development and international environmental sustainability (Idroes et al., 2024). Given that energy security risks frequently correlate with diminished economic stability (Banna et al., 2023), this analysis provides a vital empirical foundation for navigating the systemic complexities inherent in modern emerging-market energy transitions. By characterizing the interplay between geopolitical risk, income volatility, and investment efficacy, this research establishes a vital empirical baseline for the post-pandemic era. Through this methodological lens, the study effectively isolates the structural shifts in capital allocation that have emerged as decisive factors in defining the long-term viability of renewable resource expenditure (Pata et al., 2023). Moreover, this study critically evaluates whether the post-COVID-19 macroeconomic climate necessitates a recalibration of investment policies to better support social equity and economic viability in the face of persistent environmental challenges (Ghorbani et al., 2023; Qalati et al., 2023). Such an examination is imperative to determine how financial integration and institutional quality can be better synergized to ensure that energy-sector FDI yields equitable dividends rather than compounding systemic regional inequalities (Omri & Jabeur, 2024). By leveraging modern panel data techniques to reconcile these institutional nuances with evolving technological trends, the study addresses a critical scholarly priority in understanding the trajectory of post-pandemic global development (Adanma & Ogunbiyi, 2024; Erdoğan et al., 2023). Furthermore, this research empirically validates the hypothesis that the alignment between financial deepening and sustainable technological innovation acts as a decisive moderator in the nexus between foreign capital and ecological performance (Apeaning & Labaran, 2025; Musah et al., 2024). By situating this analysis within the evolving framework of the Environmental Kuznets Curve, this research provides a comprehensive assessment of whether foreign-led energy projects accelerate the transition toward green growth or merely displace environmental burdens (Alvarado et al., 2024). Ultimately, discerning these impacts is essential for policy formulation, as financial institutions and capital markets frequently exhibit disparate preferences for energy-intensive projects versus green initiatives, thereby complicating the realization of sustainable development goals (Horky & Fidrmuc, 2024). By explicitly examining how institutional quality and financial stability influence the deployment of energy capital, this research elucidates the essential conditions under which foreign investment can effectively catalyze, rather than inhibit, sustainable economic transitions in middle-income economies (Halldén et al., 2025). Specifically, this study contributes to the empirical debate on whether energy-sector FDI acts as a conduit for environmental efficiency or merely serves as a mechanism for resource extraction, a tension that has become particularly salient given the recent volatility in institutional quality across emerging markets (Balsalobre-Lorente et al., 2023; Qamruzzaman, 2024). By synthesizing longitudinal data with advanced panel econometrics, this analysis seeks to reconcile these contradictory empirical outcomes, ultimately offering a robust framework for assessing the determinants of sustainable development in the post-pandemic era (Alola et al., 2024). By bridging these analytical divides, this study provides a vital empirical foundation for policymakers tasked with navigating the precarious balance between securing immediate economic growth and achieving long-term decarbonization goals. This research agenda is particularly pressing as global energy transitions increasingly rely on cross-border capital to bridge the substantial funding gap required for climate-resilient infrastructure. Specifically, this research aims to determine whether the mechanisms facilitating energy innovation and financial integration sufficiently mitigate the ecological deficits often associated with rapid industrialization in developing contexts (Chen et al., 2023; Shabir et al., 2023). As global energy transitions necessitate substantial cross-border capital to meet climate-resilient infrastructure targets, identifying the specific institutional mediators that maximize these environmental externalities remains a paramount research priority (Adanma & Ogunbiyi, 2024; Dinu et al., 2024). Accordingly, this study systematically analyzes the trajectory of foreign direct investment within the energy sector from 1975 to 2024, providing a longitudinal evaluation of how macroeconomic shocks—specifically the pre- and post-COVID-19 periods—have fundamentally reshaped the dynamics of capital allocation in emerging markets (Olanrewaju et al., 2024). By disentangling the structural determinants of these investment flows, the research offers a granular assessment of how shifts in global economic policy have influenced the capacity for clean energy adoption across diverse institutional landscapes (Bakhsh et al., 2024). This study ultimately addresses the critical necessity of understanding whether such capital inflows function as a genuine catalyst for long-term growth or as a latent driver of environmental degradation in the post-pandemic era (Bai et al., 2023). In this context, the research illuminates the extent to which global FDI serves as a primary vehicle for achieving the Sustainable Development Goals by mitigating the ecological damages often exacerbated by traditional industrial growth (Ezeigweneme et al., 2024). Given the divergence in energy transition policies across disparate geographical contexts, it is essential to synthesize how international collaborations and regulatory mechanisms have evolved to incentivize sustainable practices (Adelekan et al., 2024). Bridging these disparities remains critical, as mobilizing private capital for green energy projects is essential to overcoming persistent geographical investment gaps (Mohnot et al., 2025). Consequently, this research addresses a significant gap by evaluating how climate finance and institutional quality moderate the efficacy of foreign energy capital in fostering resilience (Digitemie & Ekemezie, 2024), (Iyke, 2023). thereby offering a rigorous analysis of how cross-border resource flows can be optimized to balance economic expansion with environmental stewardship (Attílio & Silva, 2025). This analytical endeavor is particularly timely, as the global energy landscape undergoes a profound paradigm shift necessitating the alignment of investment flows with stringent ESG criteria to ensure long-term viability (Ikevuje et al., 2024a, 2024b). Central to this investigation is the empirical verification of whether such capital inflows, particularly in the renewable energy sector, effectively stimulate economic growth while navigating the institutional distance that frequently complicates resource allocation in developing nations (Chen et al., 2023). By integrating institutional quality with renewable energy investment metrics, this study provides a novel empirical perspective on how governance frameworks modulate the transformative potential of foreign capital in emerging markets (Yasmeen et al., 2023). Furthermore, by employing rigorous econometric methodologies to address endogeneity, this study clarifies the heterogeneous impact of market-oriented reforms on energy sector development across varying income levels (Abban et al., 2025). This investigation further contributes to the literature by accounting for cross-sectional dependency and structural breaks, which often obfuscate the long-term relationship between capital formation and environmental sustainability

2. Literature Review

The existing literature on the foreign direct investment-growth nexus is largely grounded in neoclassical growth models, which posit that capital inflows accelerate output by addressing domestic savings deficits and facilitating technology transfers. Conversely, endogenous growth theories emphasize that these inflows act as primary vehicles for human capital accumulation and the diffusion of technological innovations, which are essential for long-term productivity improvements (Sampene et al., 2024). These theoretical frameworks further suggest that when directed toward the energy sector, such investment enhances generation capacity and facilitates the diffusion of cleaner technologies, thereby fostering an enabling environment for sustainable economic expansion (Qi & Qian, 2023). Furthermore, recent empirical scholarship highlights that the synergy between financial inclusion and private investment in renewable energy is fundamental to augmenting energy efficiency and curbing carbon emissions (Usman et al., 2024). However, the post-pandemic landscape has introduced significant volatility, as empirical evidence suggests that institutional quality acts as a critical mediator in determining whether these capital inflows translate into robust green growth or merely perpetuate existing carbon dependencies (Murshed, 2024). As institutional quality varies significantly across emerging economies, it necessitates a nuanced assessment of how governance frameworks—ranging from labor market regulations to capital market integrity—either catalyze or constrain the productivity gains derived from foreign energy investments (Bagh et al., 2023), (Degbedji et al., 2023). Furthermore, existing studies indicate that the transition to renewable energy consumption is not uniform, as technological innovation and political stability serve as essential moderators for optimizing these capital-intensive projects (Guliyev, 2025; Qamruzzaman & Karim, 2024). Moreover, the systemic disruption caused by COVID-19 underscores the vulnerability of these cross-border capital flows to global economic shocks, necessitating a comparative analysis of pre- and post-pandemic investment resilience (Hwang & Díez, 2024). By contrasting the structural shifts in capital allocation before and after 2020, this analysis aims to elucidate whether recent recovery policies have successfully redirected foreign energy investment toward long-term green infrastructure or merely reinforced pre-existing fossil fuel extraction patterns (N et al., 2024). This inquiry is particularly vital given the widening investment chasm in emerging markets, where bridging the financing gap is a prerequisite for achieving global climate targets and ensuring stable energy transitions (Çağlar et al., 2024). Ultimately, a rigorous examination of these dynamics is imperative for policymakers seeking to align macroeconomic stability with the decarbonization mandates necessary to close the prevailing investment gap in sustainable energy (Brindha & Ramakrishna, 2023). Such an evaluation is essential for reconciling the urgent need for infrastructure development with the structural shifts required to attain long-term ecological modernization (Mwita et al., 2025). Such an analytical framework is crucial for reconciling the urgent need for sustainable infrastructure with the global imperative to mitigate the volatility inherent in cross-border energy financing (Commission & OECD, 2023; Ibekwe et al., 2024). By evaluating these investment patterns across the pre- and post-COVID-19 divide, this research seeks to establish whether the recent proliferation of green finance frameworks has successfully mitigated the risk-return asymmetries that historically hampered renewable energy integration in emerging markets (Alexandra et al., 2023). Consequently, identifying the mechanisms through which these frameworks harmonize financial performance with environmental impacts remains a critical research priority for sustaining economic progress in the post-pandemic era (Adebayo et al., 2026; Nwobodo et al., 2024). Moreover, assessing how infectious disease-related uncertainty influences the volatility of energy assets is essential for understanding the resilience of these capital flows amidst recurring global shocks (Dutta et al., 2024). Furthermore, exploring the intricate linkages between green financial markets and artificial intelligence assets provides a deeper understanding of the technological synergies driving modern energy investments (Zeng et al., 2024). This synthesis underscores the necessity of examining how algorithmic integration within the energy sector influences the efficacy of cross-border capital, particularly as data-driven interventions emerge as key determinants of green technological diffusion (Yin et al., 2023). By leveraging standardized metrics and ESG-integrated indices, stakeholders can now better evaluate the sustainability performance of these capital-intensive initiatives against the backdrop of shifting regulatory incentives (Olanrewaju et al., 2024). Consequently, this research fills a critical gap by empirically analyzing the extent to which these governance-driven mechanisms effectively shield emerging markets from the heightened systemic risks and investment outflows observed since 2020. This analytical approach emphasizes the pivotal role of transparency and accountability in mediating the impact of green finance, thereby offering a robust framework for assessing long-term investment viability in emerging markets (Udeh et al., 2024). By synthesizing these regulatory and technological dimensions, this study provides a comprehensive roadmap for optimizing capital allocation strategies to ensure that energy-sector FDI serves as a durable engine for economic resilience. By evaluating the specific interplay between environmental disclosure quality and capital flow stability, this paper offers a novel perspective on how emerging economies can harmonize financial incentives with ecological mandates. Specifically, this analysis addresses the ambiguity surrounding whether institutional disclosures can effectively mitigate the risks associated with the financialization of environmental assets (Yan et al., 2023). By examining whether standardized ESG reporting frameworks act as sufficient buffers against market volatility, this research clarifies the extent to which transparency can alleviate investor skepticism in post-crisis recovery periods (Lim, 2024). Ultimately, by bridging the divide between theoretical growth models and contemporary empirical evidence, this study provides actionable insights for policymakers to incentivize sustainable capital flows that are resilient to future systemic shocks. In this context, analyzing the nexus between foreign direct investment and sectoral productivity becomes essential to validate whether capital inflows foster substantive economic expansion or merely perpetuate legacy dependencies (Ho et al., 2023). Building upon classical growth theories, this research assesses whether the influx of foreign capital effectively enhances domestic capital formation or if it displaces local investment, thereby conditioning the long-term sustainability outcomes for developing nations (Ogundipe et al., 2024). This examination is particularly timely as emerging economies grapple with the dual challenges of attracting stable capital amidst heightened macroeconomic uncertainty and transitioning toward sustainable, green-growth trajectories (Hossain et al., 2024), (Agunbiade, 2025). as the post-COVID-19 landscape necessitates a re-evaluation of how capital allocation strategies can prioritize low-carbon energy sources to catalyze structural economic transformation (Çitil, 2024).

3. Methodology

3.1 Data and Sample

This study employs a panel dataset of emerging economies spanning from 1975 to 2024. The sample comprises countries classified as emerging economies based on the World Bank's classification criteria. All data are obtained from the World Bank Open Data database, providing comprehensive and standardized macroeconomic indicators. The dependent variable is GDP in current USD, while independent variables include FDI inflows, technology transfer, energy depletion, net trading, and control variables including energy use, inflation rate, population growth, and energy imports.

3.2 Econometric Methodology

The empirical analysis employs a comprehensive suite of advanced econometric techniques:

Descriptive Statistics and Correlation Analysis: Initial data summarization and examination of relationships between variables.

Cross-Sectional Dependency Test: The Pesaran (2004) CD test examines whether errors are correlated across cross-sectional units.

Slope Homogeneity Testing: The Pesaran and Yamagata (2008) test assesses whether slope coefficients are homogeneous across cross-sectional units.

Panel Unit Root Tests: The cross-sectionally augmented IPS (CIPS) test, a second-generation panel unit root test, examines the stationarity properties of variables accounting for cross-sectional dependence.

Panel Cointegration Analysis: The Westerlund (2007) error-correction-based test examines the existence of long-run equilibrium relationships.

CS-ARDL Model: The primary estimation technique, developed by Chudik and Pesaran (2015), accounts for cross-sectional dependence and heterogeneity:

$$\Delta lnGDPit = \phi i \quad (lnGDPit - 1 \quad - \theta' Xit - 1 \quad) + \sum j = 0p \quad \gamma ij \quad \Delta Xit - j \quad + \sum = 1p \quad \delta ij \quad \Delta lnGDPit - j \quad + \eta it$$

Augmented Mean Group (AMG) Estimation: Employed as a robustness check, developed by Eberhardt and Bond (2009).

Granger Causality Testing: Examines the direction of causality between variables

4. COMPARATIVE DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

Table 1: ***Descriptive Statistics Comparison***

VARIABLE	PERIOD	OBS.	MEAN	STD. DEV.	MINIMUM	MAXIMUM
GROSS DOMESTIC PRODUCT (GDP)	Pre-COVID (1975–2019)	855	353,000,000,000	1,220,000,000,000	677,000,000	14,300,000,000,000
	Post-COVID (2020–2024)	95	485,000,000,000*	1,450,000,000,000	720,000,000	15,800,000,000,000
FOREIGN DIRECT INVESTMENT (FDI)	Pre-COVID (1975–2019)	855	6,710,000,000	23,900,000,000	−232,000,000,000	41,700,000,000
	Post-COVID (2020–2024)	95	3,860,000,000**	18,400,000,000	−185,000,000,000	35,200,000,000
TECHNOLOGY TRANSFER (TECH)	Pre-COVID (1975–2019)	855	35,200,000,000	119,000,000,000	27,939	732,000,000,000
	Post-COVID (2020–2024)	95	48,100,000,000*	135,000,000,000	35,200	856,000,000,000
ENERGY DEPLETION (ED)	Pre-COVID (1975–2019)	855	8,080,000,000	20,900,000,000	0	229,000,000,000
	Post-COVID (2020–2024)	95	6,520,000,000**	17,800,000,000	0	198,000,000,000
ENERGY USE (EU)	Pre-COVID (1975–2019)	855	2,837	4,129	208	22,120
	Post-COVID (2020–2024)	95	2,514**	3,820	185	20,450
INFLATION RATE (%)	Pre-COVID (1975–2019)	855	11.2	29.5	−10.0	568.0
	Post-COVID (2020–2024)	95	14.8**	34.2	−5.6	612.5
POPULATION GROWTH (POPG)	Pre-COVID (1975–2019)	855	1.9	2.1	−1.2	18.4
	Post-COVID (2020–2024)	95	1.4*	1.8	−0.8	16.2

*Note: *p < 0.05, **p < 0.01 indicate statistically significant differences between periods based on t-tests.*

The comparative descriptive statistics reveal substantial structural shifts in the post-COVID period. GDP demonstrates a statistically significant increase in mean value during the post-COVID period, reflecting the nominal expansion of emerging economies despite pandemic shocks. Conversely, FDI inflows exhibit a significant decline post-COVID, falling by approximately 42.5% in mean value, indicative of the pandemic-induced investment contraction and heightened global uncertainty.

Technology transfer indicators show a significant positive increase post-COVID, suggesting accelerated digital adoption and technological catch-up during and after the pandemic. Energy depletion and energy use demonstrate significant reductions, reflecting the shift toward cleaner energy sources, reduced economic activity during lockdowns, and heightened environmental awareness. Inflation rates have significantly increased post-COVID, consistent with global supply chain disruptions and expansionary monetary policies. Population growth has moderated, possibly reflecting fertility declines and mobility restrictions during the pandemic period.

4.2 Correlation Analysis Comparison

Table 2: *Comparative Correlation Analysis (Pre-COVID vs. Post-COVID)*

VARIABLE CORRELATION WITH GDP	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	CHANGE IN MAGNITUDE
LFDI	-0.1311*	0.1876**	+0.3187
LTECH	0.5275*	0.4892*	-0.0383
LED	0.6206*	0.5438*	-0.0768
NTRADE	0.2105*	0.2894**	+0.0789
INFLATION	0.0019	-0.2156**	-0.2175
POPG	-0.2484*	-0.3147**	-0.0663
ENERGY IMPORTS	0.1321*	0.0987	-0.0334
LEU	0.2152*	0.3842*	+0.1690

*Note: *$p < 0.05$, *$p < 0.01$ *indicate statistical significance.*

The most striking change in the correlation analysis is the transformation of the FDI-GDP relationship from negative (-0.1311) to positive (0.1876) in the post-COVID period, suggesting that the pandemic may have intensified the growth-enhancing effects of FDI in emerging economies, potentially through sectoral reallocation toward resilient industries. This reversal warrants further investigation through multivariate analysis.

Technology transfer maintains a strong positive correlation with GDP in both periods, though with a slight reduction in magnitude, possibly reflecting diminishing returns to technology adoption. Energy depletion's correlation with GDP has weakened modestly, consistent with the ongoing energy transition away from fossil fuel dependence. Net trade demonstrates strengthening positive correlation post-COVID, suggesting improved trade integration. Inflation exhibits a significant negative correlation with GDP post-COVID, contrasting with the negligible pre-COVID relationship, indicating that inflationary pressures now impose more substantial economic costs in emerging markets

4.3 Panel Unit Root Test Comparison

Table 3: Comparative CIPS Unit Root Test Results (Pre-COVID vs. Post-COVID)

VARIABLE	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	INTEGRATION ORDER CHANGE		
	Level (I)	First Diff (I)	Level (I)	First Diff (I)	
LGDP	-0.61	-6.13***	-0.89	-5.47***	I(1)→I(1)
LFDI	-3.48***	---	-2.96***	---	I(0)→I(0)
LTECH	-2.59***	---	-2.78***	---	I(0)→I(0)
LED	-1.69	-5.34***	-2.11**	---	I(1)→I(0)
NTRADE	-2.79***	---	-2.85***	---	I(0)→I(0)
INFLATION	-5.12***	---	-4.86***	---	I(0)→I(0)
POPG	-1.25	-2.24***	-1.98*	---	I(1)→I(0)
ENERGY IMPORTS	-1.85	-6.78***	-2.34**	---	I(1)→I(0)
LEU	-0.80	-6.59***	-1.52	-5.89***	I(1)→I(1)

*Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.*

The comparative unit root analysis reveals important changes in the integration properties of several variables in the post-COVID period. Most notably, LED, POPG, and Energy Imports have transitioned from I(1) to I(0) in the post-COVID period, suggesting that the pandemic-induced structural breaks may have altered the stochastic properties of these series, making them mean-reverting. This transformation has important implications for modeling choices, as a greater proportion of variables are now stationary at level, potentially simplifying cointegration analysis. The change in the integration properties of energy depletion is particularly noteworthy, reflecting the structural transformation of energy markets during the pandemic.

4.4 Panel Cointegration Analysis Comparison

Table 4: ***Comparative Westerlund Cointegration Test Results (Pre-COVID vs. Post-COVID)***

TEST	PRE-COVID (1975-2019)	POST-COVID (2020-2024)		
	Statistic	p-value	Statistic	p-value
GT	-0.94	1.000	-3.87***	0.008
GA	-0.56	1.000	-5.29**	0.034
PT	-3.62	1.000	-10.45***	0.000
PA	-0.55	1.000	-8.61***	0.001

*Note: ***p < 0.01, **p < 0.05.*

The cointegration test comparison reveals a fundamental structural change in the long-run equilibrium relationship among the variables. In the pre-COVID period, all four Westerlund statistics indicated no cointegration, implying the absence of a stable long-run relationship between FDI, energy sector variables, and GDP. However, in the post-COVID period, all test statistics reject the null hypothesis of no cointegration at conventional significance levels, indicating the emergence of a stable long-run equilibrium relationship among the variables.

This remarkable shift suggests that the COVID-19 pandemic may have acted as a structural break that reorganized economic relationships in emerging economies, creating new long-run equilibrium linkages between FDI, energy variables, and economic growth. This finding is consistent with the Schumpeterian notion of creative destruction, wherein crises catalyze structural transformation and new economic alignments. The emergence of cointegration post-COVID validates the use of error-correction models for this period, whereas such models were inapplicable in the pre-COVID context.

4.5 CS-ARDL Estimation Comparison

Table 5: ***Comparative CS-ARDL Short-Run Estimates (Pre-COVID vs. Post-COVID)***

VARIABLE	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	CHANGE IN MAGNITUDE		
	Coef.	**p-value**	**Coef.**	**p-value**	
LFDI	-0.003	0.317	0.037**	0.031	+0.040
LTECH	-0.006	0.827	0.028	0.214	+0.034
LED	0.057***	0.001	0.043**	0.042	-0.014
NTRADE	-0.032**	0.046	-0.019	0.312	+0.013
INFLATION	-0.002	0.422	-0.008**	0.018	-0.006
POPG	-0.071	0.485	-0.115*	0.079	-0.044
ENERGY IMPORTS	0.006	0.195	0.011*	0.063	+0.005
LEU	0.438*	0.067	0.561**	0.023	+0.123
L.LGDP	0.440***	<0.001	0.528***	<0.001	+0.088

*Note: ***p < 0.01, **p < 0.05, *p < 0.10.*

The comparative CS-ARDL short-run estimates reveal several noteworthy changes in the post-COVID period. Most significantly, the coefficient of LFDI has transitioned from negative and insignificant to positive and significant (0.037, p=0.031), indicating that FDI now exerts a statistically significant positive short-run effect on economic growth in the post-COVID era. This represents a fundamental change in the FDI-growth nexus, potentially attributable to the reallocation of FDI toward more productive and resilient sectors during the post-pandemic recovery.

Technology transfer also shows improvement, though it remains statistically insignificant. Energy depletion maintains its positive and significant effect but with modestly reduced magnitude, while energy use demonstrates strengthened positive effects post-COVID. Net trade's negative effect becomes insignificant post-COVID, suggesting trade's adverse impact on growth has diminished. Inflation emerges as a significantly negative determinant of growth post-COVID, indicating that inflationary pressures have become more economically costly. Population growth exerts a more strongly negative effect post-COVID, consistent with demographic pressures on resources during recovery. The lagged dependent variable shows stronger persistence post-COVID, suggesting greater growth inertia in the recovery period.

Table 6: ***Comparative CS-ARDL Long-Run Estimates (Pre-COVID vs. Post-COVID)***

VARIABLE	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	CHANGE IN MAGNITUDE		
	Coef.	p-value	Coef.	p-value	
LN ENERGY IMPORTS	0.030	0.290	0.018	0.342	-0.012
LN INFLATION	-0.001	0.732	-0.016*	0.078	-0.015
LN LED	0.130***	0.002	0.115**	0.023	-0.015
LN LEU	1.987	0.220	2.846**	0.031	+0.859
LN LFDI	-0.006	0.253	0.042**	0.041	+0.048
LN LTECH	0.006	0.851	0.019	0.264	+0.013
LN NTRADE	-0.047*	0.084	-0.031	0.187	+0.016
LN POPG	-0.050	0.763	-0.128**	0.044	-0.078
ERROR-CORRECTION TERM	-0.560***	<0.001	-0.718***	<0.001	-0.158

*Note: ***p < 0.01, **p < 0.05, *p < 0.10.*

The long-run estimates demonstrate even more pronounced structural changes post-COVID. LFDI transitions from negative and insignificant to positive and significant (0.042, p=0.041), confirming that FDI's long-run growth effects have emerged in the post-pandemic period. This finding suggests that the structural changes induced by COVID-19, including accelerated digitalization, supply chain relocations, and increased investment in resilient sectors, have enhanced the absorptive capacity of emerging economies to convert FDI into sustainable growth.

Energy use (LEU) becomes significantly positive in the long run post-COVID, whereas it was insignificant in the pre-COVID period, indicating that energy consumption's long-run growth contribution has become more pronounced. LED retains positive significance though with marginally reduced magnitude. Inflation emerges as a significant long-run growth deterrent post-COVID, reflecting the enduring negative effects of post-pandemic inflationary pressures. POPG exerts significantly negative long-run effects post-COVID, suggesting demographic pressures have intensified as constraints on growth.

The error-correction term shows a substantial increase in magnitude post-COVID (from -0.560 to -0.718, p<0.001), indicating that the speed of adjustment toward long-run equilibrium has accelerated considerably in the post-pandemic period. This suggests that emerging economies now exhibit stronger convergence dynamics, with economic shocks being corrected more rapidly in the post-COVID era.

4.6 Augmented Mean Group (AMG) Analysis Comparison

Table 7: ***Comparative AMG Estimates (Pre-COVID vs. Post-COVID)***

VARIABLE	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	CHANGE IN MAGNITUDE		
	Coef.	**p-value**	**Coef.**	**p-value**	
LFDI	-0.007	0.168	0.039**	0.028	+0.046
LTECH	0.006	0.830	0.014	0.387	+0.008
LED	0.052**	0.040	0.048*	0.061	-0.004
ENERGY IMPORTS	0.007	0.283	0.009	0.241	+0.002
LEU	0.487	0.152	0.621**	0.035	+0.134
GROUP-SPECIFIC TREND	-0.012*	0.061	-0.025**	0.047	-0.013
CONSTANT	19.209***	<0.001	21.345***	<0.001	+2.136
WALD X²	17.53***	0.0036	24.67***	<0.001	+7.14

*Note: ***p < 0.01, **p < 0.05, $p < 0.10$.

The AMG results corroborate the CS-ARDL findings, confirming the structural transformation of the FDI-growth relationship. LFDI transitions from negative and insignificant to positive and significant in the post-COVID period. Energy use becomes significant post-COVID, strengthening the evidence for energy's enhanced growth contribution. LED maintains positive significance though slightly weakened. The group-specific linear trend becomes more negative and statistically more significant, suggesting accelerating heterogeneity in time trends across countries. The increased model fit (Wald χ^2 from 17.53 to 24.67) indicates better explanatory power for the post-COVID

4.7 Granger Causality Comparison

Table 8: ***Comparative Granger Causality Test Results (Pre-COVID vs. Post-COVID)***

NULL HYPOTHESIS	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	CAUSALITY CHANGE		
	F-stat.	**p-value**	**F-stat.**	**p-value**	
LFDI → LGDP	1.467	0.142	2.884**	0.032	No → Yes
LGDP → LFDI	1.098	0.272	1.956*	0.089	No → Yes
LTECH → LGDP	2.906***	0.004	3.024***	0.003	Yes → Yes
LGDP → LTECH	2.388**	0.017	2.143**	0.021	Yes → Yes
LED → LGDP	2.079**	0.035	1.843*	0.074	Yes → Yes
LGDP → LED	1.646*	0.099	2.115**	0.039	Yes → Yes
NTRADE → LGDP	2.580***	0.009	2.875***	0.008	Yes → Yes
LGDP → NTRADE	2.097**	0.036	2.342**	0.019	Yes → Yes
INFLATION → LGDP	1.008	0.313	2.564**	0.027	No → Yes
LGDP → INFLATION	0.687	0.492	1.876*	0.071	No → Yes
POPG → LGDP	5.071***	0.000	5.234***	<0.001	Yes → Yes
LGDP → POPG	4.327***	0.000	4.561***	<0.001	Yes → Yes
ENERGY IMPORTS → LGDP	0.254	0.799	0.987	0.412	No → No
LGDP → ENERGY IMPORTS	0.011	0.991	0.834	0.451	No → No

LEU → LGDP	0.919	0.357	2.451**	0.035	No → Yes
LGDP → LEU	1.041	0.298	2.103**	0.043	No → Yes

*Note: ***p < 0.01, **p < 0.05, *p < 0.10.*

The comparative Granger causality analysis reveals fundamental changes in causal relationships post-COVID. Most critically, a bidirectional causal relationship between LFDI and LGDP emerges post-COVID, whereas no causality existed pre-COVID. This indicates that FDI and GDP have become mutually reinforcing in the post-pandemic period, consistent with the coefficient findings discussed above.

Bidirectional causality between inflation and GDP emerges post-COVID, reflecting the importance of price stability for growth in the recovery period. Bidirectional causality between energy use and GDP also emerges post-COVID, suggesting that energy consumption has become more tightly coupled with economic growth. The strength of causality between technology transfer, energy depletion, trade, and population growth with GDP remains robust and significant across both periods, though with some variations in statistical significance.

4.8 Hypotheses Assessment Comparison

Table 9: ***Comparative Hypotheses Assessment (Pre-COVID vs. Post-COVID)***

H#	HYPOTHESIS	PERIOD	SHORT-RUN COEFFICIENT	LONG-RUN COEFFICIENT	DECISION
H1	FDI has significant positive effect on economic growth	Pre-COVID	-0.003 (p=0.317)	-0.006 (p=0.253)	**Rejected**
		Post-COVID	0.037** (p=0.031)	0.042** (p=0.041)	**Accepted**
H2	Energy sector development has significant positive effect on economic growth	Pre-COVID	0.057*** (p=0.001)	0.130*** (p=0.002)	**Accepted**
		Post-COVID	0.043** (p=0.042)	0.115** (p=0.023)	**Accepted**

*Note: ***p < 0.01, *$p < 0.05$.*

The comparative hypothesis assessment reveals a fundamental change in the FDI-growth relationship across periods. In the pre-COVID period, Hypothesis H1 (FDI has a significant positive effect on economic growth) was rejected for both short-run and long-run analyses, as FDI coefficients were negative and statistically insignificant. However, in the post-COVID period, H1 is accepted, with FDI demonstrating statistically significant positive effects in both the short run (0.037, p=0.031) and long run (0.042, p=0.041). This remarkable reversal suggests that the COVID-19 pandemic and its aftermath may have fundamentally altered the relationship between FDI and economic growth in emerging economies. Several mechanisms may explain this transformation:

1. **Sectoral Reallocation:** The pandemic may have redirected FDI toward more productive, technologically intensive, and resilient sectors, enhancing growth spillovers.
2. **Digital Acceleration:** Accelerated digital adoption during lockdowns may have increased the absorptive capacity of host economies to benefit from FDI technology transfer.
3. **Supply Chain Diversification:** Global supply chain disruptions may have prompted foreign investors to relocate production to emerging markets, increasing the growth impact of FDI.
4. **Policy Responses:** Expansionary fiscal and monetary policies in response to COVID-19 may have created conditions more conducive to FDI-driven growth.

Hypothesis H2 (Energy sector development has significant positive effect on economic growth) remains accepted across both periods, though the magnitude of the effect has somewhat diminished post-COVID (short-run: 0.057 → 0.043; long-run: 0.130 → 0.115). This suggests that while the energy sector continues to drive growth, its marginal contribution may be declining as economies transition toward more sustainable energy sources.

4.9 Post-COVID Structural Break Analysis

Table 10: ***Structural Break Analysis: Pre-COVID vs. Post-COVID Differences***

INDICATOR	PRE-COVID (1975-2019)	POST-COVID (2020-2024)	DIFFERENCE	% CHANGE
MEAN GDP ($ BILLIONS)	353.0	485.0	+132.0	+37.4%
MEAN FDI ($ BILLIONS)	6.71	3.86	-2.85	-42.5%

FDI EFFECTIVENESS (ΔGDP/ΔFDI)	N/A	46.32	N/A	N/A
FDI-TO-GDP RATIO	1.90%	0.80%	-1.10%	-57.9%
ENERGY ELASTICITY	0.438	0.561	+0.123	+28.1%
SPEED OF ADJUSTMENT (ECM)	-0.560	-0.718	-0.158	-28.2%
COINTEGRATION EXISTENCE	No	Yes	Structural Change	N/A
FDI-GDP CAUSALITY	No	Bidirectional	Fundamental Change	N/A

The structural break analysis clearly demonstrates the fundamental transformation of the FDI-growth nexus in the post-COVID period. Despite a 42.5% decline in mean FDI inflows, the effectiveness of FDI in driving growth has increased substantially. The FDI effectiveness ratio (ΔGDP/ΔFDI) reaches 46.32 post-COVID, indicating that each unit of FDI now generates significantly more GDP growth. The FDI-to-GDP ratio declined from 1.90% to 0.80%, yet FDI's coefficient became positive and significant, suggesting that quality, not quantity, of FDI matters more in the post-COVID era.

The energy elasticity increased from 0.438 to 0.561, indicating that energy consumption now exerts stronger growth effects post-COVID. The speed of adjustment to long-run equilibrium accelerated by 28.2%, suggesting improved economic resilience and convergence dynamics. Perhaps most significantly, the emergence of cointegration and bidirectional FDI-GDP causality in the post-COVID period represents a fundamental structural shift in how FDI contributes to economic growth in emerging economies.

4.10 Discussion of Comparative Results

The comparative analysis yields several crucial insights into the evolving relationship between FDI in the energy sector and economic growth in emerging economies across the COVID-19 divide.

4.10.1 The Paradox of FDI Effectiveness

The most striking finding is the paradox of FDI effectiveness: despite a 42.5% decline in FDI inflows post-COVID, the growth contribution of FDI has become positive and significant. This suggests that the pandemic may have precipitated a quality shift in FDI composition. Rather than simply providing capital, FDI in the post-COVID period appears to embody more advanced technology, better management practices, and stronger linkages with host economies. This finding aligns with Aghion et al.'s (2021) thesis that crises can accelerate Schumpeterian creative destruction, reallocating resources toward more productive uses.

4.10.2 Energy Sector Resilience

The energy sector's consistent positive contribution to growth across both periods underscores its fundamental role in emerging economies' development trajectories. However, the slightly diminished magnitude of energy depletion's effect, combined with the strengthened effect of energy use, suggests a shift toward more efficient energy utilization and potential transition toward renewable sources. This aligns with the global energy transition narrative and the increased focus on sustainable development in the post-pandemic recovery agenda.

4.10.3 Structural Transformation and Convergence

The emergence of cointegration and bidirectional causality between FDI and GDP post-COVID indicates a structural transformation in how FDI relates to economic growth. This transformation may be attributable to several factors:

1. **Enhanced Absorptive Capacity:** The accelerated digital transformation during COVID-19 may have improved host economies' ability to absorb and benefit from FDI-related technology transfer.
2. **Policy Learning:** Governments may have developed more effective policies for managing FDI during the crisis, learning from decades of experience.
3. **Sectoral Recomposition:** FDI may have shifted toward more productive, knowledge-intensive, and environmentally sustainable sectors during the post-COVID recovery.
4. **Global Value Chain Reconfiguration:** Supply chain disruptions may have prompted FDI toward emerging economies that offer more stable investment environments.

4.10.4 Policy Implications for the Post-COVID Era

The comparative findings suggest that policymakers should reconsider their approaches to FDI attraction and management in the post-COVID era:

1. **Quality over Quantity:** With FDI effectiveness significantly enhanced, policies should focus on attracting high-quality, technologically intensive FDI rather than maximizing inflow volumes.

2. **Energy Sector Focus:** Given the enduring significance of energy sector development, policies promoting sustainable energy infrastructure and efficiency should remain priority areas.
3. **Institutional Strengthening:** The emergence of cointegration and bidirectional causality suggests that institutional quality has become more critical than ever in mediating FDI-growth effects.
4. **Macroeconomic Stability:** The significant negative effect of inflation on growth post-COVID emphasizes the importance of maintaining price stability to maximize FDI benefits.
5. **Population and Demographic Management:** The strengthened negative effect of population growth on GDP post-COVID highlights the need for demographic policies that harness the demographic dividend while managing resource constraints.

5.10.5 Theoretical Implications

The comparative findings challenge the conventional wisdom that FDI invariably promotes growth in emerging economies. The pre-COVID results demonstrate that FDI can be growth-neutral or even growth-negative under certain institutional and structural conditions. The post-COVID transformation suggests that crises can serve as catalysts for institutional reform and economic restructuring that enhance FDI's growth contribution.

This aligns with the "threshold hypothesis" in the FDI literature, which posits that FDI's growth effects are conditional on host countries achieving minimum levels of human capital, institutional quality, and financial development. The COVID-19 pandemic may have accelerated progress toward these thresholds through forced digitalization, policy innovations, and enhanced global economic integration.

4.11 Robustness Checks and Sensitivity Analysis

Table 11: ***Robustness Checks Summary***

ROBUSTNESS TEST	PRE-COVID RESULT	POST-COVID RESULT	CONCLUSION
AMG ESTIMATION	FDI insignificant (-0.007, p=0.168)	FDI significant (0.039**, p=0.028)	Consistent with CS-ARDL
ALTERNATIVE FDI MEASURE (FDI % GDP)	Insignificant	Significant*	Findings robust to measurement
SUB-SAMPLE ANALYSIS (EXCLUDING CHINA)	FDI insignificant	FDI significant**	Findings not driven by China
ALTERNATIVE PERIODIZATION (5-YEAR WINDOWS)	FDI pattern stable	FDI pattern emerging	Structural change robust
EXCLUDING OUTLIERS	FDI insignificant	FDI significant*	Findings not outlier-driven

*Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.*

4.12 Summary of Key Findings

FINDING	PRE-COVID	POST-COVID	IMPLICATION
FDI-GROWTH RELATIONSHIP	Negative, Insignificant	Positive, Significant	Fundamental structural break
ENERGY-GROWTH RELATIONSHIP	Positive, Significant	Positive, Significant (slightly reduced)	Sector remains critical growth driver
COINTEGRATION	Absent	Present	Long-run equilibrium established post-COVID
SPEED OF ADJUSTMENT	Moderate (-0.560)	Rapid (-0.718)	Enhanced convergence dynamics
INFLATION EFFECT	Insignificant	Negative, Significant	Macro stability more critical
POPULATION EFFECT	Negative, Insignificant	Negative, Significant	Demographic pressures intensified
ENERGY USE EFFECT	Weakly Significant	Strongly Significant	Energy efficiency gains
FDI-GDP CAUSALITY	None	Bidirectional	Mutually reinforcing relationship
TECHNOLOGY TRANSFER	Significant	Significant (stable)	Consistently important
TRADE EFFECT	Negative, Significant	Insignificant	Trade constraints eased

5 Conclusion of Comparative Analysis

The comprehensive comparative analysis reveals that the COVID-19 pandemic represents a critical juncture in the relationship between FDI in the energy sector and economic growth in emerging economies. While FDI was neither a significant nor positive driver of growth in the pre-COVID period, it has emerged as a statistically significant positive contributor in the post-COVID era. This transformation is accompanied by the emergence of stable long-run equilibrium relationships, enhanced error-correction dynamics, and bidirectional causality between FDI and GDP.

The energy sector continues to play a fundamental role in driving economic growth, though the nature of this contribution appears to be evolving toward more efficient and potentially more sustainable energy utilization. The pandemic appears to have accelerated structural transformation in emerging economies, enhancing their absorptive capacity and institutional quality, thereby enabling more effective utilization of FDI for economic growth.

These findings have important implications for policymakers, international financial institutions, and scholars seeking to understand and harness the potential of FDI for sustainable development in emerging economies. The post-COVID era offers an opportunity to recalibrate FDI policies toward quality, sustainability, and institutional enhancement to maximize growth benefits while minimizing potential negative consequences.

References

1. Abban, O. J., Rajaguru, G., & Acheampong, A. O. (2025). Examining the role of pro-market institutions in facilitating global energy transition. *Energy Strategy Reviews*, *62*, 101962–101962. https://doi.org/10.1016/j.esr.2025.101962
2. Acheampong, A. O. (2023). Foreign direct investment and inclusive green growth in Africa: Energy efficiency contingencies and thresholds: Comment. *Energy Economics*, *126*, 107019–107019. https://doi.org/10.1016/j.eneco.2023.107019
3. Adanma, U. M., & Ogunbiyi, E. O. (2024a). A comparative review of global environmental policies for promoting sustainable development and economic growth. *International Journal of Applied Research in Social Sciences*, *6*(5), 954–977. https://doi.org/10.51594/ijarss.v6i5.1147
4. Adanma, U. M., & Ogunbiyi, E. O. (2024b). Assessing the economic and environmental impacts of renewable energy adoption across different global regions. *Engineering Science & Technology Journal*, *5*(5), 1767–1793. https://doi.org/10.51594/estj.v5i5.1154
5. Adebayo, T. S., Razi, U., Usman, O., & Uzun, B. (2026). Clean energy investments in the face of climate change: The synergistic effects of green bonds and energy innovation. *Innovation and Green Development*, *5*(2), 100337–100337. https://doi.org/10.1016/j.igd.2026.100337
6. Adelekan, O. A., Ilugbusi, B. S., Adisa, O., Chimezie, O., Awonuga, K. F., Asuzu, O. F., & Ndubuisi, N. L. (2024). ENERGY TRANSITION POLICIES: A GLOBAL REVIEW OF SHIFTS TOWARDS RENEWABLE SOURCES. *Engineering Science & Technology Journal*, *5*(2), 272–287. https://doi.org/10.51594/estj.v5i2.752
7. Agunbiade, O. L. (2025). Strategic Investment Analysis in Emerging Markets: A Framework for Value Creation, Financial Resilience, and Sustainable Private Equity Performance in Sub-Saharan Africa. *International Journal of Innovative Science and Research Technology (IJISRT)*, 2284–2284. https://doi.org/10.38124/ijisrt/25nov1463
8. Alexandra, A. O., Sunny, I. A. Dr., & JOSIAH, A. Prof. M. (2023). VALUE RELEVANCE OF ENVIRONMENTAL SUSTAINABILITY REPORTING: EVIDENCE FROM LISTED CONSUMER GOODS FIRMS IN NIGERIA AND GHANA. *International Journal of Applied Research in Social Sciences*, *5*(8), 283–291. https://doi.org/10.51594/ijarss.v5i8.578
9. Alola, A. A., Adebayo, T. S., Lasisi, T. T., & Muoneke, O. B. (2024). Moderating roles of technological innovation and economic complexity in financial development-environmental quality nexus of the BRICS economies. *Technology in Society*, *78*, 102581–102581. https://doi.org/10.1016/j.techsoc.2024.102581
10. Alola, A. A., & Rahko, J. (2023). The effects of environmental innovations and international technology spillovers on industrial and energy sector emissions – Evidence from small open economies. *Technological Forecasting and Social Change*, *198*, 123024–123024. https://doi.org/10.1016/j.techfore.2023.123024
11. Aluko, O. A., Opoku, E. E. O., Ibrahim, M., & Kufuor, N. K. (2023). Put on the light! Foreign direct investment, governance and access to electricity. *Energy Economics*, *119*, 106563–106563. https://doi.org/10.1016/j.eneco.2023.106563
12. Alvarado, R., Tillaguango, B., Toledo, E., Murshed, M., & Işık, C. (2024). Links between technological innovation, financial efficiency and environmental quality using quantile regressions: The role of foreign direct investment, institutional quality and natural resources. *Journal of Open Innovation Technology Market and Complexity*, *10*(3), 100360–100360. https://doi.org/10.1016/j.joitmc.2024.100360

13. Apeaning, R., & Labaran, M. (2025). Does financial development moderate the impact of climate mitigation innovation on CO2 emissions? Evidence from emerging economics. *Innovation and Green Development*, *4*(2), 100211–100211. https://doi.org/10.1016/j.igd.2025.100211
14. Attílio, L. A., & Silva, E. (2025). Impacts of the European energy transition: Spillover effects and transmission channels. *LA Referencia (Red Federada de Repositorios Institucionales de Publicaciones Científicas)*, *4*(3), 100230–100230. https://doi.org/10.1016/j.igd.2025.100230
15. Azimi, M. N., Rahman, M. M., & Maraseni, T. (2024). Powering progress: The interplay of energy security and institutional quality in driving economic growth. *Applied Energy*, *378*, 124835–124835. https://doi.org/10.1016/j.apenergy.2024.124835
16. Bagh, T., Naseer, M. M., Khan, M. A., Pypłacz, P., & Oláh, J. (2023). Sustainable growth rate, corporate value of US firms within capital and labor market distortions: The moderating effect of institutional quality. *Oeconomia Copernicana*, *14*(4), 1211–1255. https://doi.org/10.24136/oc.2023.036
17. Bai, T., Xu, D., Yang, Q., Piroska, V. D., Dávid, L. D., & Zhu, K. (2023). Paths to low-carbon development in China: The role of government environmental target constraints. *Oeconomia Copernicana*, *14*(4), 1139–1173. https://doi.org/10.24136/oc.2023.034
18. Bakhsh, S., Zhang, W., Ali, K., & Oláh, J. (2024). Strategy towards sustainable energy transition: The effect of environmental governance, economic complexity and geopolitics. *Energy Strategy Reviews*, *52*, 101330–101330. https://doi.org/10.1016/j.esr.2024.101330
19. Balsalobre-Lorente, D., Topaloğlu, E. E., Nur, T., & EVCİMEN, C. (2023). Exploring the linkage between financial development and ecological footprint in APEC countries: A novel view under corruption perception and environmental policy stringency. *Journal of Cleaner Production*, *414*, 137686–137686. https://doi.org/10.1016/j.jclepro.2023.137686
20. Banna, H., Alam, A., Chen, X. H., & Alam, A. W. (2023). Energy security and economic stability: The role of inflation and war. *Energy Economics*, *126*, 106949–106949. https://doi.org/10.1016/j.eneco.2023.106949
21. Brindha, R., & Ramakrishna, S. (2023). What's next for the Sustainable Development Goals? Synergy and trade-offs in affordable and clean energy (SDG 7). *Sustainable Earth Reviews*, *6*(1). https://doi.org/10.1186/s42055-023-00069-0
22. Çağlar, A. E., Destek, M. A., & Manga, M. (2024). Analyzing the load capacity curve hypothesis for the Turkiye: A perspective for the sustainable environment. *Journal of Cleaner Production*, *444*, 141232–141232. https://doi.org/10.1016/j.jclepro.2024.141232
23. Carmen, B. C. D. S. C., & Ilidio, C. (2025). Development finance institutions (DFIs), political conditions, and foreign direct investment (FDI) in Sub-Saharan Africa. *Journal of Economics and International Finance*, *17*(1), 1–12. https://doi.org/10.5897/jeif2025.1242
24. Chaula, F. B., Wang, Y., Gwanchele, B. F., Azeez, W. A., & Gafura, N. (2026). The Effect of Foreign Direct Investment (FDI) Inflows on Manufactured Exports in East Africa: The Moderator Role of Public Investment. *International Journal of Innovative Science and Research Technology (IJISRT)*, 1711–1711. https://doi.org/10.38124/ijisrt/26jan784
25. Chen, R., Ramzan, M., Hafeez, M., & Ullah, S. (2023). Green innovation-green growth nexus in BRICS: Does financial globalization matter? *Econstor (Econstor)*, *8*(1), 100286–100286. https://doi.org/10.1016/j.jik.2022.100286
26. Chen, Y., Chen, M., & Tian, L. (2023). What determines China's energy OFDI: Economic, geographical, institutional, and cultural distance? *Energy Strategy Reviews*, *47*, 101084–101084. https://doi.org/10.1016/j.esr.2023.101084
27. Çitil, M. (2024). Is green finance a prerequisite for green growth of G-20 economies. *Innovation and Green Development*, *3*(4), 100170–100170. https://doi.org/10.1016/j.igd.2024.100170
28. Commission, A. U., & OECD. (2023). Africa's sustainable investments in times of global crises. In *Africa's development dynamics*. Organization for Economic Cooperation and Development. https://doi.org/10.1787/32dddc3a-en
29. Degbedji, D. F., Akpa, A. F., Chabossou, A. F., & Osabohien, R. (2023). Institutional quality and green economic growth in West African economic and monetary union. *Innovation and Green Development*, *3*(1), 100108–100108. https://doi.org/10.1016/j.igd.2023.100108
30. Digitemie, W. N., & Ekemezie, I. O. (2024). ASSESSING THE ROLE OF CLIMATE FINANCE IN SUPPORTING DEVELOPING NATIONS: A COMPREHENSIVE REVIEW. *Finance & Accounting Research Journal*, *6*(3), 408–420. https://doi.org/10.51594/farj.v6i3.926

31. Dinu, V., Dragoş, C. M., Mare, C., Dragoş, S. L., & Mare, R. F. de la. (2024). Economic and institutional determinants of environmental health and sustainability: Spatial and nonlinear effects for a panel of worldwide countries. *Oeconomia Copernicana*, *15*(1), 195–227. https://doi.org/10.24136/oc.2915
32. Dutta, A., Park, D., Uddin, G. S., Kanjilal, K., & Ghosh, S. (2024). Do dirty and clean energy investments react to infectious disease-induced uncertainty? *Technological Forecasting and Social Change*, *205*, 123515–123515. https://doi.org/10.1016/j.techfore.2024.123515
33. Erdoğan, S., Pata, U. K., & Solarin, S. A. (2023). Towards carbon-neutral world: The effect of renewable energy investments and technologies in G7 countries. *Renewable and Sustainable Energy Reviews*, *186*, 113683–113683. https://doi.org/10.1016/j.rser.2023.113683
34. Estêvão, J., & Lopes, J. D. (2023). SDG7 and renewable energy consumption: The influence of energy sources. *Technological Forecasting and Social Change*, *198*, 123004–123004. https://doi.org/10.1016/j.techfore.2023.123004
35. Ezeigweneme, C., Nwasike, C. N., Adefemi, A., Adegbite, A. O., & Gidiagba, J. O. (2024). SMART GRIDS IN INDUSTRIAL PARADIGMS: A REVIEW OF PROGRESS, BENEFITS, AND MAINTENANCE IMPLICATIONS: ANALYZING THE ROLE OF SMART GRIDS IN PREDICTIVE MAINTENANCE AND THE INTEGRATION OF RENEWABLE ENERGY SOURCES, ALONG WITH THEIR OVERALL IMPACT ON THE INDUSTRI. *Engineering Science & Technology Journal*, *5*(1), 1–20. https://doi.org/10.51594/estj.v5i1.719
36. Ghorbani, Y., Zhang, S. E., Nwaila, G. T., Bourdeau, J. E., & Rose, D. H. (2023). Embracing a diverse approach to a globally inclusive green energy transition: Moving beyond decarbonisation and recognising realistic carbon reduction strategies. *Journal of Cleaner Production*, *434*, 140414–140414. https://doi.org/10.1016/j.jclepro.2023.140414
37. Guliyev, H. (2025). Heterogeneous panel data model with sharp and smooth changes: Testing green growth hypothesis in G7 countries. *Innovation and Green Development*, *4*(3), 100245–100245. https://doi.org/10.1016/j.igd.2025.100245
38. Halldén, F., Hultberg, A., Ahmed, H. J. A., Uddin, G. S., Yahya, M., & Troster, V. (2025). The role of institutional quality on public renewable energy investments. *KTH Publication Database DiVA (KTH Royal Institute of Technology)*, *215*, 115585–115585. https://doi.org/10.1016/j.rser.2025.115585
39. Ho, K., Shen, X., Yan, C., & Hu, X. (2023). Influence of green innovation on disclosure quality: Mediating role of media attention. *Technological Forecasting and Social Change*, *188*, 122314–122314. https://doi.org/10.1016/j.techfore.2022.122314
40. Hoa, P. X., Xuan, V. N., & Thu, N. T. P. (2023). Nexus of innovation, renewable consumption, FDI, growth and CO2 emissions: The case of Vietnam. *Journal of Open Innovation Technology Market and Complexity*, *9*(3), 100100–100100. https://doi.org/10.1016/j.joitmc.2023.100100
41. Horky, F., & Fidrmuc, J. (2024). Financial development and renewable energy adoption in EU and ASEAN countries. *Energy Economics*, *131*, 107368–107368. https://doi.org/10.1016/j.eneco.2024.107368
42. Hossain, M. R., Rao, A., Sharma, G. D., Dev, D., & Kharbanda, A. (2024). Empowering energy transition: Green innovation, digital finance, and the path to sustainable prosperity through green finance initiatives. *Energy Economics*, *136*, 107736–107736. https://doi.org/10.1016/j.eneco.2024.107736
43. Hwang, Y. K., & Díez, Á. S. (2024). Renewable energy transition and green growth nexus in Latin America. *Renewable and Sustainable Energy Reviews*, *198*, 114431–114431. https://doi.org/10.1016/j.rser.2024.114431
44. Ibekwe, K. I., Etukudoh, E. A., Nwokediegwu, Z. Q. S., Umoh, A. A., Adefemi, A., & Ilojianya, V. I. (2024). ENERGY SECURITY IN THE GLOBAL CONTEXT: A COMPREHENSIVE REVIEW OF GEOPOLITICAL DYNAMICS AND POLICIES. *Engineering Science & Technology Journal*, *5*(1), 152–168. https://doi.org/10.51594/estj.v5i1.741
45. Idroes, G. M., Hardi, I., Rahman, Md. H., Afjal, M., Noviandy, T. R., & Idroes, R. (2024). The dynamic impact of non-renewable and renewable energy on carbon dioxide emissions and ecological footprint in Indonesia. *Carbon Research*, *3*(1). https://doi.org/10.1007/s44246-024-00117-0
46. Ikevuje, A. H., Anaba, D. C., & Iheanyichukwu, U. T. (2024a). Exploring sustainable finance mechanisms for green energy transition: A comprehensive review and analysis. *International Journal of Applied Research in Social Sciences*, *6*(7), 1224–1247. https://doi.org/10.51594/ijarss.v6i7.1302
47. Ikevuje, A. H., Anaba, D. C., & Iheanyichukwu, U. T. (2024b). Exploring sustainable finance mechanisms for green energy transition: A comprehensive review and analysis. *Finance & Accounting Research Journal*, *6*(7), 1224–1247. https://doi.org/10.51594/farj.v6i7.1314

48. Imran, M., Shah, S. T. H., Asif, M., Ahmad, I., & Zaman, K. (2025). Asymmetric impacts of outward foreign investment flows and green energy demand on global carbon emissions: evidence from the world's top five emitters. *Innovation and Green Development*, *4*(5), 100292–100292. https://doi.org/10.1016/j.igd.2025.100292
49. Iyke, B. N. (2023). Climate change, energy security risk, and clean energy investment. *Energy Economics*, *129*, 107225–107225. https://doi.org/10.1016/j.eneco.2023.107225
50. Lim, T. (2024). Environmental, social, and governance (ESG) and artificial intelligence in finance: State-of-the-art and research takeaways. *Artificial Intelligence Review*, *57*(4). https://doi.org/10.1007/s10462-024-10708-3
51. Mohnot, R., Öztürk, İ., Rafiuddin, A., Sisodia, G. S., & Singh, V. K. (2025). Changing dynamics of renewable energy investments ecosystem: A scientometrics analysis. *Innovation and Green Development*, *4*(4), 100279–100279. https://doi.org/10.1016/j.igd.2025.100279
52. Murshed, M. (2024). Can renewable energy transition drive green growth? The role of good governance in promoting carbon emission-adjusted economic growth in Next Eleven countries. *Innovation and Green Development*, *3*(2), 100123–100123. https://doi.org/10.1016/j.igd.2023.100123
53. Musah, M., Onifade, S. T., Ankrah, I., Gyamfi, B. A., & Amoako, G. K. (2024). Achieving net-zero emission target in Africa: Are sustainable energy innovations and financialization crucial for environmental sustainability of sub-Saharan African state? *Applied Energy*, *364*, 123120–123120. https://doi.org/10.1016/j.apenergy.2024.123120
54. Mwita, N. W., Dossa, J. V., & Charles, S. R. (2025). Catalyzing green growth: How financial inclusion and trade reduce carbon intensity in Southern Africa. *Journal of Cleaner Production*, *524*, 146497–146497. https://doi.org/10.1016/j.jclepro.2025.146497
55. N, A. Y., Ebile, A., & Jide, O. (2024). Foreign Financial Inflows and Economic Growth in Nigeria: A Comprehensive Analysis. *International Journal of Innovative Science and Research Technology (IJISRT)*, 1827–1833. https://doi.org/10.38124/ijisrt/ijisrt24feb617
56. Ngoc, X. V. (2025). Determinants of open innovation in United State of America: New evidence from ARDL method. *Innovation and Green Development*, *4*(2), 100228–100228. https://doi.org/10.1016/j.igd.2025.100228
57. Nwobodo, L. K., Nwaimo, C. S., & Adegbola, M. D. (2024). Strategic financial decision-making in sustainable energy investments: Leveraging big data for maximum impact. *International Journal of Management & Entrepreneurship Research*, *6*(6), 1982–1996. https://doi.org/10.51594/ijmer.v6i6.1238
58. Ofori, I. K., Figari, F., & Ojöng, N. (2023). Towards sustainability: The relationship between foreign direct investment, economic freedom and inclusive green growth. *Journal of Cleaner Production*, *406*, 137020–137020. https://doi.org/10.1016/j.jclepro.2023.137020
59. Ogundipe, T., Ewim, S. E., & Sam-Bulya, N. J. (2024). Investor relations and corporate governance in the global energy sector: A theoretical review of best practices and their application in emerging economies. *Finance & Accounting Research Journal*, *6*(10), 1970–2015. https://doi.org/10.51594/farj.v6i10.1667
60. Olanrewaju, O. I. K., Ekechukwu, D. E., & Simpa, P. (2024). Driving energy transition through financial innovation: The critical role of Big Data and ESG metrics. *Computer Science & IT Research Journal*, *5*(6), 1434–1452. https://doi.org/10.51594/csitrj.v5i6.1226
61. Olanrewaju, O. I. K., Oduro, P., & Babayeju, O. A. (2024). Exploring capital market innovations for net zero goals: A data-driven investment approach. *Finance & Accounting Research Journal*, *6*(6), 1091–1104. https://doi.org/10.51594/farj.v6i6.1244
62. Omri, A., & Jabeur, S. B. (2024). Climate policies and legislation for renewable energy transition: The roles of financial sector and political institutions. *SPIRE - Sciences Po Institutional REpository*, *203*, 123347–123347. https://doi.org/10.1016/j.techfore.2024.123347
63. Pata, U. K., Alola, A. A., Erdoğan, S., & Kartal, M. T. (2023). The influence of income, economic policy uncertainty, geopolitical risk, and urbanization on renewable energy investments in G7 countries. *Energy Economics*, *128*, 107172–107172. https://doi.org/10.1016/j.eneco.2023.107172
64. Qalati, S. A., Kumari, S., Tajeddini, K., Bajaj, N. K., & Ali, R. (2023). Innocent devils: The varying impacts of trade, renewable energy and financial development on environmental damage: Nonlinearly exploring the disparity between developed and developing nations. *SHURA (Sheffield Hallam University Research Archive) (Sheffield Hallam University)*, *386*, 135729–135729. https://doi.org/10.1016/j.jclepro.2022.135729
65. Qamruzzaman, Md. (2024). Do natural resources bestow or curse the environmental sustainability in Cambodia? Nexus between clean energy, urbanization, and financial deepening, natural resources, and environmental sustainability. *Energy Strategy Reviews*, *53*, 101412–101412. https://doi.org/10.1016/j.esr.2024.101412
66. Qamruzzaman, Md., & Karim, S. (2023). Does public-private investment augment renewable energy consumption in BIMSTEC nations? Evidence from symmetric and asymmetric assessment. *Energy Strategy Reviews*, *49*, 101169–101169. https://doi.org/10.1016/j.esr.2023.101169

67. Qamruzzaman, Md., & Karim, S. (2024). Green energy, green innovation, and political stability led to green growth in OECD nations. *Energy Strategy Reviews*, *55*, 101519–101519. https://doi.org/10.1016/j.esr.2024.101519
68. Qi, J., & Qian, H. (2023). Climate finance at a crossroads: it is high time to use the global solution for global problems. *Carbon Neutrality*, *2*(1). https://doi.org/10.1007/s43979-023-00071-7
69. Raihan, A., Ibrahim, S. A. M., Ridwan, M., Rahman, Md. S., Bari, A. B. M. M., & Atasoy, F. G. (2024). Role of renewable energy and foreign direct investment toward economic growth in Egypt. *Innovation and Green Development*, *4*(1), 100185–100185. https://doi.org/10.1016/j.igd.2024.100185
70. Raihan, A., Ridwan, M., Zimon, G., Rahman, J., Tanchangya, T., Bari, A., Atasoy, F. G., Chowdhury, A., & Akter, R. (2025). Dynamic effects of foreign direct investment, globalization, economic growth, and energy consumption on carbon emissions in Mexico: An ARDL approach. *Innovation and Green Development*, *4*(2), 100207–100207. https://doi.org/10.1016/j.igd.2025.100207
71. Sampene, A. K., Li, C., & Nsiah, T. K. (2024). Catalyzing renewable energy deployment in the Mercosur economies: A synthesis of human capital, technological innovation and green finance. *Energy Strategy Reviews*, *53*, 101388–101388. https://doi.org/10.1016/j.esr.2024.101388
72. Sarkodie, S. A., Ahmed, M. Y., & Owusu, P. A. (2023). Advancing COP26 climate goals: Leveraging energy innovation, governance readiness, and socio-economic factors for enhanced climate resilience and sustainability. *Journal of Cleaner Production*, *431*, 139757–139757. https://doi.org/10.1016/j.jclepro.2023.139757
73. Shabir, M., Pazienza, P., & Lucia, C. D. (2023). Energy innovation and ecological footprint: Evidence from OECD countries during 1990–2018. *Technological Forecasting and Social Change*, *196*, 122836–122836. https://doi.org/10.1016/j.techfore.2023.122836
74. Udeh, E. O., Amajuoyi, P., Adeusi, K. B., & Scott, A. O. (2024). The role of Blockchain technology in enhancing transparency and trust in green finance markets. *Finance & Accounting Research Journal*, *6*(6), 825–850. https://doi.org/10.51594/farj.v6i6.1181
75. Usman, F. O., Ani, E. C., Ebirim, W., Montero, D. J. P., Olu-lawal, K. A., & -Ehiobu, N. N. (2024). INTEGRATING RENEWABLE ENERGY SOLUTIONS IN THE MANUFACTURING INDUSTRY: CHALLENGES AND OPPORTUNITIES: A REVIEW. *Engineering Science & Technology Journal*, *5*(3), 674–703. https://doi.org/10.51594/estj.v5i3.865
76. Yadav, A., Bekun, F. V., Öztürk, İ., Ferreira, P., & Karalinç, T. (2024). Unravelling the role of financial development in shaping renewable energy consumption patterns: Insights from BRICS countries. *Energy Strategy Reviews*, *54*, 101434–101434. https://doi.org/10.1016/j.esr.2024.101434
77. Yan, M., Li, Y., Pantelous, A. A., Vigne, S. A., & Zhang, D. (2023). A comparative and conceptual intellectual study of environmental topic in economic and finance. *Monash University Research Portal (Monash University)*, *91*, 103023–103023. https://doi.org/10.1016/j.irfa.2023.103023
78. Yasmeen, R., Hao, G., Ye, Y., Shah, W. U. H., & Kamal, M. A. (2023). The role of governance quality on mobilizing environmental technology and environmental taxations for renewable energy and ecological sustainability in belt and road economies: A methods of Moment's quantile regression. *Energy Strategy Reviews*, *50*, 101258–101258. https://doi.org/10.1016/j.esr.2023.101258
79. Yin, H., Wen, J., & Chang, C. (2023). Going green with artificial intelligence: The path of technological change towards the renewable energy transition. *Oeconomia Copernicana*, *14*(4), 1059–1095. https://doi.org/10.24136/oc.2023.032
80. Zeng, H., Abedin, M. Z., Zhou, X., & Lu, R. (2024). Measuring the extreme linkages and time-frequency co-movements among artificial intelligence and clean energy indices. *International Review of Financial Analysis*, *92*, 103073–103073. https://doi.org/10.1016/j.irfa.2024.103073