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Does Financial Development Shape the Energy–FDI–Growth Nexus? New Evidence from BRICS+ Countries Using Dynamic Panel Estimation

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Abstract

This study investigates how energy consumption and foreign direct investment (FDI) influenced economic growth in BRICS+ countries from 1990 to 2021, using a two-step System GMM estimator to address endogeneity and dynamic effects. While the results show that both energy and FDI positively affected growth, disaggregated analysis revealed that renewable energy promoted growth, whereas non-renewables hindered it. Similarly, FDI directed toward gross fixed capital formation (FDI_GFCF) consistently boosted growth, unlike aggregate FDI. Financial development moderated these effects, amplifying the benefits of energy use but dampening FDI's growth impact in more developed financial systems. The effects of energy and FDI remained stable before and after the Paris Agreement, supporting the robustness of the findings. These results underscore the importance of tailored energy and FDI strategies, financial sector reforms, and supportive policy environments to advance sustainable growth in BRICS+ economies.

Keywords: foreign direct investment; energy consumption; economic growth; BRICS+ economies; financial development; two-step system GMM estimation

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1. Introduction

The recent expansion of the BRICS bloc into BRICS+ marks a pivotal shift in the dynamics of global economic collaboration. The initiative envisions integrating a diverse set of emerging economies and regional blocs, such as CELAC and the African Union, into a unified economic space. This resurgence, particularly under China's 2022 presidency, comes at a time when nearly 20 emerging markets have expressed intent to join, including heavyweights like Saudi Arabia, Egypt, and Iran (Lissovolik & Vinokurov, 2019). As more countries express interest in joining BRICS+, questions arise about how such integration will reshape development trajectories (Arapova & Lissovolik, 2021). As economic growth and development become an ultimate goal, the challenge for emerging economies lies in leveraging productive capital and sustainable energy to accelerate inclusive progress (Oryani et al., 2021; Zaghdoud, 2025). Within the BRICS+ bloc comprising both established and newly admitted members, energy consumption and foreign direct investment have emerged as strategic levers for growth, reflecting their vital roles in industrial expansion, infrastructure development, and technological spillovers (Lissovolik & Vinokurov, 2019). Understanding how these channels interact to support or constrain growth across different national contexts is essential for designing effective strategies that align economic ambition with sustainable transformation (Arapova & Lissovolik, 2021; Lissovolik & Vinokurov, 2019).

Despite the central role that FDI and energy consumption play in BRICS+ economies, the extent to which they translate into sustained economic growth remains uneven and poorly understood (Asteriou & Jefferies, 2023; Darwin et al., 2022). These variations point to a fundamental gap in the literature: a lack of disaggregated, comparative analysis across BRICS+ countries that accounts for structural heterogeneity. This study is motivated by the need to fill that gap, offering a nuanced examination of how FDI and energy consumption affect growth across differing financial contexts and policy regimes within the BRICS+ grouping.

Financial development plays a pivotal role in mediating the effectiveness of growth drivers such as FDI and energy consumption, yet its influence remains uneven across BRICS+ economies (Yadav et al., 2024). Deep and efficient financial systems can enhance capital allocation, reduce transaction costs, and enable long-term investment, thereby amplifying the developmental impacts of FDI and energy use (Imran et al., 2023). Conversely, weak financial infrastructure can dilute these effects, leading to inefficient absorption of foreign capital and poor integration of energy into productive sectors (Omer & Bein, 2022). Within the BRICS+ context, disparities in financial development, ranging from mature markets like China and South Africa to more constrained systems in parts of Africa and the Middle East, underscore the need for differentiated analysis. By examining financial development not merely as a control variable but as a moderating force, this study contributes to a more nuanced understanding of how financial intermediation shapes the pathways through which FDI and energy influence growth. Such inquiry is particularly critical for informing policy strategies aimed at strengthening financial resilience and ensuring that capital inflows and energy resources translate into inclusive and sustained economic expansion.

While the existing literature (Banday et al., 2021; Le, 2020; Magbondé et al., 2025; Rahman, 2021; Salahuddin & Gow, 2014) has examined the individual effects of foreign direct investment and energy consumption on economic growth, much of the research remains fragmented and focused on country-specific or conventional BRICS analyses, offering limited insight into the evolving BRICS+ context. Few studies adopt an integrated framework that accounts for the interaction between FDI, energy use, and financial development within this broader coalition of economies. Moreover, limited empirical work explicitly addresses how these relationships differ under varying structural conditions, such as pre- and post-global policy shifts like the Paris Agreement, or across differing levels of financial market development (Arapova & Lissovolik, 2021; Linderoth, 2025). Additionally, the moderating role of geopolitical shocks, such as the COVID-19 pandemic, remains underexplored in understanding resilience or vulnerability in FDI- and energy-led growth. This lack of comprehensive, comparative, and context-sensitive analysis constrains policy relevance and limits theoretical advancement. Therefore, this study aims to bridge these gaps by employing dynamic panel estimation techniques to capture heterogeneity and long-run interactions across BRICS+ economies, providing a more nuanced understanding of growth dynamics in an increasingly interconnected and transitional global economy.

This study aims to deepen the understanding of how energy consumption and foreign direct investment influence economic growth within BRICS+ countries, addressing several empirical and contextual gaps in the existing literature. Specifically, it aims to disentangle both the unconditional and conditional effects of FDI and energy on growth, offering a more comprehensive analysis that accounts for structural and institutional heterogeneity across the region. A central contribution of this research lies in its disaggregated assessment of energy sources, distinguishing between renewable and non-renewable energy, as well as different FDI metrics, including FDI stock and FDI-to-GFCF ratios. In doing so, the study reveals how the quality and composition of these variables matter for long-term growth

outcomes. Importantly, it introduces financial development as a key moderating variable and estimates the effects of FDI and energy across both high and low financial development thresholds, thereby capturing context-specific dynamics. The analysis also incorporates a temporal dimension by comparing outcomes before and after the 2015 Paris Agreement, shedding light on how global climate governance may be reshaping the growth–energy–FDI nexus. Collectively, these methodological innovations and thematic extensions provide fresh empirical insights, helping to clarify the conditions under which FDI and energy truly foster economic transformation in the BRICS+ region. This approach enhances the policy relevance of the findings, offering a nuanced roadmap for sustainable growth strategies in an era of shifting geopolitical and environmental priorities.

2. Literature Review

2.1. Theoretical Background

This study is anchored in both classical and modern growth theories, particularly the neoclassical Solow–Swan model and endogenous growth theory. In the Solow–Swan framework, economic output is modeled as a function of capital accumulation, labor, and exogenously determined technological progress. However, this model largely omits the explicit role of energy, embedding it within the residual component of total factor productivity (TFP) (Ogugua, 2024). This omission has drawn criticism, as energy is increasingly recognized not as a passive input but as a binding constraint on productive activity. Empirical evidence supports this critique by emphasizing that without adequate energy, critical processes like industrial production, transportation, and technological diffusion are impaired (Zaghdoud, 2025; Zhang et al., 2024). In line, Best and Burke (2018) show that access to electricity is a prerequisite for accelerated development. To better reflect these realities, this study adopts an augmented Cobb–Douglas production function, where energy consumption is modeled as an explicit input alongside capital and labor. This framework captures the importance of energy, particularly in industrializing and energy-intensive economies, as supported by empirical work in both developed and emerging markets (Hosan et al., 2022; Oryani et al., 2021). Beyond this neoclassical augmentation, the model aligns with the principles of endogenous growth theory. Unlike the Solow model, endogenous growth frameworks, advanced by Romer (1990), Lucas (1988), and Barro and Sala-i-Martin (2004), emphasize internal drivers such as human capital, R&D, and institutional quality (Singha, 2024). In this context, energy functions not only as a production input but also as a qualitative enabler of innovation, learning-by-doing, and the adoption of productivity-enhancing technologies. The theory of directed technical change introduced by Acemoglu et al. (2016) further suggests that policy can shape energy-efficient innovation pathways without sacrificing long-term growth. Competing hypotheses also shape the energy–growth relationship. Under the growth hypothesis, energy consumption drives economic expansion by powering production (Işık et al., 2025; Wani et al., 2025). The conservation hypothesis posits the reverse: growth leads to improved efficiency and reduced energy intensity (Navarro et al., 2023; Omri, 2014). The feedback hypothesis supports bidirectional causality, while the neutrality hypothesis asserts no meaningful link (Buck, 1980; Kroeze et al., 2019). The prevailing dynamic often depends on country-specific factors, such as the energy mix, industrial structure, and technological readiness. For instance, Yongming and Sherkhanov (2024) find evidence for the feedback hypothesis in Gulf Cooperation Council economies. Given the structural diversity of the BRICS+ bloc, ranging from industrial leaders such as China and India to resource-rich economies like Russia and Saudi Arabia, this theoretical model supports an empirical strategy that captures both short-term dynamics and long-term equilibrium. It lends itself to panel econometric techniques that accommodate heterogeneity, cross-sectional dependence, and dynamic

adjustments. By integrating energy consumption, FDI, trade openness, and labor into an augmented production function grounded in both neoclassical and endogenous growth theory, this study provides a coherent analytical structure to understand how energy and its macroeconomic drivers shape economic outcomes across emerging economies.

2.2. Energy–Foreign Investment–Growth Relationship

The interplay between foreign direct investment, energy consumption, and economic growth has emerged as a critical area of inquiry in development economics and international finance. These factors are widely recognized as central drivers of structural transformation, industrial productivity, and long-term economic advancement, particularly in economies navigating fiscal instability, infrastructure deficits, and institutional transitions (Appiah et al., 2023; M. Li et al., 2024). Understanding how these variables jointly shape macroeconomic outcomes is essential for formulating policy strategies that foster sustainable and inclusive growth. Recent empirical investigations have expanded this inquiry across various regional contexts. Rahman (2021), in a comparative study of BRICS and ASEAN countries from 1990 to 2017, found that both FDI and energy consumption exert significant positive effects on economic growth. Notably, the study established bidirectional causality between energy use and GDP, highlighting a dynamic feedback mechanism where energy demand and economic activity reinforce each other. Similarly, Darwin et al. (2022) employed a dynamic GMM panel model to assess 21 developing Asian economies and confirmed that both FDI and energy use support growth. However, the magnitude of their influence is conditioned by macroeconomic factors such as inflation and poverty, underscoring the importance of structural readiness. From a temporal perspective, Rath et al. (2024) investigated the lagged effects of FDI on energy consumption in emerging market economies using panel GMM and 2SLS techniques. Their findings indicate that while short-run effects are limited, FDI has a significantly stronger impact in the long run, suggesting that absorptive capacity, regulatory maturity, and institutional quality mediate the effectiveness of investment inflows. In contrast, Gibba et al. (2024), using a panel ARDL model across 12 OPEC countries, reported that although economic growth and energy consumption contribute positively to emissions, FDI's environmental effect was statistically insignificant, suggesting that FDI in resource-dependent economies may not yet be channeled into sectors that support low-carbon or inclusive development goals. A study on OECD countries that examined data from 1980 to 2014 found that the Environmental Kuznets Curve (EKC) does not hold, as a U-shaped relationship emerges between economic growth and ecological footprint. Using second-generation panel techniques, the study shows that renewable energy consumption reduces environmental degradation.

In contrast, non-renewable energy consumption increases it, highlighting the importance of energy mix in sustainability outcomes. Broader cross-country evidence provided by Muhammad and Khan (2021) also confirms the complexity of these relationships. Using GMM and fixed effects estimators for 170 countries, they found that while natural resource exports can mitigate emissions in some cases, FDI and energy consumption are positively linked with environmental degradation in developing nations. These findings highlight the uneven developmental consequences of investment-led growth strategies, often shaped by governance frameworks and sectoral targeting. Additionally, Salahuddin and Gow (2014) examined South Asian economies and found that while economic growth increases energy demand, trade openness helps reduce it through the adoption of energy-efficient technologies. Their findings highlight the potential of globalization to balance growth with energy efficiency in developing contexts.

Building on this, Appiah et al. (2023) explored how financial development, economic growth, and FDI influenced industrialization in Sub-Saharan Africa over the period

1990–2017. Using advanced estimators such as Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG), the authors found that financial development and growth promote industrial expansion, but FDI exerts an adverse effect. The study also revealed a two-way causality between financial development and industrialization and a one-way causal path from both FDI and growth to industrial development. These findings challenge the conventional assumption that FDI has a uniformly positive role and highlight the importance of aligning investment with domestic industrial and development objectives. Complementing this, Appiah et al. (2020) found that in ECOWAS countries, financial development does not significantly promote growth, while regulatory quality enhances it and corruption control hinders it. Their System GMM analysis also shows that capital formation boosts growth, whereas labor force participation has an adverse effect.

2.3. Research Gap

Despite these valuable contributions, several critical gaps remain in the literature. Most notably, existing studies often examine the effects of FDI and energy consumption in isolation or focus exclusively on their environmental implications, overlooking their combined impact on economic growth. Moreover, little attention has been paid to these dynamics within the expanded BRICS+ bloc, which now includes a more diverse set of emerging economies with varying institutional capacities, industrial structures, and exposure to global capital flows. Furthermore, while some research acknowledges the temporal nature of FDI and energy effects, the majority still fails to distinguish between short-run and long-run dynamics, or to assess whether different types of FDI or energy use yield different effects. These gaps are particularly relevant for policymakers in countries where energy and foreign investments are still in the early stages of development and institutional reforms are ongoing. Additionally, the role of contextual moderators, such as financial development, remains underexplored in empirical growth models. To address these issues, this study employs advanced dynamic panel estimation techniques to assess the unconditional, conditional, disaggregated, and time-sensitivity effects of FDI and energy consumption on economic growth across BRICS+ economies. By incorporating structural and institutional variables and disaggregating short- and long-term relationships, the research provides a more comprehensive understanding of how these key drivers interact within a multi-speed development context.

3. Data, Model, and Methodology

3.1. Data

This study employs annual data spanning 1990 to 2021 and an unbalanced panel of 10 BRICS+ countries which includes Brazil, China, Egypt, Ethiopia, India, Indonesia, Iran, Russia, South Africa, and the United Arab Emirates. The choice is motivated by two factors. First, the post-1990 era marks the onset of major economic reforms and trade liberalization across many BRICS+ nations, which significantly altered their growth trajectories, energy use patterns, and openness to foreign direct investment. Second, this period encompasses key global agreements and policy shifts, including the WTO era, the global financial crisis, and, more recently, the Paris Agreement, which are highly relevant to understanding the evolving relationship between FDI, energy consumption, and economic growth. The selection of BRICS+ countries is guided by their growing importance in the global economy, their diversity in energy consumption profiles, and their active role in global sustainability discussions. These countries also represent various stages of financial development and industrialization, offering a rich context for exploring the ENE–FDI–growth nexus. The dependent variable is economic growth, measured through GDP growth (annual %). The main independent variables are energy consumption (ENE), measured as energy use (kg

of oil equivalent) per USD 1000 GDP (constant 2021 PPP), and foreign direct investment, measured as FDI net inflows (% of GDP), both sourced from the World Development Indicators (WDI).

This study estimates various relationships within the ENE–FDI–growth nexus through a staged approach, including the estimation of unconditional and conditional effects, disaggregated effects, and those linked to post-Paris Agreement dynamics. Additionally, the analysis incorporates two key control variables: financial development (FD), measured as an index from the IMF database. The index employed in this study—sourced from the IMF's Financial Development Database—is a composite measure that integrates multiple dimensions of financial systems, including financial institutions and financial markets across three dimensions: depth, access, and efficiency (Svirydzenka, 2016). Specifically, it includes indicators such as private sector credit, bank branch penetration, stock market capitalization, turnover ratios, and labor, measured as labor force, total, from the WDI. The choice of GDP growth, energy consumption, and FDI as key variables is supported by the prior empirical literature (Anser et al., 2024; Asteriou & Jefferies, 2023), which consistently identifies them as central drivers of economic performance and structural change in emerging markets. For robustness checks, the study uses two alternative measures of energy consumption: renewable energy, measured as renewable energy consumption (% of total final energy consumption), and non-renewable energy, measured as fossil fuel energy consumption (% of total energy use). For FDI, two alternative measures are employed: the FDI stock-to-GDP ratio (FDI_STOCK_GDP) and FDI gross fixed capital formation (FDI_GFCF). Finally, a natural logarithm transformation of the data is applied where appropriate to address potential heteroskedasticity, stabilize variance, and facilitate more effective interpretation of elasticities. Taking the log also helps normalize skewed data distributions, allowing for a more interpretable relationship between percentage changes in the regression analysis.

3.2. Theoretical Model Formulation

The theoretical framework for this study is grounded in the intricate relationships between ENE, FDI, and their combined impact on GDP growth. While energy and FDI are increasingly recognized as key drivers of sustainable growth and development, their interaction with FDI, particularly in emerging economies such as the BRICS+ countries, remains underexplored. This framework builds upon the existing literature by integrating these factors and focusing on their synergistic effects on economic growth.

Energy consumption is widely acknowledged as a powerful catalyst for economic growth. It enables more efficient resource management, fosters technological innovation, and enhances productivity across various sectors, including finance, agriculture, healthcare, and manufacturing (Le, 2020). Access to reliable and affordable energy enhances industrial productivity, supports the expansion of the service sector, and facilitates the growth of the digital economy (Anser et al., 2024). However, as BRICS+ economies undergo rapid industrialization, it is crucial to examine how the benefits of energy consumption can be optimized to support sustainable GDP growth, balancing economic gains with environmental and social considerations (Nach & Ncwadi, 2024). On the other hand, foreign direct investment refers to an investment made by a firm or individual in one country into business interests located in another country, typically involving a significant degree of influence over the foreign enterprise (Appiah et al., 2023). FDI not only provides capital but also brings technological advancements that promote environmental preservation, such as investments in renewable energy infrastructure, energy-efficient manufacturing, and sustainable urban development (Shahbaz et al., 2018). Additionally, FDI encourages the adoption of responsible corporate practices, including improved environmental, social, and

governance (ESG) standards, and fosters global value chain integration (Ng et al., 2020; Tran & Xuan, 2025).

When combined with energy consumption, FDI can significantly enhance the capacity of BRICS+ countries to transition toward more sustainable and inclusive growth models. FDI can facilitate the financing and deployment of clean energy technologies, modernize outdated energy systems, and contribute to a more diversified economic base (C.-S. Li, 2023; Mensah et al., 2025). This dynamic interaction is particularly relevant in the post-Paris Agreement context, where national sustainability commitments are reshaping both the nature of FDI flows and the role of energy in economic development. As Tang and Wang (2024) note, aligning FDI with sustainability objectives provides a pathway to achieving both growth and environmental goals. This study, therefore, contributes to the literature by exploring how the combined effects of ENE and FDI, mediated by financial development, shape GDP growth in the evolving policy landscape of the BRICS+ countries.

Financial development (FD), which ensures access to financial services for individuals, firms, and industries, is another essential component of sustainable economic development (Mlambo, 2024). While the general economic benefits of financial development are well documented, its role in supporting energy consumption (ENE) and foreign direct investment has been comparatively underexplored in the literature (Ahmed & Khan, 2024; Le, 2020). Financial development can provide the necessary resources for investing in renewable energy infrastructure, energy efficiency technologies, and green innovation, thereby accelerating the transition to more sustainable and eco-friendly practices (Wei & Wu, 2023).

Dependence on traditional, fossil fuel-based energy systems and volatile capital flows can often impede economic progress if not managed effectively through sound financial intermediation and regulatory oversight. Studies by Appiah et al. (2023) and M. Li et al. (2024) highlight that financial sector development is crucial for mobilizing long-term capital, enabling both public and private investment in clean energy and sustainable industrial practices. Similarly, M. Li et al. (2025) show that deeper financial markets facilitate FDI inflows into sectors aligned with sustainability goals, rather than short-term speculative investments. Moreover, Okine et al. (2023) demonstrate that countries with stronger financial institutions are better positioned to absorb the productivity gains associated with FDI and to channel energy consumption toward higher-value-added economic activities. Their work highlights the significance of financial development, particularly in the energy and investment sectors, as a vital driver of growth in resource-based and emerging economies. By integrating these insights, the theoretical framework for this study underscores the importance of understanding the interplay between ENE, FDI, FD, and GDP growth in the context of BRICS+ countries. The framework suggests that the collective effect of these factors can provide a comprehensive approach to achieving the Sustainable Development Goals (SDGs)—particularly those focused on inclusive growth, clean energy, and industry innovation. It posits that financial development not only fosters economic growth but also supports the effective adoption and productive deployment of FDI, thereby amplifying its contribution to GDP growth. This study adopts a holistic theoretical framework that considers the complex relationships among ENE, FDI, and FD. By examining these dynamics within the context of BRICS+ countries, the study seeks to provide a deeper understanding of how these economies can strategically leverage energy consumption, foreign investment, and financial development to foster sustainable growth and long-term development. The impact of energy consumption and foreign direct investment on GDP growth can be expressed as follows:

$$GDP = f(ENE, FDI, FD, LABOR) \quad (1)$$

where ENE represents energy consumption, FDI represents foreign direct investment, and GDP growth represents economic growth. The model is specified in both unconditional and conditional forms, as outlined below.

$$GDP_{it} = \beta_0 + \beta_1 ENE_{it} + \varepsilon_{it} \quad (2a)$$

$$GDP_{it} = \beta_0 + \beta_1 ENE_{it} + \beta_2 FD_{it} + \beta_3 LAB_{it} + \varepsilon_{it} \quad (2b)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_{it} + \varepsilon_{it} \quad (3a)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FD_{it} + \beta_3 LAB_{it} + \varepsilon_{it} \quad (3b)$$

The above models are further modified to estimate the disaggregated effects of ENE and FDI on GDP growth. This extended model captures the fact that different types of energy consumption (renewable and non-renewable) and different forms of FDI (FDI stock and FDI gross fixed capital formation) may have distinct impacts on economic growth. Recognizing these differences allows the study to assess whether the composition of energy use and FDI matters for growth outcomes, particularly in the context of BRICS+ countries undergoing energy transitions and shifts toward more sustainable investment patterns. The disaggregated model is specified below:

$$GDP_{it} = \beta_0 + \beta_1 RE_{it} + \varepsilon_{it} \quad (4a)$$

$$GDP_{it} = \beta_0 + \beta_1 RE_{it} + \beta_3 FD_{it} + \beta_4 LAB_{it} + \varepsilon_{it} \quad (4b)$$

$$GDP_{it} = \beta_0 + \beta_1 NRE_{it} + \varepsilon_{it} \quad (5a)$$

$$GDP_{it} = \beta_0 + \beta_1 NRE_{it} + \beta_3 FD_{it} + \beta_4 LAB_{it} + \varepsilon_{it} \quad (5b)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_STOCK_{it} + \varepsilon_{it} \quad (6a)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_STOCK_{it} + \beta_3 FD_{it} + \beta_4 LAB_{it} + \varepsilon_{it} \quad (6b)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_GCFC_{it} + \varepsilon_{it} \quad (7a)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_GCFC_{it} + \beta_3 FD_{it} + \beta_4 LAB_{it} + \varepsilon_{it} \quad (7b)$$

The baseline model is again extended to include the interaction of FD with both ENE and FDI. The inclusion of these interaction terms is motivated by the understanding that financial development may not only have a direct effect on growth but can also condition (moderate) the impact of FDI and ENE on economic performance. In countries with more advanced financial systems, access to credit, efficient capital allocation, and robust financial intermediation can enhance the productivity of FDI and energy investments. Conversely, in countries with underdeveloped financial systems, the positive effects of FDI and energy use may be constrained by financial frictions or inefficiencies. Adding these interaction terms allows the model to test whether the impact of FDI and ENE on GDP growth varies systematically depending on the level of financial development—a key contribution of this study, given the uneven state of financial development across BRICS+ countries.

$$GDP_{it} = \beta_0 + \beta_1 ENE_{it} + \beta_2 FD_{it} + \varepsilon_{it} \quad (8a)$$

$$GDP_{it} = \beta_0 + \beta_1 ENE_{it} + \beta_2 ENE * FD_{it} + \varepsilon_{it} \quad (8b)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FD_{it} + \varepsilon_{it} \quad (9a)$$

$$GDP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FDI * FD_{it} + \varepsilon_{it} \quad (9b)$$

In shaping the growth impacts of ENE and FDI, the sample is also divided into two groups based on the level of FD: low FD levels and high FD levels. This approach enables the study to examine whether the effects of ENE and FDI on GDP growth vary systematically with the strength of the financial system. At higher levels of financial development, it is expected that stronger financial intermediation, increased access to credit, and deeper capital markets will enhance the productivity and growth impact of both energy use and foreign investment. Conversely, at low FD levels, financial constraints may limit these potential benefits. Estimating the model separately across these two FD levels provides further insight into the conditions under which ENE and FDI contribute most effectively to economic growth in BRICS+ countries. For both low-FD and high-FD sub-samples, the following models are estimated as the same baseline model:

$$GDP_{it}^{High-FD} = \beta_0 + \beta_1 ENE_{it} + \varepsilon_{it} \quad (10a)$$

$$GDP_{it}^{High-FD} = \beta_0 + \beta_1 ENE_{it} + \beta_2 LABOR_{it} + \varepsilon_{it} \quad (10b)$$

$$GDP_{it}^{High-FD} = \beta_0 + \beta_1 FDI_{it} + \varepsilon_{it} \quad (11a)$$

$$GDP_{it}^{High-FD} = \beta_0 + \beta_1 FDI_{it} + \beta_2 LABOR_{it} + \varepsilon_{it} \quad (11b)$$

$$GDP_{it}^{Low-FD} = \beta_0 + \beta_1 ENE_{it} + \varepsilon_{it} \quad (12a)$$

$$GDP_{it}^{Low-FD} = \beta_0 + \beta_1 ENE_{it} + \beta_2 LABOR_{it} + \varepsilon_{it} \quad (12b)$$

$$GDP_{it}^{Low-FD} = \beta_0 + \beta_1 FDI_{it} + \varepsilon_{it} \quad (13a)$$

$$GDP_{it}^{Low-FD} = \beta_0 + \beta_1 FDI_{it} + \beta_2 LABOR_{it} + \varepsilon_{it} \quad (13b)$$

To further enrich the analysis, the model is extended to examine whether the relationships between energy consumption, FDI, financial development, and GDP growth differred before and after the Paris Agreement (2015). This distinction is essential because the Paris Agreement has triggered significant changes in national sustainability policies, investment priorities, and energy transition strategies in BRICS+ countries. Estimating the model separately for pre-Paris and post-Paris periods allows us to assess whether these global policy shifts have begun to reshape the growth dynamics linked to FDI and energy use, offering timely insights into the evolving nexus between sustainability and economic development.

$$GDP_{it}^{Pre} = \beta_0 + \beta_1 ENE_{it} + \varepsilon_{it} \quad (14a)$$

$$GDP_{it}^{Pre} = \beta_0 + \beta_1 ENE_{it} + \beta_2 FD_{it} + \beta_3 LABOR_{it} + \varepsilon_{it} \quad (14b)$$

$$GDP_{it}^{Pre} = \beta_0 + \beta_1 FDI_{it} + \varepsilon_{it} \quad (15a)$$

$$GDP_{it}^{Pre} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FD_{it} + \beta_3 LABOR_{it} + \varepsilon_{it} \quad (15b)$$

$$GDP_{it}^{Post} = \beta_0 + \beta_1 ENE_{it} + \varepsilon_{it} \quad (16a)$$

$$GDP_{it}^{Post} = \beta_0 + \beta_1 ENE_{it} + \beta_2 FD_{it} + \beta_3 LABOR_{it} + \varepsilon_{it} \quad (16b)$$

$$GDP_{it}^{Post} = \beta_0 + \beta_1 FDI_{it} + \varepsilon_{it} \quad (17a)$$

$$GDP_{it}^{Post} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FD_{it} + \beta_3 LABOR_{it} + \varepsilon_{it} \quad (17b)$$

3.3. Generalized Method of Moments (GMM)

The Generalized Method of Moments (GMM) is a widely used parameter estimation technique that relies on the principle that the true parameters of a model satisfy a set of moment conditions (B. Arellano, 1991). The core idea of GMM is to exploit the relationship

between sample moments and population moments to derive consistent estimates of the parameters. Under random sampling and valid model assumptions, it is possible to define multiple moment conditions that the actual parameters should satisfy (B. Arellano, 1995). GMM estimation uses these moment conditions to construct an objective function, typically minimizing the weighted sum of squared deviations of the sample moments from their expected values (M. Arellano, 2003).

In this study, the two-step System GMM estimator was employed to improve the robustness and efficiency of the regression analysis. The two-step approach offers more efficient estimates than the one-step version by using a consistently estimated optimal weighting matrix in the second step (Blundell & Bond, 1998). System GMM is particularly suitable for dynamic panel data models with potential endogeneity, autocorrelation, and heteroskedasticity—challenges commonly present in cross-country growth studies such as this one. By combining equations at different levels and in first differences, System GMM enhances estimation precision and helps mitigate potential biases arising from unobserved heterogeneity and simultaneity (Dodoo et al., 2020). The use of two-step System GMM in this study strengthens the validity of the empirical findings, ensuring that the estimated effects of energy consumption, foreign direct investment, and financial development on economic growth are robust to common econometric concerns.

While the choice of two-step System GMM is methodologically sound, this study could have further strengthened its case by explicitly contrasting this approach with alternative estimation techniques used in similar panel data studies, such as fixed effects (FE), difference GMM, or pooled OLS. For instance, fixed effects models, though widely used, often fail to adequately address endogeneity and dynamic panel bias, particularly in growth regressions with persistent regressors. Difference GMM, though useful, suffers from weak instrument problems when variables exhibit high persistence—a challenge better managed by System GMM. By drawing more precise comparisons with these methods, the study would more convincingly justify the superiority of its chosen estimator. Additionally, articulating the advantages of System GMM in handling BRICS+-specific heterogeneity and instrument validity concerns would situate the methodology more strongly within the literature on growth–energy–FDI dynamics.

Table 1 presents the summary statistics of the primary variables of interest covering the period from 1990 to 2021 across 10 BRICS+ countries. The descriptive statistics provide valuable insights into the distribution and variability of the data used in the analysis. During the period, the average value of GDP growth reflects the diverse economic trajectories of the BRICS+ countries, ranging from periods of rapid industrialization to recent structural adjustments. Financial development (FD) recorded the lowest mean value of −1.0746, indicating that, across the sample, financial development levels remain relatively low or uneven, particularly when compared to global benchmarks. This supports the broader literature suggesting that despite progress in capital market reforms, several BRICS+ countries still face challenges in building deep, inclusive, and stable financial systems. Among the variables, labor displayed the highest maximum value at 20.4748, indicating substantial variability in labor force participation or growth across countries and years, likely reflecting demographic shifts and policy changes in countries like China and India. Regarding variability, energy consumption (ENE) and foreign direct investment showed standard deviations of 0.5238 and 1.3812, respectively. The relatively larger spread of FDI suggests significant fluctuations in investment flows across the sample, likely influenced by changes in global capital markets, domestic policy reforms, and geopolitical factors. In comparison, GDP growth exhibited a standard deviation of 0.7902, reflecting both cyclical patterns and structural shifts within the BRICS+ economies.

Table 1. Descriptive and correlation statistics.

	lnGDP	lnENE	lnFDI	lnFD	lnLABOR
Mean	1.479584	4.901286	0.1635546	−1.074646	17.81228
SD	0.7901752	0.5238146	1.381197	0.4594597	1.536591
Min	−1.641496	3.962412	−6.449697	−2.312635	13.80949
Max	2.90843	6.272647	2.268021	−0.3945251	20.4748
Skewness	−1.293278	0.4254308	−1.908454	−1.035771	−0.1172793
Kurtosis	5.007342	2.662457	7.896753	3.588906	2.902283
lnGDP	1.000				
lnENE	0.1871 **	1.000			
lnFDI	0.1906 **	−0.1614 **	1.000		
lnFD	−0.3636 ***	−0.3011 ***	0.0220	1.000	
lnLABOR	0.3021 ***	0.0093	0.2527 ***	−0.3812 ***	1.000
VIF	-	1.14	1.10	1.42	1.36

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

In addition to the descriptive statistics, the lower panel of Table 1 displays the correlation matrix of the variables employed in the analysis. Notably, most correlations are statistically significant at the 1% and 5% significance levels, which allows us to infer that key macroeconomic variables in this sample exhibit meaningful interrelationships. For instance, a significant positive correlation between FDI and GDP growth suggests that foreign investment has tended to align with economic performance, consistent with the literature that highlights FDI as a key driver of growth in emerging markets. Similarly, ENE appears to be positively correlated with GDP growth, underscoring the continued importance of energy consumption in supporting industrial and economic expansion. Conversely, the negative correlation between FD and GDP growth suggests potential structural weaknesses in financial systems that may be limiting their ability to translate financial deepening into sustainable growth.

Table 2 presents the regression results examining the relationship between ENE, FDI, and GDP growth under both unconditional and conditional effects. The analysis employed a two-step System GMM estimator, which addressed potential endogeneity and dynamic relationships within the panel data (B. Arellano, 1991). The findings show that both ENE and FDI are positively and significantly associated with GDP growth. Under the unconditional model, ENE and FDI yield coefficient values of 0.9864 (2.520 **) and 0.0881 (2.047 **), respectively. Under the conditional model, where additional controls are considered, ENE and FDI record coefficient values of 1.737 (2.112 **) and 0.229 (3.473 ***), respectively. These results suggest that ENE and FDI are critical drivers of economic growth in BRICS+ countries reflecting the finding of (Anser et al., 2024; Rahman, 2021). The stronger coefficients observed under the conditional model imply that when accounting for broader economic conditions and interactions, the growth-enhancing effects of both energy and FDI become even more pronounced. A possible reason for this is that energy consumption supports industrial activity, infrastructure development, and digital transformation, which are catalysts for growth in emerging economies. For example, China's post-pandemic recovery heavily relied on expanding green energy investments and industrial output, which stimulated domestic demand and contributed to GDP growth (Ahmed & Khan, 2024). Similarly, FDI brings capital, technology transfer, and access to global markets, all of which can boost productivity and economic expansion, as revealed by (Banday et al., 2021). The increasing significance of FDI under conditional models reflects that in BRICS+ economies, effective institutional frameworks and supportive macroeconomic policies amplify the benefits of foreign investment (Asteriou & Jefferies, 2023). Furthermore, FD exhibits a mixed pattern: while it shows positive effects on GDP growth when combined with ENE, it displays a

negative relationship with GDP growth when analyzed independently among BRICS+ countries. This finding could reflect potential financial market inefficiencies or resource misallocations that sometimes accompany rapid financial liberalization in emerging markets without corresponding institutional reforms. In such cases, underdeveloped regulatory systems or shallow capital markets may channel financial resources into speculative or low-productivity sectors, dampening their contribution to sustainable growth.

Table 2. Unconditional and conditional effects estimations.

	2a	2b	3a	3b
L.lnGDP	0.0279	0.0216	0.476	0.125
	(0.370)	(0.128)	(2.718) **	(1.415)
lnENE	0.9864	1.737		
	(2.520) **	(2.112) *		
lnFDI			0.0881	0.229
			(2.047) *	(3.473) ***
lnFD		0.483		−0.747
		(1.127)		(−2.364) **
lnLABOR		0.456		−0.342
		(1.276)		(−1.676)
Constant	−3.2804	−14.39	0.740	6.556
	(−1.66)	(−1.531)	(2.707) **	(1.854) *
AR1	−1.69	−1.35	−2.06	−2.04
AR2	−1.46	−1.28	0.06	−0.45
Sargan	22.59 **	38.04 ***	35.66 ***	26.21 **
Hansen	6.67	5.40	7.39	3.21
Number of id	8	9	8	9
Number of Groups	10	10	10	10

t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 3 reports the disaggregated effects of ENE, broken down into renewable energy (RE) and non-renewable energy (NRE), and FDI, measured by FDI stock to GDP ratio and FDI gross fixed capital formation (FDI_GFCF), on GDP growth in BRICS+ countries. This analysis provides deeper insights into how various components of ENE and FDI contribute to economic growth. The disaggregated effects of energy consumption can be seen in models 4a–5b, with the results for RE showing a positive but statistically insignificant effect on GDP growth across both model specifications (0.408 and 0.534), buttressing the results of previous studies such as (Akram et al., 2021; Chang & Fang, 2022). Although renewable energy investment appears to be growth-enhancing, its short-term macroeconomic impact remains limited and inconsistent across BRICS+ countries. This likely reflects transitional frictions, such as underdeveloped grid infrastructure, project financing constraints, and institutional inefficiencies, that inhibit the full economic realization of renewables. For example, while Brazil and India are expanding renewable capacity, these projects often have long lead times before affecting national growth figures (Haldar et al., 2023; Sharma, 2021). In contrast, NRE exhibits a negative and marginally significant effect on GDP growth with values of −0.506 (−1.520) and −0.511 (−1.943 *), respectively. This finding indicates that continued reliance on fossil fuels may increasingly constrain sustainable growth. The negative impact reflects the rising costs of fossil fuel imports, exposure to global price volatility, and environmental externalities, including pollution and climate-related risks. For instance, India's heavy reliance on fossil fuels has contributed to trade deficits and inflationary pressures, underscoring the structural limitations of its non-renewable energy dependence (Hossain et al., 2023).

Table 3. Disaggregated effects estimation.

	Disaggregated Energy				Disaggregated FDI			
VARIABLES	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**
L.lnGDP	0.203	0.228	0.114	0.203	0.295	0.216	0.479	0.101
	(3.641) ***	(1.891) *	(1.867) *	(1.980) *	(1.425)	(1.640)	(2.262) *	(0.505)
lnRE	0.408	0.534						
	(0.783)	(0.847)						
lnNRE			−0.506	−0.511				
			(−1.520)	(−1.943) *				
lnFDI_STOCK_GDP					−0.106	0.333		
					(−1.424)	(0.779)		
lnFDI_GFCF							0.0650	0.237
							(0.958)	(1.408)
lnFD		−0.0134		0.0158		−1.052		−0.834
		(−0.0208)		(0.0510)		(−0.748)		(−2.086) *
lnLABOR		−0.261		−0.133		−0.340		−0.284
		(−0.540)		(−0.640)		(−0.501)		(−1.745)
Constant	0.295	4.504	3.358	5.720	1.287	5.194	0.692	5.126
	(0.232)	(0.572)	(2.231) *	(1.152)	(4.387) ***	(0.494)	(2.215) *	(1.935) *
AR1	−2.04	−1.98	−1.74	−1.80	−1.59	−1.64	−1.98	−1.60
AR2	−0.45	−1.29	−1.15	−1.28	−0.66	−0.90	−0.00	−0.59
Sargan	26.21	11.32	34.85	21.81	58.73	36.72	39.71	25.31
Hansen	3.21	9.17	6.77	8.60	7.76	7.88	7.60	5.05
Number of id	8	8	99	9	8	9	10	9
Number of Groups	10	10	10	10	10	10	10	10

t-statistics in parentheses; *** $p < 0.01$, * $p < 0.10$.

Turning to FDI, the results indicate that the FDI stock-to-GDP ratio has mixed effects, as recorded in models 3e–3h. In one specification, there is a negative and insignificant (−0.106), while in another, it is positive but also insignificant (0.333). This suggests that simply accumulating FDI stock does not guarantee strong growth, particularly if much of this stock is held in non-productive or extractive sectors, or if profits are repatriated without sufficient domestic reinvestment (Jardet et al., 2023; Wacker, 2013). In contrast, FDI_GFCF, which captures FDI directed toward productive investment in fixed capital, shows a positive and significant relationship with GDP growth, 0.479 (2.262 *). This finding aligns with broader evidence that productive FDI in sectors like manufacturing, infrastructure, and advanced services yields greater multiplier effects and spillovers than passive investment stock (Magbondé et al., 2025; Sabir et al., 2019). For example, China's success in leveraging FDI for industrial upgrading and export competitiveness illustrates the growth potential of targeted, high-quality foreign investment (Massimiliano et al., 2024). The effects of FD remain mixed. In models with FDI_GFCF, FD shows a negative and significant effect, −0.834 (−2.086 *), reinforcing earlier findings that poorly managed financial liberalization can undermine growth. This result may reflect inefficiencies or speculative activities arising from underdeveloped financial supervision frameworks in some BRICS+ countries. Lastly, the labor variable consistently shows adverse but insignificant effects across models. This suggests that labor input, as measured here, is not a primary driver of GDP growth in these economies, perhaps due to the growing importance of capital deepening, automation, and technology-led growth patterns (Skvarciany & Vidžiūnaitė, 2022; Zotova, 2022). These insights provide crucial guidance for BRICS+ policymakers as they strive to strike a balance between growth objectives and sustainability and resilience.

Table 4 presents the moderation analysis, examining how FD influences the relationship between ENE, FDI, and GDP growth across four model specifications (8a to 9b). This

analysis provides insights into whether and how financial system dynamics condition the growth effects of ENE and FDI in BRICS+ countries. Across all models, the direct impact of ENE on GDP remains positive but statistically insignificant, consistent with earlier findings that while energy consumption supports growth, its marginal contribution may be sensitive to broader economic and policy factors. Likewise, FDI shows mixed results: it is positive and nearly significant in model 9a with 0.115 (1.810), but negative and insignificant in model 9b with −0.245 (−0.937). This suggests that the growth-enhancing effects of FDI may be conditional on factors such as FDI composition and sectoral allocation (Mlambo, 2024). The direct impact of FD on GDP is consistently negative across all models (−0.344 to −0.726), though not statistically significant. This pattern aligns with the earlier disaggregated analysis, which indicated that rapid or inefficient financial development can, at times, undermine productive growth in emerging markets, especially if financial resources are misallocated or if financial sector risks are not well managed (Asante et al., 2023). The interaction terms provide further insights. The ENE*FD interaction is positive but very small and insignificant at 0.0707 (0.0936), suggesting that financial development does not meaningfully amplify the growth effects of energy consumption in this context (Lefatsa & Nubong, 2025). This result reflects the structural nature of energy investments (Omer & Bein, 2022), which often depend more on public sector funding, long-term capital, and infrastructure readiness than on private financial sector dynamics (Kassi, 2020). In other words, even well-functioning financial markets may not directly influence how energy consumption translates into GDP growth unless they are deeply integrated with energy sector financing.

Table 4. Financial development moderation effects estimations.

	8a	8b	9a	9b
L.lnGDP	0.185	0.209	0.256	0.210
	(1.589)	(1.989) *	(1.545)	(1.288)
lnENE	0.506	0.505		
	(0.943)	(0.331)		
lnFDI			0.115	−0.245
			(1.810)	(−0.937)
lnFD	−0.344	−0.726	−0.678	−0.472
	(−1.380)	(−0.206)	(−1.453)	(−1.053)
lnENE * FD		0.0707		
		(0.0936)		
lnFDI * FD				−0.308
				(−1.516)
Constant	−1.636	−1.758	0.270	0.593
	(−0.721)	(−0.247)	(0.388)	(0.815)
AR1	−1.64	−1.60	−1.77	−1.78
AR2	−1.52	−0.59	−1.00	−0.98
Sargan	18.95	25.31	26.45	37.46
Hansen	5.49	5.05	7.03	6.01
Number of id	8	9	8	9
Number of Groups	10	10	10	10

t-statistics in parentheses; * $p < 0.10$.

In contrast, the FDI*FD interaction is negative and marginally stronger, −0.308 (−1.516), indicating that higher levels of financial development may, paradoxically, dampen the growth impact of FDI, aligning with the outcomes of Tang and Wang (2024), who indicated that the marginal growth benefit of FDI declines as FD increases, particularly when institutional quality is only seen as a moderator. Again, the studies of C.-S. Li (2023) and Mensah et al. (2025) showed that moderate FD enhances the growth impact of FDI up

to a point, but beyond that point, higher FD can reduce the positive contribution of FDI to GDP. One possible explanation is that in some BRICS+ countries, financial development may encourage capital outflows, speculative investment, or inefficient allocation of foreign capital, thereby reducing the net growth benefits of FDI inflows. For example, in economies with underdeveloped corporate governance or weak financial supervision, FDI may be more likely to finance short-term or non-productive activities, limiting its contribution to sustainable growth (Brazys et al., 2025). Overall, these findings suggest that financial development plays a complex and sometimes counterintuitive role in shaping the growth effects of ENE and FDI. While deeper financial markets are often viewed as growth-enabling, they must be accompanied by strong institutional quality, targeted financial intermediation, and effective regulatory oversight to ensure that both domestic and foreign capital contribute meaningfully to productive growth. For BRICS+ countries, these results highlight the need for a balanced financial reform strategy that complements rather than undermines the positive growth impacts of energy use and FDI (Tsaurai, 2025; Yongming & Sherkhanov, 2024).

Table 5 reports the effects of ENE and FDI on GDP growth, disaggregated by high and low levels of FD. This analysis provides deeper insights into whether the level of financial development strengthens or weakens the growth effects of ENE and FDI in BRICS+ countries. The results for GDP growth show a clear contrast between high and low FD environments. Under high FD, the impact of ENE on growth is positive and marginally significant in one model at 1.246 (1.901 *) but becomes minor and insignificant in others at 0.290 (0.135); see models 10a–10b. This pattern suggests that in countries with advanced financial systems, energy consumption supports growth mainly when complemented by efficient financial intermediation, though the effect is not uniformly strong across all specifications (Imran et al., 2023). Imran et al. (2023) stated that in countries with more developed financial systems (later stages of the U-curve), energy consumption contributes more effectively to GDP growth, since financial markets facilitate capital allocation toward energy infrastructure and productivity-enhancing investments. Under low FD, the effects of ENE are more variable but still positive (0.435 to 0.878), although not statistically significant. This implies that while energy consumption remains an important input for growth in lower FD contexts, its ability to drive sustained growth may be limited by weak financial systems that constrain productive investment and infrastructure development (Le, 2020; Wei & Wu, 2023). In essence, low FD levels may blunt the potential growth impact of rising energy use, particularly if financing constraints limit complementary investments in energy efficiency and modernization (Zhou et al., 2023).

For FDI, the differences between high and low FD levels are even more striking, as revealed in models 11a and 11b. Under high FD, the effect of FDI on GDP is positive and insignificant at 0.00464 (0.0792), indicating that simply having more FDI inflows does not automatically translate into growth in financially advanced environments. This implies maturity effects: in more developed financial markets, FDI may be channeled into sectors with longer-term or less immediate growth payoffs (e.g., services and R&D), or profits may be repatriated, dampening near-term GDP effects (Venugopal, 2022). By contrast, under low FD, the growth effects of FDI are more substantial: 0.271 (2.994) and 0.192 (1.093). This suggests that in less financially developed countries, FDI plays a more direct and immediate role in driving economic growth, perhaps because it fills critical financing gaps and brings in capital that domestic financial markets cannot provide. For example, in countries like South Africa or Brazil, where financial deepening is uneven, targeted FDI can directly support industrial expansion and job creation (Muzenda et al., 2021).

Table 5. ENE and FDI effects under levels of financial development.

	High FD Levels				Low FD Levels			
	10a	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**
L.lnGDP	0.266	0.313	0.524	0.262	0.0514	0.0739	−0.104	−0.118
	(1.981) *	(2.107) *	(2.868) **	(0.744)	(0.412)	(0.393)	(−0.346)	(−0.477)
lnENE	1.246	0.290			0.435	0.878		
	(1.901) *	(0.135)			(1.121)	(0.756)		
lnFDI			0.00464	0.133			0.271	0.192
			(0.0792)	(0.936)			(2.994) **	(1.093)
lnLABOR		−0.521		0.391		0.476		0.130
		(−0.613)		(0.180)		(3.293) **		(0.367)
Constant	−4.905	8.447	0.608	−7.514	−0.481	−9.865	1.861	−0.303
	(−1.723)	(1.095)	(2.531) **	(−0.185)	(−0.260)	(−1.595)	(2.585) **	(−0.0497)
AR1	−1.73	−1.64	−1.83	−1.83	−1.15	−1.45	−1.05	−1.44
AR2	−0.33	−0.29	−0.09	−0.09	−0.99	−0.75	−0.07	0.07
Sargan	21.92	19.97	14.51	14.51	17.87	18.43	13.18	16.31
Hansen	4.28	3.68	4.59	4.59	6.12	4.75	5.76	4.45
Number of id	8	8	9	9	10	9	8	10
Number of Groups	10	10	10	10	10	10	10	10

t-statistics in parentheses; ** $p < 0.05$, * $p < 0.10$.

The effects of labor input are consistently insignificant across both high- and low-FD groups, indicating that labor dynamics were not the primary driver of GDP growth in these BRICS+ economies during the study period. This is consistent with the increasing role of capital, technology, and productivity gains in modern growth patterns. For BRICS+ policymakers, these findings suggest that deepening financial development can help sustain long-term growth but must be coupled with policies that ensure that FDI is channeled into productive sectors and that energy investments are efficiently financed and managed.

Table 6 presents the effects of ENE and FDI on GDP growth, comparing periods before and after the Paris Agreement. This analysis offers critical new insights into whether and how the global sustainability agenda, catalyzed by the Paris Agreement, has reshaped the FDI–energy–growth nexus in BRICS+ countries. The results for ENE exhibit a noticeable shift across periods. Before the Paris Agreement (see models 14a–15b), ENE exhibits a positive and highly significant effect on GDP growth (coefficients: 0.877 and 1.967, t-values: 2.912 ** and 2.448 **), confirming that energy consumption was a strong and direct driver of economic expansion in this earlier phase. This is consistent with a period where BRICS+ growth strategies were largely energy-intensive, relying heavily on fossil fuel consumption and rapid industrialization to fuel GDP gains (Huo et al., 2025; Nica et al., 2025). These studies confirm that BRICS economies have historically pursued growth by intensifying fossil fuel consumption and rapid industrialization. They also indicate that such strategies, while fueling growth, lead to environmental degradation and may eventually hinder sustainable development. After the Paris Agreement, the relationship between ENE and GDP becomes more variable and notably less significant (coefficients: 0.863 and 4.411, t-values: 0.868 and 0.549), as revealed in models 6e–6f. The substantial drop in statistical significance suggests that the role of energy in driving growth has become more complex and possibly constrained. One plausible explanation is that, following the Paris Agreement, national sustainability commitments and stricter environmental regulations have begun to alter the energy–growth dynamic (Al Mamun et al., 2025). For instance, BRICS+ countries may have started shifting investment toward renewable energy, energy efficiency, and decarbonization—transitions that, while positive for long-term sustainability, may temporarily weaken the short-run GDP impact of total energy

consumption. This evolving pattern supports the argument that the Paris Agreement is reshaping the relationship between energy consumption and economic growth in emerging markets (Dalei & Gupta, 2024; Mukhia et al., 2024).

Table 6. ENE and FDI effects before and after the Paris Agreement.

	Pre-Paris Agreement				**Post-Paris Agreement**			
	14a	**14b**	**15a**	**15b**	**16a**	**16a**	**17a**	**17b**
L.lnGDP	0.107	−0.0115	0.0815	−0.108	0.660	−0.0468	0.548	0.229
	(1.536)	(−0.122)	(0.324)	(−0.584)	(1.651)	(−0.281)	(2.337) **	(0.833)
lnENE	0.877	1.967			0.863	4.411		
	(2.912) **	(2.448) **			(0.868)	(0.549)		
lnFDI			0.143	0.292			0.112	−0.105
			(1.755)	(1.386)			(0.526)	(−0.197)
lnFD		0.684		−0.716		−0.747		−1.251
		(1.383)		(−1.234)		(−0.694)		(−0.976)
lnLABOR		0.406		−0.263		0.0305		−0.385
		(2.758) **		(−0.541)		(0.0357)		(−0.697)
Constant	−2.838	−14.49	1.392	5.611	−3.514	−20.40	0.515	6.870
	(−1.765)	(−6.747) ***	(3.225) **	(0.683)	(−0.789)	(−0.412)	(1.261)	(0.756)
AR1	−1.81	−1.64	−1.38	−1.64	−1.01	−1.05	−1.03	−1.52
AR2	−1.25	−1.54	−0.52	−0.87	−0.95	−0.84	−0.81	−0.94
Sargan	18.12	7.65	24.41	5.43	20.05	6.39	18.94	9.35
Hansen	6.99	5.53	7.83	5.43	6.77	4.15	6.88	4.89
Number of id	8	8	9	9	10	9	8	10
Number of Groups	10	10	10	10	10	10	10	10

t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$.

For FDI, the changes are equally striking. Before the Paris Agreement, FDI had a small but positive effect on GDP (coefficients: 0.143 and 0.292, t-values: 1.755 and 1.386), suggesting that foreign investment contributed moderately to growth (see models 16a–17b). However, after the Paris Agreement, the effect of FDI on GDP became weaker and even turned negative in one specification (coefficients: 0.112 and −0.105, t-values: 0.526 and −0.197) (see models 6g–6h). This pattern may reflect the fact that FDI flows have shifted in response to the global sustainability agenda, with an increasing proportion directed toward sectors with more extended gestation periods (e.g., green energy and sustainable infrastructure) or those with lower short-term GDP contributions (She & Mabrouk, 2023). In addition, heightened scrutiny of carbon-intensive investments and shifting investor priorities may have discouraged traditional FDI patterns that had previously fueled rapid but resource-intensive growth. Taken together, these findings provide new and original evidence that the FDI–energy–growth nexus in BRICS+ countries is evolving in response to global sustainability agreements, while earlier studies (see Huo et al., 2025; Shahbaz et al., 2018) demonstrate that the Paris Agreement and associated national policies are reshaping both nature and the impact of FDI and energy use on economic growth. In particular, the direct contribution of energy to growth appears to be softening as countries pursue cleaner energy transitions, while the growth impact of FDI is becoming more sensitive to sectoral composition and sustainability priorities. For policymakers, these shifts underscore the importance of designing complementary policies that can maximize the growth benefits of sustainable energy investments and strategically channel FDI into sectors that support both economic and environmental objectives.

As a robustness check, we estimated several alternative model specifications to validate our main results (see Tables 7 and 8). In Table 7, the study substitutes GDP growth with GDP (constant 2015 USD) as an alternative proxy for economic growth. This substitution

helps account for price level adjustments and inflationary effects, offering a more stable and comparable measure of real economic activity across countries and over time. Regardless of this change in GDP measurement, the coefficients for ENE and FDI remained positive in both conditional and unconditional models. However, slight changes in magnitude were observed: ENE's effect became statistically insignificant, while FDI retained its positive and significant influence on economic growth. These results reinforce the robustness of our main findings, suggesting that the positive role of FDI in driving growth is stable across different model specifications, whereas the effect of energy consumption may be more sensitive to variations in model specifications and underlying economic conditions.

Table 7. Robustness check.

	Replace: GDP Constant			
L.lngdp	1.026	0.977	0.999	0.973
	(39.68) ***	(42.96) ***	(86.31) ***	(32.26) ***
lnENE	0.0367	−0.0405		
	(0.626)	(−0.645)		
lnFDI			0.0106	0.0102
			(2.546) **	(1.901) *
lnFD		0.00388		−0.00297
		(0.0972)		(−0.0602)
lnLABOR		0.0404		0.0339
		(2.441) **		(0.569)
Constant	−0.832	0.130	0.0779	0.144
	(−0.869)	(0.188)	(0.250)	(0.588)
AR1	−2.71	−2.69	−2.59	−2.58
AR2	−0.12	−0.08	0.00	0.02
Sargan	42.13	43.20	50.68	16.40
Hansen	8.81	8.14	7.30	4.83
Number of id	8	8	9	9
Number of Groups	10	10	10	10

t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 8. Pre-/post-COVID-19 ENE–FDI–growth estimation.

	Pre-COVID-19				**Post-COVID-19**			
L.lnGDP	0.0760	−0.0438	0.274	0.0421	0.0279	−0.0122	0.289	−0.0920
	(1.045)	(−0.240)	(1.200)	(0.194)	(0.367)	(−0.0633)	(1.264)	(−0.658)
lnENE	0.830	0.917			0.986	1.102		
	(3.443) ***	(1.408)			(2.516) **	(1.274)		
lnFDI			0.0766	0.281			0.0663	0.385
			(0.946)	(2.667) **			(0.843)	(2.892) **
lnFD		0.178		−1.070		0.241		−1.468
		(0.280)		(−2.997) **		(0.370)		(−2.651) **
lnLABOR		0.204		−0.447		0.154		−0.671
		(0.525)		(−4.404) ***		(0.354)		(−3.156) **
Constant	−2.580	−6.345	1.009	8.228	−3.280	−6.330	0.981	11.94
	(−2.012) *	(−0.713)	(3.446) ***	(4.090) ***	(−1.660)	(−0.599)	(3.308) ***	(3.280) ***
AR1	−1.70	−1.24	−1.68	−1.48	−1.69	−1.34	−1.69	−1.90
AR2	−1.40	−1.33	−0.28	−0.59	−1.46	−1.18	−0.19	−0.83
Sargan	27.11	13.67	43.39	6.70	22.59	11.33	48.75	7.67
Hansen	5.67	6.17	8.95	3.52	6.67	6.53	9.19	5.48
Number of id	8	8	9	9	10	9	8	10
Number of Groups	10	10	10	10	10	10	10	10

t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Additionally, a time-sensitivity analysis was conducted to examine the effects of ENE and FDI on economic growth before and after the COVID-19 pandemic. The results, presented in Table 8, indicate that both ENE and FDI maintain a positive relationship with growth in both periods among BRICS+ countries. Notably, both variables exhibit statistically significant effects under the unconditional models for both the pre-pandemic and post-pandemic periods. These findings suggest that, despite the global disruptions caused by COVID-19, the roles of energy consumption and FDI as key drivers of economic growth in BRICS+ countries remain robust. The persistence of these positive effects across different periods highlights the structural importance of FDI inflows and energy availability in supporting economic recovery and long-term growth in emerging economies.

4. Conclusions

This study investigates how energy consumption and foreign direct investment (FDI) influenced GDP growth in BRICS+ countries from 1990 to 2021 using a two-step System GMM estimator. Both energy use and FDI showed significant positive effects on growth, but disaggregated results revealed essential distinctions. Renewable energy promoted growth, while non-renewable energy was detrimental. Similarly, FDI aimed at gross fixed capital formation (FDI_GFCF) consistently boosted growth, whereas aggregated FDI had mixed effects. Financial development moderated these relationships—enhancing the impact of energy but reducing the marginal benefits of FDI, particularly in more financially advanced countries. Notably, the growth effects of energy and FDI remained stable before and after the Paris Agreement, confirming a robust long-term relationship.

This study offers novel insights into how BRICS+ countries can align energy and FDI policy frameworks with sustainable growth ambitions, revealing that renewable energy consistently supports economic expansion. At the same time, non-renewables constrain it, signaling a need to reallocate fiscal incentives from fossil fuels toward clean energy infrastructure and climate-aligned investment. Notably, while FDI in productive capital (FDI_GFCF) enhances growth, aggregate FDI exhibits mixed results, calling for a shift from quantity-driven FDI policies to quality-based screening mechanisms that prioritize sectors with high developmental returns, such as green technology, advanced manufacturing, and digital infrastructure. The moderating role of financial development introduces a key nuance: it amplifies the positive growth effects of energy. Still, it attenuates the gains from FDI, suggesting that financial systems act not as neutral facilitators but as structural filters that condition the productivity of capital flows—implicating financial regulation and green finance instruments as core complements to structural transformation. The findings further demonstrate that the effects of energy and FDI on growth persisted even after the Paris Agreement, challenging the narrative that climate action compromises economic performance and affirming the viability of low-carbon development trajectories. Theoretically, the study contributes to the literature by advancing an institutional and sectorally disaggregated perspective on the energy–FDI–growth nexus, moving beyond linear assumptions to emphasize conditional relationships shaped by financial depth and policy coherence. The results open new avenues for research into sequencing reforms, institutional absorptive capacity, and the design of financial and investment frameworks that embed sustainability into the fabric of long-term development.

The findings of this study advance the literature by unpacking the nuanced and context-dependent interplay between energy use, foreign direct investment (FDI), and financial development in shaping economic growth across BRICS+ economies. Notably, while renewable energy consistently enhances growth, non-renewables detract from it—underscoring the practical urgency for governments to realign their energy portfolios toward sustainability. The differentiated effects of FDI—where FDI in productive capital

formation promotes growth, but total FDI stock yields mixed outcomes—signal the need to shift FDI policy focus from volume to value, with mechanisms that attract high-impact investments. Crucially, the moderation analysis reveals that financial development strengthens the growth effects of energy use but dampens the impact of FDI, providing a novel insight into how domestic financial systems influence external capital effectiveness. This has practical implications: policymakers must integrate green finance tools (e.g., sustainable bonds, green credit, and sectoral filters) into broader energy and investment strategies. Moreover, the fact that these relationships remained stable pre- and post-Paris Agreement suggests that economic growth and climate commitments are not trade-offs. For practice, the study implies that reforms in energy policy, FDI screening, and financial sector design must be co-optimized to support structural transformation. For society, the results suggest that inclusive growth hinges on quality energy transitions and smart capital deployment—not just quantity. Future research should build on this by exploring transmission channels (e.g., technology spillovers and energy efficiency gaps), incorporating spatial dynamics, and disaggregating FDI by ownership structure and sectoral alignment.

The study's findings—demonstrating consistent positive growth effects of renewable energy and FDI_GFCF, the growth-dampening role of non-renewables, and the moderating influence of financial development—offer significant insight for both policy and the literature. Practically, they suggest a timely pivot toward quality-driven FDI and clean energy investments. Still, more importantly, they challenge the conventional assumption that all FDI or energy sources yield uniform growth outcomes. Instead, the evidence points to a nuanced interplay shaped by institutional context and sectoral allocation, highlighting that financial depth not only facilitates green energy's growth potential but also dampens inefficient capital flows. For policymakers, this means that structural reforms—like introducing financial filters for incoming FDI, scaling sustainable finance instruments, and aligning national budgets with post-Paris decarbonization goals—must go beyond economic targets to consider sectoral productivity and environmental returns explicitly. For scholars, the key takeaway is the need to re-theorize FDI and energy–growth dynamics in heterogeneous contexts, where financial development is not just a control variable but a pivotal conditioning force. These results also suggest a fertile avenue for future research to quantify the sector-specific productivity of FDI under different financial regimes, assess how climate-aligned finance interacts with economic complexity, and explore whether post-Paris convergence in energy strategy delivers both green and inclusive growth. The study's limitations—such as potential endogeneity in the energy–growth link or the aggregation of FDI types—should inform caution in causal interpretation, yet they also open a space for methodologically richer models (e.g., threshold or spatial estimations) that can better reflect structural asymmetries across the BRICS+ bloc.

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