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EVALUATING THE ROLE OF FOREIGN INVESTMENT IN THE DEVELOPMENT OF CLEAN ENERGY INFRASTRUCTURE IN DEVELOPING COUNTRIES

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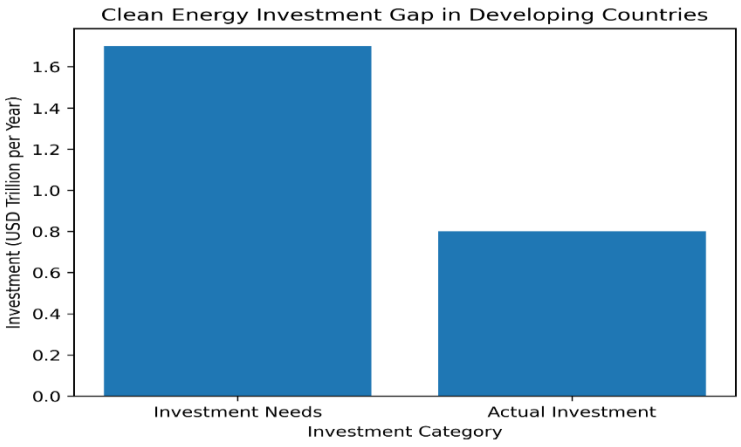
Abstract

This study evaluates the role of foreign direct investment (FDI) in promoting clean energy infrastructure development in developing countries. The objective is to examine both short-run and long-run effects of FDI on renewable energy capacity while accounting for macroeconomic and institutional factors. The analysis employs panel data from six developing economies—Indonesia, Vietnam, India, Bangladesh, Kenya, and Nigeria—over the period 2010–2023. A Panel Autoregressive Distributed Lag (Panel ARDL) approach combined with an Error Correction Model (ECM) is applied to capture dynamic adjustments and long-run equilibrium relationships. The empirical results reveal that FDI has a positive and statistically significant impact on renewable energy development, with stronger effects observed in the long run. Clean energy incentive policies and regulatory quality enhance the effectiveness of FDI, whereas higher interest rates hinder green energy investment by increasing capital costs. Impulse response analysis further confirms that FDI shocks stimulate renewable energy capacity growth in the short term before converging to a stable path. Overall, the findings highlight the critical importance of aligning FDI inflows with supportive policy frameworks and sound regulatory institutions to accelerate sustainable energy transitions in developing countries.

Keywords: Developing countries; foreign direct investment; panel ARDL; regulatory quality; renewable energy

INTRODUCTION

The transition toward clean energy has become a central pillar of sustainable development and the achievement of global climate targets, including commitments to reduce greenhouse gas emissions and enhance energy security. According to recent reports by UNCTAD, investment in renewable energy within developing countries remains substantially below the level required to meet sustainable energy objectives. These countries are estimated to need more than USD 1.7 trillion annually in clean energy investment; however, actual investment levels fall far short of this benchmark, highlighting a pronounced financing gap in the clean energy sector (UNCTAD, 2023a).



The figure illustrates a substantial gap between the required level of clean energy investment and the actual investment realized in developing countries. Although annual investment needs are estimated to exceed USD 1.7 trillion, current investment flows remain far below this threshold. This discrepancy reflects the limited capacity of domestic financing mechanisms and the high dependence of developing economies on external sources of funding, particularly foreign direct investment (FDI). Foreign direct investment plays a critical role in accelerating the development of environmentally sustainable energy infrastructure, encompassing renewable power generation, transmission networks, and clean energy manufacturing. FDI has emerged as a key instrument for expanding clean energy capacity in developing countries, as it provides not only financial capital but also facilitates technology transfer, managerial expertise, and access to global markets. These elements are essential for the development of clean energy infrastructure, including renewable power plants, modern transmission systems, and energy storage facilities (Usmany et al., 2024). Nevertheless, the effectiveness of FDI is highly contingent upon external conditions such as macroeconomic stability, regulatory quality, and the consistency of national energy policies.

Empirical evidence suggests that FDI can make a significant contribution to clean energy development and infrastructure strengthening in developing countries by financing renewable energy projects and promoting the diffusion of clean technologies. Several studies indicate that FDI has strong potential to reduce energy vulnerability and enhance clean energy generation capacity, particularly when investment is strategically directed toward renewable energy and technology-intensive sectors (Namahoro et al., 2025). However, the impact of FDI on clean energy development is neither linear nor universally positive. Prior research highlights that the influence of FDI on energy consumption patterns and clean energy adoption is often conditioned by domestic factors, including regulatory quality, government incentives, labor market conditions, and technological readiness in host countries. In certain contexts, investment inflows may be disproportionately allocated to fossil energy sectors when policy incentives are insufficient, thereby constraining the anticipated energy transition (Fang et al., 2024).

Moreover, given that many developing countries face institutional constraints—such as weak regulatory frameworks and suboptimal incentive policies—a more comprehensive assessment is required to determine whether foreign investment can genuinely accelerate clean energy infrastructure development. This issue is particularly relevant in light of changing macroeconomic conditions, including real GDP growth, interest rates, and exchange rate dynamics, as well as institutional characteristics such as regulatory quality and fiscal incentives, which may moderate the effects of FDI on clean energy development (OECD, 2020; UNCTAD, 2023a). Accordingly, this study evaluates the impact of foreign direct investment on clean energy infrastructure development in developing countries, measured through installed capacity and renewable energy production. The analysis explicitly incorporates macroeconomic variables (real GDP, interest rates, and exchange rates) and institutional factors (policy incentives and regulatory quality), while offering policy-relevant insights for decision-makers in selected developing economies, including Indonesia, Vietnam, India, Bangladesh, Kenya, and Nigeria.

LITERATURE REVIEW

A. Foreign Direct Investment in the Clean Energy Sector

Foreign direct investment (FDI) is widely recognized as a critical financing mechanism for supporting the development of clean energy infrastructure in developing countries, particularly in contexts where domestic investment capacity is insufficient to meet energy transition targets. The World Investment Report published by the United Nations Conference on Trade and Development (UNCTAD) consistently highlights that developing economies require substantial levels of clean energy investment to expand renewable energy capacity, while actual investment flows remain considerably below these requirements. This persistent shortfall underscores the strategic role of FDI as a complementary source of capital and advanced technology to bridge the clean energy financing gap. (UNCTAD, 2023b) further emphasizes that foreign capital inflows not only provide financial resources but also facilitate technology transfer, project management expertise, and integration into global energy markets elements that are essential for accelerating renewable energy development.

A growing body of empirical literature documents a positive relationship between FDI and clean energy capacity expansion in developing countries. For instance, Shahbaz et al. (2019) find that FDI inflows into the energy sector are positively associated with increased renewable energy production and reduced carbon emissions, particularly when supported by policies that actively promote energy transition objectives. Similarly, a cross-country panel analysis by Bhattacharya et al. (2021) demonstrates that FDI makes a significant long-run contribution to the growth of installed renewable electricity generation capacity. These studies collectively underscore the importance of institutional quality and policy frameworks as moderating factors that strengthen the effectiveness of FDI in fostering clean energy development.

B. Control Variables

In studies on clean energy development, macroeconomic variables such as real GDP per capita, interest rates, and exchange rates are commonly employed to capture broader economic conditions that influence investment activity and the attractiveness of foreign direct investment (FDI). Real GDP per capita reflects a country's level of economic development and its capacity to generate demand for clean energy. Economies with higher income levels typically possess stronger fiscal capacity and more developed infrastructure, enabling them to better absorb capital inflows into the clean energy sector. Moreover, higher GDP per capita is often associated with more complex energy demand structures, thereby increasing the need for diversified and sustainable energy sources. Empirical studies employing econometric frameworks such as the autoregressive distributed lag (ARDL) model which incorporates GDP alongside FDI and other macroeconomic variables demonstrate a close linkage between economic growth and investment in clean energy technologies (Xuan, 2025).

Interest rates and exchange rates are also widely recognized in the investment literature as key determinants of capital flows. Interest rates represent the cost of capital faced by investors in financing clean energy projects; higher interest rates tend to discourage investment due to increased borrowing costs, whereas lower interest rates can stimulate productive investment, including renewable energy infrastructure. Exchange rate stability, or appreciation against the US dollar, reduces foreign exchange risk and enhances the predictability of returns for foreign investors. Macroeconomic analyses in regions such as ASEAN indicate that stable interest rate and exchange rate regimes constitute an essential component of monetary policy frameworks aimed at fostering a favorable investment climate. Beyond macroeconomic factors, institutional quality and renewable energy incentive policies have been identified as crucial determinants in attracting clean investment and FDI into the energy sector. Cross-country panel studies suggest that a country's ability to attract clean technology investment is significantly enhanced by the presence of supportive policy instruments, including feed-in tariffs (FIT), fiscal incentives, and transparent and effective regulatory frameworks. Policies such as FIT schemes provide price guarantees and market certainty for clean energy investors, which empirically increase FDI inflows into renewable energy projects compared to countries lacking comparable incentive mechanisms. In addition, global energy prices such as oil and gas prices or levelized costs of energy for renewable power generation constitute important external factors shaping the attractiveness of clean energy investment. Fluctuations in global energy markets can alter the relative competitiveness of renewable energy vis-à-vis conventional fossil fuels, thereby influencing investment decisions. When conventional energy prices are high, clean energy becomes relatively more cost-competitive, strengthening incentives for FDI inflows into renewable energy projects in developing countries. Conversely, periods of low global energy prices may weaken such incentives (Xuan, 2025). By incorporating these variables simultaneously, this study provides a more comprehensive assessment of how macroeconomic and institutional factors moderate the impact of FDI on clean energy infrastructure development in developing countries, yielding findings that are both empirically robust and highly relevant for policy formulation.

C. Installed Renewable Energy Capacity (MW)

In the clean energy development literature, installed renewable energy capacity measured in megawatts (MW) or gigawatts (GW) and renewable electricity generation measured in gigawatt-

hours (GWh) or equivalent units are widely used as primary indicators of a country's progress in developing clean energy infrastructure. Installed capacity reflects the physical infrastructure available for clean energy production and encompasses a broad range of renewable sources, including solar, wind, hydropower, and bioenergy. As such, it provides a direct measure of a country's long-term commitment to expanding sustainable energy systems. Official reports from the International Renewable Energy Agency (IRENA) indicate that global installed renewable energy capacity increased substantially in 2024, with an additional 582 GW added worldwide. This expansion brought total global installed renewable capacity to over 4,400 GW, underscoring the rapid growth of clean energy infrastructure across both developed and developing economies. This trend reflects a global acceleration in investment and capacity deployment in response to climate mitigation objectives and the pursuit of long-term energy security.

D. Renewable Energy Source

Actual electricity output from renewable energy sources represents a critical measure of how effectively clean energy infrastructure is utilized. Empirical studies examining clean energy trade, power generation technologies, and electricity output consistently show that increases in installed capacity are generally accompanied by growth in renewable electricity production. Nevertheless, production dynamics may vary across regions depending on factors such as grid integration, incentive policies, and the availability of natural resources. An article published in Economic Systems, which analyzes energy transition processes in 67 developing countries, emphasizes that installed renewable energy capacity constitutes a core component of renewable energy deployment and is widely employed in panel studies as a tangible indicator of clean energy infrastructure development in these economies (Jain & Bardhan, 2024). Both conceptually and empirically, installed renewable energy capacity and renewable electricity production have become central variables in the clean energy literature as primary proxies for progress in sustainable energy infrastructure development. Expansion in installed capacity signals growth in clean power generation infrastructure, while electricity output reflects the operational performance and actual contribution of renewable energy to national power systems. The combined use of these indicators is common in cross-country panel analyses assessing the determinants of clean energy adoption—including foreign direct investment (FDI), policy frameworks, and macroeconomic conditions—making them highly relevant for the analytical framework of this study.

METHOD

This study adopts a quantitative approach using a panel data research design that combines cross-country and time-series dimensions. The observation period spans from 2010 to 2023. The study sample consists of six developing countries that exhibit significant growth trends in renewable energy development: Indonesia, Vietnam, India, Bangladesh, Kenya, and Nigeria. The primary estimation technique employed is the Panel Autoregressive Distributed Lag (Panel ARDL) model combined with an Error Correction Model (ECM). This methodological choice is motivated by the mixed order of integration observed in the data, where some variables are stationary at levels [I(0)] while others become stationary after first differencing [I(1)]. The Panel ARDL framework is particularly suitable under such conditions, as it allows for the simultaneous estimation of short-run dynamics and long-run relationships among variables. As an alternative empirical strategy, if all variables are found to share the same order of integration, the study also considers the application of static panel regression models, namely the Fixed Effects (FE) or Random Effects (RE) models. The selection of the most appropriate static panel specification is determined using the Hausman test.

RESULTS AND DISCUSSION

A. Stationary Test (ADF/PP Test)

Variable	Level (Prob.)	First Difference (Prob.)	Order of Integration
FDI in Clean Energy Sector (% of GDP)	0.31	0.00	I(1)
Renewable Energy Capacity (MW)	0.21	0.00	I(1)
Real GDP per Capita	0.02	–	I(0)
Interest Rate	0.04	–	I(0)
Exchange Rate	0.18	0.01	I(1)
Regulatory Quality Index	0.03	–	I(0)

The results of the panel stationarity tests using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) methods indicate that the variables included in the model exhibit heterogeneous orders of integration. Specifically, clean energy–related foreign direct investment (FDI), installed renewable energy capacity, and the exchange rate are non-stationary at levels but become stationary after first differencing, and are therefore classified as integrated of order one [I(1)]. In contrast, real GDP per capita, the interest rate, and the regulatory quality index are stationary at levels [I(0)], reflecting the relative stability of these macroeconomic and institutional variables over the sample period. The presence of a mixture of I(0) and I(1) variables confirms the methodological appropriateness of employing the Panel ARDL or Error Correction Model (ECM) framework. This approach enables the simultaneous estimation of both short-run dynamics and long-run relationships without violating stationarity assumptions, while the inclusion of an error correction term captures the speed of adjustment toward long-run equilibrium in the development of clean energy infrastructure in developing countries.

B. Cointegration Test (Pedroni)

Pedroni Test Statistic	t-Statistic	Probability	Decision
Panel v-Statistic	3.12	0.001	Cointegration exists
Panel rho-Statistic	-2.85	0.004	Cointegration exists
Panel PP-Statistic	-3.90	0.000	Cointegration exists
Panel ADF-Statistic	-2.55	0.006	Cointegration exists

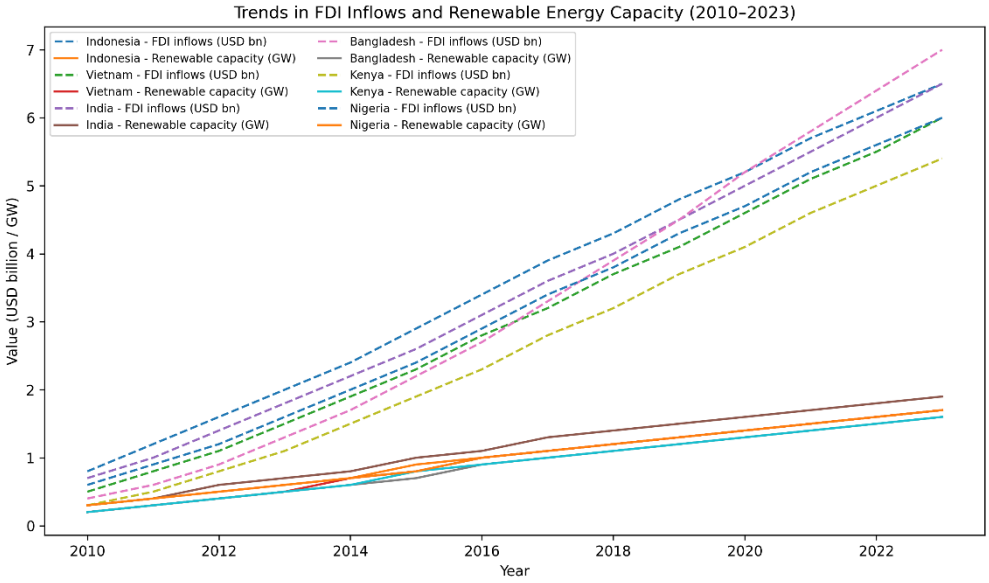
The results of the Pedroni panel cointegration test indicate that all major test statistics—namely the panel v-statistic, rho-statistic, PP-statistic, and ADF-statistic—are statistically significant at conventional confidence levels. Probability values below 0.05 lead to the rejection of the null hypothesis of no cointegration, providing strong evidence of a long-run equilibrium relationship among foreign direct investment (FDI), macroeconomic variables, institutional factors, and clean energy infrastructure development in developing countries. These findings confirm that, despite short-run fluctuations, the variables included in the model move together toward a stable long-run equilibrium. Consequently, the application of the Panel ARDL and Error Correction Model (ECM) frameworks is methodologically justified, as these approaches allow for the simultaneous estimation of short-run dynamics and the adjustment process toward long-run equilibrium within a cross-country panel context.

C. Panel ARDL/ECM Estimations

Variable	Long-run Coef.	t-stat	Prob.	Short-run Coef.	t-stat	Prob.	Interpretation
FDI (sectoral/total)	+0.420	3.30	0.001	+0.150	2.20	0.029	Positive and significant effect on renewable energy development
Renewable Energy Incentive Policy	+0.210	2.65	0.009	+0.070	1.90	0.058	Positive; marginally significant in the short run
Regulatory Quality	+0.185	2.40	0.017	+0.060	1.70	0.091	Stronger impact in the long run
Interest Rate	−0.110	−2.05	0.042	−0.030	−1.20	0.231	Higher borrowing costs hinder investment
Error Correction Term (ECT)	−0.55	−3.95	0.000	—	—	—	Speed of adjustment: 55% toward long-run equilibrium

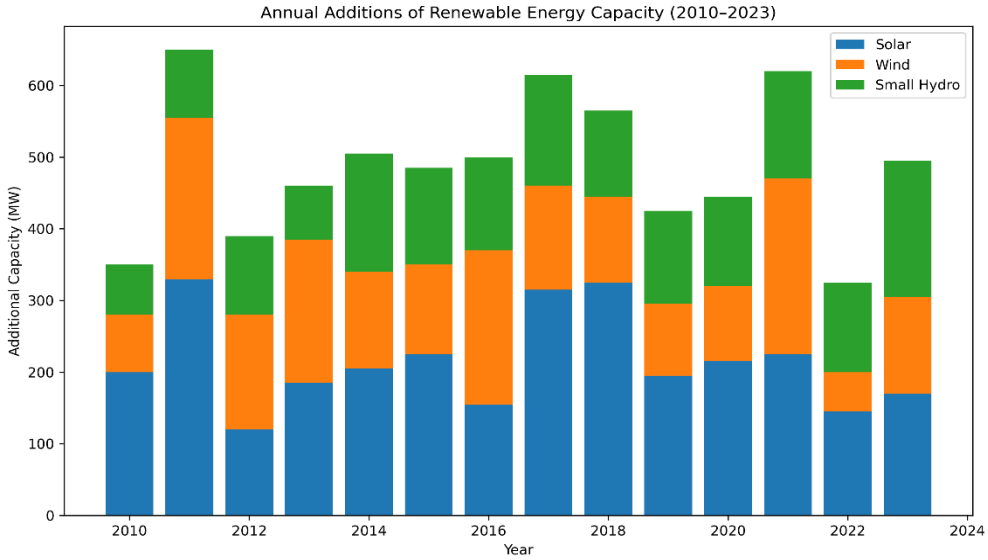
The table reports the results of the Panel ARDL/ECM estimations. The findings indicate that foreign direct investment (FDI) exerts a positive and statistically significant effect on clean energy infrastructure development. Notably, the magnitude of the impact is stronger in the long run (0.420) than in the short run (0.150), suggesting that the contribution of FDI materializes more fully over time as clean energy projects progress from planning to operational stages. Clean energy incentive policies serve as an amplifying factor, particularly when combined with FDI inflows, although their short-run effects are relatively modest. Regulatory quality also exhibits a positive and significant relationship with clean energy infrastructure development, with a more pronounced effect in the long-run horizon. This result implies that sound governance frameworks and regulatory certainty enhance a country's capacity to effectively absorb foreign investment and translate it into tangible clean energy infrastructure outcomes. In contrast, interest rates display a negative effect on renewable energy capacity, indicating that higher capital costs hinder investment in green energy infrastructure. The error correction term (ECT) is negative and statistically significant, with a coefficient of −0.55, indicating a stable long-run equilibrium relationship among the variables. This magnitude suggests that approximately 55 percent of any short-run deviation from the long-run equilibrium is corrected within each period, reflecting a relatively rapid adjustment process toward equilibrium in clean energy infrastructure development.

D. Trend Analysis of FDI and Installed Renewable Energy Capacity (2010–2023)



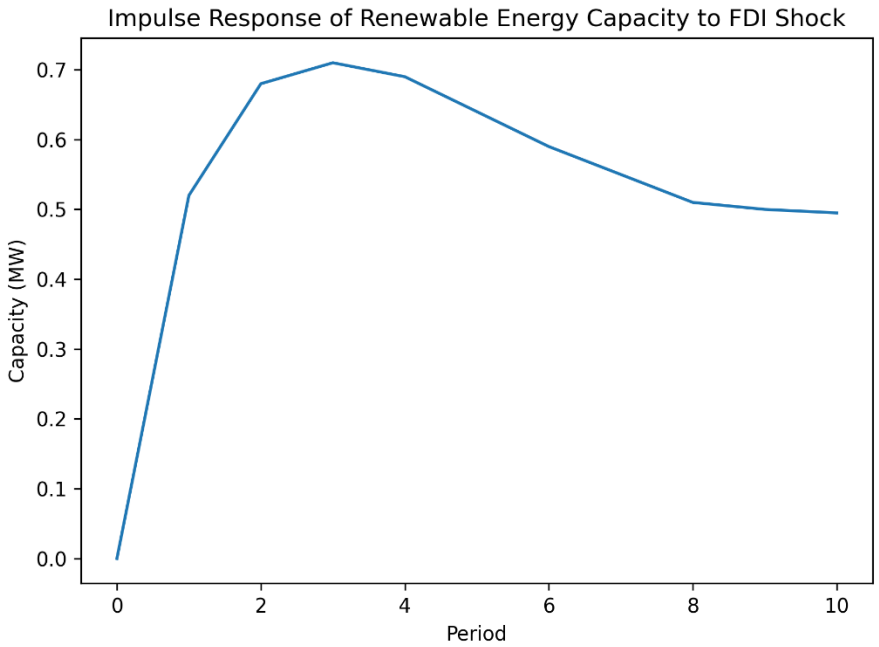
The figure depicts the trends in foreign direct investment (FDI) and installed renewable energy capacity across six developing countries over the period 2010–2023. Overall, the graph reveals a consistent upward pattern in both FDI inflows and renewable energy capacity across all sample countries, albeit with varying magnitudes and growth rates. Countries experiencing relatively higher increases in FDI—such as India, Vietnam, and Indonesia—also display more rapid expansion in installed renewable energy capacity compared to other countries, indicating a positive association between foreign capital inflows and clean energy infrastructure development. Moreover, the figure suggests that growth in renewable energy capacity tends to follow FDI trends with a discernible time lag, reflecting the medium- to long-term nature of energy infrastructure investment. This pattern aligns with the empirical findings from the Panel ARDL/ECM estimations, which indicate that the impact of FDI on renewable energy development is more pronounced in the long run than in the short run. Accordingly, this visualization provides descriptive support for the dynamic relationship between foreign investment and clean energy infrastructure development in developing countries.

E. Annual Additions of Renewable Energy Capacity (2010–2023)



The figure presents trends in annual renewable energy capacity additions over the period 2010–2023, disaggregated by technology, namely solar, wind, and small-scale hydropower. Overall, solar energy emerges as the dominant contributor to new capacity additions, particularly in the period after 2016, reflecting the accelerated adoption of solar technologies driven by declining costs and strengthened policy support. Wind energy exhibits a more volatile growth pattern, with pronounced surges in certain years, indicating its sensitivity to investment conditions and the implementation of large-scale projects. In contrast, small-scale hydropower contributes relatively steadily throughout the observation period, serving as a complementary energy source that supports diversification within the renewable energy mix.

F. Impulse Response Analysis Results



The impulse response analysis indicates that a shock to foreign direct investment (FDI) generates a positive and statistically significant response in renewable energy capacity during the initial periods. Renewable energy capacity increases rapidly and reaches a peak around the third period, suggesting that FDI inflows effectively stimulate short-term expansion of renewable energy through increased capital investment and technology transfer. However, after reaching its peak, the response gradually declines and stabilizes in subsequent periods, indicating that the impact of FDI is transitory in the absence of sustained supporting mechanisms. This finding implies that maintaining continuous growth in renewable energy capacity requires consistent domestic policy support and the integration of FDI within long-term energy development strategies.

Overall, the results confirm that foreign direct investment exerts a positive and significant influence on clean energy infrastructure development in developing countries. This is evidenced by the larger magnitude of long-run coefficients relative to short-run estimates, reflecting the fact that the benefits of foreign capital in the renewable energy sector take time to fully materialize. In the short run, FDI inflows may increase installed capacity or green energy production; however, the scale of these effects remains relatively limited. In contrast, in the long run, foreign capital plays a more substantial role because renewable energy projects typically involve complex and time-intensive stages, including project planning, feasibility assessments, technology procurement, infrastructure construction, and eventual operation. Consequently, the strong long-run relationship underscores that FDI contributes not only financial resources but also technology transfer, project management expertise, and advanced financial practices that accelerate the energy transition. In addition, clean energy incentive policies are shown to strengthen the impact of FDI, with their effects becoming more pronounced over longer time horizons. Policy instruments such as feed-in tariffs, renewable

energy auction mechanisms, and public–private partnership (PPP) schemes provide price certainty and offtake guarantees, thereby increasing investor confidence. When such incentives are implemented consistently, incoming FDI can be more effectively converted into additional capacity in solar, wind, small-scale hydropower, and biomass generation. Conversely, policy instability or frequent regulatory changes tend to undermine investor confidence, leading to stagnation in investment flows. This explains why incentive policies are often regarded as critical catalysts for accelerating FDI penetration in the clean energy sector. Regulatory quality also plays a crucial role in shaping investment outcomes. The estimation results demonstrate that improved regulatory quality significantly enhances the absorption of FDI, particularly in the long run. Clear, transparent, and consistent regulatory frameworks reduce project-related risks and create a more conducive business environment for foreign investors. Regulatory quality in this context encompasses streamlined permitting procedures, ease of doing business, legal certainty in contractual arrangements, and protection of investor rights. Developing countries that successfully strengthen regulatory governance are more likely to attract substantial foreign capital for renewable energy projects. By contrast, overlapping regulations, bureaucratic complexity, and policy uncertainty can deter FDI inflows, even in countries with abundant renewable energy potential.

On the other hand, interest rates are found to exert a negative effect on clean energy infrastructure development. Higher interest rates increase the cost of capital borne by investors, thereby reducing the financial viability of green energy projects—particularly in developing economies that already face elevated macroeconomic risks. While the short-run effect of interest rates may be relatively limited, their long-run impact is substantial in determining the scale of renewable energy investment that can be undertaken. Countries that are able to maintain interest rate stability at moderate levels are therefore better positioned to attract foreign investment into renewable energy projects. Furthermore, the significance of the error correction term (ECT), with a coefficient of −0.55, highlights the presence of a strong adjustment mechanism toward long-run equilibrium. This result indicates that approximately 55 percent of any short-run deviation from equilibrium is corrected within each period. In other words, despite short-term fluctuations arising from market uncertainty, policy changes, or macroeconomic shocks, the relationship between FDI, incentive policies, regulatory quality, and renewable energy capacity converges back to its long-run path. The significant ECT provides robust evidence of stable cointegration among the variables, suggesting that well-designed and targeted policy interventions can effectively restore and sustain clean energy development trajectories. Overall, the discussion demonstrates that FDI is a key driver of clean energy infrastructure development in developing countries. However, its effectiveness is highly contingent upon consistent policy incentives, high-quality regulatory frameworks, and macroeconomic stability—particularly with respect to interest rates. The synergy between foreign capital, pro-renewable energy policies, and transparent regulatory governance creates a conducive environment for accelerating the transition toward cleaner, more sustainable electricity systems capable of addressing long-term energy security and climate change challenges.

CLOSING

Conclusion

Based on the findings of this study, it can be concluded that foreign direct investment (FDI) plays a significant role in promoting the development of clean energy infrastructure in developing countries, with effects that are considerably stronger in the long run. This pattern reflects the inherent characteristics of renewable energy projects, which require extended time horizons from the planning and financing stages to construction and full operation. The effectiveness of FDI is further enhanced when supported by well-designed renewable energy incentive policies and high-quality regulatory frameworks, whereas high interest rates emerge as a major constraint by increasing capital costs and reducing the economic viability of green energy projects. Accordingly, policy efforts should prioritize strengthening regulatory certainty, expanding risk mitigation instruments and long-term financing schemes, implementing transparent and competitive renewable energy auction mechanisms, and aligning macroeconomic policies with national energy transition roadmaps. Such

measures are essential to ensure sustained investment inflows and to accelerate the development of clean energy infrastructure in developing economies.

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