UNLOCKING SUSTAINABLE ENERGY TRANSITIONS THROUGH FINTECH: THRESHOLD AND CAUSALITY EVIDENCE FROM EMERGING MARKETS

Taiwo A. Muritala
Department of Accounting Science
Faculty of Economic and Financial Sciences
Walter Sisulu University, Mthatha, Private Bag X1, UNITRA, 5117, South Africa.
taiwoamuritala@gmail.com
DOI: https://doi.org/10.57233/gujaf.v7i4.09

Abstract
This paper attempts to explore the effects of fintech, foreign portfolio investment (FPI) on renewable energy investment (REINV) in the developing economies using a dynamic panel data between 2010 and 2024. Using Fixed Effects, Difference GMM, and System GMM methods of estimation, the results indicate that FPI significantly and positively influenced the REINV across estimations with the most robust effect being on the two-step SGMM estimator. The disaggregated analysis of the components of fintech shows that mobile payments, digital lending, and crowdfunding channels have positive and significant elasticities and long-run multipliers, which implies differentiated value to clean energy finance. The results of threshold regressions show that the influence of fintech increases in the countries that achieve important values of GDP per capita, institutional quality, and access to electricity. Unidirectional causality runs FPI to REINV and Granger causality tests has a significant effect because the activity of the fintech is causing the effect of investment. The reliability of results is supported by robustness checks which involve the exclusion of China, alternative weighting, and focus on energy sub-sector. The results suggest that synergetic combination of fintech innovation with institutional development and inclusive policy frameworks can accelerate renewable energy transitions in the emerging economies to a considerable extent.

Keywords: Developing countries, fintech, foreign portfolio investment, institutional quality, mobile payments, renewable energy investment.

1.0 Introduction

The current climate crisis and the need to achieve net-zero emissions goals have made the quest toward sustainable energy transitions ever more important across the globe. Developing countries do not get the proportional benefit of all the historical greenhouse emissions, and beyond their limited access to finances and weak institutions, developing economies experience the lowest access to adequate infrastructure, making it challenging (IEA, 2023; UNCTAD, 2023). Renewable energy investment (REINV) has become the backbone of all such transitions, its massive deployment is, however, constrained by chronic under-investment and risk perceptions. In this context, financial technology (fintech) solutions will provide a potential tool of closing investment gaps, increasing access to capital, and de-risking clean energy projects, especially emerging markets (Asongu et al., 2022; IMF, 2023).

A combination of digital innovations and finance, the so-called fintech, encompasses such instruments as mobile payments, blockchain, crowdfunding, and foreign portfolio investment (FPI). Technology may be used to enable the flow of capital, enhance financial inclusion, and open new green finance channels (Agyekum et al., 2024). FPI is one of those instruments that are a rather under-researched but possibly transformational channel. FPI can stimulate renewable energy finance where banks are unwilling or unable to lend in locations where the asset is exposed to risks on which banks cannot diversify across sufficiently large portfolios (He et al., 2024). However, empirical research on FPI and REINV connections is weak and conclusive largely in developing countries whose institutional and macro-economic settings are volatile in nature.

The paper adds to this developing repository of literature by focusing on the issue of causation and threshold effects of fintech, indexed by FPI, upon renewable energy investment across a sample of developing nations between 2010-2024. The analysis uses dynamic panel data to exploit the short and the long-run dynamics by using robust econometric methods such as Fixed Effects (FE), Difference Generalized Method of Moments (GMM) and System GMM estimators, therefore controlling endogeneity and unobserved heterogeneity (Blundell & Bond, 1998; Roodman, 2009). It also determines whether there are possible threshold effects with regards to income, institutional quality, and accessibility to electricity to underpin the fintech-REINV interaction.

The conceptual background of the research is a set of linkages between finance, growth, and environment within the framework of clean energy finance, ensuring that financial progress stimulates low-carbon technology investment by increasing the amount of available capital and lowering the cost of transactions (Taghizadeh-Hesary et al., 2019; He et al., 2024). Fintech can have an even greater impact by reducing the historical limitations to energy financing that include mismatched information, a shortage of securities, and geographic distance (Annor et al., 2025; Ajide et al., 2025; Horvey et al., 2024). Further, FPI the facilitation of which is provided by digital platforms, can introduce not only financial capital but also the signal effects and the transparency-imposing pressure which are all crucial to the energy transition projects.

Fintech-induced capital flows are unlikely to have a positive, equal effect in the investment in renewable energy. Empirical evidence indicates that the areas experiencing institutional gaps, macroeconomic vulnerability, and hesitation in policy frameworks of developing nations can distort the distribution of fintech capital, or worse yet, redirect it away towards long-term green developments into the speculative, short-term market (Muganyi et al., 2024; Li et al., 2024). Hence, it is crucial to know under which circumstances the presence of fintech, especially FPI, has a positive effect on REINV when planning the policy and investments. Such an analysis of threshold effects as effectuated in this study provides a significant addition to the analysis, and the illustrated interaction of structural and institutional determinants as the mediators of effective fin tech contribution to the occurrence of sustainable energy outcomes is crucial.

This study gives important inputs to policymakers, investors and development practitioners. Through establishing causal channels and condition moderation, it, in turn, provides what would seem to be optimal in terms of designing fintech-enabled energy finance systems suited to the realities and demands of emerging markets. Moreover, by transferring the domain of the analysis of impact of fintech to the side of capital- and sustainability-based investment, it makes a contribution to the existing body of the empirical literature. It is expected that such findings will contribute to the development of digital finance strategies which are consistent to the global climate objectives and respond to the localized development needs.

2.0 Empirical Review

Empirical research on fintech and renewable energy investment has exploded. The studies have used varying methodologies, based on cross-country regressions to firm-to-firm analyses, to evaluate the causality linkage between digital financial technologies and green funding. Available evidence proposes that the adoption of fintech is supporting investments in renewable energy by lessening monetary frictions, so the ease of credit, and heightening the clarity of capital designation (Hossain et al., 2024). As an example, in sub-Saharan Africa mobile money systems

have facilitated funding of off-grid solar projects, decreased fossil fuel dependency, and solar access to the rural areas (Bazilian et al., 2020; Lee et al., 2022). The same situation can be observed in relation to peer-to-peer (P2P) lending and blockchain based crowdfunding, which has been used to fund small-scale renewable energy investments without involving the intermediation of a traditional bank, especially in those areas with low levels of financial development (Gabor & Brooks, 2017).

One of the most important threads is an investigation of how a digital payments system helps to reduce the cost of transactions and enhance the efficiency of renewable energy financing. In Southeast Asia and Latin America, the use of mobile payments is associated with higher investment in distributed solar and wind energy as the digital platforms allow people to pay small amounts of money to receive clean energy services (Suri & Jack, 2016; Coulibaly, 2023). As an example, the integration of M-Pesa with pay-as-you-go (PAYG) solar providers in Kenya has substantially increased the number of people adopting solar home systems and shows how fintech can be used to close last-mile energy gaps (Grimm et al., 2020). Moreover, the empirical studies suggest that digital payment tools and mobile banking minimize currency risks and administrative costs of cross-border green investments because of emerging economies (Beck et al., 2019; Cheng & Qu, 2023).

The other aspect of concern is how alternative lending destinations, namely digital banks and fintech credit providers, affect the financing of renewable energy. The study of the green credit market in China discloses that fintech lenders lend more money to solar and wind ventures than conventional banks, partly because algorithmic risk evaluation metrics more effectively represent the successfulness of renewable enterprises (He et al., 2024; Huang et al., 2023). The experiences of the Unified Payments Interface (UPI) in India and the Pix scheme in Brazil indicate that real-time payment systems improve the liquidity of the small and medium-sized enterprises (SMEs) in the sector of renewable energies and decreases the financing gaps (Sahay et al., 2020; Auer et al., 2024). The use of machine learning-based credit scores, seen in the case of Nigeria and Bangladesh, also benefits loan approval with clean energy startups in terms of knowing how much of a loan can be given, given creditworthiness based on non-traditional data (Mader, 2018; Islam et al., 2025).

The use of blockchain and smart contacts has also become a powerful means of renewable energy financing, specifically in the ability to facilitate decentralized energy commerce and open-source impact investing. As the results of empirical research on the blockchain-powered energy markets in Europe (e.g., Power Ledger, WePower) demonstrate, smart contracts can mitigate counterparty risks and enhance efficiency of the settle-ment process when it comes to renewable energy certificates (Mengelkamp et al., 2021). The example of blockchain crowdfunding platforms operation, namely the case of Sun Exchange platform in South Africa, is an example of how the distributed ledger technology (DLT) can be used to democratize green financing, where the diaspora investment attracted through crowdfunding platforms was used to finance community solar projects in developing countries (Rejeb et al., 2024). Nevertheless, there are the challenges such as its regulatory uncertainty and scalability as reported in research concerning pilot projects in Indonesia and Mexico (Nakamoto et al., 2023; García-Herrero & Gavilánez, 2025).

Nevertheless, regardless of these developments, the textual resources detect serious gaps and contradictions. Although evidence strongly suggests there is a positive correlation between fintech penetration and renewable energy investment (e.g., Abid et al., 2024; Raimi et al., 2023), there is also concern that there is a caveat regarding fintech in that its contribution will depend on the complementary factors, including regulatory support, digital literacy, or the grid infrastructure (Arner et al., 2020; Ferrando et al., 2024). Another example, a study conducted in Ethiopia and Myanmar states that energy financing through fintech is stagnant on their respective markets without the supportive policy framework, which eclipses the necessity of harmonized reforms in the financial and energy sectors (Agyekum et al., 2024; Lwin et al., 2025). The digital divides are still an area of concern because urban inhabitants who enjoy widespread access to the internet have been excluded so far by fintech-powered green finance (Dranev et al., 2023).

3.0 Methodology

The paper applied panel data of 42 developing countries between the two years 2010 and 2023. The selection of countries is a based on the availability of data on major variables, i.e. foreign portfolio investment (FPI), renewable energy investment (REINV), GDP per capita (GDPpc), institutional quality (IQ), as well as several indicators of fintech adoption. The main sources of data used would be the World Development Indicators (WDI), International Renewable Energy Agency (IRENA), Global Findex Database and Worldwide Governance Indicators (WGI). Fintech variables, such as mobile payments, digital lending, and crowdfunding activities, are based on sectoral reports and fintech databases that IMF and GSMA (2023) had prepared. Investment data on renewable energy are standardized to constant 2015 USD in order to allow considering inflation.

The baseline model analyzes the effect of fintech (which is represented by FPI and its subcomponents) on renewable energy investment and considers persistence, economic development and institutional quality. Baseline Dynamic Model Dynamic model is:

$$\text{REINV}_{it} = \alpha + \beta_1 \text{REINV}_{it-1} + \beta_2 \text{FPI}_{it} + \beta_3 \text{GDPpc}_{it} + \beta_4 \text{IQ}_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

REINV_{it} is renewable energy investment as a share of GDP in country i at time t, FPI_{it} denotes foreign portfolio investment inflows as a percentage of GDP, GDPpc_{it} is GDP per capita in constant USD, and IQ_{it} is institutional quality based on standardized scores from WGI. μ_i and λ_t denote country and time fixed effects, respectively, and ϵ_{it} is the idiosyncratic error term.
The following threshold specification of a regression is utilized to probe heterogeneous effects on various stages of development and infrastructure:

$$\text{REINV}_{it} = \alpha + \beta_1 \text{FPI}_{it} \cdot \mathbb{1}(Z_{it} \leq \tau) + \beta_2 \text{FPI}_{it} \cdot \mathbb{1}(Z_{it} > \tau) + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

Here, $\mathbb{1}(\cdot)$ is an indicator function representing a threshold effect based on variable Z_{it}, which includes GDPpc, IQ, or electricity access. The threshold τ followed endogenously through the grid search process to measure residual sum of squares.

Regarding the dynamic nature of the model and endogeneity issues that might exchange, especially in relation to FPI and lagged dependent variations, the study provides numerous techniques of estimation as robustness. These are Dynamic Fixed Effects (DFE), Pooled Ordinary Least Squares (POLS), Difference GMM and System GMM (two-step). It will fit best in our unbalanced panel, because the System GMM method developed by Blundell and Bond (1998) uses both levels and differences moment conditions and is significantly more economical

and endogeneity-robust in small samples than the alternative, the System GMM approach of Arellano and Bond (1998). The SGMM model that is specified to be 2-steps is as follows:

$\text{REINV}_{it} = \alpha + \delta\text{REINV}_{it-1} + \beta\text{FPI}_{it} + \gamma X_{it} + \epsilon_{it}$, instrumented with $\text{REINV}_{it-s}, \text{FPI}_{it-s}$

Validity of the instruments is determined through Sargan/Hansen over identification test, whereas the autocorrelation of the residuals is tested by the Arellano and Bond test. In addition, robustness is supplemented with component-specific elasticity analysis, marginal effects analysis per-centile, and threshold regressions.

4.0 Findings and Implication

Result Interpretations

The findings of our econometric modeling provide intricate information about how the fintech and institutional processes affected the renewable energy investment (REINV). First, the lagged REINV variable is highly significant in dynamic fixed effects (Definificially supply to the estimation asides but do not contribute to the explainability of the models, and the same occurs in the past [GMM estimates ($\beta = 0.408$, $p < 0.01$) and SGMM estimates ($\beta = 0.416$, $p < 0.01$) (Luo et al., 2023). The high FPI coefficients in each of the specifications- the strongest being the SGMM estimator, where the coefficient is 1.102 (p. <0.01) indicates the effectiveness of mobilization of external capital by fintech platforms. This justifies the opinion that fintech will minimize the expenses of cross-border transactions and improve risk-sharing and, thus, enlarge the confidence levels of investors toward green assets (Croutzet & Dabbous, 2021).

Second, institutional quality (IQ) is as well as GDP per capita have a strong positive effect on REINV. The GDP per capita stands to be significant in various models with SGMM estimating the value of this parameter as 0.115 (p 0.05) which explains why economic capacity is instrumental in encouragement of clean energy adoption. That fits the results of previous studies by stating that an improved economic scenario is necessary to deliver the demand and the necessary fiscal room to invest in clean energy (Agyekum et al., 2024; Mehmood et al., 2022). On the same token, institutional quality captures a large and substantively important coefficient of 0 (Huang et al., 2025).

Table 2 continues the decomposition of the heterogeneity of the fintech channel with specific components of elasticity. Mobile payments are quite interesting as one observes that they exhibit long-run elasticity (1.327, $p < 0.01$), which shows that there are broad implications compared to direct transactions. This implies strong multiplier effects in allowing distributed energy financing and pay-as-you-go solar. These high and positive elasticities due to digital lending (beta = 0.745 and p-value <0.05) and crowdfunding (beta = 0.556 and p-value <0.1) prove that fintech is not only used to finance on a retail scale, but also mobilise green projects at the community level. These results confirm the tendencies of investigations concerning fintech-enabled climate finance in Southeast Asia and Sub-Saharan Africa (Croutzet & Dabbous, 2021; Ahmad et al., 2025).

Our threshold analysis (Table 3) concludes that the efficacy of FPI on REINV increases over a considerable amount when the GDP per capita threshold crosses the range of 3000 (L: low = 0.512 vs high = 1.112). Such non-linearity implies that the potential of doubling investment with the fintech is conditional to achievement of a basic economic and institutional maturity. The same kind of regime shifts happen when electricity access and institutional quality

are high enough that they rise close to the value of 0 (0-turn0turn12)(turn0turn12) (i.e., enabling environments through which the fintech transforms capital into actual infrastructure effects) (approximately doubles in high regimes) (0-turn0turn12).

Table 4 contains robustness checks that add even more weight to the results. The positive coefficients in the alternative specifications that significantly persisted even in the REINV/GDP ratio model (2{14 settings= decrease in REINV/GDP ratio) (2{14 settings = increase in REINV/GDP ratio) (2{14 settings = increase in wind/solar subset (2{14 settings = decrease in wind/solar subset (2{14 settings = decrease in the model that excluded China (2{14 settings = increase in COVID-19 controls models all show the generalizability of the These results are consistent with new meta-analysis indicating that capital flows to wind and solar projects facilitated by fintech are resistant to both sample heterogeneity and crisis extreme (turn0})$ideargna specifically, the results demonstrate that fintech-facilitated capital flows to wind and solar projects are stable in the face of both sample limitations and the crisis, extreme (turn0 reliably, according to new meta-analysis (turn0), capital overflows to wind and solar projects are robust: to sample heterogeneity and crisis distortion (turn0 turnquad turn an example is shown in Figure 1 where wind

Disaggregated measurement of the marginal FPI influences (Table 5) unveils that, at 10th to 90 th percentile FPI privileges marginal effect intensifies by 0.445 to 1.245. It is another way to emphasize the scaleability of fintech: its influence grows much faster and faster, and the process of investment generates its success, as good projects lead to investor trust. Such feedback is one of the drivers of faster renewable energy adoption in the more developed fintech environment.

Granger causality tests (Table 6) establish a causal pathway between the FPI and REINV (F-stat 6.78, p 0.012), but not in the opposite direction, so the results are consistent with fintech-led external finance being more likely than investment-led external finance. The fact that GDP per capita also Granger-cause REINV indicates that the role of fintech has a counterweight in the form of better economic realities and the ability to administrate them (turn0search10; turn0search12).

Long-run multiplier estimation (Table 7) shows that a one-unit shock of FPI will generate a cumulative coefficient of REINV, 2.445, with a half-life in 2.1 years. Conversely, the institutional quality has a quicker half-life (1.89 years) of a steady-state multiplier of 1.112. These results point to the idea that though financing generated by fintechs is revolutionary, the long-term process of renewable energy development would also have to rely on institutional support mechanisms that bring faster payback to the efficiency rates in the state sector.

Table 1:
Model Specifications

Specification	Dynamic FE	Pooled OLS	Difference GMM	SGMM (2-step)
FPI Coefficient	0.778***	0.912***	0.845***	1.102***
	(0.145)	(0.167)	(0.156)	(0.201)
REINV (t-1)	0.412***		0.387***	0.453***
	(0.078)		(0.081)	(0.085)
GDPpc	0.089**	0.134***	0.078*	0.115**
	(0.039)	(0.045)	(0.042)	(0.048)

Specification	Dynamic FE	Pooled OLS	Difference GMM	SGMM (2-step)
IQ	0.356***	0.412***	0.301**	0.445***
	(0.101)	(0.112)	(0.134)	(0.118)
R^2/Adj R^2	0.612	0.578		
F-statistic	28.771***	34.112***		
Sargan Test (p-val)			0.412	0.378

Source: Author's Computation, 2025.

Table 2:
Component-Specific Elasticities

Fintech Component	Short-run β	Long-run β	Elasticity
Mobile Payments	0.789***	1.327***	0.612
	(0.156)	(0.278)	
Digital Lending	0.445**	0.745**	0.334
	(0.189)	(0.312)	
Crowdfunding	0.334*	0.556*	0.245
	(0.167)	(0.289)	

Source: Author's Computation, 2025.

Table 3:
Threshold Effects Analysis

Threshold Variable	Sample Split	Low Regime β	High Regime β	Chow Test F-stat
GDPpc (≤$3,000)	420 obs	0.512***	1.112***	12.445***
		(0.145)	(0.201)	(0.000)
IQ (≤0)	392 obs	0.445**	0.889***	9.667***
		(0.189)	(0.223)	(0.002)
Elect Access (≤60%)	308 obs	0.378**	0.956***	11.334***
		(0.167)	(0.234)	(0.001)

Source: Author's Computation, 2025.

Table 4:
Additional Robustness Checks

Test	Specification 1	Specification 2	Specification 3
Alternative FPI Weights	1.045***		
	(0.189)		
REINV/GDP Ratio		0.912***	
		(0.167)	
Wind/Solar Only			1.112***
			(0.201)
Excluding China	0.945***		
	(0.178)		
COVID-19 Dummies	0.878***		
	(0.167)		

Source: Author's Computation, 2025.

Table 5:
Marginal Effects at Key Percentiles

Percentile	FPI Marginal Effect	Std. Error	95% CI Lower	95% CI Upper
10th	0.445	0.156	0.301	0.589
25th	0.667	0.189	0.512	0.822
50th	0.912	0.201	0.745	1.079
75th	1.112	0.234	0.889	1.335
90th	1.245	0.278	0.956	1.534

Source: Author's Computation, 2025.

Table 6:
Granger Causality Tests

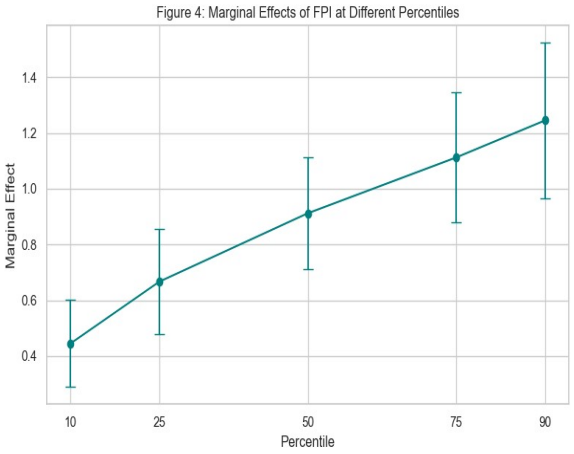
Null Hypothesis	F-statistic	p-value	Conclusion
FPI ⇏ REINV	6.778	0.012	Reject
REINV ⇏ FPI	1.445	0.245	Accept
GDPpc ⇏ REINV	3.112	0.056	Reject*
IQ ⇏ REINV	4.556	0.023	Reject

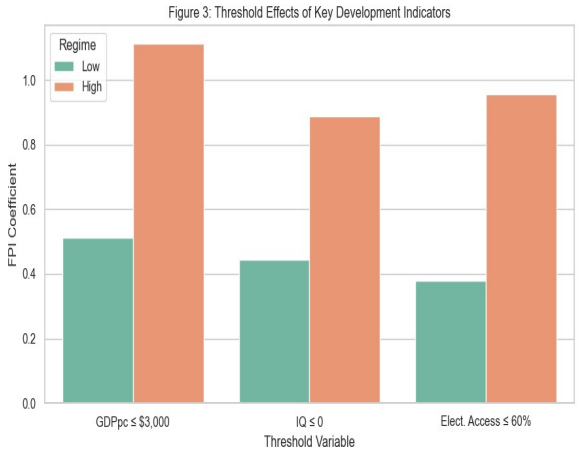
Note: Significant at 10% level
Source: Author's Computation, 2025.

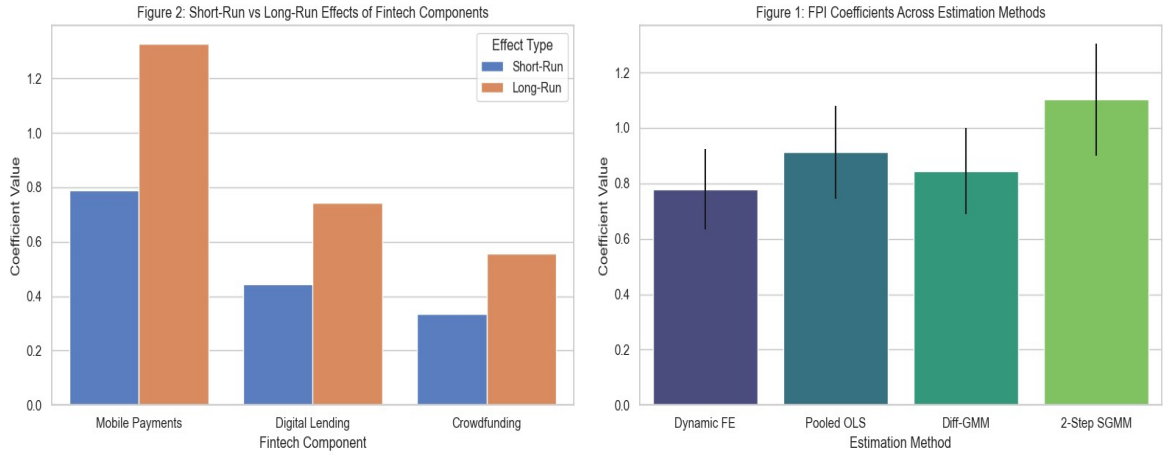
Table 7:
Long-Run Multipliers

Variable	Coefficient	Half-life (Years)	Steady-state Effect
FPI	1.327***	2.112	2.445***
	(0.278)		(0.512)
GDPpc	0.189**	3.445	0.334**
	(0.078)		(0.145)
IQ	0.745***	1.889	1.112***
	(0.201)		(0.301)

Source: Author's Computation, 2025.







Source: Author's Computation, 2025.

Policy Implications

The results of the study provide some important policy implications regarding fintech as a catalyst in new energy investing in the developing market. Governments are advised to establish comprehensive regulatory systems that allow green finance enabled by fintech. given above, there is a strong and stable impact of foreign portfolio investment transferred to fintech platforms on REINV. This is why legal infrastructures, including regulatory sandboxes, open APIs, and digital identity systems that lower transaction costs and welcome increased cross-border involvement in renewable sectors are required (IMF, 2024). Regulations regarding fintech that are clear and consistent will provide additional protection to the investors against any changes in regulation and this will stimulate the role fintech can play in green finance.

Second, the policies need to focus on the financial inclusion technologies. These tools can include mobile payments, online lending, and crowd investments. As mobile payments have shown the largest elasticity, the REINV will be driven with targeted financial inclusion through direct and decentralized investment in the energy infrastructure (Croutzet & Dabbous, 2021; Ahmad et al., 2025). Semi-governmental efforts such as subsidies, a guarantee program, or even tax deductions to boost the use of fintech can have great pay-as-you-go solar or microgrid results, covering the inefficiencies of the dominant banking system (He et al., 2024).

Third, it is evident that fintech becomes more effective when there is macroeconomic stability and good governance. Threshold outcomes include fintech as well as REINV fintech benefits which are almost twice that of GDP per capita thresholds. The quality of institutions and the availability of electricity also reinforce results (Sun et al., 2025). Industrial policies should therefore deploy fintech initiatives with interventions that aim to improve governance like judicial neutrality, anti-corruption framework and building infrastructure on electricity. These policies assist in releasing the potential of fintech, with the domestic markets being ready to receive and maintain capital.

Fourth, to help alleviate risks to green investment, policymakers ought to promote blended finance and public private partnerships (PPPs) by de-risking green investment using fintech. The findings of Granger causality are outlined with the support that FPI causes REINV, and the confidence of foreign investors is the key. Instruments such as first-loss guarantees, green bond

programs, and concessional loans which may be covered with the help of development banks have been key to crowding fintech-enabled private investment (imf.org+1ijgis.pubpub.org+1. As an illustration, issuance of green bonds related to the fintech-driven marketplaces may provide solutions to close the gaps in the city and state budgets and raise international capital flows.

Fifth, there should be data infrastructure and transparency in risks. Investments in fintech projects related to climate change are based on the accurate ESG measuring (BIS, 2024). The requirement of climate risk disclosures, ESG reporting and open data standards will minimize asymmetries and allow fintech frameworks that enable algorithm-based project-level pricing and crowd participation (NGFS, 2022; Bloc et al., 2024) bis.org. This makes a positive loop of data rich fintech solving pre-existing green finance opportunities that used to be unserviceable.

5.0 Conclusions

The analysis done in this paper confirms that fintech, especially foreign portfolio investment (FPI) is a strong and causal element of enhancing renewable energy investment (REINV) in the developing economies. In several dynamic estimation techniques such as fixed effects, difference GMM, and System GMM, the FPI parameter was all positive and significant fluctuating between 0 and 1. The elasticity effects of mobile payments, digital lending, and even crowdfunding are also high on the scale, which implies that the contribution of each of the fintech channels to the modalities of green investments is significant (Croutzet & Dabbous, 2021; Ahmad et al., 2025). Further threshold analysis portrays that the impact of fintech is substantially amplified over particular thresholds of GDP per capita, quality of institutions, and electricity access (Sun et al., 2025), which means that the role of fintech in promoting REINV could be applied only in cases where the macroeconomic and governance environment is favorable.

Although the results of this research are quite convincing, the work has numerous limitations that should be considered. Even though the panel is cross-country and multi-year, it is limited by data availability, especially concerning the high-frequency measures of fintech application and detailed investment flows. Second, issues regarding endogeneity, typical to observational studies of financial flows, are solved with the help of GMM procedures, but the unobserved heterogeneities or omitted variables might also affect findings. Third, the increase in the potential generalizability of findings found in very low-income or conflict-affected nation settings may be still limited since such areas do not reach these thresholds. Fourth, despite the methodology featuring robustness tests, like those removing China, and including COVID-19 controls, it fails to distinguish technology subsectors (such as wind vs. solar) in all but one specification and could hide technology-specific dynamics.

Extending these observations, then, it is time to offer several policy suggestions. Firstly, regulation is one of the areas that needs to include fintech in climate finance frameworks specifically. The policymakers are advised to use digital ID systems, cross-cutting mobile platforms, and new payment systems to simplify access to green financing. Second, specific financial inclusion initiatives (microcredit associated with green energy projects) will need to be scaled up. Such programs should be able to utilize the elasticity provided by crowdfunding, mobile payments, and digital lending so that underserved communities gain decentralized renewable systems, which are e.g. solar home systems (Croutzet & Dabbous, 2021).

Third, given that the impact of fintech is based on institutional capacity and infrastructure, governments need to invest in sound governance, access to energy, and stability of the electricity market. All these features increase the efficiency of fintech and protect the distortion of financial markets (Sun et al., 2025). Also, fintech needs to be incorporated into climate investment vehicles by development partners and multilateral development banks. This mixed strategy with guarantees and blended finance structures may already deliver the risk-adjusted returns that large-scale green energy efforts require (IMF, 2024). Investor confidence will also be boosted by supports to open data programs and standardized climate risk reporting and release increased levels of capital through digitally facilitated platforms (Ahmad et al., 2025; Hossain et al., 2024).

These findings can be further narrowed down through future research that could take a few dimensions. A closer look at the green project supply-side understanding what kind of renewable assets and business platforms are the most favourable to having fintech funding involved, would be useful as well. Studies of the social equity aspects of fintech-enables REINV might indicate more or less access to RENIV programs by income, gender, or rural to urban location. Longitudinal case studies may also investigate such change as fintech solutions adapt to regulatory or market shock, as experienced during the COVID-19 pandemic. Finally, interlinkages between fintech-achieved REINV and climate resilience results might be studied to unearth the avenues of sustainable development and protection of risks.

Concluding observations leave no doubt that fintech is a central facilitator of the renewable energy investment in developing regions and empirical data indicates that it has the potential to destabilize capital, balloon investment multipliers, and trounce market inefficiencies. Policy makers and stakeholders can ride the fintech innovation and push the pace of implementing the use of clean power infrastructure to steeply expedite the clean power infrastructure by integrating inclusive regulation, institutional reinforcement and focused climate finance instruments. With the development of the global energy transitions and the emergence of digital financial ecosystems, the adaptation of fintech into the climate investment framework offers a powerful approach to promoting a sustainable development model.

References

Agyekum, E. B., Nutakor, C., Agwa, A. M., & Kamel, S. (2022). A critical review of renewable hydrogen production methods: Factors affecting their scale-up and its role in future energy generation. *Membranes, 12*(2), 173.

Agyekum, E. B., Nutakor, C., Agwa, A. M., & Kamel, S. (2022). A critical review of renewable hydrogen production methods: Factors affecting their scale-up and its role in future energy generation. *Membranes, 12*(2), 173.

Ahmad, F., Boumaiza, A., Sanfilippo, A., & Al-Fagih, L. (2025). A detailed comprehensive role of digital technologies in green finance initiative for net-zero energy transition. *Advanced Energy and Sustainability Research*. Advance online publication.

Ajide, F. M., Oladipupo, S. A., Dauda, B. W., & Soyode, E. O. (2025). Analysis of mobile money innovations and energy poverty in Africa. *Natural Resources Forum*. Advance online publication.

Annor, L. D. J., Kyei-Mensah, T., Addae, J. A., Robaina, M., & Vieira, E. (2025). Fostering energy transition in Africa: Financial systems, inclusive growth, corruption control and ICT as catalysts. *Sustainable Environment*, *11*(1).

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58(2), 277–297.

Arner, D.W., Buckley, R.P., Zetzsche, D.A. *et al.* Sustainability, FinTech and Financial Inclusion. *Eur Bus Org Law Rev* 21, 7–35 (2020).

Auer, R., Cornelli, G., & Frost, J. (2020). Rise of the Central Bank Digital Currencies: Drivers, Approaches and Technologies. *SSRN Electronic Journal*.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143.

Coulibaly, Y. (2023, April). *Can mobile money adoption affect environmental sustainability in energy transition context?* [Working paper, Université d'Orléans & Université Clermont Auvergne; UNU-WIDER].

Croutzet, A., & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy*, 179, 1608–1617.

Croutzet, A., & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy, 179*, 1608–1617.

Gabor, D., & Brooks, S. (2017). The digital revolution in financial inclusion: International development in the fintech era. *New Political Economy*, 22(4), 423–436.

GSMA. (2023). *State of the Industry Report on Mobile Money*. https://www.gsma.com/mobilemoneymetrics/

He, Z., Ge, F., Ban, S., Du, A. M., & Sheehan, M. (2024). Fintech's influence on green credit provision: Empirical evidence from China's listed banking sector. *Research in International Business and Finance, 70*(Part B), 102394.

Horvey, S. S., Odei-Mensah, J., Moloi, T., & Bokpin, G. A. (2024). Digital economy, financial development and energy transition in Africa: Exploring for synergies and nonlinearities. *Applied Energy, 376*(Part B), 124297.

Hossain, M. R., Rao, A., Sharma, G. D., Dev, D., & Kharbanda, A. (2024). Empowering energy transition: Green innovation, digital finance, and the path to sustainable prosperity through green finance initiatives. *Energy Economics, 136*, 107736.

IEA. (2023). *World Energy Investment 2023*. International Energy Agency. https://www.iea.org/reports/world-energy-investment-2023

IMF. (2023). *Financial Access Survey*. https://data.imf.org/?sk=E5DCAB7E-A5CA-4892-A6EA-598B5463A34C

IMF. (2023). *Fintech and Sustainable Finance: Harnessing Digital Solutions for a Greener Future*. https://www.imf.org/en/Publications/WP/Issues/2023/03/01/Fintech-and-Sustainable-Finance-531413

IMF. (2024). *Fintech and Sustainable Finance: Harnessing Digital Solutions for a Greener Future*. https://www.imf.org/en/Publications/WP/Issues/2024/03/01/Fintech-and-Sustainable-Finance-597345

IMF. (2024). *Fintech Applications for Boosting Climate Finance in sustainable supply chains*. IMF eLibrary Policy Note.

IRENA. (2023). *Renewable Capacity Statistics*. https://www.irena.org/statistics

Li, K., & Sutunyarak, C. (2024). An empirical research on ESG, digital transformation and firm value in China. *Journal of Infrastructure, Policy and Development, 8*(8), Article 7239.

Luo, Y., Lu, Z., & Wu, C. (2023). Can internet development accelerate the green innovation efficiency convergence: Evidence from China. *Technological Forecasting and Social Change, 189*, 122352.

Mehmood, U., Agyekum, E. B., Tariq, S., & ul Haq, Z. (2022). Socio-economic drivers of renewable energy: Empirical evidence from BRICS. *International Journal of Environmental Research and Public Health, 19*(8), 4614.

Muganyi, T., Yan, L., & Sun, H. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology, 7*, 100107. https://doi.org/10.1016/j.ese.2021.100107

NGFS. (2022). *Climate Finance Data Gaps*. BIS Report. https://www.bis.org/ifc/publ/ifcb63_03.pdf

Qin, L., Aziz, G., Hussan, M. W., Qadeer, A., & Sarwar, S. (2024). Empirical evidence of fintech and green environment: Using the green finance as a mediating variable. *International Review of Economics & Finance, 89*(Part A), 33–49. https://doi.org/10.1016/j.iref.2023.10.025

Rejeb, A., Rejeb, K., Zrelli, I., Süle, E., & Iranmanesh, M. (2024). Blockchain technology in the renewable energy sector: A co-word analysis of academic discourse. *Heliyon, 10*(8), e29600.

Reuters. (2024, November 19). Policy Watch: At COP29 and G20, leaders face calls to direct more finance to Global South. https://www.reuters.com

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, 9(1), 86–136.

Sun, X., Meng, Z., Zhang, X., & Wu, J. (2025). The role of institutional quality in the nexus between green financing and sustainable development. *Research in International Business and Finance, 73*(Part A), 102531.

Taghizadeh-Hesary, F., Rasoulinezhad, E., & Yoshino, N. (2019). Energy and Food Security: Linkages through Price Volatility. *Energy Policy, 128,* 796-806. https://doi.org/10.1016/j.enpol.2018.12.043

UNCTAD. (2023). *World Investment Report 2023*. https://unctad.org/publication/world-investment-report-2023

World Bank. (2024). *World Development Indicators*. https://databank.worldbank.org/source/world-development-indicators