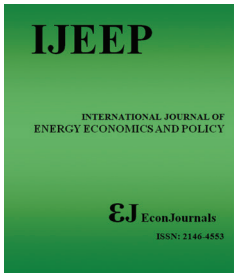

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Green Finance and Renewable Energy in Emerging Markets: Exploring the Roles of Financial Development

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ABSTRACT

The high economic potential of emerging economies is expected to experience a surge in energy demand owing to high economic activity. This increase is closely linked to population growth and rising per capita energy consumption, as shown in advanced countries. However, this trend is likely to lead to environmental degradation with reliance on fossil fuels, whose use has a devastating impact on living conditions through the environment. This is the scenario that makes the renewable energy option more appropriate. The study mainly examined how green finance affected renewable energy in 21 emerging economies from 2010 to 2022, taking into consideration the different structures of financial development, markets, and institutions. The empirical results showed that both TSLS and FMOLS analyses confirmed that only having more green finance commitments is not enough to drive progress in renewables due to poor regulation. Green finance also worked well with financial development, financial markets, and the institutions involved, resulting in positive and significant effects, meaning that financial development is needed to support green finance to deliver a more effective impact on renewable energy. On the policy side, emerging economies need efforts to promote green finance as well as improve the financial system.

Keywords: Green Finance, Financial Development, Renewable Energy, Emerging Economies, Panel Analysis
JEL Classifications: Q2, Q5, O13

1. INTRODUCTION

The issue of renewable energy is gaining prominence across the globe, more so in the developing nations where the problem of climate change, energy security, and sustainable growth are paramount concerns. India, as an emerging country example, is a rapidly growing country both economically and in population, thus increasing the consumption of energy and carbon dioxide (CO_2) emissions. To this end, there is a need to resort to renewable ones like wind, solar, and hydropower (Samant et al., 2020). The above scenario is not drastically different in the case of other emerging economies that frequently experience excessive dependence on fossil fuels, resulting in environmental issues and increased susceptibility to energy market changes (Alofaysan et al., 2024). Even if renewable energy does not entirely solve the burden of imported fuel, it will stabilize the foreign exchange rate and job creation (Deka et al., 2023). However, infrastructural limitations and financial constraints are often the predominant inhibitors of renewable energy in emerging nations and those that are growing economically with environmental responsibility.

To this end, commitments to green finance, green bonds, specialized environmental loans and government environmental expenditures, are seen as innovative financial initiatives that also support large-scale renewable energy (Shaheen et al., 2024; Chen et al., 2023; Soltani, 2024). Dependence on these green financing schemes does not just facilitate the sustainable energy transitions but also enhances financial sector development by promoting the creation of specialized financial instruments (Mavlutova et al., 2023; Nepal et al., 2024a). This is based on the grounds that green finance addresses the capital constraint required for making renewable energy investments (Shaheen et al., 2024; Tsai, 2024), but this can be made possible when the financial system is developed to the extent that green finance has more

access to private and public funds that have been dedicated to renewable energy initiatives (Mavlutova et al., 2023; Grumann et al., 2024; Subramaniam and Loganathan, 2024). Under a developed financial system, we expect, at least either the financial markets or institutions, to deliver effective financial services that also involve sustainable investment plans and lending operations (Chen et al., 2024; Yadav et al., 2024). Besides, green finance also benefits from the high institutional quality that birthed financial development (Osman et al., 2025). These premises make financial development structures a significant requirement for green finance to be effective in impacting the advancement of renewable energy.

Despite the promising financial support available for advancing renewable energy, emerging countries continue to struggle with many difficulties that keep them from advancing sustainable energy. To further complicate the challenge of the transition to renewables, emerging economies are faced with energy poverty, poor regulatory environment, and developmental challenges (Habiba and Xinbang, 2022; Prempeh et al., 2024b). This situation causes the underutilization of abundant renewable resources like solar and wind which require overcoming regulatory and infrastructural deficits to increase energy supply (Van Nguyen, 2024; Tanchangya et al., 2023). Even though emerging countries like China have demonstrated how policy support is important to renewable energy development, poor technological innovation can hinder successful renewable energy transitions (Nepal et al., 2024a), as such successes remain uneven across other emerging economies. While many studies have evidentially shown how green finance supports renewable energy growth (Alharbi et al., 2023; Tsai, 2024; Khemnar and Pandey, 2024), some studies identified that green finance requires supporting frameworks, like institutional efficiency and financial, to deliver the expected impact (Chen et al., 2024; Grumann et al., 2024). With the undeveloped financial sector in emerging economies which can impede renewable energy (Van Nguyen, 2024; Alshagri et al., 2024), there is need to examine how enhancing financial development in emerging economies has been to the green finance-renewable energy link, considering that financial development is also an enabler of renewable energy.

Assessing the importance of this study to renewable energy, this research looks at which aspect of financial development matters in how green finance influences renewable energy in emerging economies from a new perspective. Assessing the partnership between these two key factors helps the study fill a notable gap in earlier works and also encourages policymakers, investment and stakeholder roles by providing direct, helpful insights for promoting the move to clean energy. It is clear from the research that using well-thought-out policies in finance together with green financing methods leads to better environmental results for renewable projects. Such an approach is most needed by emerging and similar developing economies trying to manage both economic growth and protection of the environment. The formulation of social and environmental policies will be guided by the findings from this study, by encouraging sustainable investment practices and aiding efforts to fight global climate change. Thus, the study encourages changing the way renewable energy investments are managed and promoted by emphasizing the synergy between financial development and those using green finance initiatives to support sustainable development goals.

The following segments are arranged in the following order: The second segment of the study explains the concepts and theoretical foundations, the third segment is dedicated to explaining the nature of data, methodology and model, the fourth segment will treat results and their discussions, while the fifth segment concludes by outlining key findings and what they imply for policy.

2. LITERATURE REVIEW

2.1. Theoretical Framework

Renewable energy is natural energy sourced from replenishable means like wind, solar, hydro and geothermal energies (Yadav et al., 2024; Mavlutova et al., 2023; Gruman et al., 2024; Subramaniam and Loganathan, 2024). Being innovative energies, renewable energy transition in emerging economies is challenged by financial constraints that rely on how developed the financial sector of a country is, including the innovation in green finances. In this regard, the sustainability theory, in unveiling the interrelationship of financial development in how green finance influence renewable energy, explains that a well-balanced integration of economic goals with those of the environment for long-term development (Ibrahim et al., 2024). The theory advocates that financial systems must undergo restructuring to help with environmentally sustainable investments. Green finance helps set up the funding for eco-friendly and renewable projects so that environmental objectives are met, and financial development ensures the necessary capital and funds are mobilized and allocated. The synergy between financial development and green finance increases both the adoption and the efficiency of renewable energy as well as integrating more environmental goals into the financial system.

The relevant empirical studies will be looked at in two main areas: how financial development affects renewable energy and how green finance promises affect renewable energy. There will also be themes that talk about these situations.

2.2. Green Finance and Renewable Energy

There is strong proof from many studies that green finance has undoubtedly and positively affected renewable energy. Using data from 2013 to 2022, Chen et al. (2023) did a study on the evolving links between sustainable growth and renewable energy in China. The study draws the conclusion that the time-varying parameter MCMC method and VAR-SV model show that green finance, sustainable growth and renewable energy are all connected in a variety of ways. The CCEP estimate was used by Alharbi et al. (2023) to consider the way renewable energy is affected by green finance in 44 countries from 2007 to 2020. The outcome of the analysis showed that renewable energy generation is substantially affected by green finance. Tsai (2024) employed systematic data mining techniques on data from Taiwan spanning 2010 to 2023, concluding that green finance has substantially bolstered renewable energy development, a finding that aligns with Khemnar and Pandey's (2024) results for India.

Nepal et al. (2024a) looked into how new developments in renewable energy technologies were linked to green finance in China from 2010 to 2021. The difference-in-difference (DID) model showed that green funding made it much easier for new renewable energy technologies to be developed. The DOLS method was applied by Subramaniam and Loganathan to looked into how renewable energy was influenced by green finance in Singapore from 2000 to 2020. The research indicated that advancements in renewable energy production was favourably facilitated by green finance. Shi and Yu (2024) used the Using Nonlinear ARDL and 2SLS methods on the E7 countries from 1988 to 2022 to establish that insufficient green investments slow down the progress of green energy efficiency. From 1985 to 2020, Sinha et al. (2023) explored the nature of the relationship that renewable energy output has with green finance. Multivariate quantile-on-quantile regression (M-QQR) analysis revealed that the production of renewable energy was highly influenced by green finance.

Additional studies have suggested the role of many supporting financial frameworks that green finance requires to be effective. Shaheen et al. (2024) found that renewable energy development is encouraged by green finance under a favourable regulatory framework regardless of financial constraints. Thirty developing nations were studied by Chen et al. (2024) from 1990 to 2018. The GMM estimation showed that the banking sector is key to the strong relationship green finance share with renewable energy investments. Grumann et al. (2024) used various case studies and publicly available data to determine that green finance risks include financial instruments, investee enterprises, and operational issues. These uncertainties will affect how green finance exerts influence on renewable energy. This will subject emerging economies to persisting carbon emissions. By using the CS-ARDL model, Yadav et al. (2024) proved that BRICS nations can reduce carbon emissions when green finance is assisted with effective governance. The results show that renewable energy needs green finance and governance to reduce carbon emissions. Mavlutova et al. (2023) examined EU OECD green financing trends and issues in 2021 using bibliometrics. The study found that green bonds reduce carbon emissions.

2.3. Financial Development and Renewable Energy

Van Nguyen (2024) looked at Vietnam and some South Asian countries between 1970 and 2022 and found, relying on pooled OLS, FE, RE, and DOLS techniques, that financial development reduced renewable energy use, whereas foreign direct investment improved it. In the 38 Sub-Saharan Africa countries investigated by Prempeh et al. (2024b), data was observed throughout the time range of 2002-2019. The PCSE and FGLS approaches established that the improvements in renewable energy were halted by financial development. Habiba and Xinbang (2022) considered how different components of financial development relate to renewable energy and carbon emissions in 46 Sub-Saharan African countries from 1991 to 2016. They employed the system GMM and found out that, while financial development increased carbon emissions, despite that, renewable energy decreased it.

According to Soltani (2024), analyzing the transition of renewable energy in 25 countries including members of G20, established the dependence of green finance on digitalization to accelerate renewable energy. Prempeh (2023) found that Ghana's financial development supported renewable energy between 1990 and 2019 using ARDL, FMOLS, CCR, and DOLS. Thebuho et al. (2022) employed both the ARDL and NARDL approach in demonstrating that the financial development supported energy use in the long-run. Xu et al. (2023) revealed that, even though financial development possess the potential to advance renewable energy, its role to significantly reduce carbon emission was based on supportive globalization and institutional quality frameworks.

3. DATA AND ECONOMETRIC METHODOLOGY

The analysis uses yearly data from 2010 to 2023 for twenty-one emerging economies based on the appreciable green finance data that can be sourced from the international monetary fund (IMF) climate dashboard. Based on this, the countries sampled are Argentina, Chile, China, Colombia, Hungary, Russia, India, Indonesia, Malaysia, Mauritius, Nigeria, Peru, Philippines, Poland, South Africa, Thailand, United Arab Emirates, Vietnam, Mexico, Brazil and Turkey. These groups of countries are also expected to control a significant part of global production and consumption (Yadav et al., 2024). These countries also contain the EAGLEs group of countries, that were conceptualized by the Banco Bilbao Vizcaya Argentaria (BBVA) as the fastest growing economies in the world.

The time period also depends on data accessibility. The dependent variable used was the proportion of renewable energy in aggregate energy consumption. One of the main independent variables was green finance commitments, which slightly modifies the concept of green bond issuance used in earlier studies (Mavlutova et al., 2023; Khemnar and Pandey, 2024; Chen et al., 2024; Nepal et al., 2024a; Sinha et al., 2023) by adding environmental expenditure to it. According to scholars (Mavlutova et al., 2023; Shaheen et al., 2024; Chen et al., 2023; Soltani, 2024), green finance is more justified when governmental expenditure on the environment is also regarded.

In similar fashion, the second independent variable, financial development, is going to consider two variants of it: financial institutions, financial market, and aggregate financial development index. This is a modification to literature that relies on private sector credits to GDP ratio. Breaking down financial development in emerging economies into an aggregate index, financial market index and financial institutions index allow us to understand how each element uniquely influence the overall renewable energy of emerging economies (Alshagri et al., 2024). It points out problems in the expansion of financial sectors, provides chances for selective policy actions, helps carry out more exact studies and enables watchful monitoring of changes in institutions. It also helps with comparing different countries and shows that financial development is not the same everywhere in emerging countries. Table 1 provides the definitions of variables and associated sources:

Table 1: Variables and their sources

Variable	Acronym	Description	Source
Dependent variable			
Renewable energy	RENENG	Renewable energy consumption (% of total final energy consumption)	WDI
Independent variable			
Green finance commitments	GFCM	Sum of green bonds and environmental expenditures to GDP	IMF Climate Dashboard
Financial development index (aggregate)	FDVI	Aggregate index financial market and financial development	IMF
Financial market development index	FMI	Financial market development	IMF
Financial institutions development index	FNI	Financial institutions development	IMF
Control variable			
Economic growth	LNPCG	Natural log of per capita GDP	WDI
Regulatory quality	REGQ	Index of the effectiveness of of a country's regulation	WDI
Foreign direct investment	FDI	Net inflows of all foreign direct investment countries divided by GDP	WDI

Source: Compilation by Authors (2025)

In addition, we use other explanatory variables: FDI inflows as percentage of GDP, per capita income and regulatory quality. Including foreign direct investment, per capita income and regulatory quality in the analysis makes sense since they show how financial, economic and institutional changes matter for developing renewable energy in emerging economies. By depending on foreign direct investment, countries can invest in clean energy projects and benefit from technology and infrastructure since those resources are not always widely available within the country. When incomes rise, more people tend to act for the environment and have the financial means to switch to renewable energy (Belloumi and Aljazoa, 2024). When it comes to regulation, quality is the system that steers the effective and clear distribution and consumption of green funds, makes the process safer and upholds environmental protections (Yadav et al., 2024; Tsai, 2024; Chen et al., 2024; Subramaniam and Loganathan, 2024; Mavlutova et al., 2023). Aggregately, they strengthen the model by showing the key aspects that can guide green finance for renewable energy growth in emerging markets.

3.1. Model Specification

In the first instance, the study intends to look at the individual influence of green finance commitments on renewable energy under macroeconomic controls. This will inform us on the exclusive importance of green finance, particularly to renewable energy in emerging economies. The model for this is specified in equation 1:

$$RENENG_{it} = \partial_{it} + \emptyset_{1,it} GFCM_{it} + \emptyset_{j,it} K_{it} + \varepsilon_{it} \quad (1)$$

The green finance commitments (GFCM) influence the increased use of renewable energy (RENENG) by the emerging economies through the influence of financial development index (FDVI), financial market index (FMI) and financial institutions index (FNI). The specification of our empirical model is:

$$RENENG_{it} = \alpha_{it} + \beta_{1,it} GFCM_{it} + \beta_{2,it} FD_{it} + \beta_{2,it} GFCM_{it}*FD_{it} + \emptyset_{4,it} K_{it} + \epsilon_{it} \quad (2)$$

Where, the term $RENENG_{it}$ refers to renewable energy that comes out of natural, infinite sources. $GFCM_{it}$ means green finance commitments and FD represents the abbreviation of financial development. With financial development comprising of three aforementioned components, green finance commitments interacting with all these components of financial development is represented as $GFCM_{it}*FD_{it}$. K_{it} in the model is the control variable a vector; identified to be economic growth (LNPCG), regulatory quality (REGQ) and foreign direct investments (FDI). The ε_{it} and ϵ_{it} are the error terms of the first and second models, respectively.

3.2. Techniques of Model

3.2.1. Two-stage least squares (2SLS)

One effective method to investigate the relationship involving green finance, renewable energy, and financial development in emerging countries is the two-stage least squares (2SLS) approach. This is mainly because green finance and renewable energy can affect each other (Nepal et al., 2024b). Since it is common to face problems like reverse causality and missing variables in research on green finance and renewable energy, it is important to use models that can deal with these challenges. Leading from this, this study adopts the 2SLS technique. The 2SLS is an instrumental variable (IV) technique employed to resolve endogeneity issues in a given regression mode by replacing stochastic endogenous regressors with linear combinations of predetermined regressors (Osaro et al., 2024).

If Z is the set of instruments that are correlated with GFCM, FDVI, FMI, FNI and K correlated with the error terms, then the predetermined regressors in our models 1 and 2 above will be their respective lagged values. By so doing, the 2SLS estimation will be:

$$\hat{\beta}_{2SLS} = \left(X' P_Z X\right)^{-1} X' P_Z Y \quad (3)$$

Where, $\hat{\beta}_{2SLS}$ is the coefficients to be estimated by 2SLS; X is the regressors of our model; Z is the instrumental variables which are the lagged values of the regressors and satisfy the condition of being correlated with regressors and also endogeneity that is uncorrelated with the error terms; $P_Z = Z(Z' Z)^{-1} Z'$ which is the projection matrix by instruments.

3.2.2. Panel fully modified ordinary least squares (FMOLS)

Again, the FMOLS is used in panel studies because it can also handle both problems of serial correlation and endogeneity that appear in cointegration with this study panels. Cross-sectional heterogeneity is a frequent problem with panel data and the FMOLS method resolves this issue well. Doing this prevents any biases in the estimates due to differences between panel

units (Pedroni, 2001). For panel FMOLS, the coefficients in equations 1 and 2, as specified by Pedroni (2001) and Khan et al. (2019) will be:

$$\hat{\beta}_{FMOLS} = \left(\sum_{i=1}^{N} \sum_{i=1}^{T} (X_{it} - \bar{X}_i)'(X_{it} - \bar{X}_i) \right)^{-1} \left(\sum_{i=1}^{N} \sum_{i=1}^{T} (X_{it} - \bar{X}_i)'(X^*_{it} - \bar{X}^*_i) \right) \quad (4)$$

Where, Y_{it} represent renewable energy for each emerging country at time t; X_{it} is green finance commitments, financial development, and the control variables of each emerging country at time t; $\bar{X}_i$ and $\bar{Y}_i$ represent time averages for each emerging country at time t; Y^*_{it} is the transformed version of Y_{it} that accounts for endogeneity and serial correlation; N is the number of cross-section of countries; T is time periods.

4. EMPIRICAL FINDINGS

Descriptive and correlational analyses were done as preliminary procedures so that we are able to observe the primary characteristics of the data and become aware of how the variables included in the dataset associate with each other.

4.1. Descriptive Statistics

Table 2 shows the summary and statistical characteristics of the data used in the study Renewable energy had an average share of 21.77% of total energy output, yet its very broad span, from 0.10% to 86.00%, and a standard deviation almost equal to the mean revealed pronounced inequality in deployment across the sample. Green finance commitments were typically modest (mean 0.45% of GDP) but fluctuated sharply relative to their scale, while the three financial development measures clustered around similar mid-range means (0.42–0.48) but differed in dispersion: aggregate financial development (FDVI) appeared the most stable, the FMI is the most volatile, and the FNI lay between the two. Regulatory quality averaged just 0.18 on the normalized scale but spanned from −1.07 to 1.54, indicating episodes of both weak and strong governance. Foreign direct investment dominated the monetary variables in magnitude; although its mean inflow of 3.30% of GDP seemed moderate, the extreme maximum (106.43%) and minimum (−40.26%) alongside a large standard deviation underscored episodic surges as well as net disinvestments.

Renewable energy showed strong positive correlations with financial development (0.39), financial market development (0.31), financial institutions (0.39), regulatory quality (0.41), and especially per capita income (0.63), all significant at the 1 per cent level, indicating that better financial systems, improved governance, and higher income levels tend to support renewable energy expansion. Green finance commitments also correlated positively with renewable energy (0.24), financial development (0.21), and regulatory quality (0.29), suggesting that institutional and financial environments shape green investment decisions. A particularly strong relationship existed between financial development and its sub-indices, financial market index (0.91) and financial institutions index (0.88), highlighting their internal consistency.

Table 2: Descriptive statistics

Variables	Obs.	Mean	Max.	Min	SD
RENENG	252	21.77	86.00	0.10	17.96
GFCM	252	0.45	2.85	0.00	0.60
FDVI	252	0.46	0.74	0.19	0.12
FMI	252	0.42	0.74	0.18	0.15
FNI	252	0.48	0.72	0.18	0.13
REGQ	252	0.18	1.54	−1.07	0.59
FDI	252	3.30	106.43	−40.26	8.95
LNPCG	252	8.94	10.86	7.21	0.76

SD: Standard deviation

The matrix, in general, points out that renewable energy, green finance and the quality of institutions depend closely on one another and are highly shaped by wider developments in the financial sectors and income growth.

Table 4 applied four tests for cross-sectional dependence to check for connections between countries. All the variables, including renewable energy, green financing commitments and financial development indices, showed meaningful relationships among the countries. Specifically, the key Pesaran CD results for green finance (16.16), financial development measures (FDVI: 14.27, FMI: 6.29, FNI: 11.89) and renewable energy (2.20) suggest that there are links between countries or regions where policies affecting financial green sectors could potentially affect renewable energy developments. Together, these results highlighted the systemic and regionally integrated nature of financial development and green finance as crucial enablers of renewable energy transition.

Results of the test for panel unit root in Table 5 showed that aggregate financial development (FDVI), which was stationary at level, that is I(0), is the only variable, while the others became stationary only taking their first differences, making them integrated of order one, that is I(1). Renewable energy, green finance commitments, financial market development, financial institutions development, regulatory quality, foreign direct investment and per capita income were all stationary at first difference but non-stationary at level, according to their significant test statistics and P-values. This integration orders prompts the test for cointegration to further determine the appropriate estimation methods to use given the structural form of the data.

The cointegration test results in Table 6 show that the P-values of Model 1, 0.031 and Models 2 to 4, all 0.000, indicate that variables are significantly cointegrated in each model tested. It means that although they change in different orders, renewable energy, green finance commitments and financial development are still related in the long run which allows for deeper exploration and explanation of their relationship.

4.2. Estimation Results

To meet our objective, we used the two-stage least squares (TSLS) and the fully modified ordinary least squares (FMOLS) technique as robustness checks. In the TSLS method in Table 7, the regression results showed that green finance commitments (GFCM) is not

Table 3: Correlation matrix

Variables	RENENG	GFCM	FDVI	FMI	FNI	REGQ	FDI	LNPCG
RENENG	1							
GFCM	0.24***	1						
FDVI	0.39***	0.21***	1					
FMI	0.31***	0.22***	0.91***	1				
FNI	0.39***	0.16**	0.88***	0.59***	1			
REGQ	0.41***	0.29***	0.30***	0.14***	0.41***	1		
FDI	0.03***	0.11*	0.01	0.02	0.05	0.1	1	
LNPCG	0.63***	0.34***	0.33***	0.23***	0.38***	0.59***	0.1	1

***, ** and * are significant at 1%, 5% and 10%, respectively

significant to renewable energy, as reflected by the high P = 0.390. Although previous studies (Khemnar and Pandey, 2024; Tsai, 2024; Alharbi et al., 2023) agree with the enhancing effect of green finance on renewable energy, but their results disagree with this study's outcome which shows that the independent influence of green finance does not matter to renewable energy in emerging economies. Even though a number of authors, like Shi and Yu (2024), point out concerns with insufficient or minimal investments, they still highlight the generally significant positive relationship. This goes against the idea of no impact on emerging markets. Some structural and contextual differences in emerging economies can be the reason for the divergence in these results. Unlike advanced countries, the financial systems of many emerging economies are underdeveloped which might limit funds allocation to finance renewable energy projects through the available green finance instruments. Again, despite the cases where green finance are available, their volumes and implementation scales can be insufficient to deliver appreciable results for renewable energy. Lastly, emerging economies, with varying levels of structural deficiencies, will require time for green finance to fully register the required level of influence on renewable energy.

In different vein, regulatory quality (REGQ) showed a consistently strong and corrosive influence on renewable energy across in the first model, but statistically insignificant in models 2, 3 and 4. In other words, though green finance is supposed to help increase use of renewable energy, poor regulations may keep it from working as intended. Because of REGQ, if the rules or regulations are not strong, green finance may not have its full positive impact on renewable energy, so better governance systems are needed. This finding agrees with that of Mavlutova et al. (2023) who conditioned the effect of green finance commitments on the effectiveness of governance, including regulatory quality. While their study established a strong positive influence on renewable energy, our study has shown that green finance has negligible impact on emerging economies as evident in a detrimental or inadequate support of regulation. Shaheen et al. (2024) further agrees with our finding by emphasizing the importance of a supportive regulatory environment for green finance commitments. This is because effective regulations are required to protect green investors (Yadav et al., 2024; Grumann et al., 2024).

The results in Table 7 revealed a nuanced relationship involving green finance commitments (GFCM), financial development, and renewable energy, which highlights how financial development significantly moderates the relationship. In the first instance, models 2, 3 and 4 showed that when both GFCM and financial development were observed independently, they appeared to be detrimental to renewable energy in emerging economies (Van Nguyen, 2024; Prempeh et al., 2024b). This result means that either a rise in green finance or an increase in financial development alone did not promote renewables. However, the interaction terms, that is GFCM_FDVI, GFCM_FMII and GFCM_FNI, were positive and statistically significant in models 2, 3 and 4. These results also suggest that when green finance operates in the context of developed financial system, markets and institutions, it significantly enhances renewable energy outcomes (Soltani, 2024). This points out that the success of green finance depends on how well and deeply the broader financial system, markets and institutions operates. What is more, although regulations do not appear significant at 5% in models 2, 3 and 4, the result showed that the role of institutional environment is more involved with

Table 4: Cross-sectional dependence test

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
RENENG	702.04***	24.01***	23.05***	2.20**
GFCM	539.32***	16.07***	15.19***	16.16***
FDVI	847.46***	31.10***	30.23***	14.27***
FMI	427.04***	10.59***	9.72***	6.29***
FNI	805.35***	29.05***	28.17***	11.89***
REGQ	928.99***	35.08***	34.21***	1.80*
FDI	386.93***	8.63***	7.76***	0.23
LNPCG	886.39***	33.00***	32.13***	13.74***

***, ** and * are significant at 1%, 5% and 10%, respectively

Table 5: Panel second generation unit root tests

Variables	Levels		First difference		Order of integration
	Statistics	P-value	Statistics	P-value	
RENENG	−0.06	0.477	−2.45	0.007***	*I* (1)
GFCM	0.46	0.677	−8.38	0.000***	*I* (1)
FDVI	−2.68	0.004***			*I* (0)
FMI	−1.31	0.096*	−1.90	0.029**	*I* (1)
FNI	−0.92	0.180	−3.10	0.001***	*I* (1)
REGQ	1.49	0.931	−5.44	0.000***	*I* (1)
FDI	0.59	0.722	−2.02	0.022**	*I* (1)
LNPCG	1.95	0.975	−4.29	0.000***	*I* (1)

***, ** and * are significant at 1%, 5% and 10%, respectively

Table 6: Panel Westerlund cointegration test

Models	Statistics	Probability	Decision
Model 1	1.87	0.031**	Cointegrated
Model 2	6.27	0.000***	Cointegrated
Model 3	6.12	0.000***	Cointegrated
Model 4	6.68	0.000***	Cointegrated

***, ** and * are sig. at 1%, 5% and 10%, respectively

Table 7: 2SLS estimation

Variables	Model 1	Model 2	Model 3	Model 4
REGQ	−2.65***	0.55	−0.68	−1.82*
	(0.007)	(0.789)	(0.744)	(0.058)
FDI	0.004	0.43	0.43	0.001
	(0.835)	(0.424)	(0.427)	(0.959)
LNPCG	−4.09	−13.27***	−13.73***	−3.28***
	(0.001)	(0.000)	(0.000)	(0.003)
GFCM	0.44	−17.94**	−10.95*	−5.42**
	(0.390)	(0.035)	(0.071)	(0.011)
FDVI		−36.54***		
		(0.001)		
GFCM_FDVI		32.74**		
		(0.032)		
FMI			−0.26.59***	
			(0.001)	
GFCM_FMI			2.086**	
			(0.050)	
FNI				−18.98***
				(0.000)
GFCM_FNI				10.20***
				(0.009)
Constant	58.58***	156.49***	154.93	60.67***
	(0.000)	(0.000)	(0.000)	(0.000)
R-sq.	0.99	0.42	0.41	0.99
Adj. R-sq.	0.98	0.4	0.39	0.98
F-statistics./ probability	461.71***	29.08***	27.79***	637.10***

***, ** and * are sig. at 1%, 5% and 10%, respectively

Table 8: Robustness checks: FMOLS estimation

Variables	Model 1	Model 2	Model 3	Model 4
REGQ	−2.34***	−0.82***	−1.35***	−0.82*
	(0.000)	(0.007)	(0.001)	(0.057)
FDI	−0.00004	0.001	0.001	0.001
	(0.961)	(0.874)	(0.913)	(0.871)
LNPCG	−4.39***	−2.11***	−1.96***	−1.88***
	(0.000)	(0.000)	(0.000)	(0.000)
GFCM	−0.22	−4.06***	−2.31***	−5.44***
	(0.343)	(0.000)	(0.001)	(0.000)
FDVI		−8.38***		
		(0.000)		
GFCM_FDVI		7.58***		
		(0.000)		
FMI			−0.97	
			(0.521)	
GFCM_FMI			4.24***	
			(0.001)	
				−19.90***
				(0.000)
				10.41***
				(0.000)
R-sq.	0.99	0.98	0.98	0.98
Adj. R-sq.	0.98	0.97	0.97	0.98

***, ** and * are sig. at 1%, 5% and 10%, respectively

a developed financial sector, even when the broader regulatory structures are insignificant.

This study also established that green finance needs the support of strong financial system, markets and institutions to positively impact on expanding renewable energy in emerging economies. Previous studies also support this finding, specifically Chen et al. (2023) who mentioned that advancing the financial industry can boost renewable energy use and promote green initiatives. Likewise, Mavlutova et al. (2023) and Shaheen et al. (2024) demonstrated how green finance investors are able to overcome the financial hurdles when the capital market is developed and advanced. Nevertheless, although Van Nguyen (2024), Prempeh et al. (2024b) and Yadav et al. (2024) supported that financial development reduces renewable energy use, they highlight that regulatory effectiveness in the financial sector, and not the economy, can change the adverse relationship financial development and green finance have with renewable energy in emerging economies. Grumann et al. (2024) specifically looked at the regulations and innovations in Europe and indirectly support the findings of this study by mentioning how green finance assists growth in well-established financial markets.

The FMOLS results shown in Table 8 showed that both green finance promises (GFCM) and financial development had adverse impacts on renewable energy use. When they interacted together, that is GFCM_FDVI, GFCM_FMI, and GFCM_FNI, their influences reversed to become supportive in the four estimated models. This informs a favourable synergy between green finance and the developed financial system, markets, and institutions, which substantially boost renewable energy outcomes. As a result, green finance measures have a stronger effect on renewable energy when financial systems, markets and institutional infrastructures are well-developed, most likely leading to more capital, risk control and better investment decisions. Additionally, the significance of regulatory quality in FMOLS (negative and significant) reaffirms that institutional foundations can constrain green finance effectiveness unless accompanied by sound governance.

The evidence that solid financial institutions play a positive role in advancing renewable energy in emerging economies agrees with other studies. Chen et al. (2024) noted that the banking industry is vital for green finance and that having solid banking policies is associated with having quality institutions that align with financing green projects. In addition, Sinha et al. (2023) found that developed financial markets are the basis for how impactful green finance is, and once again supporting the premise that strong institutions matter for the best outcomes of green finance. Further, government effectiveness also makes green finance more helpful for sustainability along the argument that better institutions can eliminate the adverse effect in the financial sector. Nepal et al. (2024a) and Soltani (2024) further confirmed this by illustrating that proper development in finance and green finance increases opportunities for renewable energy technologies and attracts financial support. Besides, Subramaniam and Loganathan (2024) and Shi and Yu (2024) pointed out that improved financial systems help encourage renewable energy, mainly by backing up investment attraction with fintech in emerging economies.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Emerging economies, primarily made up of countries with very high potential to develop economically, are expected to experience a surge in energy demand owing to high economic activities on

account of growing per capita energy use from an increasing population. However, this trend is likely to lead to environmental degradation with reliance on fossil fuels, whose use has a devastating impact on living conditions through the environment. This is the scenario that makes the renewable energy option more appropriate. Renewable energies, like wind, solar, and hydro, have been discovered to be more environmentally friendly than fossil fuels. This is the main motivation for this study.

The empirical results showed that committing more funds through green finance instruments alone is not enough to drive progress in renewables. An ongoing problem is that poor regulations get in the way of renewables success. Green finance also worked well with financial development, financial markets and the institutions involved, resulting in positive and significant effects, meaning that financial development is needed to support green finance deliver more effective impact on renewable energy. They point out that with well-developed financial services, it becomes easier to grow by accessing capital, handling risks and deciding on investments which can help the field of green finance succeed. Although data quality made the economy more stable, strong public administration was still needed due to issues with regulatory quality. It is clear that how well green finance supports renewable energy relies substantially on the quality of institutions and the maturity of financial markets.

5.2. Policy Recommendations

It showed that just making green finance commitments was not useful for raising renewable energy use, mainly because poor regulations tended to have a significant negative impact. Therefore, policymakers ought to give top priority to improving governance and regulatory systems to allow green finance to succeed. Since foreign direct investment and per capita income do not help much and remain negative, it is important to make specific regulations for the renewable energy sector to prevent resources from running into problems caused by the economy or existing institutions. Hence, developing new policies in the financial sector depends on strengthening institutions.

Besides, the favourable impact of the interaction of financial development and green finance proves that the effectiveness of green finance products is closely tied to how developed the domestic financial system is. Efforts to promote green finance should go hand in hand with steps to improve the financial markets and institutions to direct such funds into investments in renewable energy. By improving these systems, more funds can be invested in green projects and risks can be shared more effectively which can strengthen the confidence of investors. Practicing green finance must be supported by coordination with sound laws and the ongoing development of the financial system.

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