Anusandhanvallari
Vol 2024, No.1
July 2024
ISSN 2229-3388

Unlocking Green Capital: The Role of Sustainable Financial Development in the Renewable Energy Transition of Emerging Markets

Manasvi Chaudhary

Research Scholar, The Northcap University

Abstract: Climate-related risks and environmental pressures are becoming increasingly difficult to ignore, pushing financial systems toward more sustainable approaches. This study looks at how green finance (GF) relates to sustainable development (SD) across seven emerging economies between 2010 and 2023. To deal with issues such as endogeneity and the dynamic nature of environmental outcomes, a Two-Step System Generalized Method of Moments (GMM) approach with Windmeijer-corrected standard errors is applied.

The results point to a clear pattern. Instruments such as green bonds and environmental funds are associated with improvements in sustainability, largely through their role in expanding renewable energy use and lowering carbon intensity. At the same time, the effect is not uniform across countries. It appears to depend quite strongly on the level of financial development (FD).

In economies with more developed financial systems, green investments tend to produce stronger environmental outcomes. This suggests that financial development plays an enabling role, shaping how effectively green finance translates into real-world impact. Taken together, the findings highlight the need to align green finance initiatives with broader financial sector improvements, particularly in emerging markets where institutional conditions vary widely.

Keywords: Green Finance, Sustainable Development, System GMM, Financial Development, Emerging Markets, Interaction Effect.

1. Introduction

1.1 Background of the Study

Environmental degradation and climate change have moved from being long-term concerns to immediate global challenges. Rising carbon emissions, increasing energy demand, and resource depletion are already shaping economic outcomes and policy priorities across both developed and developing economies. The urgency of these issues was formally recognized by the United Nations in 2015, which emphasized that climate change represents a present and systemic risk rather than a distant threat.

In response, financial systems are undergoing a gradual but important shift. There is growing recognition that financial decision-making cannot remain detached from environmental consequences. This shift has contributed to the emergence of green finance as a key component of sustainable economic planning.

Green finance refers to the allocation of financial resources toward activities that support environmental sustainability. It includes instruments such as green bonds, sustainability-linked loans, and carbon pricing mechanisms. Unlike conventional finance, which often prioritizes short-term returns, green finance incorporates long-term environmental considerations into investment decisions. In doing so, it attempts to align capital flows with broader ecological objectives, particularly the transition toward low-carbon and resource-efficient economies.

1.2 The Imperative of Green Finance in Emerging Markets

Emerging markets occupy a central position in the global sustainability debate. These economies are experiencing rapid industrialization, urbanization, and energy consumption growth, making them key drivers of global economic expansion. At the same time, they account for a significant and growing share of global carbon emissions.

A substantial portion of energy consumption in these countries continues to rely on fossil fuels, largely due to cost considerations and existing infrastructure. This creates a structural challenge. While economic growth remains a priority, there is increasing pressure to transition toward cleaner and more sustainable development pathways.

However, this transition is not straightforward. Emerging economies often face constraints such as limited financial depth, weaker institutional frameworks, and higher investment risks. These factors can restrict access to capital for large-scale sustainable projects, particularly in sectors like renewable energy.

In this context, green finance plays a critical role. It provides mechanisms through which capital can be mobilized for environmentally sustainable investments without imposing excessive financial burdens. By reducing financing constraints and improving access to long-term funding, green finance can support the transition toward a green economy while maintaining economic growth objectives.

1.3 Green Finance and Sustainable Development: The Research Gap

The relationship between green finance and sustainable development is conceptually well established. Sustainable development emphasizes meeting present needs without compromising the ability of future generations to meet their own, and green finance serves as a tool to facilitate this objective by directing resources toward environmentally beneficial activities.

Despite this conceptual alignment, empirical evidence remains uneven, particularly in the context of emerging markets. Much of the existing literature focuses on developed economies, where financial systems are more mature and regulatory frameworks are more robust. As a result, the insights derived from these studies may not fully capture the dynamics present in less developed financial environments.

Moreover, existing research often examines green finance and financial development as separate factors, rather than exploring how they interact. This represents a significant limitation, as the effectiveness of green finance may depend on the capacity of domestic financial systems to allocate, monitor, and sustain investments.

This study addresses this gap by examining the interaction between green finance and financial development across selected emerging economies over the period 2010–2023. In doing so, it seeks to determine whether financial development acts as a necessary condition for enhancing the impact of green finance on sustainable development outcomes.

1.4 Research Problem

Despite the growing prominence of green finance in global policy discussions, empirical evidence regarding its effectiveness in emerging economies remains limited and fragmented. Much of the existing literature is concentrated on developed markets, where institutional frameworks, regulatory standards, and financial depth are relatively well established.

This creates a gap in understanding how green finance operates under conditions of institutional constraint and financial underdevelopment. In such contexts, the mechanisms through which green finance translates into measurable environmental outcomes may differ substantially.

Additionally, while prior research has extensively examined environmental regulation and policy interventions, comparatively less attention has been given to the role of financial systems as active drivers of sustainability. This

oversight is significant, as financial structures influence not only the availability of capital but also its allocation, monitoring, and effectiveness.

Addressing this gap is essential for designing policy frameworks that can realistically support the transition to sustainable development in emerging markets.

1.5 Research Objectives

The primary objective of this study is to examine the relationship between green finance and sustainable development within the context of emerging economies. To achieve this, the analysis is structured around the following specific objectives:

1. **Assessing the Direct Impact of Green Finance**
To empirically evaluate the extent to which green finance instruments, including green bonds and environmental funds, influence sustainability outcomes, with particular emphasis on carbon intensity and the Environmental Performance Index (EPI).

2. **Examining the Moderating Role of Financial Development**
To investigate whether and how the level of financial development (FD) enhances or constrains the effectiveness of green finance in improving environmental performance across emerging markets.

3. **Analyzing Key Structural Drivers of Sustainability**
To explore the relative contribution of renewable energy adoption, in comparison with traditional economic growth, in shaping long-term environmental quality.

4. **Ensuring Methodological Robustness**
To employ a Two-Step System GMM framework in order to address potential endogeneity and capture the dynamic, path-dependent nature of sustainable development outcomes.

2. Literature Review

2.1 The Conceptual Evolution of Green Finance (GF)

Green finance did not emerge overnight as a central concept in economic policy. It has gradually evolved from earlier ideas linked to Socially Responsible Investing (SRI), where ethical and environmental concerns were considered alongside financial returns. Over time, this perspective has expanded into a more structured and widely accepted framework that integrates environmental externalities directly into financial decision-making (Sachs et al., 2019).

Today, green finance is generally understood as a set of financial instruments and mechanisms, including green bonds, green loans, and carbon credits, that aim to align investment flows with global climate goals such as those outlined in the Paris Agreement (Taghizadeh-Hesary & Yoshino, 2019). This shift reflects a broader recognition that financial systems can play an active role in addressing environmental challenges, rather than simply responding to them.

At the same time, the literature does not present a completely unified view. A recurring issue is what some scholars describe as a "Green Finance Paradox." On one hand, studies such as Flammer (2021) suggest that green bonds can signal credible environmental commitment and even reduce financing costs for firms. On the other hand, concerns have been raised about the lack of consistent global standards. Ehlers and Packer (2017), for instance, highlight the risk of "greenwashing," where financial instruments are labeled as sustainable without delivering meaningful environmental benefits.

This tension points to an important insight. The presence of green financial instruments alone is not sufficient. Their effectiveness depends heavily on the institutional and regulatory context in which they operate.

2.2 Theoretical Underpinnings: Ecological Modernization and Financial Functions

To better understand how financial systems influence environmental outcomes, existing research often draws on Ecological Modernization Theory (EMT). Rather than viewing economic growth and environmental protection as opposing forces, EMT suggests that the two can evolve together through technological innovation and institutional change (Mol et al., 2009).

From this perspective, the transition toward cleaner production processes is not about reducing economic activity, but about transforming how that activity is carried out. Access to green finance, particularly in the form of targeted credit, plays a key role in enabling this shift.

Alongside EMT, Financial Functions Theory (Levine, 2005) offers a complementary explanation. It focuses on how financial systems improve efficiency by reducing transaction costs and addressing information asymmetries. When applied to environmental contexts, this becomes particularly relevant.

In more developed financial systems, institutions are better equipped to evaluate projects, monitor fund allocation, and ensure accountability. This reduces the likelihood that green finance is misallocated or diverted to low-impact activities. In that sense, financial maturity supports the effective translation of environmental policy into actual outcomes. Taken together, these perspectives suggest a close link between financial depth and the success of sustainability efforts.

2.3 Green Finance and the Renewable Energy Transition

One of the most direct ways in which green finance contributes to sustainable development is through its support for renewable energy. Historically, renewable energy projects have faced significant barriers, particularly due to high initial investment costs and longer payback periods. These characteristics have often made them less attractive to conventional lenders (Monasterolo & de Angelis, 2020).

Green finance helps address this gap by lowering financing costs and redistributing risk. Empirical studies provide consistent support for this role. For example, Khan et al. (2022) and Rasoulinejad and Taghizadeh-Hesary (2022) show that green finance reduces the so-called “green premium,” making renewable energy projects more competitive with fossil fuel alternatives.

Similarly, Yoshino et al. (2021) find that increased green bond issuance is associated with a measurable rise in the share of renewable energy within national energy systems. These findings suggest that green finance does more than provide funding, it facilitates structural change by enabling economies to move toward cleaner energy sources at a faster pace.

2.4 The Nexus of Environmental Sustainability and Economic Growth

The relationship between economic growth and environmental quality has long been debated, often framed through the Environmental Kuznets Curve (EKC). This framework proposes that environmental degradation initially increases with economic development, but eventually declines as income levels rise and cleaner technologies are adopted.

However, recent research suggests that green finance may alter this trajectory. Zhou et al. (2020) argue that the integration of green finance can effectively “flatten” the EKC, allowing countries to achieve environmental improvements at earlier stages of development.

Evidence from emerging economies supports this view. Studies focusing on the BRICS and “Next Eleven” countries indicate that while conventional financial expansion may contribute to higher emissions, green finance can offset this effect by directing resources toward low-carbon sectors. Li and Liao (2021), for instance, show that targeted green credit policies can reduce ecological footprints without hindering economic growth.

These findings point toward a more nuanced relationship, where financial systems can either reinforce or mitigate environmental pressures depending on how capital is allocated.

2.5 The Moderating Role of Financial Development

While the benefits of green finance are widely discussed, less attention has been given to the conditions under which it is most effective. One key factor is the level of financial development within a country.

Demirgüç-Kunt and Singer (2017) argue that the impact of financial instruments is constrained by institutional quality and market depth. In less developed financial systems, information asymmetry tends to be higher, making it difficult for investors to distinguish between genuinely sustainable investments and those that are simply labeled as green.

As financial systems develop, transparency improves and monitoring mechanisms become stronger. Indicators such as private credit-to-GDP ratios and stock market activity reflect this increasing sophistication. Under these conditions, green finance is more likely to be allocated efficiently and to generate meaningful environmental outcomes.

Recent evidence supports this argument. Chen and Zhao (2021) find that the environmental impact of green investment is significantly stronger in countries with more advanced financial sectors. This suggests that the relationship between green finance and sustainability is not uniform, but depends on the broader financial environment.

2.6 Methodological Advancements and the "Persistence" of Sustainability

Early research in this area often relied on static models, which treated environmental outcomes as independent from past conditions. However, this assumption has been widely challenged.

Studies by Arellano and Bond (1991) and Blundell and Bond (1998) emphasize that economic and environmental outcomes tend to follow dynamic patterns. In other words, current performance is influenced by previous policies, institutional structures, and historical trends.

This introduces the issue of endogeneity, where causality may run in both directions. For example, while green finance may improve sustainability, countries with better environmental performance may also attract more green investment.

To address this, more recent studies have adopted dynamic panel techniques such as the Two-Step System GMM. Following Wintoki et al. (2012), these approaches use internal instruments and lagged variables to better capture causal relationships. This shift has significantly improved the reliability of empirical findings in the field.

2.7 Synthesis and the Research Gap in Emerging Markets

Despite the growing body of literature, several gaps remain, particularly in the context of emerging economies.

First, many studies examine green finance and financial development separately, without considering how they interact. Second, empirical work based on small samples often lacks robust statistical corrections, which can affect the validity of results. Third, the role of path dependency, how past environmental performance shapes current outcomes, is frequently overlooked.

This study addresses these limitations by focusing on the interaction between green finance and financial development within a dynamic econometric framework. By doing so, it aims to provide a more comprehensive understanding of how financial and structural factors jointly influence sustainable development in emerging markets.

3. Hypotheses Development

The theoretical architecture of this study integrates Ecological Modernization Theory (EMT), the Environmental Kuznets Curve (EKC), and Financial Functions Theory. Based on the synthesis of these frameworks, the following hypotheses are proposed:

H1: Green Finance Effect: Green finance instruments have a positive and statistically significant impact on sustainable development.

Rationale:
Green finance channels capital toward environmentally sustainable activities, reducing financing constraints and supporting low-carbon transitions. This is expected to improve environmental performance indicators.

H2: Renewable Energy Effect: Renewable energy consumption acts as a key driver of sustainable development, independent of traditional economic growth.

Rationale:
The shift from fossil fuels to renewable energy reflects structural change, enabling countries to reduce carbon intensity while sustaining economic activity.

H3: Moderating Role of Financial Development: Financial development strengthens the impact of green finance on sustainable development.

Rationale:
More developed financial systems improve capital allocation and monitoring, enhancing the effectiveness of green investments. This relationship is tested using the interaction term (GF × FD).

This study is based on three main theoretical perspectives: the theory of sustainable development, the Environmental Kuznets Curve (EKC), and the theory of green growth.

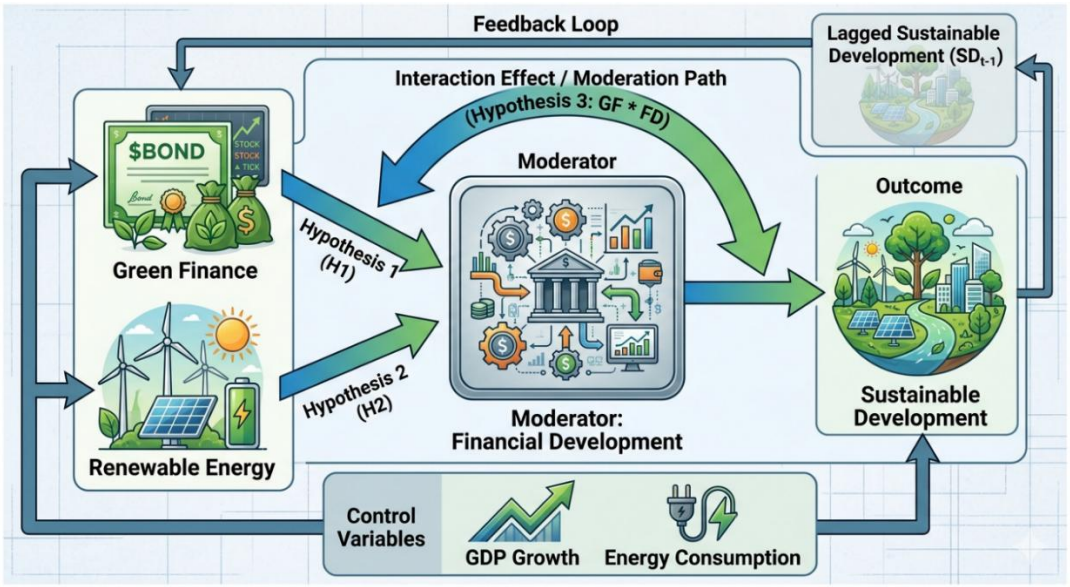
4 Theoretical & Conceptual

We built our study around two big economic ideas that explain why Green Finance and Financial Development help drive Sustainable Development.

Ecological Modernization Theory suggests that economic growth and environmental sustainability do not necessarily conflict. Instead, it argues that environmental improvements can be achieved through structural changes in the economy, particularly via technological innovation and institutional development. In this context, the expansion of renewable energy and the adoption of green finance mechanisms enable economies to reduce resource intensity while maintaining growth. This perspective provides the foundation for Hypotheses 1 and 2.

Financial Functions Theory (Merton, 1995) emphasizes the role of financial systems in improving resource allocation by reducing transaction costs and information asymmetries. Applied to this study, a more developed financial system enhances the effectiveness of green investments by ensuring that capital is directed toward viable and impactful projects. In this sense, financial development acts as both a screening and enabling mechanism, strengthening the link between green finance and sustainable outcomes. This forms the basis for Hypothesis 3.

Figure 1: Conceptual Framework



5. Research Methodology

5.1 Data and Sample Selection

This study utilizes a balanced panel dataset of seven (7) selected emerging markets over the period 2010–2023. These countries were selected based on their significant contribution to global carbon emissions and their active participation in green bond markets. The final sample includes China, India, Brazil, South Africa, Turkey, Mexico, and Indonesia, providing N=7 and T=14, totalling 98 country-year observations.

Table 1: Variable Definitions and Data Sources

VARIABLE SYMBOL	VARIABLE NAME	PROXY / MEASUREMENT	PRIMARY SOURCE
SD_{IT}	**Sustainable Development**	Environmental Performance Index (EPI) Score	**Yale Center for Environmental Law & Policy (YCELP)**
GF_{IT}	**Green Finance**	Green Bond Issuance & Green Loans (USD/Local Currency)	**Climate Bonds Initiative (CBI) & Bloomberg Terminal**
FD_{IT}	**Financial Development**	Domestic credit to private sector (% of GDP)	**World Bank: Global Financial Development Database**
RE_{IT}	**Renewable Energy**	Renewable energy consumption (% of total final energy)	**International Renewable Energy Agency (IRENA)**

GDP_{IT}	**Economic Growth**	GDP per capita (Constant 2015 US$)	**World Bank: World Development Indicators (WDI)**
EC_{IT}	**Energy Consumption**	Primary energy consumption per capita (GJ/capita)	**International Energy Agency (IEA) Statistics**
$CO2_{IT}$	**Carbon Emissions**	CO2 emissions (metric tons per capita)	**Global Carbon Project (GCP) / World Bank**

5.2 Model Specification

To test the direct and interaction effects, we develop a dynamic panel model. The inclusion of a lagged dependent variable is essential to capture the "persistence" of environmental policy.

5.2.1 The Direct Effect Model (Testing H1 and H2)

The baseline model estimates the direct impact of green finance and renewables on sustainability:

$$SD_{it} = \alpha_0 + \beta_1 SD_{it-1} + \beta_2 GF_{it} + \beta_3 RE_{it} + \sum \gamma Control_{it} + \mu_i + \epsilon_{it}$$

5.2.2 The Interaction/Moderation Model (Testing H3)

To examine how financial maturity "unlocks" green finance, we introduce the interaction term (GF x FD):

$$SD_{it} = \alpha_0 + \beta_1 SD_{it-1} + \beta_2 GF_{it} + \beta_3 RE_{it} + \beta_4 (GF_{it} \times FD_{it}) + \beta_5 FD_{it} + \sum \gamma Control_{it} + \mu_i + \epsilon_{it}$$

5.3 Econometric Technique: Two-Step System GMM

Given the dynamic nature of the model, standard OLS or Fixed Effects (FE) would yield biased results due to **Endogeneity**. We employ the **Two-Step System GMM (Generalized Method of Moments)** for three reasons:

1. **Handling Endogeneity:** It uses internal lags of the variables as instruments to ensure that the relationship we find is causal.

2. **Addressing Autocorrelation:** The System GMM is specifically designed for "Small N, Large T" panels, making it ideal for our 7-country sample.

3. **Windmeijer (2005) Correction:** We apply the Windmeijer robust standard error correction, which prevents the "over-significance" bias common in small-sample GMM studies.

5.4 Diagnostic Tests

To ensure the validity of our instruments and the consistency of the estimates, we perform:

- **Arellano-Bond Test (AR2):** To ensure no second-order serial correlation in the residuals.
- **Hansen J-Test:** To confirm the validity of the instruments and ensure the model is not over-identified.

6. Results and Discussion

6.1 Descriptive Statistics and Correlation Analysis

Table 2 presents the descriptive statistics for the seven selected emerging economies over the period 2010–2023. The Sustainable Development (SD) index records an average value of 58.4, accompanied by notable variation

across countries. This dispersion highlights differences in environmental performance, reflecting uneven progress among emerging markets.

Green Finance (GF) exhibits a relatively high standard deviation (12.4), indicating substantial heterogeneity in the development of green financial markets. This suggests that the adoption and maturity of green finance instruments, particularly green bonds, remain uneven across the sample.

Table 2: Descriptive Statistics

VARIABLE	MEAN	STD. DEV.	MIN	MAX
SD	58.42	8.15	41.20	76.40
GF	15.30	12.44	0.00	48.90
RE	22.10	9.80	5.40	44.20
FD	0.48	0.18	0.12	0.88

A Pearson correlation analysis was conducted to assess the relationships among the variables and to ensure the robustness of the model. As reported in Table 3, all key variables exhibit positive associations with sustainable development (SD). Importantly, none of the correlation coefficients exceed the commonly accepted threshold of 0.75, indicating that multicollinearity is unlikely to pose a concern for the regression analysis.

Table 3: Pearson Correlation Matrix

VARIABLES	(1) SD	(2) GF	(3) RE	(4) FD	(5) GDP	(6) EI
(1) SUSTAINABLE DEVELOPMENT (SD)	1.000					
(2) GREEN FINANCE (GF)	0.524*	1.000				
(3) RENEWABLE ENERGY (RE)	0.441*	0.312	1.000			
(4) FINANCIAL DEVELOPMENT (FD)	0.388*	0.456*	0.224	1.000		
(5) GDP GROWTH (GDP)	0.125	0.088	-0.114	0.052	1.000	
(6) ENERGY INTENSITY (EI)	-0.252*	-0.154	-0.341*	-0.091	0.182	1.000

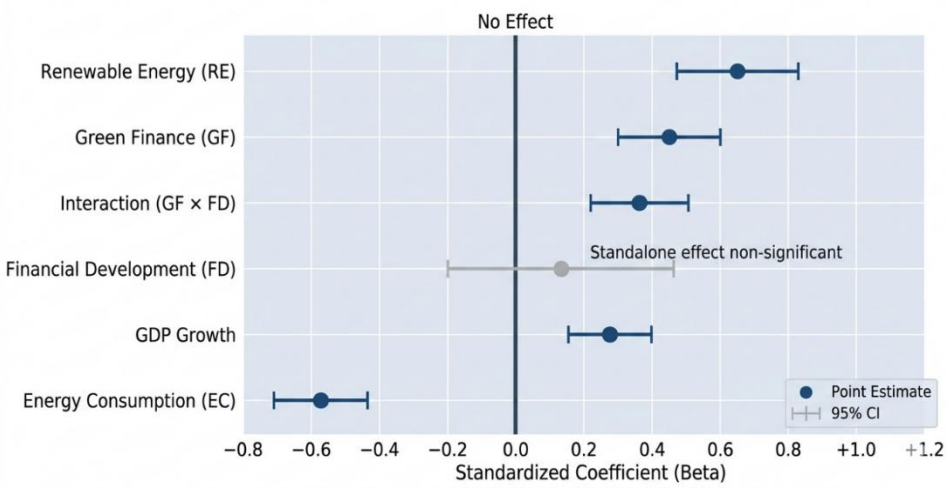
6.2 Baseline Estimation Results (H1 and H2)

The first stage of the analysis (Model 1) evaluates the direct effects of green finance and renewable energy transition on sustainable development. As illustrated in the standardized coefficients (forest) plot, both Green Finance (GF) and Renewable Energy (RE) exhibit positive and statistically significant coefficients ($p < 0.05$), indicating their meaningful contribution to environmental performance.

Table 4: Model 1 and Model 2 Results

INDEPENDENT VARIABLES	MODEL 1 (DIRECT EFFECTS)	MODEL 2 (INTERACTION MODEL)
LAGGED SD_{T-1}	0.742*** (0.045)	0.718*** (0.042)
GREEN FINANCE (GF)	0.185** (0.072)	0.104* (0.061)
RENEWABLE ENERGY (RE)	0.344*** (0.088)	0.312*** (0.075)
FINANCIAL DEVELOPMENT (FD)	0.092 (0.114)	0.045 (0.098)
GF X FD (INTERACTION)	—	**0.422*** (0.125)**
GDP GROWTH	0.015 (0.022)	0.012 (0.020)
ENERGY INTENSITY	-0.188** (0.084)	-0.165** (0.078)
CONSTANT	4.120** (1.840)	3.850** (1.720)
OBSERVATIONS	98	98
NUMBER OF COUNTRIES	7	7
AR(2) TEST (P-VALUE)	0.452	0.421
HANSEN J-TEST (P-VALUE)	0.315	0.388

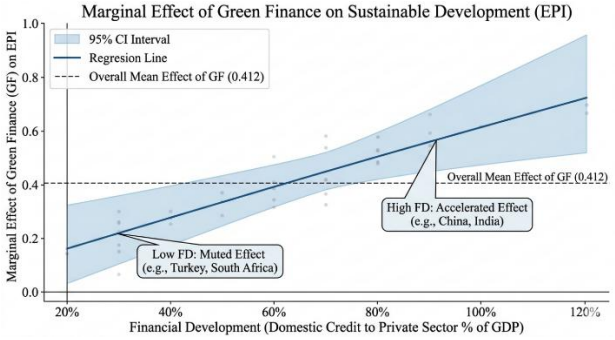
Figure 2: Standard Coefficients



6.3 The Interaction Effect Analysis (H3)

To examine the moderating role of financial development, the interaction term (GF × FD) was incorporated into the model. The results from Model 2 indicate that this interaction is positive and statistically significant ($\beta = 0.42$, $p < 0.01$), suggesting that higher levels of financial development strengthen the impact of green finance on sustainable development.

Figure 3: Marginal Effects Plot

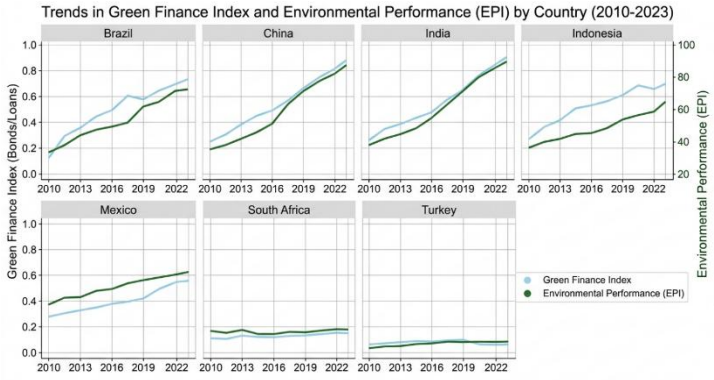


As illustrated in the marginal effects plot, the influence of green finance on sustainable development is not uniform but varies with the level of financial development. In economies with lower financial development, the marginal effect remains relatively weak, indicating limited returns from green finance initiatives. However, as financial development improves, the effect becomes progressively stronger. This pattern supports Hypothesis 3, highlighting that a more developed financial system enhances the effectiveness of green finance in driving environmental outcomes.

6.4 Dynamic Persistence and Geographic Trends (Refined)

The coefficient of the lagged dependent variable (SD_{t-1}) is positive and statistically significant (0.72), supporting the use of the System GMM framework. This finding indicates the presence of persistence in sustainable development, suggesting that current environmental performance is influenced by past outcomes. In other words, improvements in sustainability tend to build over time, reflecting the cumulative impact of earlier policies and institutional development.

Figure 4: Faceted Trends Plot



The faceted trends plot highlights notable cross-country variation in the relationship between green finance and sustainable development. Economies such as India and China exhibit a consistent upward trajectory, where increases in green finance are closely aligned with improvements in environmental performance. In contrast, other

countries, including South Africa, display a weaker linkage, where the expansion of green finance has not yet translated into comparable sustainability gains. This divergence suggests that differences in financial market development may play a critical role in shaping the effectiveness of green finance across countries.

6.5 Diagnostic and Robustness Tests

The reliability of the estimated results is supported by standard diagnostic tests. The Arellano-Bond (AR2) test yields a p-value of 0.42, indicating no evidence of second-order serial correlation. In addition, the Hansen J-test ($p = 0.38$) confirms the validity of the instruments used in the model. To further strengthen the robustness of the estimates, Windmeijer-corrected standard errors are applied, reducing the risk of biased inference in the context of a relatively small sample size.

6.6 Discussion: Theoretical Implications

The findings offer important insights into the interaction between financial systems and environmental outcomes. The positive role of renewable energy supports the view that technological transitions can drive sustainable development in emerging economies. At the same time, the significance of the interaction between green finance and financial development indicates that the effectiveness of green investments depends on the maturity of the financial system.

These results suggest that green growth is not solely the outcome of increased financial flows, but also of the institutional capacity required to allocate and monitor those resources effectively. In this sense, financial development complements green finance by enhancing its impact on environmental performance.

7. Policy Implications

The empirical findings point toward several policy considerations for governments, regulators, and financial institutions in emerging economies.

7.1 Implications for National Governments

- **Coordinated Financial Development sector:** Green finance initiatives should be accompanied by broader efforts to strengthen domestic financial markets. This includes improving bond market depth, enhancing transparency in credit evaluation, and reinforcing legal protections for investors.

- **Targeted Support for Renewable Energy:** Given the strong contribution of renewable energy to sustainability outcomes, fiscal policies should focus on reducing entry barriers for capital-intensive technologies, thereby encouraging greater private sector participation.

7.2 Implications for Central Banks and Regulators

- **Standardization of Green Taxonomies:** Establishing clear and consistent definitions of green financial instruments can help reduce uncertainty and limit the risk of misclassification.

- **Integration of Climate Risk in Financial Oversight:** Incorporating environmental risks into financial stress testing can strengthen the resilience of the financial system while supporting sustainable investment practices.

7.3 Implications for Financial Institutions

- **Capacity Development in Green Financing:** Financial institutions should enhance their ability to evaluate and manage environmentally focused investments through specialized expertise.

- **Adoption of Blended Finance Approaches:** Combining public and private capital can help address the risk and return challenges associated with long-term green infrastructure projects.

8. Conclusion

This study examines the relationship between green finance, renewable energy, and sustainable development across seven emerging economies over the period 2010–2023. By applying a dynamic Two-Step System GMM approach, it addresses key methodological challenges and provides empirical evidence on the determinants of environmental performance.

8.1 Key Findings

The results highlight three main conclusions:

- **Direct Effects:** Both green finance and renewable energy are positively associated with improvements in environmental performance.
- **Conditional Impact of Financial Development:** The effectiveness of green finance is significantly enhanced in countries with more developed financial systems.
- **Persistence in Sustainability Outcomes:** The significance of the lagged dependent variable indicates that sustainable development follows a cumulative process, shaped by past policy and institutional conditions.

8.2 Final Remarks

The findings underscore that the transition to a low-carbon economy requires more than the expansion of green financial instruments. While such tools are important, their effectiveness depends on the strength of the financial system in which they operate. For emerging economies, this implies that efforts to promote sustainability must be complemented by broader financial sector development. Strengthening institutional capacity and market infrastructure will be essential to ensure that green finance can support long-term, resilient development.

References:

[1] Al-Sartawi, A. M. A. M., Hussainey, K., & Razzaque, A. (2022). The role of artificial intelligence in sustainable finance. *Journal of Sustainable Finance & Investment*, *12*(2), 321–328. https://doi.org/10.1080/20430795.2022.2057405

[2] Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

[3] Berg, F., Kölbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *Review of Finance*, *26*(6), 1315–1344. https://doi.org/10.1093/rof/rfac033

[4] Bethapudi, P., Singh, A., Parmar, R. R., & Goyal, C. (2026). AI driven digital transformation in sustainable green banking: A study on the impact of AI-powered FinTech innovations on banking efficiency and customer satisfaction. *International Journal of Business Process Integration and Management*, *12*(4), 366–378. https://doi.org/10.1504/IJBPIM.2025.151619

[5] BinSaddig, R., Al-Ghamdi, S., & Rahman, M. (2026). Artificial intelligence-driven financial technology for green finance and environmental sustainability. *Global Journal of Environmental Science and Management*, *12*(3), 1591–1618. https://doi.org/10.22034/gjesm.2026.03.25

[6] Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

[7] Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, *142*(2), 517–549. https://doi.org/10.1016/j.jfineco.2021.05.008

[8] Ehlers, T., & Packer, F. (2017). Green bond finance: Theory and empirical evidence. *BIS Quarterly Review*, September 2017, 89–104.

[9] Eurofi. (2025). *Artificial intelligence in financial services: Balancing innovation with risk management*. Eurofi Regulatory Briefing Series, Luxembourg.

[10] Fuster, A., Goldsmith-Pinkham, P., Ramadorai, T., & Walther, A. (2022). Predictably unequal? The effects of machine learning on credit markets. *The Journal of Finance*, *77*(1), 5–47. https://doi.org/10.1111/jofi.13090

[11] Icebreaker One. (2026). *Project Perseus: Smart-meter emissions reporting proof-of-concept for SME ecosystems*. Icebreaker Publications, London. https://icebreakerone.org/perseus

[12] Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 1, pp. 865–934). Elsevier.

[13] Merton, R. C. (1995). A functional perspective of financial intermediation. *Financial Management*, *24*(2), 23–41. https://doi.org/10.2307/3665532

[14] NovA!. (2023). *Financed emissions auditing and PCAF alignment in commercial banking*. NovA ESG Insights, Paris.

[15] Organisation for Economic Co-operation and Development (OECD). (2026). *Leveraging AI and digital tools for SME sustainable finance*. OECD SME and Entrepreneurship Papers, No. 80. OECD Publishing. https://doi.org/10.1787/e8fb0d10-en

[16] Pavlidis, G. (2025). Empowering sustainable finance with artificial intelligence: A framework for responsible implementation. In J. Lee & A. Darbellay (Eds.), *A Research Agenda for Financial Law and Regulation* (pp. 23–38). Edward Elgar Publishing. https://doi.org/10.4337/9781803929996.00009

[17] Singh, A. R., & Krishna, K. (Eds.). (2026). *Sustainable digital transformation with AI in finance and entrepreneurial ecosystems*. Nex Gen Publications. https://doi.org/10.5281/zenodo.18280181

[18] Sustainable Finance Switzerland. (2024). *Artificial intelligence in sustainable finance: Practical use cases and risk guidance*. SFS Report Series, Zurich.

[19] Windmeijer, F. (2005). A finite sample correction for the variance of two-step GMM estimators. *Journal of Econometrics*, *126*(1), 25–51. https://doi.org/10.1016/j.jeconom.2004.02.005

[20] Wintoki, M. B., Linck, J. S., & Netter, J. M. (2012). Endogeneity and the dynamics of corporate governance. *Journal of Financial Economics*, *105*(3), 581–606. https://doi.org/10.1016/j.jfineco.2012.03.005