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TECHNOLOGICAL INNOVATION AND GREEN FINANCE: CATALYSTS FOR SUSTAINABLE DEVELOPMENT IN DEVELOPING ECONOMIES

[1]Amjad Ali, [2]Nadeem Abbas, [3]Asghar Kamal

1. Lahore School of Accountancy and Finance, University of Lahore, Pakistan
2. Lahore School of Accountancy and Finance, University of Lahore, Pakistan
3. Assistant Professor, Department of Business Administration, Sarhad University, Peshawar

Abstract

This research investigates the transformative impact of technological innovation on green finance and its vital contribution to sustainable development in developing economies, covering the period 2008 to 2023. Green finance, enhanced by technologies such as blockchain, artificial intelligence, and big data analytics, influences renewable energy consumption and shapes public attitudes toward sustainability. Two empirical models were employed, and the first assesses the relationship between green finance and renewable energy growth, finding that increased access to green finance significantly accelerates the adoption of renewable energy sources. Notably, this effect is amplified by macroeconomic factors such as GDP growth, trade openness, and urbanization, which create a supportive environment for sustainable investment. The second model explores the determinants of public sentiment regarding green finance, revealing that digital infrastructure (as measured by internet access) and environmental transparency (linked to ESG performance and disclosure) are critical drivers of positive public attitudes. This underscores the importance of digital access and environmental governance in fostering a culture of sustainability. The findings indicate that technological advancements are not only improving the transparency and traceability of green investments, thereby mitigating the risk of greenwashing, but are also facilitating real-time ESG analytics. This technological progress builds investor confidence and accelerates the mainstreaming of sustainable finance. In summary, the research highlights the interconnected roles of technology, green finance, and supportive macroeconomic and digital environments in advancing the transition to sustainability in the

developing world.

Keywords: Green Finance, Technological Innovation, Renewable Energy, Sustainable Development

Introduction

Green finance has emerged as a pivotal force in addressing climate change and advancing sustainability, particularly within developing countries. It encompasses a range of financial instruments, such as green bonds, green loans, and investment funds dedicated to sustainable initiatives, all designed to support projects with environmental benefits. As the global economy transitions toward reduced carbon emissions, the role of financial markets in enabling sustainable development has become increasingly significant, especially through the integration of innovative technological solutions (Delis et al., 2022; Ito & Zhang, 2025). Progress in digital technologies, notably blockchain, artificial intelligence, and big data analytics, is reshaping the landscape of green finance. These advances enhance transparency, decrease investment risk, and improve the reliability of sustainability reporting. Blockchain, for instance, provides a secure and transparent ledger for transactions, facilitating the monitoring of green finance flows and reducing the risks associated with misleading environmental claims (Rauchs et al., 2019; Wang & Zaman, 2025). As green finance continues to evolve, maintaining its credibility and integrity remains essential. Blockchain technology, by promoting transparency, builds stakeholder trust and supports broader participation in sustainable finance. Furthermore, artificial intelligence and machine learning algorithms assist financial institutions in analyzing large volumes of environmental, social, and governance data, thereby refining risk assessment and sustainability performance evaluation. Brennan et al. (2022) indicate that analytics driven by artificial intelligence deliver timely investment insights, equipping

organizations to identify and evaluate green investment prospects with greater accuracy. These tools are fundamental in advancing from statements of corporate social responsibility to measurable sustainability achievements.

Big data analytics is also integral to the formulation of evidence-based policies and more effective investment strategies. Zhan and de Jong (2023) highlight that the integration of big data into green finance allows for more flexible and responsive tracking of environmental outcomes, which leads to more efficient allocation of capital by institutions. This strengthens the linkage between environmental, social, and governance performance and the attractiveness of investments, making green finance not only a prudent financial choice but also a catalyst for transformative environmental progress. The interaction between technology and public sentiment further drives the proliferation of green finance. In the contemporary digital age, greater accessibility to environmental information empowers citizens to influence corporate behavior and financial trends. Research demonstrates that internet access has a substantial effect on shaping public perceptions regarding sustainability, particularly in urban areas (Tian et al., 2022; Ramanust, 2023; Jamel & Zhang, 2024; Khalid & Abdul, 2025). Therefore, the development of robust digital infrastructure is critical to promoting financial inclusion and fostering environmental consciousness. In addition, stakeholder theory and signaling theory offer essential perspectives on the dynamics of green finance. Freeman et al. (2020) assert that organizations must actively involve a diverse set of stakeholders—including investors, governmental bodies, and the public—through transparent and ethical engagement. Organizations that demonstrate a genuine commitment to environmental, social, and governance principles secure the trust of investors and bolster

their legitimacy within the market. Connelly et al. (2011) further argue that the disclosure of sustainability practices acts as a reliable signal of organizational credibility and long-term value creation. Nevertheless, green finance faces notable challenges, including inconsistent policy frameworks, divergent data standards, and unequal digital access. Xu and Zhu (2022) underscore the need for clearly defined regulatory systems and standardized taxonomies for green finance to facilitate scalability and global cohesion. Such challenges can inhibit the realization of green finance's full potential, particularly in developing regions.

The combination of technological advancement with ecological innovation stands to broaden the scope of green finance significantly. Olayinka et al. (2018) emphasize the importance of synergistic relationships among technology experts, financial institutions, and ecological enterprises. Their research proposes that such collaborations encourage the creation of new mechanisms to advance and extend sustainable finance solutions. They argue that partnerships can improve the efficiency of green finance by introducing innovative financial products that further the sustainability agenda. By fostering collaboration, stakeholders are better positioned to address the multifaceted challenges inherent in sustainable finance, drawing on a variety of skills and insights.

The central focus of this research is to examine how technological innovations fundamentally improve the effectiveness and scope of green finance. Digital enablers such as blockchain technology, artificial intelligence, and big data analytics are crucial in advancing renewable energy and positively shaping public attitudes toward sustainable finance. When financial instruments designed to support environmental objectives are reinforced by technological advancements, they attract investment while also guaranteeing the transparency and accountability required to

cultivate stakeholder trust and achieve alignment with policy goals. The expansion of renewable energy is positively influenced by green finance, economic growth, increased urbanization, and openness to international trade, whereas inflation remains a constraining influence.

Literature Review

Green finance has become a vital solution to the urgent necessity of protecting the environment through sustainable development. It encompasses a broad spectrum of financial products and services designed to facilitate projects with significant positive environmental impacts. The United Nations Environment Programme defines green finance as the practice of directing financial investments toward projects and activities that promote sustainable development, thereby supporting a sustainable economy. The United Nations Environment Programme (2016) offers a detailed conceptualization of green finance, highlighting its central role in advancing global sustainable development projects. This framework underscores the importance of integrating environmental considerations into financial decision-making processes to achieve long-term sustainability objectives. The United Nations Environment Programme further elaborates that green finance extends beyond simple funding, constituting a multifaceted concept involving policy formulation, investment planning, and active stakeholder engagement to ensure that financial flows contribute to the construction of an environmentally sustainable future.

Key instruments of green finance include green bonds, green loans, and funds dedicated to sustainable investments. Notably, green bonds have become prominent tools for financing environmentally focused initiatives, with the international green bond market experiencing exponential growth since its inception in

2007. The Climate Bonds Initiative (2020) provides a comprehensive overview of the green bond market, detailing its development and its critical function as a source of funding for environmentally beneficial projects. The report highlights that green bonds are strictly allocated to initiatives aimed at mitigating global warming, supporting renewable energy, enhancing energy efficiency, and promoting sustainable land use. The Climate Bonds Initiative also equips investors with clear guidelines for identifying projects that align with their sustainability strategies, thereby clarifying what constitutes a green investment. The sustained interest from institutional investors has played a key role in strengthening the green bond market and underscores the significant potential of green finance to attract substantial capital flows.

The importance of green finance is reinforced by international frameworks such as the Paris Agreement, which underscores the necessity for substantial financial commitments to facilitate the transition toward a low-carbon economy. The Paris Agreement, as articulated by the United Nations Framework Convention on Climate Change (2015), establishes ambitious goals for limiting global temperature increases and enhancing nations' capacities to address the impacts of climate change. This agreement places strong emphasis on the need for green finance to mobilize funding for renewable energy initiatives, sustainable infrastructure, climate adaptation measures, and related efforts. The United Nations Framework Convention on Climate Change notes that achieving the targets set out in the Paris Agreement will require a fundamental transformation of financial structures, steering investments toward low-carbon and climate-resilient development. Realizing this vision calls for coordinated action among governments, the financial sector, and the business community to

foster conditions conducive to the flourishing of green finance (Wang & Li, 2024).

Technological innovation is driving transformative changes within the financial sector, reshaping both the delivery and consumption of financial services. Financial technology, encompassing developments such as online payments, peer-to-peer lending, automated investment advisors, and blockchain, represents a significant evolution in the industry. Arner et al. (2016) discuss the regulation and progression of financial technology, noting that technological advancements are fundamentally altering the financial landscape and significantly influencing sustainable finance. These authors suggest that financial technology can improve efficiency, reduce costs, and expand access, thereby creating new opportunities for sustainable investment. However, the rapid pace of technological change also presents regulatory challenges, necessitating that frameworks be updated to accommodate new technologies while maintaining consumer protection and market stability.

The intersection of technology and sustainability has attracted considerable attention as financial institutions increasingly leverage technological advancements to deepen their engagement with green finance. Khan et al. (2024) explore the integration of artificial intelligence into sustainable finance, examining how these technologies can enhance investment decision-making and sustainability analysis. Artificial intelligence is capable of processing large datasets to detect patterns, evaluate the environmental impacts of investments, and determine optimal investment strategies. Through machine learning, financial institutions can assess the sustainability performance of companies and projects, thereby enabling investors to make more informed decisions. This capability is especially valuable in green finance,

where clear insights into the environmental effects of investments are paramount for both financial actors and broader stakeholder groups.

Significant technological developments, such as big data analytics, can substantially shape the landscape of green finance. Wang et al. (2019) examine the role of big data analytics in logistics and supply chain management, highlighting its potential to improve sustainability performance and financial decision-making. By adopting big data, financial institutions can achieve greater accuracy and timeliness in sustainability measurement and reporting, allowing them to more effectively gauge the impact of investments. Big data analytics also offer insights into market trends, consumer behavior, and environmental risk, which support precise sustainability assessments. Enhanced analytical capabilities empower financial institutions to make evidence-based decisions that align with sustainability targets, creating a more responsible investment environment (Kosyak & Popov, 2020; Saluy & Nuryanto, 2023; Lawal et al., 2024).

Another key innovation is blockchain technology, which offers the potential to transform green finance practices. Tapscott and Tapscott (2016) analyze the impact of blockchain technology across various domains, including finance, and highlight its ability to increase transparency and trust in the industry. Blockchain can enable the accurate tracking of funds directed toward green projects, reducing the risk of capital misuse. Such transparency is critical for mitigating the threat of greenwashing, where entities may misrepresent their environmental practices. By ensuring secure and immutable transaction records, blockchain enhances accountability in green finance, empowering investors to verify the environmental outcomes of their investments and fostering greater trust among stakeholders.

Regulatory frameworks play a fundamental role in shaping the green finance ecosystem. Sundarasen et al. (2024) note that the pace of technological development often exceeds that of regulatory adaptation, resulting in ambiguity and exposing financial institutions to unanticipated risks. These authors highlight the urgent need for regulatory systems that strike a balance between promoting innovation and safeguarding market integrity and stability. Thoughtful regulation is essential for cultivating an environment in which sustainable finance can thrive while mitigating the risks associated with rapid technological progress. Sundarasen et al. (2024) further recommend that regulators engage collaboratively with industry participants to design adaptable structures that integrate emerging technologies and uphold sustainability objectives. Education and increased awareness are also vital in driving the adoption of green finance among investors. Dincer et al. (2023) address the persistent lack of education on the benefits of green finance and the role of technology, which continues to hinder broader investor participation. The authors advocate for greater dissemination of knowledge to encourage more individuals to engage with sustainable investment practices. Educational initiatives can equip investors with the skills and understanding necessary to effectively navigate green finance, while financial institutions can bridge the knowledge gap by offering targeted resources and promoting environmentally responsible investment strategies. These efforts serve to motivate more investors to consider environmental impacts when constructing their investment portfolios.

Strengthened accountability is essential for fostering trust between stakeholders and investors. Almashhadani and Almashhadani (2023) emphasize the considerable effect that technological innovations have on increasing transparency in

financial transactions, which supports both trust and the mobilization of capital toward green initiatives. Increased transparency reduces skepticism regarding the credibility of sustainability claims, thereby enhancing the effectiveness of green finance. Financial institutions can use blockchain and big data analytics to provide stakeholders with real-time access to investment information and environmental impact assessments, thereby promoting accountability and responsible investment practices.

The integration of advanced technologies within green finance also leads to improved risk assessment methodologies. Amran and Ping (2024) argue that artificial intelligence and big data analytics reinforce risk management capabilities. By leveraging available data, advanced analytics can identify potential challenges and support more robust investment decision-making. Investment firms can incorporate environmental risk assessments into their risk management frameworks, thereby enhancing resilience to climate-related threats while furthering sustainability objectives.

Despite the promise of technological integration within green finance, several challenges must be addressed to realize its full potential. Nnedu (2024) identifies the absence of consistent metrics for sustainability assessment as a significant barrier, impeding investors' ability to effectively evaluate the environmental performance of their investments. Variations in data quality undermine informed decision-making and obstruct the effective implementation of green investment strategies. The author advocates for the development of standard metrics to facilitate comparability and enhance the credibility of sustainability assessments. Establishing clear rules and standards for sustainability reporting will empower investors to make more

responsive decisions, directing capital toward projects with demonstrably positive impacts on environmental sustainability and green finance, as supported by Khunkaew et al. (2023), Nyantakyi et al. (2023), Oware and Worae (2023), Escamilla-Solano et al. (2024), Suhartini et al. (2024), and Razan & Ibrahim (2025).

Despite the accelerating adoption of technological innovation in green finance—including blockchain, artificial intelligence, and big data analytics—several important gaps persist in the literature regarding their effectiveness in shaping sustainable investment and public opinion, especially within developing economies (Arner et al., 2016; Khan et al., 2024; Tapscott & Tapscott, 2016; Wang et al., 2019; Bootal et al., 2025). While prior studies have documented the capacity of blockchain to enhance transparency and reduce greenwashing (Rauchs et al., 2019; Tapscott & Tapscott, 2016; Almashhadani & Almashhadani, 2023; Naeem et al., 2025), and artificial intelligence to improve ESG analytics and risk assessment (Ali et al., 2021; Brennan et al., 2022; Amran & Ping, 2024; Mehdi et al., 2025), few empirical works have systematically examined how these technologies, together with macroeconomic enablers such as digital infrastructure and policy frameworks (Marc et al., 2020; Ali et al., 2021; Xu & Zhu, 2022; Sundarasen et al., 2024; Sadiq et al., 2025), directly influence public attitudes and the mainstreaming of green finance in the context of rapid urbanization and economic development (Delis et al., 2022; Tian et al., 2022). Furthermore, much of the existing literature has focused on advanced economies or the technical dimensions of green finance instruments (Climate Bonds Initiative, 2020; United Nations Environment Programme, 2016; UNFCCC, 2015), with limited attention to how digital access, environmental transparency, and education interact to foster a culture of sustainability in developing regions (Dincer et al., 2023; Lawal et al., 2024).

Recent research has also highlighted persistent challenges such as inconsistent data standards, regulatory ambiguity, and the lack of robust, standardized metrics for sustainability assessment, all of which hinder the scalability and credibility of green finance (Nnedu, 2024; Khunkaew et al., 2023; Nyantakyi et al., 2023; Oware & Worae, 2023; Escamilla-Solano et al., 2024; Suhartini et al., 2024). Although some studies advocate for stronger partnerships and regulatory frameworks to advance sustainable finance solutions (Olayinka et al., 2018; Sundarasen et al., 2024), there remains a paucity of panel-data-based empirical evidence exploring how technological innovation bridges gaps in public perception and accelerates renewable energy adoption across diverse developing country settings. In particular, the dynamic interplay between green finance access, digital infrastructure, and public opinion—mediated by new technologies and macroeconomic factors—has not been sufficiently explored. This research directly addresses these gaps by integrating panel econometric analysis of multiple developing economies, examining how blockchain, AI, and big data in green finance not only drive renewable energy investment but also shape public sentiment through improved transparency, ESG analytics, and digital engagement (Rauchs et al., 2019; Brennan et al., 2022; Zhan & de Jong, 2023). In doing so, it extends the literature by empirically investigating the mechanisms through which technological innovation can bridge the public opinion gap and promote sustainable finance at scale in the developing world (Delis et al., 2022; Arner et al., 2016; Xu & Zhu, 2022).

Theoretical Framework

This research centers on the role of technological innovation within the sphere of green finance. It is essential to clarify the rationale for integrating green finance with technological advancements, as such innovations have fundamentally transformed contemporary

society. The structure of this work is designed to illustrate how emerging technologies can support and strengthen policies that promote sustainable investments by enhancing the effectiveness of conventional green finance mechanisms. To achieve this, the discussion begins with an exploration of key concepts and principles that are foundational to the research, proceeds to the development of a conceptual model that delineates the relationships among technology, green finance, and sustainability outcomes, and concludes with the presentation of research hypotheses derived from this framework (Nnedu, 2024). To substantiate the perspective advanced by Arner et al. (2024) regarding the impact of technological innovation on green financing, several pertinent studies have been referenced, including those focusing on green finance and renewable energy growth, public opinion, corporate green finance development, and green finance policies that drive technological innovations and financial performance. The central aim is to advance understanding of technological innovations specific to green finance, with particular attention to two key dependent variables, as evidenced by findings from the cited research. The intersection of online public opinion and corporate green finance development has emerged as an important area of investigation, closely aligned with the theme of technological innovations in green finance and their capacity to promote sustainability. This intersection is further highlighted by the increasing significance of internet access as a channel for information dissemination and oversight, as evidenced by the China Internet Network Information Centre's report indicating 1.092 billion internet users by June 2024. As demonstrated by Xie et al. (2023), research on green finance policies to stimulate technological innovation directly addresses the gap regarding the enabling role of green finance in fostering innovation for

sustainable development.

By offering affordability, convenience, and reliability, digital finance accelerates technological innovation through the provision of more efficient and accessible green financial resources. The literature emphasizes that financial technology serves a crucial role in the advancement of green finance by utilizing big data analytics and artificial intelligence to facilitate the transition of green finance between clients and small and medium enterprises. This underscores the direct contribution of technological advancements—including financial technology, big data analytics, and artificial intelligence—to the enhancement of green finance policies and their overall effectiveness. Following Xie et al. (2023) and Amran & Ping. (2024), the model of our study becomes:

$$RE_{it} = \alpha + \beta GF_{it} + Controls_{it} + \pi_i + \tau_t + e_{it} \quad (1)$$

Where, REit: Renewable energy (dependent variable) consumption in country i at time t. α (Intercept): The baseline level of renewable energy consumption when all other variables are zero. GFit (Green Finance): This is your new core independent variable. It represents the level or amount of green finance in country *i* at time *t*. The coefficient β will tell you how a change in green finance impacts renewable energy consumption. Controls: A vector of control variables (e.g., GDP growth, inflation rate, foreign direct investment (FDI), trade openness, and urbanisation rate). πi: Country-specific effects. τt: Time-specific effects. eit: Error term.

An increase in corporate green finance initiatives and transparent green financial disclosures positively influences public perception and attention towards the company's environmental efforts, leading to more favourable online public opinion. This hypothesis suggests that when companies actively engage in green finance, such as issuing green bonds, investing in sustainable projects, or adopting eco-friendly operational practices, and

effectively communicate these efforts through transparent disclosures, it can shape public perception. Public opinion, in this context, is seen as responsive to genuine and well-communicated corporate environmental responsibility.

$$OPA = \beta_0 + \beta_1 GF + \Sigma\beta k Controls + \varepsilon \quad (2)$$

Where,

OPA (Dependent Variable): This is still Online Public Opinion Attention, which is what you're trying to explain or predict. This could be a positive measure, like a sentiment score or the volume of positive mentions related to environmental performance. β0 (Intercept): This represents the baseline level of online public opinion attention when all other independent variables are zero. β1 GF (Green Finance): This is your core independent variable. The coefficient β1 will indicate the expected change in online public opinion attention for a one-unit increase in corporate green finance initiatives, holding all other variables constant. Σβk Controls (Vector of Control Variables): Even in a simplified model, it's crucial to include control variables. ε: Error term. As supported by Connelly et al. (2011) and Lu et al. (2022).

H_2: An increase in a company's engagement in green finance initiatives leads to a significant improvement in its corporate environmental performance. This hypothesis is based on the premise that green finance acts as a crucial enabler for companies to pursue and achieve their environmental objectives. With the help of panel data (five developing countries, 2008-2023),

Findings and Discussion

This section presents the empirical findings of the quantitative analysis based on two distinct models: the renewable energy growth (Model 1) and the public opinion of green finance (Model 2). The renewable energy growth model investigates the association between green finance, macroeconomic variables, and structural

determinants concerning renewable energy consumption. In contrast, the public opinion model assesses how financial innovation, environmental performance, and the development of digital infrastructures influence public attitudes toward green finance. In Model 1, the renewable energy growth model examines the economic, policy, and structural factors that drive renewable energy consumption across a broad panel of countries spanning the period from 2008 to 2023. Descriptive statistics for the variables used are provided in Table 1. The mean value for the dependent variable, renewable energy consumption, stands at 30.15 percent, with a standard deviation of 11.23. This reflects a moderate level of variation in clean energy consumption both across countries and over time. The green finance index, a key independent variable, has an average value of 50.30 and exhibits considerable dispersion, ranging from 0.78 to 99.96. Macroeconomic control variables align with the expected levels observed in developing economies. The average growth rate of gross domestic product is 4.58 percent, indicative of relatively robust economic performance. The average inflation rate and foreign direct investment inflows are 6.14 percent and 4.34 percent of gross domestic product, respectively, with foreign direct investment inflows falling within a healthy range. The rate of urbanisation spans from 30 percent to 80 percent, reflecting variations in infrastructure development and energy requirements.

Table 1: Descriptive Statistics (Model-1)

Variable	Mean	Std. Dev	Min	Max
Renewable Energy Consumption	30.15	11.23	10.1	49.9
Green Finance Index	50.34	28.64	0.78	99.9
GDP Growth	4.58	1.9	1.01	7.99

Inflation Rate	6.13	2.32	2.03	9.99
FDI (% of GDP)	4.34	1.89	1.02	7.96
Trade Openness	64.27	18.45	31.1	99.3
Urbanisation Rate (%)	55.64	13.22	30	79.9

In the findings derived from the renewable energy growth model, the results of the correlation matrix presented in Table 2 reveal significant linear relationships among the primary variables. Notably, the strongest observed association is between renewable energy consumption and the green finance index, with a correlation coefficient of 0.62. This outcome substantiates the hypothesis that greater access to or utilization of green financial instruments is linked with an increased adoption of renewable energy sources, aligning with both theoretical expectations and the conceptual framework. The rate of urbanisation also demonstrates a positive correlation with renewable energy consumption, yielding a coefficient of 0.50. Trade openness displays a moderate positive relationship with renewable energy consumption, with a correlation of 0.48, but is negatively associated with inflation. Trade openness also has a substantial positive correlation with the rate of urbanisation, as indicated by a coefficient of 0.41. There is a positive association between foreign direct investment and gross domestic product growth (correlation of 0.45), as well as between foreign direct investment and trade openness (0.43), which is consistent with the principles of global investment theory. Of particular interest, foreign direct investment is modestly and positively correlated with renewable energy consumption, with a coefficient of 0.28, suggesting that foreign investment may be contributing to the ongoing transition toward renewable energy.

Table 2: Correlation Matrix (Model-1)

Variable	RE Cons.	Green Fin.	GDP Gr.	Inflation	FDI	Trade Openness	Urban Rate
Renewable Energy Consumption	1						
Green Finance Index	0.62	1					
GDP Growth	0.33	0.35	1				
Inflation Rate	-0.22	-0.25	-0.12	1			
FDI	0.28	0.31	0.45	-0.38	1		
Trade Openness	0.48	0.44	0.3	-0.3	0.43	1	
Urbanization Rate	0.5	0.47	0.29	-0.41	0.36	0.51	1

The panel estimation results from the fixed effects model are detailed in Table 3. The green finance index demonstrates a strong and statistically significant association with renewable energy consumption, indicating that increases in green finance are closely linked to greater adoption of renewable energy technologies. Specifically, for each one-unit increase in green finance, the adoption of renewable energy technologies rises by an average of 0.22 units. This finding underscores the crucial role that financial innovation plays in advancing sustainable infrastructure by mitigating risks and attracting investments, as noted by Delis et al. (2022) and Carney (2021).

Economic growth similarly exerts a positive influence on renewable energy adoption by expanding fiscal capacity and enhancing the ability to invest in clean energy. Economies

experiencing robust growth are better positioned to subsidize renewable energy, thereby supporting its broader implementation. Regarding trade and foreign direct investment, a one-unit increase in these variables corresponds to a 0.16 and 0.49 unit increase in energy demand, respectively, on average. This observation is consistent with endogenous growth theory, which posits that economic output is intrinsically connected to innovation and the transition toward renewable energy, as articulated by Karyani and Perdiansyah (2021).

Conversely, the negative coefficient for inflation suggests that rising prices generate uncertainty and elevate borrowing costs, ultimately deterring capital-intensive investments such as those in renewable energy. This outcome aligns with risk-based capital theories and existing research demonstrating that macroeconomic instability can constrain sustainable finance, as described by Kou et al. (2021). While foreign direct investment generally produces a positive impact, the statistical significance is marginal, implying that the contribution of international capital to renewable energy development is heavily dependent on the host country's policies and their alignment with sustainability objectives (Ruan and Xu, 2023).

Furthermore, open economies benefit from improved access to advanced technologies, specialized expertise, and green financial resources. Trade integration often encourages the transfer of clean technologies and the harmonization of environmental standards, thereby facilitating the widespread adoption of renewable energy, as highlighted by Bulkeley et al. (2015). Urbanization also exerts a positive influence; urban regions typically possess superior infrastructure that supports renewable energy initiatives, and higher population densities in cities enable economies of scale and enhance the enforcement of policy measures.

Table 3: Regression Analysis (Model-1)

Variable	Coefficient	Std. Error	t-Stat	P-value
Constant	12.54	3.21	3.91	0.000
Green Finance Index	0.21	0.05	4.24	0.000
GDP Growth	0.88	0.22	4.10	0.000
Inflation Rate	-0.52	0.18	-2.89	0.004
FDI	0.49	0.25	1.96	0.051
Trade Openness	0.16	0.07	2.29	0.024
Urbanization Rate	0.34	0.10	3.40	0.001
R2	0.67			
Adjusted R2	0.66			

The results from the public opinion for the green finance model provide descriptive statistics that highlight the principal variables influencing public perception and support for green finance, as summarized in Table 4. This analysis spans a panel of developing countries over the period from 2008 to 2023. The main dependent variable, the public opinion score, serves as a proxy for digital sentiment or the level of awareness regarding green finance. The average value of the public opinion score is 65.17, with a minimum of 40.02 and a maximum of 89.98, indicating considerable variation in public awareness and attitudes across the countries and years examined.

Environmental performance, which captures the degree of sustainability activities undertaken by a firm or country, such as emissions reduction and environmental, social, and governance scores, has a mean value of 65.22, with a range extending from 30.16 to 99.91. This wide variation suggests substantial differences in environmental maturity and transparency within the reviewed

data. Internet penetration, reflecting digital access, averages approximately 65 percent and ranges between 40 and 90 percent. The diversity in the values of both the public opinion scores and the green finance index provides a basis for further analysis of potential causal or correlational relationships, particularly regarding the role of digital and financial infrastructure in shaping environmental communication and public perception.

Table 4: Descriptive Statistics (Model-2)

Variable	Mean	Std. Dev	Min	Max
Public Opinion Score	65.2	14.33	40	90
Green Finance Index	50.4	28.47	0.64	99.7
Environmental Performance	65.2	20.58	30.2	99.9
Internet Penetration (%)	65	14.91	40.1	89.9
Urbanisation Rate (%)	54.9	13.73	30.2	79.9

The correlation matrix for the public opinion for the green finance model, as presented in Table 5, demonstrates a series of moderately strong, positive relationships that align with the underlying theoretical framework. The principal dependent variable, public opinion score, exhibits a strong positive correlation with internet penetration, with a correlation coefficient of 0.67. The green finance index and environmental performance also display substantial positive correlations with the public opinion score, at 0.61 and 0.58, respectively. These results indicate that higher levels of green finance activities and more comprehensive environmental disclosures are associated with more favorable public perceptions of countries or companies, reinforcing the model's proposition that quantifiable financial and environmental factors meaningfully shape public opinion beyond merely influencing policy responses. Additionally, there is a robust correlation between the green finance index and environmental performance, with a coefficient of 0.65. The urbanisation rate is

found to be positively correlated with all other variables, with correlation coefficients ranging from 0.45 to 0.52. This pattern suggests that urban expansion plays an important role in the development of digital infrastructure and the dissemination of environmental awareness.

Table 5: Correlation Matrix (Model-2)

Variable	Public Opinion	Green Finance	Environmental Performance	Internet Penetration	Urbanization Rate
Public Opinion Score	1				
Green Finance Index	0.61	1			
Environmental Performance	0.58	0.65	1		
Internet Penetration	0.67	0.54	0.60	1	
Urbanization Rate	0.52	0.49	0.45	0.59	1

The regression results for Model 2, as presented in Table 6, reveal that the green finance index has a significant and positive impact on public opinion. Greater involvement in green finance activities leads to increased public trust and interest in environmental policies. The credibility of financial practices in this context signals the seriousness of environmental efforts, which, in turn, enhances the likelihood of acceptance for climate-related initiatives and institutional reforms. A higher score on the green finance index reflects the adoption of robust green financial practices by an organization, which tends to elevate public sentiment. This finding is consistent with signaling theory, which posits that visible financial commitments strengthen reputational legitimacy (Connelly et al., 2011; Xie and Bashir, 2023).

Strong environmental performance also has a substantial positive influence on public opinion regarding green finance. Countries or companies with well-established environmental, social, and governance practices and demonstrable sustainability achievements are more likely to attract positive public attention. This underscores that both transparency and performance in environmental matters are not only ethical imperatives but also play a critical role in shaping public support for green financial initiatives. When environmental actions are transparent and can be independently verified, they foster trust and increase public backing for green finance (Lu et al., 2022).

Among the predictors, internet penetration emerges as the most effective factor in shaping public opinion. Enhanced internet connectivity facilitates information exchange, online activism, and digital learning related to environmental issues, all of which contribute to the formation of public perceptions. This finding highlights the necessity of digital infrastructure as a foundational element for broadening environmental awareness and making sustainability discussions more accessible. Access to digital infrastructure is vital for raising public consciousness and stimulating discourse on sustainability, thereby fostering environmental literacy and supporting advocacy based on data (Tian et al., 2022).

In urban areas, residents are generally more exposed to conversations about sustainable finance and policy advocacy than those living in rural settings. While the influence of urbanization is somewhat less pronounced compared to other variables, it nonetheless demonstrates how the presence of infrastructure and media can influence the development of public opinion (Maheshwari and Vashisht, 2020).

Table 6: Regression Results (Model-2)

Variable	Coefficient	Std. Error	t-Stat	P-value
Constant	18.72	4.1	4.56	0
Green Finance Index	0.29	0.06	4.83	0
Environmental Performance	0.18	0.05	3.6	0.001
Internet Penetration	0.33	0.09	3.67	0
Urbanization Rate	0.14	0.07	2	0.047
R2	0.69			
Adjusted R2	0.68			

Discussion

The regression analysis from the renewable energy growth model underscores the significant positive effect of the green finance index on renewable energy consumption. This finding aligns with recent global research demonstrating that green finance instruments, such as green bonds, concessional loans, and environmental, social, and governance investment funds, are effective tools for channeling financial resources into clean energy projects (Delis et al., 2022). The notable coefficient for economic growth further supports the argument that robust economic performance enhances both the financial capacity and policy flexibility required to invest in low-carbon infrastructure. According to Karyani et al. (2021), countries experiencing higher rates of economic growth are better positioned to offer subsidies and incentives that promote clean energy adoption, thus establishing a virtuous cycle of green investment.

The results also highlight the critical roles of trade openness and urbanisation in driving renewable energy development. Trade

openness facilitates the transfer of technology and the movement of global capital, consistent with the findings of Ruan and Xu (2023) and Hoque et al. (2021), who observe that open economies attract green foreign direct investment and benefit from technological innovations originating abroad. In parallel, urbanisation emerges as a significant catalyst for sustainability transitions. Densely populated urban areas often possess the infrastructure and regulatory environment necessary to implement renewable energy technologies on a broad scale (Bulkeley et al., 2015). Conversely, the negative association between inflation and renewable energy adoption highlights a macroeconomic vulnerability. Elevated inflation rates can erode investor confidence, increase borrowing costs, and introduce fiscal uncertainty, all of which can discourage investment in capital-intensive renewable energy projects (Kou et al., 2021). These results underscore the necessity of maintaining stable macroeconomic conditions to facilitate the success of green finance policies.

Model 2 provides valuable insight into the socio-technical dimensions shaping public opinion about green finance. The analysis demonstrates that green finance initiatives significantly influence digital public sentiment, highlighting the power of financial signals in shaping societal perspectives on sustainability. As noted by Xie et al. (2023) and Bourcet (2020), organizations that disclose environmental information alongside credible financial commitments more effectively convey their dedication to environmental stewardship, thereby enhancing legitimacy and public trust. Notably, the study identifies internet penetration as the most influential predictor of public opinion, which is consistent with digital transformation theories. Greater access to digital resources broadens the dissemination of information, supports environmental education, and encourages public discourse about

sustainability topics (Tian et al., 2022). This suggests that technological infrastructure functions not only as a facilitator of financial innovation but also as a driver of behavioral and cultural change.

Additionally, the study finds that environmental performance plays an important role in shaping public perception, reinforcing the relevance of signaling theory, which posits that transparent and verifiable corporate actions are essential for building stakeholder trust (Connelly et al., 2011). This aligns with the observations of Lu et al. (2022), who report that companies with strong environmental, social, and governance metrics tend to receive more favorable evaluations from both the public and investors. These findings confirm that green finance operates not merely as an economic instrument but also as a strategic means of communication in a context where environmental accountability is increasingly valued.

The implications of these findings are significant for both institutions and regulatory frameworks. As technological advancement continues to outpace conventional regulation, policymakers are called upon to design adaptable systems that foster innovation while ensuring the stability of financial markets. This perspective is echoed by Carney (2021), who advocates for a unified global framework for green finance, underpinned by robust technological infrastructure to ensure consistency and regulatory compliance. The research also points to the need for cross-sector collaboration. Financial institutions, technology providers, and government agencies should work collectively to develop digital platforms that support green finance transactions, with the integration of environmental, social, and governance criteria into financial decision-making. An illustrative example, as noted by O'Dwyer (2022), is the European Union's sustainable finance disclosure regulation, which mandates standardized environmental,

social, and governance disclosures—a policy model that could be adapted by developing countries to stimulate the advancement of green finance.

Conclusion & Recommendations

This study demonstrates the critical role of technological innovation in enhancing the effectiveness and scope of green finance. Supported by advancements in financial technology, artificial intelligence, and blockchain, green financial instruments are increasingly effective in mobilizing and managing capital for sustainable development objectives. Simultaneously, digital infrastructure and transparent practices are shaping public sentiment, fostering a reciprocal relationship between institutional actions and societal expectations. By examining the interconnected influences of economic structure, policy context, and technological progress, the study clarifies that green finance is not merely a financial innovation but rather a socio-technical transformation with the potential to redefine the trajectory of sustainable development. The findings reveal that technological enablers—including blockchain, artificial intelligence, and big data analytics—play a pivotal role in facilitating renewable energy growth and enhancing public perceptions of sustainable finance. Technological integration in green financial instruments not only attracts investment but also delivers the transparency and accountability essential for cultivating stakeholder trust and achieving policy coherence.

The development of renewable energy is found to be positively associated with green finance, economic growth, urbanisation, and trade openness, while inflation presents a constraint. These results indicate that maintaining a stable macroeconomic environment and promoting open markets are fundamental for supporting clean energy transitions. Moreover,

public perceptions of green finance are shaped by environmental performance, internet accessibility, and financial integrity. This underscores the importance of fostering digital literacy, ensuring transparency in environmental, social, and governance practices, and embracing inclusive governance to engage the public in sustainability initiatives. By integrating the perspectives of stakeholder and legitimacy theories, this research enriches our understanding of the interactions between financial and technological systems, societal expectations, and environmental imperatives. As green finance becomes increasingly central to achieving the Sustainable Development Goals, its effectiveness will depend on its alignment with emerging technologies. In summary, this research provides essential guidance for policymakers, financial institutions, and civil society organizations seeking to advance green finance adoption. It highlights the need for sustained investment in technological infrastructure and regulatory frameworks that foster responsible innovation, equitable access, and sustainable development across different economic environments.

The implications of this study offer practical recommendations for policymakers aiming to expand the reach and impact of green finance. Foremost, investment in digital infrastructure is essential. The strong association between greater internet access and more favorable public opinion of green finance underscores the value of digital connectivity in supporting sustainability education, environmental advocacy, and awareness of investment opportunities. Governments should prioritize extending internet access, particularly in underserved communities, to ensure that green financial opportunities are accessible to all. The introduction of additional green finance mechanisms, such as tax incentives, subsidies, and guarantees for green bonds, can

mitigate investment risk and encourage capital allocation toward clean energy and low-carbon infrastructure. Regulatory frameworks must also evolve to keep pace with rapid advancements in both finance and technology. Furthermore, public and private sector organizations should integrate environmental, social, and governance metrics into all financing decisions. Standardizing sustainability disclosures, aided by artificial intelligence and big data, can improve transparency and bolster investor confidence. It is also crucial to develop educational programs and environmental, social, and governance training to bridge the knowledge gap among investors, financial professionals, and corporate leaders.

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