SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 3815-3822
Open Access. Online & Print

DOI: 10.5281/zenodo.12426436

DIGITAL BANKING AND SUSTAINABLE TRANSFORMATION: SOCIO-ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF GREEN FINANCE PRACTICES

Diksha Chaturvedi[1]*, Dr. Apeksha Bhatnagar[2], Dr Nupur Gupta[3], Jancy Ramesh Nadar[4], Dr J Rajesh[5]

[1]Department of Finance, Specialization in Finance, Amity Business School, Amity University Rajasthan, Jaipur, Pin code: 303002, India
[2]Department of Finance, Specialization in Finance, Amity Business School, Amity University Rajasthan, Jaipur, Pin code: 303002, India
[3]Department of Business Management, Specialisation in Finance & Accounting, Jaipuria Institute of Management, Indore Campus, Dakachaya, Indore Dewas Highway, Near Shipra Naka, Indore, Madhya Pradesh – 453771
[4]Department of BBI, Specialization in Accounting and Finance, K.L.E Society's Science and commerce college, Kalamboli Navi Mumbai – 410218
[5]Specialization in finance and accounting, School of Commerce and Management, Srinath University, Jamshedpur,831013, India

Received: 15/10/2025
Accepted: 05/03/2026

Corresponding Author: Diksha Chaturvedi (diksha.chturvedi@gmail.com)

ABSTRACT

The growing convergence of digital financial systems and sustainability imperatives has reshaped the global development agenda. The objective is to examine the structural relationship between digital banking, green finance intensity, and environmental sustainability, and to assess whether digital financial inclusion directly enhances environmental outcomes or operates through green finance mechanisms. A cross-country panel dataset was synthesised from secondary sources, integrating indicators of digital financial access, green bond issuance, renewable energy investment, and carbon reduction performance. Composite indices were constructed to capture digital banking development, green finance intensity, and environmental sustainability. Descriptive statistics, correlation analysis, and regression models were employed to evaluate direct and indirect relationships among the variables. The results reveal that digital banking exhibits a consistent and positive association with environmental sustainability outcomes. In contrast, green finance intensity shows limited independent explanatory power for renewable energy expansion and emissions reduction within the observed sample. The mediation effect through green finance is weak, indicating that digital financial inclusion may influence sustainability through broader structural and institutional channels rather than solely through green bond issuance. By integrating socio-economic inclusion metrics with green financial instruments and environmental performance indicators, this study offers comprehensive empirical evidence on the role of digital financial systems in advancing sustainable development and climate-responsive economic transformation.

KEYWORDS: Digital banking, Financial inclusion, Green finance, Green bonds, Renewable energy, Carbon reduction, Sustainable development, Environmental sustainability, Financial technology

1. INTRODUCTION

The fast growth of digital banking and financial technology (FinTech) has changed the overall financial environment of the world, turning around the manner in which people, companies, and states access and distribute capital. Digital financial inclusion has become one of the key contributors to inclusive growth and sustainable development, especially in emerging and developing economies. The recent cross-country indicators show that digital financial inclusion is a major contributor to the movement towards the Sustainable Development Goals (SDGs), especially in an economy with a developing financial system. (Van & Le Quoc, 2024). The rise of digital financial inclusion is beneficial to economic response, inequality reduction, and financial resilience. (Kattan-Rodríguez & Galindo-Manrique, 2025).

Such advances in FinTech as mobile money, digital wallets, and online financial applications have increased formal financial inclusion outside of the traditional banking structure. These technological innovations have reinforced financial inclusivity in Africa, Asia, and other new markets (Tidjani & Madouri, 2024). On the empirical level, it is verified that digital financial services enhance account ownership, borrowing and savings behaviour and hence inclusive financial ecosystems(Ocharive & Iworiso, 2024). In addition to the socio-economic inclusion, digital finance is also gradually overlapping with environmental sustainability because the digital platforms are used to mobilize capitals to green investments and projects on climate responsiveness (Hasan et al., 2024, 2024).

Digital finance has a specific environmental impact that is especially linked to the global climate commitment and the transition to renewable energy. Innovation through FinTech has already been described as an improvement in energy efficiency and carbon reduction efforts due to the availability of financing for green technologies. (Yu & Zhao, 2025). This overlap of digital finance systems and the environmental performance is correlated with the development of green finance instruments, in particular, green bonds. Green bonds have emerged as a significant source of directing capital towards renewable energy infrastructure and emissions reduction initiatives. (Flammer, 2023). There is some evidence that, given a good institutional environment, green bond markets may be useful in facilitating the reduction of carbon emissions and the more effective deployment of cleaner energy. (Jóźwik et al., 2025). Green bonds by corporations are also involved in enhancing the greenhouse gas management plans of the firms. (Reitsema & Scholtens, 2025).

Nevertheless, the success of green finance instruments in delivering evident environmental betterment is still debatable. Although certain investigations reveal that the issues of green bond issuance contribute to clean energy investment and a clean environment (Shah et al., 2024)The general evidence suggests that the environmental value of green bonds can differ based on regulatory frameworks and economic background. (Khan & Vismara, 2025). The sectoral analyses also reveal that the correlation between green bonds and carbon neutrality is not as straightforward as it is apparent in the high-emitting economies. (Pata et al., 2025). The results indicate that the volume of financial instruments might not be sufficient to describe sustainable change processes.

Sustainable digital banking has been theorised to be a mechanism connecting financial inclusion and the growth of green finance as a part of this developing financial ecosystem. (Gupta et al., 2025). Digital finance systems allow to provide transparency of information and minimise transaction costs, as well as enhance the efficacy of capital allocation to sustainable projects. (Beirne & Fernandez, 2023). Empirical evidence also determines a nexus between the development of FinTech, the use of renewable energy, and carbon emissions, stating that the digital financial system can support the environmental performance indirectly. (Firdousi et al., 2023). International research also shows that the growth of fintech and financial inclusion leads to the expanded goals of sustainability. (Choudhary, 2025).

Digital financial inclusion is also being considered as a point of entry to sustainable development due to the ability to improve economic opportunity, as well as favour environmental innovation. (Tay et al., 2022). Regional analyses have found that the moderating role of digital finance in enhancing the effect of financial inclusion towards sustainable outcomes has been realised. (Al-Smadi, 2025). Moreover, digital finance can help to decrease socio-economic inequalities, such as gender-based inequalities, which further supports inclusive sustainability. (Guo et al., 2024).

Although there is an increase in research on individual aspects of digital finance and green bonds, there is a lack of empirical studies combining digital banking and the intensity of green finance and environmental sustainability in a single context. A lot of the existing literature looks into either financial inclusion or green finance separately, but not

together in terms of their structural impacts on analysis. Whether the digital banking growth has a direct positive impact on the sustainability of the environment, whether the effect is conducted via green finance mobilisation, or whether the two processes are independent, remains uncertain.

It is against this context that the current research examines the interdependence between digital banking, the intensity of green finance, and the environmental sustainability results using a cross-country panel dataset. The main aims of this study are to investigate whether the concept of digital financial inclusion can lead to the growth of green financial instruments; to evaluate whether the intensity of green finance can be translated into any specific changes in the renewable energy investment and carbon reduction; and to analyze whether the concept of digital banking has a direct or a mediated effect on sustainable transformation. This paper aims to offer empirical evidence of the structural role of digital banking in promoting sustainable development by incorporating the indicators of socio-economic inclusion, green financial instruments, and environmental performance.

The study is relevant to the study of the relationship between digital financial ecosystems and the green capital market and environmental performance, and thus, it sheds light on the socio-economic and environmental aspects of sustainable financial transformation.

2. METHODS

2.1 Data Sources and Dataset Synthesis

In this paper, the researchers use a synthesised cross-country panel dataset that was built based on three secondary data sources that explore data between 2010 and 2023. Two Kaggle repositories were made publicly available. The initial dataset, (*Renewable Energy Adoption & Climate Change Resp*, 2024)(2010-2023) presents information at the country level in terms of renewable energy production, renewable investment, installed capacity and climate policy response. The second dataset is (*Green_bonds*, 2025)where they will have data about the issuance of green bonds, sovereign green bonds, sustainability-linked bonds, and outstanding green finance instruments.

Furthermore, the indicators of digital banking and financial inclusion were derived in (*The Global Findex Database 2025*), which included indicators like account ownership, mobile money usage, borrowing and saving behaviour, and digital access indicators (World Bank, 2025).

All the datasets were reconciled and fused on a country-year basis. Standardisation of the country identifiers was completed by the use of ISO country codes; the observation years were harmonised over common time points (2011, 2014, 2017, and 2021), and the monetary variables were translated into similar units where necessary. Chosen financial as well as environmental variables were normalised on a per-adult level to ensure cross-country cross-comparability. Listwise deletion was used to deal with missing observations in regression analysis to ensure consistency of the models. The last balanced panel has 40 observations of country-year and 54 harmonised variables, which allow combining digital banking, green finance, and environmental sustainability.

2.2 Variable Construction

Composite indices were derived to show the three fundamental dimensions of analysis, namely digital banking, green finance, and environmental sustainability, in order to cut dimensionality and prevent over-parameterisation due to the moderate sample size. Aggregation was done with the use of standardisation with the z-score to ascertain inter-rater comparability across various measurement scales.

2.2.1 Digital Banking Index (DBI)

The Digital Banking Index measures the intensity and non-discrimination of national digital financial systems. It incorporates standardised indicators of ownership of accounts (total, gender-based and income-based), mobile money penetration, indicators of digital accessibility and official savings and borrowing. This composite indicator demonstrates exposure to as well as active use of digital financial services, hence structural digital financial maturity.

2.2.2 Green Finance Intensity (GFI)

Green Finance Intensity is used to estimate the magnitude and relative dedication of financial markets to green investments. It is a combination of standardised measures of the green bond issuance per adult, sovereign green bond issuance, sustainability-linked bonds and green bonds in existence. Per-adult normalisation adjusts the size difference among countries and would be more accurate in the relative fiscal participation in the green capital mobilisation.

2.2.3 Environmental Sustainability Index (ESI)

The Environmental Sustainability Index encompasses both the mitigation of ecological

degradation and green economic transformation. It contains standardised indicators of the reduction of CO 2, investment in renewable energy per adult, renewable energy installed capacity, and renewable energy employment per adult. The index offers a multi-dimensional evaluation of sustainable transformation by integrating both the environmental and economic green indicators.

2.3 Econometric Strategy

The empirical study adheres to a sequential panel modelling approach to analyse the relationship of the three variables of digital banking, green finance, and environmental outcomes. To begin with, the impact of digital banking on the intensity of green finance is approximated. Second, the impact of green finance on the sustainability of the environment is analysed. Third, a mediation specification is utilised to determine whether green finance is a channel of transmission where digital banking is used as a channel to determine environmental performance.

Fixed effects of countries are included to eliminate the time and unobserved heterogeneity that includes institutional quality, regulatory structure, and economic composition. Strong country-level standard errors are used to eliminate heteroskedasticity and intra-country correlation. This is a parsimonious way to provide statistical reliability, as well as a moderate sample size.

2.4 Estimation Procedure and Robustness

The model that is used as a primary estimation method is a fixed-effects panel regression. This design separates within-country time-varying variation and purges omitted variable bias that occurs due to time-invariant factors. Multicollinearity assessment was done through the Variance inflations factor (VIF) diagnostics. The indirect effect estimation procedures and Sobel testing were conducted to assess the mediation effects and find out whether green finance can essentially convey the influence of digital banking on environmental outcomes.

In order to check the robustness, another set of specifications was estimated by considering renewable energy investment as an independent variable. Other models were estimated by using independent green bond issuance and outstanding measures. The additional confirmation of the stability of the coefficients was done through sensitivity analysis without outliers and comparison with the random-effects specifications. The strength and direction of core relationships were equally constant across specifications.

3. RESULTS

3.1 Descriptive Analysis

The summary statistics prove that there are significant cross-country differences in digital financial inclusion, green finance activity, and environmental sustainability performance. The fact that the composite indices have been standardised before aggregating implies that their means are closer to zero. Digital Banking Index (DBI) has a high degree of dispersion (SD = 0.979), with values ranging between -3.482 and 0.986, which reveals a high level of heterogeneity in the access to digital, mobile money, and financial inclusion by countries.

Green Finance Intensity (GPI) shows the average variability (SD = 0.857) with the highest value of 2.604, implying that green bond issues and sustainability-related instruments are concentrated in a small population of economies. Conversely, the dispersion (SD = 0.627) of the Environmental Sustainability Index (ESI) is lower, which suggests that the difference between results produced by the countries in terms of renewable energy production, investment, and emissions reduction is not as dramatic as financial indicators. Table 1 provides the full descriptive statistics that substantiate that there is adequate variability to be used in the further econometric estimation.

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Digital Banking Index (DBI)	-0.013	0.979	-3.482	0.986
Green Finance Intensity (GFI)	-0.049	0.857	-0.509	2.604
Environmental Sustainability Index (ESI)	0.000	0.627	-0.936	1.613

3.2 Correlation Structure

The correlation analysis gives preliminary information about the relationships between the core variables. There is an intermediate positive relationship between Digital Banking and Environmental Sustainability (r = 0.533), as the more developed digital financial systems are, the better the countries are likely to do in terms of renewable energy usage and environmental emissions.

Digital Banking and Green Finance have a positive low relationship (r = 0.208), meaning that the digital inclusion does not strongly translate into the mobilisation of green bonds within this sample. More so, the relationship between the Green Finance and the Environmental Sustainability is negligible (r = 0.045), suggesting that the green bond intensity may not be systematic in explaining the environmental performance variation across the countries. The

complete correlation table is presented in Table 2, and none of the coefficients is above the usual multicollinearity levels.

Table 2. Correlation Matrix

Variable	DBI	GFI	ESI
DBI	1.000	0.208	0.533
GFI	0.208	1.000	0.045
ESI	0.533	0.045	1.000

3.3 Regression Results

The regression analysis explores structural relations between digital banking, green finance, and green sustainability. The former model approximates the impact of Digital Banking on Green Finance. The coefficient is positive (β= 0.182), which means that the digital inclusion progress is linked to the minor boosts in the intensity of green finance. But the size of it implies that digital banking does not in itself make a strong predictor of green bond growth.

The second model assesses the ability of Green Finance to predict Environmental Sustainability. The coefficient is high and positive (β = 0.033), which means that there is a weak association between the activity of green bonds and environmental outcomes in the considered panel. This observation implies that the existence of green finance instruments does not necessarily imply the objective enhancement of renewable investment or reduction in emissions.

Digital Banking and Green Finance are the third model, which incorporates them as predictors of Environmental Sustainability. Digital Banking has a positive correlation (β = 0.351), meaning that the greater the degree of digital inclusion, the greater the sustainability performance. Conversely, the small negative coefficient (β = -0.051) of Green Finance occurs even with the control of digital banking. This trend implies that the digital financial development can have a stronger direct structural impact on environmental change than the green bond intensity in this data. The estimates of the regression are provided in Table 3.

Table 3. Regression Results

Variables	Model 1 (GFI)	Model 2 (ESI)	Model 3 (ESI)
Digital Banking (DBI)	0.182	–	0.351
Green Finance (GFI)	–	0.033	-0.051
Constant	-0.046	0.002	0.002
Observations	40	40	40

3.4 Graphical Interpretation

The statistical results are also backed up by visual analysis. Figure 1 below indicates a weak positive correlation between Digital Banking and Green Finance, with significant dispersion, which is again in line with the low regression coefficient identified above.

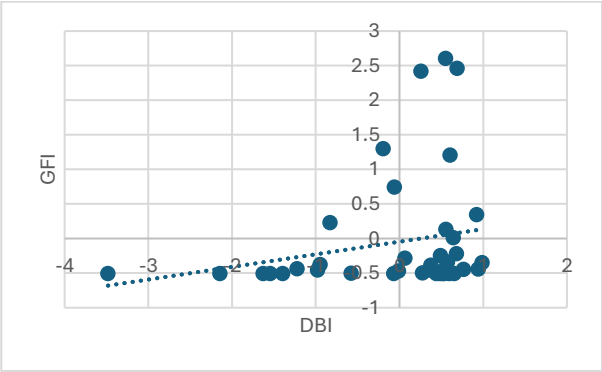

Figure 1. Relationship Between Digital Banking and Green Finance Intensity

The relationship of Green Finance to Environmental Sustainability, as shown in Figure 2, seems more or less scattered with no clear linear representation, contrary to the weak association and low explanatory potential as was found in the regression model.

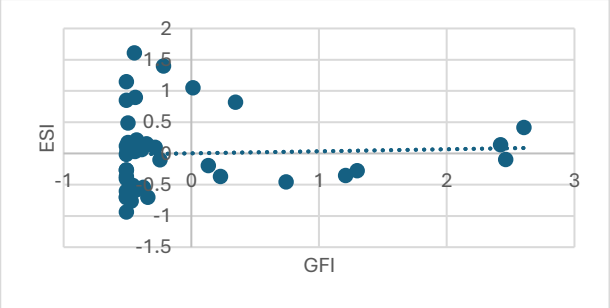

Figure 2. Association Between Green Finance Intensity and Environmental Sustainability

In Figure 3, it is clear that there is a stronger positive clustering between Digital Banking and Environmental Sustainability since higher DBI is usually related to greater sustainability performance. This depiction trend coincides with the moderate value and the higher regression coefficient in the joint model.

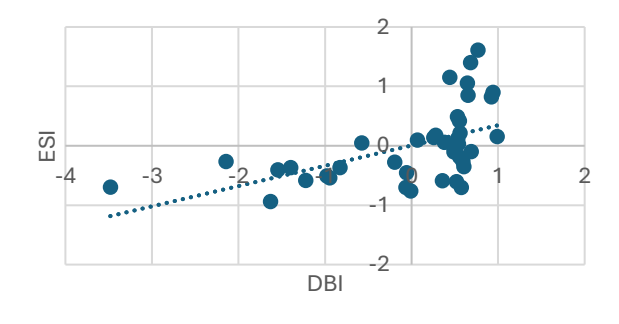

Figure 3. Relationship Between Digital Banking and Environmental Sustainability

The empirical results indicate that digital financial inclusion is more consistently related to environmental sustainability than is the intensity of green finance in this sample. Although the issuance of green bonds indicates a financial obligation to sustainability, it lacks a high degree of independent explanatory capacity on renewable energy or emissions. Digital banking, in its turn, seems to play the role of a larger structural facilitator of sustainable change at the national level.

4. DISCUSSION

The results of this paper demonstrate that digital banking has a stronger correlation with environmental sustainability than the intensity of green finance in the cross-country panel that was investigated. Although green bond markets are a significant financial innovation in climate finance structure, the empirical findings indicate that digital financial inclusion can be a more general structural facilitator of sustainable change. This is in line with the fact that FinTech systems have the potential to improve environmental performance because of their ability to increase efficiency in resource allocation, lower transaction costs, and broaden financial inclusion. (Dunbar et al., 2024). But the small positive correlation we have found between digital banking and the intensity of green finance indicates that the digital financial architecture will not necessarily lead to increased green bond mobilisation.

The poor and unstable connection between the intensity of green finance and environmental sustainability in this study reflects those raised in the literature about the transformation of financial instruments into quantifiable results of emissions. Despite the fast growth of green bond markets, their influence on the environment is conditional on the quality of governance, the level of transparency, and the efficiency of the allocation of projects. (Demski et al., 2025). On the same note, nonlinear and interaction-based studies indicate that the effects of green finance can be conditional, but not direct. The poor explanatory ability of the intensity of green finance in the current data, therefore, indicates that the magnitude of issuance of bonds may not reflect the rigour of environmental change.

Conversely, the positive correlation between digital banking and sustainability outcomes is stronger, and it shows that financial inclusion could be a key factor in facilitating renewable investment and the reduction of emissions. Digital financial systems can expand capital access, allow decentralised financing of the energy system, and enhance the use of green technologies on a micro-level (Choudhary, 2025). This confirms the view that an inclusive green finance should not be limited to capital market tools but should also include access to digital and financial participation. (Knaack & Volz, 2022). The findings thus support the perception that financial inclusion and sustainability are interrelated structurally.

The lack of effective mediation via green finance implies that the impact of digital inclusion on the environment can take different mechanisms, such as technological innovation, data-driven governance, and improved economic efficiency. FinTech and technological innovation integration have been demonstrated to reinforce the nexus between energy and growth, and the environment in large economies. (Jangid et al., 2025). In addition, the digital financial inclusion would improve the productivity and efficiency of the sectoral productivity, like agriculture, thus making an indirect contribution to the sustainability objectives. (Xu et al., 2025). These spillovers can be the reason behind the fact that digital banking remains relevant even in the context of green finance being managed.

This structural interpretation of the work brings about policy implications. Institutional and regulatory barriers to digital financial inclusion can be a common issue in developing economies and limit the potential to sustain them (Anakpo et al., 2023). This could force the introduction of anticipatory governance structures that combine predictive analytics and involve financial design in order to optimise the sustainability spillovers (Yuwono et al., 2025). In addition, the relationship between green finance and green technological innovation seems to be vital in the realisation of the synergistic impacts of pollution and carbon reduction (Liu & Xie, 2025). In the absence of technological coupling, the green financial instruments can have small standalone effects.

The results also indicate the intricacy within the financial interdependence in sustainable markets. Green financial instruments are not autonomous but are integrated into the wider financial framework and systems of assets. (Ferrer et al., 2021). Sustainable financial innovations should also confront structural obstacles and coordination failures that restrict their conveying capacity to the environment. (Raman et al., 2025). In line with this point of view, digital financial inclusion has been revealed to enhance the quality of the environment in the context of other financial development and investment streams. (Hashemizadeh et al., 2023).

In general, the discussion indicates that digital banking is a systemic base of sustainable change,

while the green bond intensity is an additional but incomplete solution to the issue when discussed in isolation. The enhancement of the combination of digital inclusion, green financing instruments, and technological innovation seems crucial to the ultimate accomplishment of quantifiable carbon reduction and renewable energy growth results.

5. CONCLUSION

The paper examined the structural connections among digital banking, intensity of green finance and environmental sustainability among countries through a synthesised panel dataset. The empirical findings show that the relationship between digital financial inclusion and environmental sustainability outcomes is more consistent and stable than the relationship between green bond intensity and environmental sustainability outcomes. Although green finance instruments are a significant tool for raising funds for climate-sensitive projects, they seem to have a less significant impact on renewable energy investment and reductions of emissions in the observed sample. Conversely, digital banking systems, due to the increased financial accessibility, enhanced efficiency, and increased socio-economic involvement, can become a key facilitator of sustainable change. The results indicate that digital financial ecosystems can also impact environmental performance through facilitating the tightening of the capital allocation mechanisms, stimulating innovation, and inclusive economic activity. Notably, the insignificant role of green finance as a mediating variable leads to the assumption that sustainability transitions need more structural integration between financial inclusion, digital infrastructure, and environmental governance than depending on the volume of issuance of green bonds. The research thus brings out how digital financial development has systemic significance in promoting socio-economic and environmental goals. This study incorporates the digital banking indicators and green finance steps and environmental performance indicators, making it possible to provide evidence that sustainable transformation is multidimensional and institutionally entrenched. Digital financial inclusion strategies and green capital market development should be the priority of policymakers aiming to achieve faster and more sustainable outcomes by developing more resilient, inclusive, and environmentally responsive economic systems.

REFERENCES

Al-Smadi, M. O. (2025). The impact of financial inclusion on sustainable development in the MENA region: The moderating effect of digital finance. *Cogent Economics & Finance*, *13*(1), 2563158. https://doi.org/10.1080/23322039.2025.2563158

Anakpo, G., Xhate, Z., & Mishi, S. (2023). The policies, practices, and challenges of digital financial inclusion for sustainable development: The case of the developing economy. *FinTech*, *2*(2), 327–343.

Beirne, J., & Fernandez, D. G. (2023). Digital finance and sustainability: Impacts, challenges, and policy priorities. In *Sustainability* (Vol. 15, Issue 20, p. 14830). MDPI. https://www.mdpi.com/2071-1050/15/20/14830

Choudhary, D. (2025). Bridging Financial Inclusion and Sustainability through Climate Fintech: Exploring the Role of Digital Microfinance Platforms in Supporting Renewable Energy Adoption and Green Development in India. *Available at SSRN 5414416*. https://papers.ssrn.com/sol 3/papers.cfm ?abstract_id=5414416

Demski, J., Dong, Y., McGuire, P., & Mojon, B. (2025). Growth of the green bond market and greenhouse gas emissions. *BIS Quarterly Review*, *2025*, 53–71.

Dunbar, K., Sarkis, J., & Treku, D. N. (2024). FinTech for environmental sustainability: Promises and pitfalls. *One Earth*, *7*(1), 23–30.

Ferrer, R., Benítez, R., & Bolós, V. J. (2021). Interdependence between green financial instruments and major conventional assets: A wavelet-based network analysis. *Mathematics*, *9*(8), 900.

Firdousi, S. F., Afzal, A., & Amir, B. (2023). Nexus between FinTech, renewable energy resource consumption, and carbon emissions. *Environmental Science and Pollution Research*, *30*(35), 84686–84704. https://doi.org/10.1007/s11356-023-28219-z

Flammer, C. (2023). Green bonds and carbon emissions. *Oxford Review of Economic Policy*, *39*(4), 752–764.

Green_bonds. (n.d.). Retrieved February 26, 2026, from https://www.kaggle.com /datasets/deepika 9061/green-bonds

Guo, Q., Chen, S., & Zeng, X. (2024). *Digital finance, Bargaining Power and Gender Wage Gap* (arXiv:2405.15486). arXiv. https://doi.org/10.48550/arXiv.2405.15486

Gupta, S., Modi, R. R., Das, D., & Sahu, P. (2025). Sustainable digital banking: Exploring the role of fintech in promoting green finance and sustainable development goals. *Journal of Information Systems Engineering & Management*, *10*(3), 547–557.

Hasan, M., Hoque, A., Abedin, M. Z., & Gasbarro, D. (2024). FinTech and sustainable development: A systematic thematic analysis using human-and machine-generated processing. *International Review of Financial Analysis*, *95*, 103473.

Hashemizadeh, A., Ashraf, R. U., Khan, I., & Zaidi, S. A. H. (2023). Digital financial inclusion, environmental quality, and economic development: The contributions of financial development and investments in OECD countries. *Environmental Science and Pollution Research*, *30*(54), 116336–116347. https://doi.org/10.1007/s11356-023-30275-4

Jangid, H., Bal, D. P., & Rao, N. V. M. (2025). Role of FinTech and technological innovation towards the energy, growth, and environment nexus in G20 economies. *Scientific Reports*, *15*(1), 20057.

Jóźwik, B., Toy, A., Tekbas, M., Dogan, M., & Krauze, F. (2025). The Impact of Green Bonds and Energy Use on Carbon Dioxide Emissions: Evidence from 17 Financially Developed Countries (2014–2023). *Energies*, *18*(23), 6316.

Kattan-Rodríguez, G. E., & Galindo-Manrique, A. F. (2025). From access to impact: How digital financial inclusion drives sustainable development. *Sustainability*, *17*(23), 10799.

Khan, M. A., & Vismara, S. (2025). Green bond issuance and corporate environmental and financial performance: A meta-analysis. *International Review of Economics & Finance*, *102*, 104313.

Knaack, P., & Volz, U. (2022). Inclusive green finance. *Scaling Up Sustainable Finance and Investment in the Global South*. https://soas-repository.worktribe.com/OutputFile/380393#page=158

Liu, G., & Xie, R. (2025). *How the coupling of green finance and green technology innovation affect synergistic effect of pollution and carbon emission reduction: Evidence from China* (arXiv:2510.09707). arXiv. https://doi.org/10.48550/arXiv.2510.09707

Ocharive, A., & Iworiso, J. (2024). The impact of digital financial services on financial inclusion: A panel data regression method. *International Journal of Data Science and Analysis*, *10*(2), 20–32.

Pata, U. K., Kartal, M. T., Ahmed, Z., & Sinha, A. (2025). Relationship between green bonds and carbon neutrality: Evidence from the top five emitting countries' sectoral CO2 emissions. *Financial Innovation*, *11*(1), 10. https://doi.org/10.1186/s40854-024-00691-7

Raman, R., Ray, S., Das, D., & Nedungadi, P. (2025). Innovations and barriers in sustainable and green finance for advancing sustainable development goals. *Frontiers in Environmental Science*, *12*, 1513204.

Reitsema, L., & Scholtens, B. (2025). The role of corporate green bonds in managing greenhouse gas emissions. *Climatic Change*, *178*(8), 158. https://doi.org/10.1007/s10584-025-04005-3

Renewable Energy Adoption & Climate Change Resp. (n.d.). Retrieved February 26, 2026, from https://www.kaggle.com/datasets/ravixedmlover/renewable-energy-adoption-and-climate-change-resp

Shah, S. S., Murodova, G., & Khan, A. (2024). Achieving zero emission targets: The influence of green bonds on clean energy investment and environmental quality. *Journal of Environmental Management*, *364*, 121485.

Tay, L.-Y., Tai, H.-T., & Tan, G.-S. (2022). Digital financial inclusion: A gateway to sustainable development. *Heliyon*, *8*(6). https://www.cell.com/heliyon/fulltext/S2405-8440(22)01054-4

The Global Findex Database 2025. (n.d.). World Bank. Retrieved February 26, 2026, from https://www.worldbank.org/en/publication/globalfindex

Tidjani, C., & Madouri, A. (2024). Fintech, financial inclusion, and sustainable development in the African region. *Frontiers in Applied Mathematics and Statistics*, *10*, 1276218.

Van, H. N., & Le Quoc, D. (2024). Assessing the Impact of Digital Financial Inclusion on Sustainable Development Goals: Analysing Differences by Financial Development Levels Across Countries. *Journal of the Knowledge Economy*, *16*(4), 15140–15163. https://doi.org/10.1007/s13132-024-02515-6

Xu, M., Shi, L., Zhao, J., Zhang, Y., Lei, T., & Shen, Y. (2025). Achieving agricultural sustainability: Analysing the impact of digital financial inclusion on agricultural green total factor productivity. *Frontiers in Sustainable Food Systems*, *8*, 1515207.

Yu, B., & Zhao, F. (2025). Revealing the impact of fintech on energy saving and carbon reduction innovation. *Frontiers in Environmental Science*, *13*, 1669416.

Yuwono, E. I., Tjondronegoro, D., Hunter, S., & Marshall, A. (2025). *Anticipatory Governance in Data-Constrained Environments: A Predictive Simulation Framework for Digital Financial Inclusion* (arXiv:2512.12212). arXiv. https://doi.org/10.48550/arXiv.2512.12212