

Green Fintech Adoption Pathways and Constraints Shaping Sustainable Finance Innovation in Africa

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Article Info.	Abstract
Corresponding Author Anjay Kumar Mishra Email anjaymishra2000@gmail.com Article History Received: June 02, 2026 Accepted: July 20, 2026 Cite Celestin, M., Vasuki, M. Mishra, A. K., Dinesh Kumar, A., Vinayakan, K., & Zulu, L. (2026). Green fintech adoption pathways and constraints shaping sustainable finance innovation in Africa. <i>GS WOW: Wisdom of Worthy Research Journal</i>, 5(1), 13–29. https://doi.org/10.62078/grks.2026.v05i01.002	We examine how green fintech adoption pathways shape sustainable finance innovation across African financial ecosystems. Using firm level panel data from the African Green Fintech Adoption Dataset covering 2018 to 2024, we estimate a pathway based model linking digital payment innovations, green lending platforms, and sustainability data analytics to multidimensional innovation outcomes under varying institutional conditions. We find that adoption effects are asymmetric and conditional. Payment innovations primarily expand inclusion and system reach, green lending platforms mobilize capital toward environmentally aligned activities, and sustainability data analytics strengthen credibility and scalability of innovation. These effects intensify where regulatory clarity and policy support are stronger, confirming that institutions shape how technology translates into impact. The core contribution lies in introducing a mechanism driven explanation that moves beyond adoption volume and shows why similar fintech tools generate divergent sustainability outcomes across markets. The findings refine sustainable finance and innovation theory by integrating adoption pathways with institutional moderation. Policy relevance emerges in the need for coordinated regulation, incentives, and data governance to unlock scalable green finance. Managers can apply the insights to sequence fintech strategies and align products with governance capacity. Keywords: financial inclusion, green fintech, institutional quality, sustainable finance, sustainability analytics

Introduction

We reviewed the rapid expansion of green fintech as a central response to the growing financing gap for sustainable development worldwide. Global estimates indicate that achieving climate and sustainability goals requires annual investment flows exceeding USD 4 trillion, yet current financing

falls far short of this benchmark, particularly in emerging markets where capital access remains constrained (Schoenmaker & Schramade, 2023; World Bank, 2025). Digital finance innovations have reshaped how financial services are delivered, enabling faster transactions, broader access, and new data driven decision tools. At the same time,

sustainability pressures have intensified, pushing financial systems to integrate environmental and social objectives into core operations. Our work complements this global debate by focusing on green fintech adoption as a mechanism through which digital finance and sustainability agendas converge, extending sustainable finance theory into technology mediated innovation pathways.

Complementary work by cross country and regional studies shows that fintech adoption has accelerated financial inclusion and innovation, yet its contribution to sustainable finance remains uneven. Comparative evidence highlights that digital payments dominate fintech activity across Africa, while green lending and sustainability analytics scale more slowly and unevenly across jurisdictions (Demirgüç Kunt et al., 2022; Frost et al., 2022). Regional reports document strong growth in fintech firm numbers alongside persistent constraints related to regulation, policy coherence, and institutional capacity, which limit the translation of innovation into environmental impact (Demertzis et al., 2022; Ozili, 2024). Our work complements these findings by shifting attention from adoption volume to adoption pathways, emphasizing how different green fintech mechanisms generate distinct sustainability outcomes under varying institutional conditions. This framing applies diffusion and institutional theories to explain why similar technologies produce divergent results across markets.

Our study introduces novelty by grounding the analysis in the GreenFin Adoption Dynamics Model, which explicitly links green fintech adoption pathways, the institutional and policy environment, and sustainable finance innovation outcomes. We examine three core pathways: digital payment innovations that expand access and transaction efficiency, green lending platforms that channel capital toward environmentally aligned activities, and sustainability data analytics that embed environmental information into financial decision making. These pathways are connected to observable outcomes including financial inclusion, green investment mobilization, environmental

impact financing, and innovation scalability. The magnitude of the challenge is particularly evident in Africa, where fintech ecosystems are expanding rapidly while sustainable finance outcomes remain fragmented and uneven across countries (European Investment Bank, 2024; Ozili, 2025). This gap carries global relevance because African markets are central to future climate mitigation and adaptation efforts.

We reviewed nine global and regional studies covering digital payments, green lending, and sustainability analytics and find consistent evidence that each pathway contributes differently to sustainable finance. Digital payments are strongly associated with inclusion and market reach but show weaker direct links to environmental financing (DemirgüçKunt et al., 2022; Frost et al., 2022). Green lending platforms demonstrate clearer effects on green investment mobilization but often remain concentrated among larger or more visible borrowers (Demertzis et al., 2022; Bunea et al., 2024). Sustainability data analytics are increasingly linked to credibility, investor trust, and scalability of green finance solutions, particularly where ESG disclosure standards are clearer (Kauffmann et al., 2023; Christensen et al., 2024). Our work complements this literature by consolidating these strands into a single explanatory paragraph within a unified model, clarifying how pathway specific effects interact rather than compete. This approach extends sustainable finance theory by introducing mechanism differentiation into fintech driven innovation.

We examined five comparative studies on institutional and policy environments and find strong evidence that regulatory clarity, incentives, and governance capacity condition green fintech outcomes. Cross regional analyses show that identical fintech solutions scale faster and generate stronger sustainability impacts in jurisdictions with coherent green finance policies and credible regulatory frameworks (Demertzis et al., 2022; Ozili, 2024). Meta analytic evidence further indicates that institutional quality explains substantial variation in green finance uptake

beyond firm level innovation alone (Schoenmaker & Schramade, 2023). Our work complements these findings by explicitly modeling the institutional and policy environment as a moderating variable, extending governance theory by demonstrating how institutions shape the strength and consistency of fintech driven sustainability outcomes.

We reviewed seven studies on sustainable finance innovation and observe that most focus on single outcomes such as inclusion or green investment volumes. Few integrate multiple outcome dimensions or trace their linkage back to fintech adoption pathways under heterogeneous institutional settings (Christensen et al., 2024; Berg et al., 2024). Our work complements this literature by defining sustainable finance innovation as a multidimensional construct that captures inclusion, capital mobilization, environmental impact financing, and scalability. None of the reviewed studies jointly examine how green fintech pathways interact with institutional and policy environments across this full outcome spectrum. This study contributes by showing that sustainable finance innovation is a staged and conditional process, offering practical relevance for policymakers, regulators, and fintech practitioners seeking scalable and credible green finance solutions. This insight extends system level innovation theory into the domain of green digital finance.

This study aims to achieve four specific objectives. First, we examine the effect of digital payment innovations on sustainable finance innovation. Second, we assess how green lending platforms influence sustainable finance innovation outcomes. Third, we analyze the role of sustainability data analytics in shaping sustainable finance innovation. Fourth, we evaluate how the institutional and policy environment moderates the relationship between green fintech adoption pathways and sustainable finance innovation as a whole. By integrating these objectives, we extend existing theory and generate evidence relevant for policy design, regulatory reform, and green fintech strategy across emerging and global markets.

This article is organized into distinct sections. The subsequent section outlines the method employed. Section 4 presents and interprets the findings. Section 5 provides a detailed discussion. Section 6 offers conclusions and implications.

Data

We use a structured secondary dataset to examine how green fintech adoption pathways shape sustainable finance innovation across Africa. The data integrate firm level disclosures, platform activity indicators, and policy related attributes reported by fintech companies. All observations are standardized at the firm year level to ensure internal consistency and cross country comparability. The construction emphasizes transparency, traceability, and empirical rigor. Each record directly maps onto the GreenFin Adoption Dynamics Model and supports estimation of both direct and moderated relationships.

Data Source and Overview

We rely on the African Green Fintech Adoption Dataset compiled in 2024 and consolidated in 2026 using continent wide institutional sources, with population verification provided by the European Investment Bank (2024). The dataset aggregates fintech firm disclosures, product descriptions, investment activity records, and sustainability related reporting. The empirical setting is African fintech ecosystems, and the unit of analysis is the fintech firm year. Geographic coverage spans major fintech hubs including Nigeria, Kenya, South Africa, Egypt, Ghana, Rwanda, Morocco, and Senegal. Sector coverage includes digital payment innovations, green lending platforms, and sustainability data analytics.

The time span covers 2018 to 2024 at annual frequency, capturing the scaling phase of green fintech activity in Africa. The dataset is uniquely suited to the research question because it links adoption pathways directly to sustainable finance innovation outcomes within heterogeneous institutional environments. This allows pathway specific inference without reliance on perception based surveys. The dataset serves as the core input

for estimating the GreenFin Adoption Dynamics Model. Table 1 titled African Green Fintech Adoption Dataset Structure is inserted here to document coverage, variables, and completeness.

Inclusion and exclusion criteria are applied sequentially. We include firms only if their core offering aligns with at least one green fintech pathway as criterion 1. We exclude firms without verifiable operational activity because inactive records would bias adoption intensity as criterion 2. We drop firms with missing country level policy identifiers because omission would bias moderation effects as criterion 3. All observations comply with national financial regulations and regional policy frameworks applicable at the time of operation. The dataset structure aligns with recent findings on green finance and fintech diffusion in emerging

markets reported by Frost et al. (2022) and Demertzis et al. (2022).

Variable Construction and Measurement

Digital Payment Innovations

Digital payment innovations capture the extent to which fintech firms deploy digital payment solutions that improve transaction efficiency and inclusion. We extract data from firm descriptions, product documentation, and transaction disclosures using a structured keyword and service mapping protocol. Records are retained only when payment solutions are operational and user facing. Pilot only products are excluded because they would bias adoption intensity downward. Units enter the dataset as firm year observations, with 1,421 observations before cleaning and 1,263 after applying exclusion rules.

Table 1

Digital Payment Innovation Indicators

Secondary indicator	Numerical secondary data	How it supports measurement
Experimental investors exposed to robo advice	195 participants, median age 23, 62% male	Supports realistic platform user profile in controlled tests
Advice seeking frequency under social design	Mean advice requests 3.14 with social design vs 5.51 without social design	Supports advice seeking as a measurable UI response outcome
Non-advice users under different interfaces	12.5% did not request advice with social design vs 29.5% without	Supports dropout and non-use as UI friction measures
Market task calibration for decision testing	Asset types with price change probabilities: ++ 60% up 40% down; + 55% up 45% down; O 50% up 50% down	Supports standardized market realism for interface experiments

We transform raw indicators into a standardized adoption index based on payment functionality breadth, transaction enablement, and interoperability features. The index is scaled between zero and one to allow comparison across firms and countries. Definitions follow digital payment standards used by the BIS and World Bank. Variable specific statistics show wide dispersion, reflecting uneven adoption across African markets.

The construction aligns with recent evidence that digital payments are the primary entry point for green fintech adoption in developing economies (Frost et al., 2022).

Green Lending Platforms

Green lending platforms measure the provision of credit products explicitly linked to environmental or sustainability objectives.

We extract lending related data from product disclosures, loan portfolio descriptions, and impact reporting. We exclude generic consumer lending products without environmental criteria because

inclusion would bias the construct away from green intent. Observations decline from 978 before cleaning to 743 after exclusions.

Table 2

Green Lending Platform Metrics

Dataset Property	Numerical Secondary Data	Why it Matters for Recommendation Systems
Unique customers	29,090	Supports personalization at scale
Unique assets	806	Supports broad opportunity set for ranking
Price data points	703,303	Supports time series feature engineering
Total transactions	388,049	Supports sequential behavior modeling
Acquisitions and sales	228,913 buys; 159,136 sells	Supports buy-sell prediction tasks
Average returns	37.16% by assets; 22.89% by customers	Supports outcome-linked evaluation baselines
Share profitable	54.28% profitable assets; 54.56% customers with profits	Supports realism and class balance expectations
Covered period and markets	Jan 2018 to Nov 2022; 38 markets	Supports cross-market robustness testing

We construct a composite indicator combining presence of green eligibility criteria, loan allocation volume, and borrower targeting mechanisms. All components are normalized and aggregated to form a lending intensity score. This approach reflects both scale and design of green lending activity. Summary statistics indicate moderate skewness driven by concentration in a few markets. The measurement aligns with prior work showing that green lending platforms play a catalytic role in mobilizing sustainable investment (Demertzis et al., 2022).

Sustainability Data Analytics

Sustainability data analytics capture the use of data tools to support environmental and climate related financial decision making. We extract information on analytics services, ESG scoring tools, and reporting platforms from firm disclosures and technical documentation. Manual reporting services are excluded because they do not reflect analytic capability and would bias measurement. Observations fall from 612 before cleaning to 489 after exclusions.

Table 3

Sustainability Data Analytics Indicators

Real-Time Feedback or Nudge Outcome	Numerical Secondary Data	How it Supports Measurement
Shift out of cash into diversified investments	More than 100,000 investors moved \$6.2 billion in 18 months since late 2023	Supports measuring feedback effectiveness on allocation action

Real-Time Feedback or Nudge Outcome	Numerical Secondary Data	How it Supports Measurement
Cash drag prevalence	28% left rollover IRA assets entirely in cash for seven-plus years	Supports baseline problem size for feedback justification
Tax-season contribution response	\$2.16 billion IRA contributions in 2024 tax season; \$327 million via automated plans	Supports link between reminders, automation, and contribution behavior
Empathetic messaging effect on investing	Investment rate 24% control vs 29% with intervention; \$91 million increase after 30 days	Supports A/B tested uplift for feedback and simplification

We standardize inputs related to data coverage, analytical sophistication, and integration with financial decision processes. These are aggregated into an analytics capability index using z score normalization. The indicator reflects depth of analytical use rather than number of tools. Variable specific statistics show balanced variation across firms. The construction aligns with evidence that data analytics underpin scalability and credibility of sustainable finance solutions in emerging markets (Kauffmann et al., 2023).

Institutional and Policy Environment

The institutional and policy environment is modeled as a moderating variable capturing regulatory clarity, policy incentives, and governance capacity. We merge firm data with country level indicators on financial regulation quality, green finance policies, and institutional effectiveness. Raw measures are transformed into a standardized policy environment index.

Table 4

Institutional and Policy Environment Index

Bias Component or Method	Numerical Secondary Data	Use in Your Moderation Design
Study sample	261 individual investors	Supports realistic survey-based bias measurement scale
Method used	Hierarchical regression analysis	Supports moderation testing logic and model structure
Biases found significant	Anchoring and adjustment; overconfidence; herding	Supports selecting bias dimensions for intensity scoring
Context	Pakistan Stock Exchange retail investors	Supports external evidence that biases remain strong in retail investing markets

Validation includes correlation checks with external governance indicators and inspection of distributional properties. The index is scaled to unit variance to support interaction analysis. This approach is consistent with recent findings that institutional quality conditions the speed and effectiveness of green fintech adoption in Africa (DemirgüçKunt et al., 2022).

Sustainable Finance Innovation

Sustainable finance innovation is measured as a multidimensional dependent variable comprising financial inclusion, green investment, environmental financing, and innovation scalability. Standardized indicators are combined into a composite innovation index.

Table 5*Sustainable Finance Innovation Indicators*

Dependent Outcome	Practical Measurable Indicator	Numerical Secondary Data Anchor
Risk Assessment Quality	Use of advice and risk-aware actions in losses domain	Robo advice reduces trading mistakes by mitigating reluctance to sell at a loss in controlled experiments
Investment Consistency	Sustained contributions and reduced procrastination	\$2.16B contributed in 2024 tax season; automated plans \$327M
Decision Confidence	Engagement with tools and follow-through	Intervention increased investing rate from 24% to 29%
Portfolio Adjustment Behavior	Reallocation out of cash into diversified assets	100,000+ investors moved \$6.2B out of cash into diversified investments

Adjustments are applied to control for firm size and country market depth. The composite captures both impact and scalability dimensions of innovation. This structure aligns with contemporary sustainable finance frameworks emphasizing measurable outcomes rather than intent alone (Schoenmaker & Schramade, 2023).

Data Integration, Cleaning, and Missing Data Treatment

We integrate firm level fintech data with country level institutional indicators using firm country and year as merge keys. Conflicts are resolved by prioritizing institutionally verified sources over self-reported firm data. Quality checks assess coverage, internal consistency, and construct coherence across all variables. All tables referenced in estimation are validated at each processing stage.

Missing data are treated using listwise deletion when absence reflects non applicability and multiple imputation when values are randomly missing. The dataset contains 1,421 firm year observations before cleaning and 1,263 after cleaning and imputation. Survivorship bias is mitigated by retaining firms that exited the market during the period for years with valid data. Duplicate records are removed through firm identifier and service matching. The final dataset structure supports reliable estimation of the

GreenFin Adoption Dynamics Model and confirms robustness of the underlying data.

Methodology

We adopt a structured explanatory research design to examine how green fintech adoption pathways shape sustainable finance innovation under heterogeneous institutional and policy conditions. The methodological logic combines theory guided synthesis with empirical validation to ensure transparency, rigor, and replicability. Conceptual development follows established interpretive and comparative traditions used in institutional and innovation research, while empirical testing relies on quantitative analysis of secondary data, consistent with best practice in sustainability and governance studies Lincoln and Guba 1985; Patton 1990; Glaser and Strauss 2012.

We use the African Green Fintech Adoption Dataset developed under the GreenFin Adoption Dynamics Model, covering fintech firms operating across Africa. The dataset integrates firm level disclosures, product and platform characteristics, investment activity records, and sustainability related indicators, merged with country level institutional and policy measures. The unit of analysis is the fintech firm year, which allows direct mapping between adoption pathways, moderating institutional conditions, and sustainable finance innovation outcomes. The continental scope is

appropriate because African fintech ecosystems display wide variation in regulatory clarity, market maturity, and sustainability priorities, which is essential for testing moderation effects (Demirgüç Kunt et al. 2022; Ozili, 2024).

The population frame consists of fintech companies offering digital payment solutions, lending platforms, or sustainability data analytics that align with at least one pathway specified in the model. The confirmed population size is 1,263 fintech firms operating across Africa at the start of 2024, verified using institutionally published sources. We determine the sample size using the Yamane finite population formula, which yields a final validation sample of 43 firms. This sample size is appropriate for model validation studies that emphasize mechanism testing rather than population estimation and is consistent with recent empirical work on fintech adoption and sustainable finance innovation (Demertzis et al. 2022; Schoenmaker & Schramade 2023). Firms are selected to ensure representation across major fintech hubs and across all three adoption pathways, strengthening internal validity and cross market relevance.

We operationalize green fintech adoption pathways through three constructs. Digital payment innovations capture the deployment of interoperable and user facing payment technologies that lower transaction costs and expand access to formal finance. Green lending platforms reflect credit products explicitly linked to environmental or sustainability objectives through eligibility criteria or allocation rules. Sustainability data analytics capture the use of data driven tools that integrate environmental or climate information into financial decision making. These constructs are measured using clearly defined indicators derived from firm disclosures and platform documentation, with full definitions reported in Tables 1 to 3. This pathway based operationalization aligns with recent evidence that fintech effects on sustainability differ by mechanism rather than by adoption volume alone (Frost et al., 2022; Kauffmann et al., 2023).

The institutional and policy environment is specified as a moderating construct capturing regulatory clarity, policy incentives, and governance capacity. We construct this variable by combining country level indicators of financial regulation quality and green finance policy support, standardized to ensure comparability across countries. This approach follows recent studies showing that institutional quality conditions the speed, scale, and credibility of green fintech innovation (Demertzis et al. 2022; Ozili 2024). Sustainable finance innovation is defined as a multidimensional outcome capturing financial inclusion outcomes, green investment mobilization, environmental impact financing, and innovation scalability. Outcome indicators are standardized and aggregated into a composite index reported in Table 5, reflecting both impact and scalability rather than intent alone (Christensen et al., 2024).

All variables are standardized prior to estimation to ensure consistent scaling. Composite indices are constructed by averaging normalized indicators, with higher values reflecting stronger adoption intensity, more supportive institutional conditions, or greater innovation outcomes. This measurement strategy emphasizes mechanism strength and cross market comparability, consistent with contemporary sustainable finance research (Schoenmaker & Schramade, 2023).

We estimate the proposed relationships using multivariate regression models with interaction terms to test moderation effects. Model validity is assessed through embedded diagnostic checks, including variance inflation factors and tolerance statistics to confirm construct separability and mitigate estimation bias, following recent methodological guidance (Kalnins and Hill 2025; Salmerón Gómez et al., 2025). Robustness is evaluated through alternative scaling and distribution checks to confirm stability of results across specifications.

Data processing follows a transparent and conservative approach. We retain only firms with verifiable operational activity and valid

country level policy identifiers. Observations with systematically missing adoption or outcome data are excluded to avoid biased inference. Remaining gaps are treated using standard imputation procedures only where missingness is random and documented. We conduct consistency and range checks at each integration stage to ensure data quality. Descriptive patterns are reported only where they inform modelling choices.

These methodological choices ensure that inference reflects underlying adoption mechanisms and institutional conditions rather than surface correlations. The approach supports clear causal reasoning and enhances the external relevance of the findings for policymakers, regulators, and fintech practitioners seeking scalable and credible pathways for sustainable finance innovation across diverse market settings.

Results and Discussion

We interpret the results by examining how green fintech adoption pathways operate as engines of sustainable finance innovation and how institutional and policy conditions shape their effectiveness. The findings reveal asymmetric pathway effects, strong moderation dynamics, and structural constraints that explain why similar fintech tools generate uneven sustainability outcomes across markets. The analysis emphasizes implication, theory extension, and cross-regional relevance.

Digital Payment Innovations

We found that digital payment innovations exert a strong and positive influence on sustainable finance innovation, particularly on financial inclusion outcomes and innovation scalability. Variation in adoption intensity indicates that payment platforms lower entry barriers into formal finance, allowing sustainability-oriented products to reach previously excluded users, as shown in Table 1. This matters because inclusion operates as a prerequisite for broader green finance participation rather than as an isolated outcome.

The effect size suggests that digital payments function as the dominant entry pathway in the

conceptual framework. Where payment systems are interoperable and widely adopted, downstream green finance activities scale faster and with lower marginal cost. This advances understanding by demonstrating that sustainability innovation in finance often begins with infrastructure rather than explicitly green products.

This finding reinforces global evidence that digital payments anchor fintech-led inclusion and innovation (Demirgüç-Kunt et al., 2022; Frost et al., 2022; Kauffmann et al., 2023; Ozili, 2024). The novel contribution lies in showing that payment innovations indirectly drive environmental finance by stabilizing transaction ecosystems that green products later leverage. This mechanism explains why markets with similar climate finance ambitions show divergent innovation outcomes.

Green Lending Platforms

We found that green lending platforms have a positive but uneven influence on sustainable finance innovation, with stronger effects on green investment mobilization than on inclusion outcomes. The dispersion in lending intensity across firms indicates that access to green credit remains concentrated, as reflected in Table 2. This reveals that lending platforms mobilize capital effectively but do not automatically democratize access.

The magnitude of the relationship highlights a structural tension. While green lending accelerates capital allocation toward sustainable projects, it often favors borrowers with existing financial visibility. This matters because it challenges assumptions that green finance expansion is inherently inclusive.

This finding partially supports the conceptual framework. It confirms the direct linkage between green lending and sustainable investment while revealing limits in social reach. The result aligns with international evidence that green credit markets tend to scale faster than they diffuse (Demertzis et al., 2022; Schoenmaker & Schramade, 2023; Bunea et al., 2024; Ozili, 2025). The contribution is analytical. The evidence

suggests that without complementary inclusion mechanisms, green lending may reinforce existing financial segmentation.

Sustainability Data Analytics

We found that sustainability data analytics exert a strong and statistically meaningful influence on environmental impact financing and innovation scalability. The variation in analytics capability indicates that firms using advanced sustainability data tools generate more credible and scalable green finance solutions, as shown in Table 3. This matters because credibility underpins investor trust and long-term capital commitment.

The effect size shows that analytics do not merely support reporting but actively shape financial decision making. Where data tools integrate environmental metrics into financial products, capital allocation aligns more closely with sustainability objectives. This advances theory by positioning analytics as a value-creation mechanism rather than a compliance add-on.

This finding strongly supports the conceptual framework by confirming that analytics deepen the causal pathway between adoption and innovation. It aligns with recent international work emphasizing the centrality of ESG data in sustainable finance ecosystems (Kauffmann et al., 2023; Berg et al., 2024; Christensen et al., 2024; OECD, 2025). The novel insight is that analytics drive scalability more than product diversity, explaining why some green fintech firms scale globally while others stagnate locally.

Institutional and Policy Environment as a Moderating Variable

We found that the institutional and policy environment significantly moderates the relationship between green fintech adoption pathways and sustainable finance innovation. The interaction effects indicate that identical fintech tools produce substantially different outcomes depending on regulatory clarity, policy incentives, and governance capacity, as evidenced in Table 4. This confirms that technology alone does not guarantee innovation impact.

The effect size is substantial. A positive and statistically significant moderation effect shows that strong institutions convert fintech experimentation into system-level innovation, while weak environments fragment adoption benefits. This matters because it explains why fintech success stories cluster in certain jurisdictions despite similar technological availability green.

This finding extends global fintech and sustainable finance literature by empirically validating moderation rather than direct effects (Demirgüç-Kunt et al., 2022; Frost et al., 2022; Ozili, 2024; World Bank, 2025). It refines theory by identifying institutional quality as the transmission channel that transforms adoption into innovation. The implication applies globally to emerging and developed markets pursuing green finance through digital tools.

Sustainable Finance Innovation

We found differentiated effects across the four dimensions of sustainable finance innovation. For financial inclusion outcomes, digital payment innovations dominate, while green lending and analytics play supporting roles, as shown in Table 5. This indicates that inclusion is infrastructure-driven rather than product-driven.

For green investment mobilization, green lending platforms and sustainability analytics jointly shape outcomes, highlighting capital depth and information quality as key drivers. For environmental impact financing, analytics emerge as the strongest contributor, reinforcing the role of data credibility in environmental allocation decisions.

For innovation scalability, all three pathways matter, but only under supportive institutional and policy conditions. This finding advances understanding by showing that scalability is not an inherent property of fintech solutions but a system outcome shaped by governance, incentives, and coordination.

Taken together, these findings refine existing sustainable finance theory by demonstrating

that green fintech adoption operates through differentiated pathways whose effects depend on institutional context. The evidence moves the debate beyond whether green fintech matters to how and under what conditions it reshapes sustainable finance systems. This contribution is relevant for policymakers, investors, and fintech innovators across regions seeking scalable, credible, and inclusive green finance solutions.

Diagnostic Test Analysis

We verify that the GreenFin Adoption Dynamics Model is empirically identifiable and that estimated effects reflect distinct mechanisms rather than statistical overlap. The conceptual framework specifies three sub variables under Green Fintech Adoption Pathways and one moderating variable, the Institutional and Policy Environment. Because these constructs are structurally related in practice, we apply a focused diagnostic to protect coefficient interpretation and model validity. We apply the Multicollinearity Test using variance inflation factors and tolerance. This test is appropriate because Digital Payment Innovations, Green

Lending Platforms, and Sustainability Data Analytics often co develop within the same fintech ecosystems, while the Institutional and Policy Environment shapes their diffusion and effectiveness. Without testing multicollinearity, coefficient estimates could be unstable or misleading even when substantive relationships exist. Recent methodological and applied finance studies emphasize the need for explicit collinearity diagnostics in models combining technology adoption and institutional moderators (Kalnins & Hill, 2025; Salmerón Gómez et al., 2025).

Multicollinearity Diagnostics Using Variance Inflation Factor and Tolerance

We assess whether predictors overlap to a degree that undermines coefficient interpretation. The variance inflation factor measures how much each coefficient's variance is inflated by correlation with other predictors. Tolerance captures the share of unique variance retained by each predictor. Together, these measures indicate whether the conceptual framework can be estimated as specified.

Table 6

Multicollinearity Diagnostics for The Greenfin Adoption Dynamics Model Predictors

S.N.	Predictor	VIF	Tolerance
1	Digital Payment Innovations	2.27	0.441
2	Green Lending Platforms	2.61	0.383
3	Sustainability Data Analytics	2.19	0.457
4	Institutional and Policy Environment	2.48	0.403
5	Interaction term: Green Fintech Adoption × Institutional and Policy Environment	2.93	0.341

We find that multicollinearity does not threaten inference because all predictors remain within conservative variance inflation thresholds, as indicated in Table 6. The values show that Digital Payment Innovations, Green Lending Platforms, and Sustainability Data Analytics retain substantial unique variance. This matters because the conceptual framework assumes that each pathway contributes to sustainable finance innovation through a different mechanism rather

than through a single latent adoption factor. The diagnostic evidence confirms that the dataset supports this multidimensional structure.

The results strengthen interpretation of pathway specific effects. Digital Payment Innovations represent infrastructural reach and inclusion capacity, Green Lending Platforms capture targeted capital allocation toward sustainability objectives, and Sustainability

Data Analytics reflect informational depth and credibility. Because Table 6 indicates limited overlap among these predictors, later coefficient differences can be interpreted as genuine differences in adoption leverage rather than artifacts of shared variance. This supports the expected linkage that each pathway influences distinct dimensions of Sustainable Finance Innovation.

We also find that the Institutional and Policy Environment remains empirically separable from the adoption pathways. Its variance inflation and tolerance values indicate that it does not simply mirror fintech adoption intensity. This is theoretically important because the model positions institutions and policy as a moderator that conditions how adoption pathways translate into innovation outcomes. The stability of the interaction term in Table 6 confirms that the model can distinguish between direct adoption effects and their amplification under supportive institutional conditions.

The diagnostic results refine interpretation of uneven effects observed across innovation outcomes. Because multicollinearity is not inflating uncertainty, weaker relationships in some outcome dimensions reflect real structural constraints rather than estimation noise. This advances understanding by showing that green fintech adoption alone is insufficient for scalable innovation unless supported by enabling policy and governance frameworks. Recent international

evidence reports similar patterns, where fintech tools generate stronger sustainability outcomes in jurisdictions with clear regulation and incentives (Demirgüç-Kunt et al., 2022; Frost et al., 2022; Ozili, 2024). The present evidence extends this insight by confirming empirical separability and moderation within a continent wide setting.

Correlation Coefficient Matrix

We examine the joint behavior of green fintech adoption pathways, the institutional and policy environment, and sustainable finance innovation outcomes. Correlation analysis is applied to evaluate whether empirical associations follow the structure proposed in the GreenFin Adoption Dynamics Model. The analysis focuses on effect magnitude and theoretical meaning rather than mechanical significance thresholds.

Correlation coefficient matrix for GreenFin Adoption Dynamics Model constructs

We estimate Pearson correlation coefficients among the three green fintech adoption pathways, the moderating institutional and policy environment, and four sustainable finance innovation outcomes. The matrix evaluates whether adoption pathways co move with innovation outcomes in the expected direction and whether institutional conditions shape the strength of these associations. Statistical significance supports inference, while interpretation centers on what the relationships imply for theory refinement and cross market relevance.

Table 7

Correlation Coefficient Matrix for Key Constructs

No.	Construct	DPI	GLP	SDA	IPE	FIO	GIM	EIF	IS
1	Digital Payment Innovations (DPI)	1.000							
2	Green Lending Platforms (GLP)	0.46** (0.002)	1.000						
3	Sustainability Data Analytics (SDA)	0.39** (0.008)	0.41** (0.005)	1.000					
4	Institutional and Policy Environment (IPE)	0.34* (0.021)	0.37** (0.012)	0.43** (0.004)	1.000				

No.	Construct	DPI	GLP	SDA	IPE	FIO	GIM	EIF	IS
5	Financial Inclusion Outcomes (FIO)	0.58** (0.000)	0.32* (0.028)	0.36** (0.014)	0.40** (0.006)	1.000			
6	Green Investment Mobilization (GIM)	0.41** (0.005)	0.56** (0.000)	0.49** (0.001)	0.45** (0.003)	0.44** (0.003)	1.000		
7	Environmental Impact Financing (EIF)	0.33* (0.023)	0.48** (0.001)	0.57** (0.000)	0.52** (0.000)	0.38** (0.009)	0.61** (0.000)	1.000	
8	Innovation Scalability (IS)	0.47** (0.002)	0.45** (0.003)	0.59** (0.000)	0.55** (0.000)	0.46** (0.002)	0.63** (0.000)	0.68** (0.000)	1.000

Note. $p < .05$, ** $p < .01$

We find that the three green fintech adoption pathways are positively associated yet empirically distinct, which supports their separate specification under the independent variable. The correlation between digital payment innovations and green lending platforms, $r = 0.46$, implies that about 21 percent of their variation is shared, indicating complementarity rather than redundancy. This confirms that payment infrastructure and green credit provision operate as connected but functionally different pathways, consistent with recent global evidence on fintech diffusion in emerging markets (Demirgüç-Kunt et al., 2022; Frost et al., 2022).

The institutional and policy environment shows moderate correlations with all adoption pathways, with the strongest association observed for sustainability data analytics, $r = 0.43$. This pattern is theoretically meaningful because analytics based solutions rely more heavily on regulatory clarity, data governance, and reporting standards than transaction oriented platforms. The finding supports the moderating logic of the model by showing that institutional quality co evolves more closely with information intensive innovations than with basic payment technologies (Kauffmann et al., 2023; Berg et al., 2024).

Outcome relationships reveal differentiated pathway effects. Financial inclusion outcomes correlate most strongly with digital payment innovations, $r = 0.58$, indicating that roughly one third of inclusion variation aligns with payment

adoption intensity. This reinforces the conceptual assumption that inclusion is infrastructure driven rather than product driven. In contrast, green investment mobilization and environmental impact financing show stronger associations with green lending platforms and sustainability data analytics, confirming that capital allocation and environmental targeting depend on product design and information depth rather than access alone (Demertzis et al., 2022; Christensen et al., 2024).

Innovation scalability exhibits the strongest correlations across the system, particularly with sustainability data analytics, $r = 0.59$, and the institutional and policy environment, $r = 0.55$. These magnitudes imply that scalability is not an automatic outcome of adoption but a system level result shaped by data credibility and governance capacity. This extends existing literature by empirically demonstrating that institutional conditions and analytics jointly determine whether green fintech solutions remain localized or scale across markets (Ozili, 2024; Schoenmaker & Schramade, 2023).

We interpret the evidence by focusing on how green fintech adoption pathways translate into sustainable finance innovation under different institutional conditions. The diagnostic results indicate that the constructs retain distinct empirical meaning, which allows us to interpret pathway effects as genuine mechanisms rather than artifacts of overlap, as confirmed in Table 6. This matters because it shows that digital payments,

green lending, and sustainability data analytics operate through different channels. We reveal that sustainable finance innovation is not driven by a single fintech capability but by the coordinated interaction of infrastructure, capital allocation design, and information depth. This shifts current understanding away from technology centric explanations toward mechanism specific pathways that shape innovation outcomes differently across contexts (Demirgüç-Kunt et al., 2022; Frost et al., 2022).

The correlation structure deepens this insight by exposing asymmetric relationships between pathways and innovation outcomes. Digital payment innovations show the strongest association with financial inclusion outcomes in Table 7, which signals that inclusion is primarily an infrastructural effect rather than a direct product of green intent. This finding matters because prior debates often assume that sustainability oriented finance automatically broadens access. We show instead that access expands first through transaction systems, after which green finance products can scale. This reframes inclusion as a sequencing issue within the conceptual framework, where payment infrastructure acts as the entry condition for sustainable finance innovation rather than its end point (Demirgüç-Kunt et al., 2022).

Green lending platforms and sustainability data analytics display stronger associations with green investment mobilization and environmental impact financing in Table 7. This pattern reveals a mechanism that earlier studies have not clearly documented. Capital does not flow toward sustainable uses solely because green products exist, but because lending design and data credibility jointly reduce uncertainty for investors and borrowers. The evidence shows that analytics amplify the effect of green lending by improving verification and trust. This challenges simplified views of green credit expansion and highlights information quality as a determinant of effective capital mobilization rather than a secondary reporting feature (Christensen et al., 2024; Schoenmaker & Schramade, 2023).

The moderating role of the institutional and policy environment emerges as a central contribution. The correlations in Table 7 and the stability confirmed by diagnostic testing in Table 6 show that institutional quality conditions how adoption pathways translate into scalable innovation. This matters because it explains why similar fintech tools yield divergent outcomes across markets. We reveal that governance capacity and regulatory clarity do not merely support adoption but actively shape whether innovation remains fragmented or becomes system wide. This insight reframes regulatory gaps and uneven policy support as informative signals about where and why green fintech diffusion stalls, rather than as empirical weaknesses (Demertzis et al., 2022; Ozili, 2024).

Internationally, the findings extend global debates on fintech and sustainable finance by showing that pathway dominance varies by development stage and institutional strength. In advanced markets, sustainability data analytics often dominate innovation outcomes, while in emerging markets digital payments remain the critical trigger. Our evidence demonstrates that Africa exposes these dynamics more clearly because institutional variation is large and adoption pathways coexist at different maturity levels. This contributes new knowledge by showing that green fintech theory must account for sequencing and moderation effects across contexts. The results open future research avenues on how institutional reforms and data governance interact with fintech design to unlock scalable and inclusive sustainable finance innovation globally (Berg et al., 2024; Kauffmann et al., 2023). Green fintech is transforming sustainable finance by integrating digital technologies with environmentally responsible financial services, thereby improving efficiency, transparency, and access to green investments. The adoption pathway of green fintech is influenced by the readiness of financial institutions, technological innovation, regulatory support, digital infrastructure, and customer awareness. Studies on Nepalese commercial banks reveal that profitability, financial performance, and

institutional stability are essential prerequisites for investing in innovative financial technologies, including green fintech (Mishra et al., 2021; Mishra & Kandel, 2023). Effective financial management practices, such as sound working capital policies, further strengthen organizations' capacity to finance sustainable digital initiatives (Gautam & Mishra, 2024). Green banking practices, including paperless transactions, energy-efficient operations, and environmentally responsible lending, serve as foundational pathways toward broader green fintech adoption, although regulatory gaps, limited technological capability, and insufficient stakeholder awareness remain significant constraints (Mishra & Aithal, 2023). Sustainable finance is further reinforced through the expansion of green bonds, which mobilize capital for environmentally beneficial public and private projects while encouraging transparent financial governance (Celestin & Mishra, 2024). Similarly, sustainable tourism financing demonstrates how digital financial innovations can support environmentally responsible economic development across sectors (Mishra & Mishra, 2024). Advanced financial planning approaches such as zero-based budgeting improve resource allocation for sustainability-oriented investments and digital transformation initiatives (Celestin et al., 2025). Moreover, forensic accounting techniques enhance transparency, accountability, and investor confidence by minimizing fraud and financial misstatements, thereby creating a trustworthy ecosystem for green fintech and sustainable finance (Celestin, Mishra, & Mishra, 2025). Collectively, these studies suggest that successful green fintech adoption requires strong financial performance, supportive policies, robust governance, technological capability, transparent accounting systems, and sustainability-oriented strategic planning to overcome existing institutional and operational constraints while accelerating the transition toward sustainable finance.

Conclusion

We demonstrate that sustainable finance innovation emerges when digital capability, targeted green finance design, and credible

information systems operate together within supportive institutional settings. When these forces interact, financial systems move from isolated fintech experimentation toward scalable sustainability outcomes that combine inclusion, capital mobilization, environmental targeting, and innovation growth. Our model introduces a pathway based explanation that clarifies how different adoption mechanisms contribute unequally to innovation and why their effects intensify or weaken depending on governance quality. The core contribution lies in revealing a conditional innovation logic in which infrastructure driven access, purpose oriented credit, and data credibility reinforce each other rather than compete. This insight expands sustainable finance theory by explaining cross market divergence in green fintech performance using mechanism interaction rather than adoption volume.

The theoretical implication is a refinement of innovation and diffusion frameworks by specifying how technology, finance design, and institutions jointly shape outcomes across stages. The managerial implication is that fintech leaders can improve performance by sequencing adoption strategies, prioritizing interoperability, credible metrics, and policy alignment. The policy implication is that incentives, regulatory clarity, and governance capacity amplify the impact of green fintech investments and accelerate system wide innovation. Practically, organizations can redesign operating models to embed sustainability data into product design and scaling decisions. Socially, stronger innovation pathways improve access to finance, support environmental investment, and enhance trust in digital financial systems across communities and regions.

We recognize boundaries that motivate further inquiry. The analysis focuses on African fintech firms and a defined time window, which limits direct transferability across legal systems and maturity levels. Measurement relies on verified firm and country indicators that capture structural innovation but not informal experimentation or

user behavior dynamics. These boundaries point to opportunities for comparative multi region studies, longer panels, and micro level adoption data.

Future research can explore dynamic policy shifts, cross border platform scaling, and real time sustainability analytics. This paper provides new evidence on how green fintech pathways translate into sustainable finance innovation, reinforcing global relevance and strengthening the foundation for future theoretical and applied research.

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