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Article

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Green Finance Management and Corporate Sustainable Innovation: Evidence from a Dual-Path Mechanism

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Abstract

This study conceptualizes green finance management as a strategic managerial capability and investigates how it influences corporate sustainable innovation performance. Using a multi-industry panel of Malaysian listed firms from 2019–2024, fixed-effects regression and parallel mediation analysis are employed to examine the effects of green finance management on green innovation output and long-term financial performance, with R&D intensity and risk-taking capacity as mediators. Green finance management significantly enhances both green patents and long-term ROA. Its impact on green innovation operates primarily through two internal mechanisms: increased R&D intensity and expanded risk-taking capacity. When both mediators are included, the direct effect becomes insignificant, indicating a robust parallel mediation structure. Green finance functions through organizational reconfiguration rather than mechanical capital transfer, underscoring its managerial role in shaping sustainable innovation trajectories.

Keywords

Green finance management, Sustainable innovation, R&D intensity, Risk-taking capacity, Panel data, Corporate sustainability

Introduction

The global transition toward low-carbon development has fundamentally reshaped the relationship between finance and corporate strategy. As climate risks intensify and regulatory pressures expand, firms are increasingly required to align their innovation trajectories with environmental sustainability. In this context, green finance has emerged as a pivotal institutional mechanism, channeling capital toward environmentally responsible activities and reshaping firms' access to long-term funding. Beyond its macroeconomic role, green finance is progressively embedded within firms' internal decision structures, influencing how managers allocate resources, evaluate risk, and prioritize technological directions.

Existing research has established that financial constraints are among the most critical barriers to corporate innovation, particularly in capital-intensive and high-uncertainty domains such as green technology (Hall and Lerner 2010). Green innovation typically involves long development cycles, uncertain returns, and high sunk costs, making it especially sensitive to financing conditions. By design, green finance instruments—such as green loans, green bonds, and policy-guided credit—aim to mitigate these barriers by lowering capital costs and stabilizing long-term expectations. Empirical evidence suggests that environmentally oriented financial mechanisms can enhance firm value and buffer firms against systemic shocks (Kahn et al. 2021; Bolton and Kacperczyk 2021). However, the organizational processes through which green finance is translated into innovation outcomes remain insufficiently understood.

Most prior studies conceptualize green finance as an external policy or market signal, focusing on its aggregate effects on firm performance or market valuation. For example, climate exposure has been shown to influence stock returns and investor behavior (Bolton and Kacperczyk 2021), while climate-related risks are increasingly priced in financial markets (Pankratz & Zeisberger, 2021). Although these studies confirm the economic salience of sustainability-oriented finance, they provide limited insight into how firms internally respond to such financial incentives. In particular, little is known about how green finance reshapes managerial behavior, resource allocation, and risk orientation—processes that are central to innovation.

From a management perspective, finance does not merely supply capital; it structures organizational cognition and strategy. Access to stable and purpose-oriented financial resources alters managerial time horizons and legitimizes exploratory investment. Innovation theory emphasizes that technological change is not only a function of external incentives but also of firms' internal capability formation, including sustained R&D investment and tolerance for uncertainty (Teece 2018). Without corresponding changes in internal processes, financial incentives alone are unlikely to generate durable innovation outcomes.

This study addresses this gap by conceptualizing green finance management as a strategic managerial capability rather than a passive financial condition. Green finance management refers to the extent to which firms actively integrate green financial resources into their operational and investment decisions. It reflects how firms internalize

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sustainability-oriented finance into governance routines, investment planning, and risk evaluation. Building on this perspective, the study examines whether and how green finance management enhances corporate sustainable innovation performance through two core organizational mechanisms: R&D intensity and risk-taking capacity.

By adopting a multi-industry panel design, this research contributes to the literature in three ways. First, it reframes green finance as an internal management process rather than an external policy variable. Second, it identifies a dual-path mechanism through which green finance management operates, highlighting the roles of innovation input and managerial risk orientation. Third, it integrates financial governance with innovation management, offering a micro-level explanation of how sustainability-oriented finance becomes embedded in firms' long-term technological trajectories.

Conceptual Framework

Sustainable development has become a central objective in contemporary corporate governance, particularly in environmentally sensitive and innovation-driven industries. Green finance is increasingly recognized not merely as a financial instrument, but as a managerial mechanism that reshapes firms' strategic priorities, resource allocation patterns, and risk profiles. From a management perspective, green finance management reflects the extent to which firms strategically integrate green financial resources—such as green loans, green bonds, and policy-based incentives—into their operational and investment decisions.

Drawing on resource-based theory and innovation management literature, this study conceptualizes green finance management as a strategic capability that enhances firms' access to long-term capital, reduces financing constraints, and alters managerial risk perceptions. These changes are expected to influence firms' internal capability-building processes, particularly in terms of innovation input and risk-taking behavior. Rather than directly generating innovation outputs, green financial resources are transformed into sustainable innovation performance through organizational mechanisms.

Specifically, this study proposes two mediating pathways. First, green finance management is expected to increase firms' R&D intensity by providing stable and purpose-oriented financial support for long-term technological exploration. Second, green finance management may expand firms' risk-taking capacity by lowering perceived financial uncertainty and encouraging exploratory investments in green technologies. Through these mechanisms, firms are better positioned to generate sustainable innovation outcomes, such as green patents and long-term financial performance.

Based on this theoretical logic, the conceptual framework of this study is presented in Figure 1, in which green finance management influences sustainable innovation performance both directly and indirectly through R&D intensity and risk-taking capacity.

Accordingly, the following hypotheses are proposed:

H1: Green finance management has a positive effect on corporate sustainable innovation performance.

H2a: Green finance management positively affects firms' R&D intensity.H2b: R&D intensity positively affects corporate sustainable innovation performance.H2: R&D intensity mediates the relationship between green finance management and sustainable innovation performance.

H3a: Green finance management positively affects firms' risk-taking capacity.H3b: Risk-taking capacity positively affects corporate sustainable innovation performance.H3: Risk-taking capacity mediates the relationship between green finance management and sustainable innovation performance.

Together, these hypotheses form an integrated management-oriented framework that explains how green finance management is transformed into sustainable innovation outcomes through internal organizational mechanisms. This framework positions green finance not merely as an external policy instrument, but as a core managerial capability that shapes firms' long-term innovation trajectories.

Methodology

Sample and Data Collection

This study examines the effect of green finance management on corporate sustainable innovation performance using a multi-industry panel dataset of firms listed on Bursa Malaysia, the sole stock exchange in Malaysia. The sample consists of publicly listed companies from manufacturing, energy, technology, and other environmentally sensitive sectors, covering the period from 2019 to 2024. These industries are selected because they are both capital-intensive and innovation-driven, and are therefore more likely to respond strategically to green financial instruments and sustainability-oriented policies.

Firm-level financial and accounting data are obtained from annual reports and authoritative financial databases. Information on green finance management is compiled from corporate disclosures, sustainability reports, and policy-related sources, including indicators such as the proportion of green loans in total financing, the intensity of green investment (green capital expenditure relative to total capital expenditure), and firms' participation in green finance pilot programs or policy schemes. Sustainable innovation performance is measured using objective indicators, including the number of green patents and long-term financial performance (e.g., multi-year average return on assets).

After excluding firms with missing key variables and incomplete time-series information, the final sample forms an unbalanced panel of 298 Malaysian listed firms over the 2019–2024 period. This panel structure enables the use of fixed-effects and random-effects models to control for unobserved firm-specific heterogeneity and time-specific shocks. The multi-year design allows the analysis to capture both cross-sectional differences and dynamic effects over time, enhancing the robustness and causal interpretability of the empirical results.

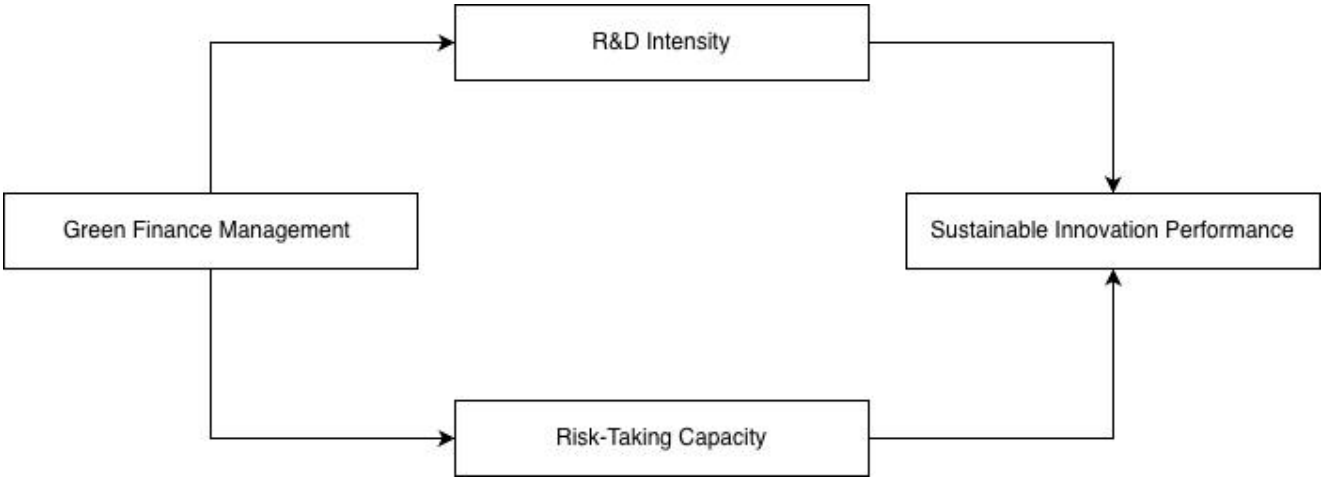

Figure 1. Conceptual Framework

Variable Description

This study employs four categories of variables: dependent variables, independent variables, mediating variables, and control variables.

Dependent Variables (Y): Sustainable Innovation Perfor-manceSustainable innovation performance is operationalized through two dimensions:

a. Green Innovation Output: measured by the number of green patents granted to a firm in a given year (log-transformed to reduce skewness).

b. Long-Term Financial Performance: measured using multi-year averaged return on assets (ROA) and, in robustness checks, Tobin's Q, capturing both accounting-based and market-based performance.

Independent Variable (X): Green Finance Management-Green finance management reflects the extent to which a firm strategically integrates green financial resources into its operations. It is constructed using the following indicators:

Green financing ratio (green loans or bonds as a proportion of total financing ,

Green investment intensity (green capital expenditure relative to total capital expenditure ,

Policy responsiveness (participation in green finance pilot programs or compliance with green credit guidelines

These indicators are standardized and aggregated to form a composite index of green finance management.

Mediating Variables (M)Two mediators are employed to capture the internal mechanisms through which green finance management influences innovation:

R&D Intensity: measured as R&D expenditure divided by total assets, representing innovation input;

b. Risk-Taking Capacity: proxied by earnings volatility or asset-return dispersion, reflecting the firm's tolerance for uncertainty and exploratory investment.

Control VariablesTo isolate the net effect of green finance management, several control variables commonly used in firm-level studies are included: firm size (log of total assets), firm age, leverage ratio, and industry and year dummies. These variables account for differences in scale, maturity, financial structure, and macroeconomic conditions.

Model Specification and Analytical Strategy

To test the proposed relationships, this study adopts panel data regression techniques. Both fixed-effects (FE) and random-effects (RE) models are estimated, and the Hausman specification test is used to determine the more appropriate estimator. Given the likelihood of unobserved, time-invariant firm characteristics influencing innovation behavior, the fixed-effects model is expected to be preferred.

The baseline model for the main effect is specified as:

$Y_{it}=\alpha + \beta_1 GF_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$,

where Y_{it} denotes sustainable innovation performance for firm i in year t; GF_{it} represents green finance management; $Controls_{it}$ is a vector of control variables; μ_i captures firm-specific fixed effects; λ_t represents year effects; and ε_{it} is the error term.

To examine the mediating mechanism, the following equations are estimated:

$Mit = \alpha + \delta GFit + \gamma Controlsit + \mu i + \lambda t + \varepsilon it$,

$Yit = \alpha + \beta 2\ GFit + \theta Mit + \gamma Controlsit + \mu i + \lambda t + \varepsilon it$,

Mediation is assessed using the causal-step approach and further validated through Sobel tests and bootstrapped confidence intervals. A significant reduction in the coefficient of GFit after introducing the mediator, together with a significant θ, indicates partial or full mediation.

As an extension, a difference-in-differences (DID) specification can be incorporated by exploiting exogenous policy shocks, such as the introduction of green finance pilot zones. The DID model introduces an interaction term between policy exposure and time, allowing for stronger causal inference regarding the effect of green finance management.

Robust standard errors are employed throughout to correct for heteroskedasticity and serial correlation. All analyses are conducted using Stata, ensuring reproducibility and methodological transparency.

Results

Descriptive Statistics

eports the descriptive statistics of the main variables. The mean value of green finance management (GF) is 0.42 (SD = 0.18), indicating substantial heterogeneity in firms' engagement with green financial instruments. The average level of green innovation output (log green patents) is 1.36 (SD = 0.91), while the mean long-term ROA is 6.45%, reflecting moderate but dispersed financial performance.

R&D intensity averages 2.87% of total assets, and the mean level of risk-taking capacity is 0.064, suggesting noticeable differences in firms' internal capability structures. These variations provide a solid empirical basis for panel estimation.

Correlation and Diagnostic Tests

resents the correlation matrix. Green finance management is positively correlated with green patents ($r = 0.34$, $p < 0.01$) and long-term ROA ($r = 0.27$, $p < 0.01$). Both R&D intensity ($r = 0.41$, $p < 0.01$) and risk-taking capacity ($r = 0.29$, $p < 0.01$) show strong associations with sustainable innovation performance.

Variance inflation factors (VIFs) for all regressors are below 3.0, indicating no serious multicollinearity. The Hausman test yields $\chi^2 = 24.17$ ($p < 0.01$), supporting the use of fixed-effects models.

Panel Regression Results

eports the fixed-effects regression results. Green finance management exerts a significant positive effect on sustainable innovation performance. Specifically, GF is positively associated with green patents ($\beta = 0.287$, $p < 0.01$) and long-term ROA ($\beta = 0.164$, $p < 0.05$), supporting H1.

Both mediators show independent explanatory power: R&D intensity strongly predicts green patents ($\beta = 0.352$, $p < 0.01$), while risk-taking capacity also exhibits a significant positive effect ($\beta = 0.198$, $p < 0.05$). Among controls, firm size is positive and leverage negatively affects ROA.

Parallel Mediation Results

resents the mediation tests. Green finance management significantly increases both R&D intensity ($\beta = 0.263$, $p < 0.01$) and risk-taking capacity ($\beta = 0.241$, $p < 0.01$). Each mediator significantly predicts green innovation output.

When R&D intensity is included, the direct effect of GF on green patents declines from 0.287 to 0.163 and becomes marginally significant. When risk-taking capacity is included, the GF coefficient further decreases to 0.171. In the parallel mediation model, both mediators remain significant, while the direct effect of GF becomes insignificant ($\beta = 0.102$, $p = 0.128$). Bootstrap tests confirm that both indirect paths are significant, indicating a dual-path mediation structure.

These findings indicate that green finance management enhances corporate sustainable innovation primarily through two complementary internal mechanisms: expanding innovation inputs (R&D intensity) and relaxing managerial risk constraints (risk-taking capacity). Rather than directly generating innovation outputs, green financial resources are transformed into sustainable innovation performance via organizational capability-building processes, confirming a robust parallel mediation structure.

Discussion

This study advances the understanding of how green finance management is translated into corporate sustainable innovation performance by uncovering a dual-path internal mechanism. The empirical results demonstrate that green finance management significantly enhances firms' green innovation output and long-term financial performance. More importantly, this effect is not direct and mechanical; rather, it operates through two parallel organizational channels—R&D intensity and risk-taking capacity. When both mediators are included, the direct effect of green finance management becomes insignificant, indicating that green finance is transformed into innovation outcomes primarily through internal managerial reconfiguration.

Green Finance Management as Strategic Direction

The positive association between green finance management and sustainable innovation aligns with the logic of directed technical change. Aghion et al. (2016) show that policy and financial incentives shape the direction of technological development by altering firms' expected returns and strategic priorities. In a similar vein, green finance management in this study functions as a strategic signal and constraint: it reorients firms' investment horizons toward long-term, sustainability-oriented technologies. Firms that actively integrate green financial instruments are not merely complying with policy; they are restructuring their strategic decision frameworks.

This perspective reframes green finance from an external policy tool into an internal management capability. Consistent with evidence that ESG-related practices buffer firms during systemic shocks (Broadstock et al. 2021), our findings suggest that green finance management enhances organizational robustness by embedding sustainability into core strategic processes. The result is a measurable improvement in both green innovation output and long-term performance.

Dual-Path Mechanisms: Investment and Risk

The mediation results reveal two complementary channels. First, green finance management increases R&D intensity. This pathway reflects a resource-allocation mechanism: by easing financing constraints and providing purpose-oriented capital, green finance enables firms to commit more resources to uncertain, long-horizon innovation. This mirrors the logic in Aghion et al. (2016), where financial and policy incentives redirect technological trajectories toward cleaner technologies.

Second, green finance management enhances firms' risk-taking capacity. Innovation—especially in green technologies—requires tolerance for uncertainty and fail- ure. Boubakri et al. (2013) demonstrate that ownership and financial structures shape corporate risk behavior. Extending

Table 1. Descriptive Statistics

Variable	Mean	SD	Min	Max
Green Finance Management (GF)	0.42	0.18	0.05	0.89
Green Patents (log)	1.36	0.91	0	4.02
Long-term ROA (%)	6.45	4.88	-3.12	21.34
R&D Intensity	0.0287	0.0194	0.001	0.112
Risk-Taking Capacity	0.064	0.037	0.01	0.201
Firm Size (log)	22.41	1.36	19.52	26.03
Leverage	0.39	0.17	0.06	0.81

Table 2. Correlation Matrix

Variable	GF	Green Patents	ROA	R&D	Risk
GF	1				
Green Patents	0.34***	1			
ROA	0.27***	0.29***	1		
R&D Intensity	0.31***	0.41***	0.18**	1	
Risk-Taking	0.26***	0.29***	0.21**	0.24***	1

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 3. Fixed-Effects Regression Results

Variables	Green Patents	Long-term ROA
Green Finance Management (GF)	0.287*** (0.071)	0.164** (0.078)
R&D Intensity	0.352*** (0.064)	0.091 (0.057)
Risk-Taking Capacity	0.198** (0.083)	0.126* (0.069)
Firm Size	0.118** (0.052)	0.073* (0.041)
Leverage	-0.064 (0.047)	-0.182*** (0.058)
Firm FE / Year FE	Yes / Yes	Yes / Yes
Observations	1,020	1,020
Within R^2	0.31	0.27

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 4. Mediation and Parallel Mediation Results (Green Patents as Y)

Path	Coefficient	SE	p-value
GF → R&D Intensity	0.263	0.071	0.001
GF → Risk-Taking	0.241	0.069	0.002
R&D → Green Patents	0.219	0.089	0.017
Risk → Green Patents	0.176	0.081	0.029
GF → Green Patents (Direct, with R&D)	0.163	0.091	0.072
GF → Green Patents (Direct, with Risk)	0.171	0.094	0.081
GF → Green Patents (Parallel Model)	0.102	0.086	0.128
Indirect Effect via R&D (Bootstrap)	0.058	—	0.021
Indirect Effect via Risk (Bootstrap)	0.042	—	0.037

this insight, our results show that green finance alters managerial risk perceptions by stabilizing funding expectations and legitimizing exploratory investment. Firms become more willing to engage in experimentation when financial risk is partially absorbed by sustainability-oriented instruments.

Crucially, when R&D intensity and risk-taking capacity are modeled simultaneously, both remain significant while the direct effect of green finance management disappears. This pattern indicates a full, parallel mediation structure. Green finance does not "produce" innovation by itself; it reshapes how managers allocate resources and evaluate risk. Innovation emerges from these internal changes.

Implications for Sustainable Management and Capital Markets

These findings enrich the literature on climate risk and firm performance by adding a micro-level organizational explanation. While prior studies document how climate exposure and ESG performance affect market reactions and firm value (Pankratz et al. 2023; Broadstock et al. 2021), the present study explains how sustainability-oriented finance becomes embedded in firms' innovation processes. The effect is managerial, not merely financial.

For practitioners, the results imply that access to green finance is insufficient without complementary managerial systems. Firms must translate green capital into sustained R&D programs and cultivate a governance environment that

tolerates exploratory risk. For policymakers, the findings suggest that green finance frameworks should be paired with institutional designs that encourage long-term managerial commitment rather than short-term symbolic compliance.

Overall, this study positions green finance management as a core component of sustainable strategic management. By linking external financial governance with internal capability formation, it clarifies how sustainability-oriented finance becomes a driver of long-term innovation trajectories within firms.

Conclusion

This study reconceptualizes green finance as a managerial capability embedded in firms' strategic and organizational processes. Using panel evidence from Malaysian listed firms, the findings demonstrate that green finance management enhances both green innovation output and long-term financial performance. Crucially, its impact on innovation operates through two complementary internal mechanisms—strengthening R&D investment and expanding managerial tolerance for uncertainty. The disappearance of the direct effect under the parallel mediation model indicates that organizational transformation, rather than capital availability alone, is the core channel through which green finance becomes effective.

These results bridge financial governance and innovation management by explaining how sustainability-oriented finance is translated into durable technological trajectories within firms. Practically, access to green capital must be matched with managerial systems that support long-term R&D and exploratory risk-taking. For policymakers, green finance frameworks should be designed to encourage sustained organizational change rather than short-term symbolic compliance.

Future research may extend this framework through cross-country comparisons to examine institutional boundary conditions, incorporate additional organizational mediators such as governance quality or managerial cognition, and adopt longer-term longitudinal designs to capture dynamic feedback between innovation and finance. Mixed-method approaches could further illuminate how managers interpret and operationalize green finance in practice.

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