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Research article

The impact of FinTech on corporate green innovation: The case of Chinese listed enterprises

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ABSTRACT

Financial technology (FinTech) has emerged as an increasingly prominent force in driving industrial structural transformation and fostering green economic development. This study takes Chinese listed enterprises from 2011 to 2023 as the research sample, employing a word frequency statistics method to measure FinTech development levels and examine its impact on corporate green innovation. The findings are as follows: First, FinTech significantly enhances corporate green innovation capabilities, with a stronger promotion effect on strategic innovation compared to substantive innovation. These conclusions remain robust after a series of sensitivity tests. Second, heterogeneity analysis reveals that FinTech's role in driving green innovation is more pronounced among high managers' cognitive endowments enterprises, non-state-owned enterprises, and non-heavily polluting enterprises. Furthermore, mechanism tests indicate that FinTech facilitates corporate green innovation through channels such as improving management capabilities and alleviating corporate financing constraints. Third, financial regulation suppresses FinTech's promotion of corporate green innovation, particularly exerting negative effects on FinTech's impact on substantive green innovation. Finally, this paper proposes corresponding policy implications based on the research findings, aiming to further enhance FinTech's empowerment capabilities and promote sustained corporate green innovation.

1. Introduction

The rapid advancement of the digital economy is profoundly reshaping the global financial landscape and business paradigms. The digital technology revolution, represented by artificial intelligence, big data, and cloud computing, is driving deep integration between traditional financial systems and emerging technologies, giving rise to a technology-driven financial innovation paradigm FinTech. As a technology-propelled financial innovation in the digital age, FinTech not only imparts fresh growth impetus to the global economy but also exerts significant, non-negligible impacts on China's pursuit of high-quality economic development (Takeda and Ito, 2021; Tang et al., 2023). Relying on core digital technologies such as big data, cloud computing, and blockchain, FinTech demonstrates distinctive technological characteristics. As an emerging financial service model in the digital economy era, it possesses unparalleled advantages over traditional financial service models in terms of financial resource allocation and adaptation to digital economic characteristics (Haddad and Hornuf, 2019; Yan et al., 2022). Currently, China's FinTech development has completed its foundational framework construction and is entering a new phase of deepened development. The Chinese government has further emphasized FinTech's pivotal role in promoting the real economy and high-quality economic growth, aiming to achieve substantial advancements in overall FinTech capabilities and core competitiveness by 2025 (Chen et al., 2022; Tao et al., 2022). The 2023 Central Financial Work Conference convened by the Chinese government further asserted that finance serves as the lifeblood of the national economy and constitutes a critical component of the country's core competitiveness, stressing the need to accelerate the construction of a financial powerhouse with FinTech serving as the core technological support and implementation pathway (Jiao et al., 2021). The development of FinTech has not only propelled the digital transformation and service efficiency enhancement of financial institutions but also injected strong vitality into the real economy and provided financial guarantees for China's high-quality economic development (Qamri et al., 2022; Huang et al., 2023; Zheng et al., 2023; Zhang et al., 2024). Statistical data

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reveals that over the past five years, Chinese financial institutions' investment in FinTech has continued to grow, rising from 225.26 billion yuan in 2019 to 355.815 billion yuan in 2023, with an average annual growth rate of 14.48%. Furthermore, following the conclusion of the pandemic and China's sustained steady economic growth, various market entities have actively engaged in FinTech investment. In 2023, China's FinTech market investment and financing scale reached 21.5 billion yuan, a 32.72% increase from the previous year. During this period, traditional financial institutions, strategically positioning to seize technological innovation highlands in FinTech and accelerate digital transformation, significantly increased investments in FinTech innovation teams, with their investment proportion surging from 10% in 2020 to 19% in 2023.[1]

FinTech, as a product of the deep integration between modern financial systems and digital technologies, has an evolutionary trajectory that profoundly reflects the symbiotic relationship between technology and finance. From a historical development perspective, its origins can be traced back to the early 1990s with Citibank's "Financial Services Technology Consortium" project in the United States, which primarily aimed to research and track technologies with revolutionary potential for the financial industry (Arner et al., 2016). While Citibank did not explicitly offer a universally recognized definition of FinTech, the initiation of the project signified the nascent formation of the FinTech concept and institutionalized the convergence of finance and technology. The 2008 global financial crisis not only unveiled the inherent vulnerabilities within traditional financial systems but also precipitated urgent demands for the application of technological innovations in the financial sector (Berg et al., 2022; Mention, 2019; Qamri et al., 2025). Subsequently, the vigorous development and widespread penetration of digital technologies laid a solid technological foundation for FinTech's evolution (Berger, 2003; Knight and Wójcik, 2020). Since 2014, cluster breakthroughs in new-generation digital technologies represented by blockchain, artificial intelligence, and big data analytics have propelled FinTech's transformation from auxiliary tools to a transformative force. Throughout this transition, the connotation of FinTech has undergone further expansion and deepening, swiftly emerging as a central focus of attention within both global academic and industrial spheres (Bollaert et al., 2021; Chen et al., 2022). The Financial Stability Board defines FinTech as "technology-driven financial innovation that may induce systemic transformations in business models, processes, and products," a definition endorsed by certain international organizations and scholars (Cao et al., 2021). From an industrial transformation perspective, the International Organization of Securities Commissions views FinTech as "an industrial ecosystem that reconstructs financial products, services, and market structures through technological innovation," transcending the limitation of perceiving FinTech merely as a technological tool by extending focus to market structure transformations and value network reconstructions (Cumming and Schwienbacher, 2021; Lai and Samers, 2021).

In the context of economic transformation, Chinese listed enterprises, due to their unique structural position, exert systemic influence on regional economic growth and green innovation, effectively serving as dual-role entities functioning as both "pressure transmission hubs" and "primary sources of innovation" (Hao et al., 2022; Lian et al., 2022). Although listed enterprises cannot fully represent all market actors, their dominant position in regional economies, the universality of their operational mechanisms, and the superior quality of their data render them ideal entry points for investigating the complex relationship between public environmental concerns and corporate green innovation (Liu and Mu, 2016; Li et al., 2024; Yang et al., 2025). The pressure-response pathways and heterogeneity patterns revealed through this lens remain critically instructive for designing green innovation policies across enterprises and hold significant practical value for exploring the efficacy of micro-level corporate innovation incentives. However, China's current R&D innovation system faces practical challenges including slowing input growth and declining output efficiency. First, corporate innovation models in China remain predominantly reliant on imitative innovation, technology transfer, and joint ventures primitive forms of development driven by extensive marketing and capacity expansion rather than R&D activities being elevated to core strategic priorities (Xu et al., 2025; Zhao et al., 2024). To address these multidimensional challenges, China has consistently positioned green innovation as the cornerstone of its new development philosophy, systematically advancing high-quality economic development. This strategic choice represents not only proactive responsibility-taking for environmental issues and climate crises but also an endogenous imperative to resolve deep-seated contradictions in economic development patterns. Consequently, resolving the dual dilemma of economic growth and environmental constraints has essentially become a pivotal institutional proposition in the co-evolutionary process of innovation in environmental regulation tools and transformation of green development models.

In the context of the digital economy profoundly reshaping global financial landscapes, FinTech as an innovation paradigm resulting from the integration of digital technology and financial systems is emerging as a critical engine driving China's high-quality economic development (Tian et al., 2022). The Chinese government has positioned FinTech as a pillar supporting five strategic domains including technology-driven finance and green finance, aiming to inject new momentum into the green transformation of the real economy by optimizing resource allocation efficiency and reducing information friction and financing constraints (Wang et al., 2025). However, existing research has yet to fully elucidate the intrinsic mechanisms and heterogeneous characteristics of FinTech's role in promoting corporate green innovation, particularly lacking systematic explanations for the dichotomous effects between strategic innovation and substantive innovation, as well as in-depth analysis of the regulatory role of financial supervision. Building on this gap, this study seeks to address the following core questions: 1) Can FinTech enhance corporate green innovation capabilities? 2) Are there structural differences in FinTech's driving effects on strategic innovation versus substantive innovation, and what are the underlying economic logics? 3) How do firms' diverse attributes and ownership structures moderate the relationship between FinTech and green innovation? 4) What role does financial regulation play in the process of FinTech-driven green innovation? To address these questions, this paper takes Chinese listed enterprises from 2011 to 2023 as the research sample, employing a word frequency statistics method to measure FinTech development levels and examine its impact on corporate green innovation. Clarifying these issues will not only provide a roadmap for precisely empowering green innovation through FinTech but also offer decision-making support for constructing incentive-compatible regulatory frameworks and facilitating the transition of innovation structures from superficial compliance to deep decarbonization, thereby holding significant strategic value for achieving the synergistic goals of high-quality economic development and ecological civilization advancement.

2. Influence mechanisms and research hypotheses

2.1. Impact of FinTech on corporate green innovation

Within the framework of the carbon neutrality strategy, FinTech, by virtue of technological integration and model innovation, has the potential to reshape the implementation avenues of corporate green innovation (Huo et al., 2022; Li et al., 2023). Based on dynamic capability theory, FinTech systematically enhances the efficiency and quality of corporate environmental technology innovation through data penetration, algorithmic synergy, and system interoperability (Tamasiga et al., 2022; Tian et al., 2023). First, FinTech provides micro-enterprises and entrepreneurs with richer financing tools and channels. The

[1] Data sources: https://www.analysys.cn/.

application of FinTech significantly reduces information opacity and expands the scope of financial services (Metawa et al., 2022). FinTech service platforms offer substantial real-time financial information and professional investment advice, improving the accuracy and effectiveness of investment decisions. For small and micro enterprises, FinTech introduces diversified financing methods and low-cost funding approaches, facilitating easier capital access and serving as a robust mechanism to reduce transaction costs (Xue et al., 2022; Zhang, 2023). For companies with lengthy R&D cycles, FinTech platforms focus on evaluating their core market competitiveness, thereby strengthening the technical component of investment and financing certification. This ensures these enterprises can steadily progress through development stages while shortening the duration of green technology R&D and application.

Second, FinTech mitigates corporate financial and operational risks. Traditional financial institutions often rely on subjective assessments and empirical judgment in risk management, leading to inherent biases and limitations (Dar et al., 2024). Leveraging big data and artificial intelligence, FinTech enables more in-depth and accurate risk assessment and monitoring for individual customers and enterprises. For instance, by analyzing individual consumers' spending habits and credit histories, tailored risk evaluations can be generated to promptly identify and preempt potential risks (Muganyi et al., 2021). Furthermore, by examining corporate operational data and supply chain details, FinTech facilitates comprehensive risk assessments, offering enterprises more precise and efficient risk management tools and significantly reducing operational risk levels. Based on the above analysis, this paper proposes Hypothesis 1.

H1. FinTech development promotes corporate green innovation levels.

2.2. Impact pathways of FinTech on corporate green innovation

FinTech systematically promotes corporate green innovation through technology empowerment and data-driven mechanisms, significantly enhancing management's strategic decision-making capabilities, risk management capabilities, and resource allocation efficiency (Ferri et al., 2025). Its core function lies in reconstructing management's cognitive frameworks and action patterns via technological means, transforming green innovation from external pressure into endogenous development momentum. First, FinTech converts fragmented environmental information into structured decision-making resources through technologies such as big data and the Internet of Things (IoT), addressing management's cognitive gaps in green innovation (Gong et al., 2024). Under traditional organizational models, information such as corporate carbon emissions data and environmental risks within the supply chain is fragmented across financial, production, and procurement departments. This fragmentation impedes the development of a systematic understanding of these environmental aspects. FinTech platforms address this issue by capturing real-time, full-chain data, thereby constructing dynamic environmental information maps. These maps serve as a crucial data foundation for firms to select appropriate directions for green technology R&D (Sannino et al., 2020). Second, AI and blockchain-enabled management decision-making tools significantly enhance the scientific rigor and foresight of green innovation decisions. At the technology selection level, green finance platforms enable real-time tracking of capital utilization efficiency in green projects, assisting management in dynamically adjusting R&D investment intensity (Khan and Urooj, 2023). Ultimately, at the level of organizational transformation, FinTech exerts a compelling force that drives corporate governance structures to evolve towards agile models. By means of digital middleware construction and cross-departmental data integration, enterprises establish governance mechanisms that are dynamically oriented towards environmental performance (Khan and Urooj, 2023; Wang et al., 2024). Institutional theory emphasizes the importance of formal and informal rules, norms, and routines in shaping organizational behavior. In the context of FinTech-driven organizational restructuring, the adoption of agile governance models and environmental performance-oriented mechanisms can be seen as a response to both external institutional pressures and internal institutional changes. Post-FinTech-driven organizational restructuring, green innovation decision-making hierarchies are streamlined, and interdepartmental collaboration efficiency improves, creating institutional safeguards for disruptive green technology breakthroughs (Tang et al., 2023; Bingxin et al., 2025).

FinTech systematically alleviates financing constraints faced by enterprises during green innovation by reconstructing the technological infrastructure and credit assessment systems of financing markets, thereby activating their environmental technology R&D and clean production investment dynamics. Specifically, intelligent risk control systems, which are constructed based on big data and IoT technologies, play a pivotal role in mitigating information asymmetry in the evaluation of green projects. In the context of traditional financing models, financial institutions faced significant challenges in internalizing the environmental externalities associated with green innovation projects. This was primarily due to their restricted access to non-financial data, including metrics such as corporate carbon intensity and energy efficiency (Allcott and Greenstone, 2012; Guo et al., 2023; Bingxin et al., 2025). FinTech resolves this by converting implicit environmental performance into quantifiable credit assets, significantly reducing transaction costs and information friction in green financing. Furthermore, AI and machine learning-based dynamic pricing models reconstruct risk assessment frameworks through multi-dimensional environmental performance indicators, enabling precise pricing of green financing costs (Sun and Zhang, 2023). Additionally, FinTech platforms expand green innovation financing channels by establishing diversified capital provider access points and leverage blockchain-based evidence preservation technologies to achieve credible traceability of environmental benefits. This effectively mitigates investors' adverse selection risks related to "greenwashing," providing market-oriented solutions to long-standing challenges in green finance (Chen et al., 2023). Based on the above analysis, this paper proposes Hypotheses 2a and 2b.

H2a. FinTech development promotes corporate green innovation by improving corporate management capabilities.

H2b. FinTech development promotes corporate green innovation by alleviating corporate financing constraints.

2.3. Impact of financial regulation on FinTech-driven corporate green innovation

When the intensity of regulation surpasses certain thresholds or lacks adaptability, the instrumental effectiveness of FinTech and market-based incentives for green innovation may undergo systemic attenuation. First, endogenous compliance costs can crowd out firms' innovation investment capacity. From the neo-institutional economics perspective, stringent regulations that necessitate data governance upgrades and algorithmic audit requirements essentially impose institutional transaction costs on corporate innovation activities (Ni et al., 2023; Hu et al., 2025). According to the Coase Theorem, when compliance costs surpass the marginal benefits of FinTech applications, enterprises will reduce green innovation investments. Second, overly detailed regulatory frameworks constrain technological enablement dimensions (Alsadoun and Alrobai, 2024). Drawing from functional regulation theory, existing regulatory systems create path dependencies that limit the functional development of FinTech tools. When regulatory frameworks focus excessively on technological minutiae rather than the economic functions enabled by technology, institutional distortions arise from regulatory overreach into technological "black boxes" (Omarova, 2021). In green finance contexts, for example, stringent leverage constraints on robo-advisors undermine the application of dynamic portfolio optimization models in green project risk pricing,

causing technological enablement to devolve from full-process empowerment to isolated tool provision (Wang and Hu, 2023). Third, prudential regulatory orientations reinforce risk-averse tendencies. Based on regulatory capture theory, when regulators overemphasize financial stability objectives, financial institutions strategically adjust risk preferences (Bromberg et al., 2018). This convergence in risk appetites fundamentally reflects institutional incompatibility between regulatory objective functions and green innovation incentives. Finally, regulatory lag effects induce technological suppression. Following institutional change theory, the 9–12 month average iteration cycle of FinTech creates a temporal mismatch with regulatory revision cycles, forming the root cause of dynamic technological-institutional imbalances (Wojcik, 2021). This institutional lag not only restricts technological experimentation spaces but also causes green FinTech application scenarios to lag behind theoretical frontiers, perpetuating a negative cycle from regulatory gaps to technological hesitation. Based on the above analysis, this paper proposes Hypothesis 3.

H3. Excessive financial regulation will inhibit FinTech's promotional effect on corporate green innovation.

3. Model setting, variables selection and data

3.1. Model setting

Building upon theoretical analysis and existing research, this section employs FinTech as the core explanatory variable and corporate green innovation (*Greino*) as the dependent variable. We empirically identify the specific impact of FinTech on corporate green innovation by constructing the following high-dimensional fixed-effects panel regression model:

$$Greino_{it} = \delta + \theta_1 Fintech_{it} + \sigma_i X_{it} + Firm_i + Year_t + Ind_s + \varepsilon_{it} \quad (1)$$

Here, the subscripts *i, t,* and *s* respectively denote firm, year, and industry. The dependent variable $Greino_{it}$ represents corporate green innovation, while $Fintech_{it}$ measures the intensity of FinTech development. X_{it} represents control variables. The model simultaneously controls for firm ($Firm_i$), year ($Year_t$), and industry (Ind_s) fixed effects to eliminate potential omitted variable biases and mitigate estimation errors arising from endogeneity.

3.2. Variables selection

3.2.1. Dependent variable

Green Innovation: Existing research primarily adopts the theoretical framework of innovation ecosystems, using green patent output as the core indicator to evaluate corporate green technology innovation performance (Moshirian et al., 2021). Regarding measurement dimensions, academic discourse has long debated between "process-oriented" patent application counts and "outcome-oriented" patent grant counts. However, the innovation lag caused by patent examination cycles cannot be overlooked. Taking invention patents as an example, the period from application submission to final authorization involves formal examination, publication, substantive examination, and other legal procedures, typically spanning 12–36 months. This temporal lag renders granted patents inadequate for reflecting real-time corporate innovation activities. In contrast, the technology disclosure mechanism during the patent application stage already generates significant knowledge spillover effects and directly influences capital market valuations (Aghion and Howitt, 1998), making application counts a more timely indicator. Based on these considerations, this paper uses the number of green patent applications as a proxy variable for corporate green innovation capacity. Operationally, we first obtain comprehensive patent application records of sample firms through the State Intellectual Property Office (SIPO) patent retrieval system, including critical fields such as IPC international classification codes, application dates, and patent types. In terms of variable construction, we disaggregate green patent applications into three dimensions: overall innovation level (*Greino*) is measured by the logarithmic transformation of the sum of green invention patents and green utility model patents; substantive innovation level (*Subino*) is captured through the logarithmic indicator of green invention patents, focusing on breakthrough technological achievements; while strategic innovation level (*Strino*) is reflected by the logarithmic treatment of green utility model patents, primarily describing incremental technological improvements.

3.2.2. Explanatory variable

FinTech: Existing research primarily employs three methodologies to measure FinTech development levels. First, the Digital Inclusive Finance Index compiled by the Peking University Digital Finance Research Center utilizes Ant Group's underlying transaction data, reflecting FinTech advancement through three dimensions: coverage breadth, usage depth, and digitization degree. Second, some studies measure regional FinTech development by counting the number of FinTech firms in specific areas. Third, text mining approaches quantify FinTech development through keyword searches in relevant documents. While the first two methods are predominantly applied in macro-level analyses at national or provincial levels, the text mining method—particularly when constructing firm-specific FinTech indices—is more suitable for micro-level institutional analyses. Consequently, this paper adopts the third approach, following methodologies outlined by Chen (2016) and Huang et al. (2023). We employ machine learning techniques to extract word frequencies of 124 FinTech-related keywords from listed firms' annual reports, categorized across six dimensions: artificial intelligence, blockchain, cloud computing, big data, digitalization, and mobility. Artificial intelligence represents algorithm-driven innovation, blockchain redefines trust mechanisms, cloud computing provides computational power infrastructure, big data enables the extraction of information value, digital technology signifies the underlying transformation process, and mobile technology points to changes in service delivery terminals. Using machine learning to extract keyword frequencies from annual reports avoids the bias associated with subjective metric design (Chen, 2016). As a legally required disclosure document, the frequency of technical terminology in annual reports objectively reflects a firm's resource allocation priorities. The vocabulary of 124 keywords has been validated through existing literature (Huang et al., 2023), ensuring that the terminology system aligns with industry practices. Compared to patent or investment data, text analysis is better suited to capturing the breadth of technology application rather than focusing solely on research and development intensity. The raw frequencies are then logarithmically transformed to derive annual FinTech development indices for individual listed firms.

3.2.3. Control variables

To mitigate estimation biases arising from omitted variables, this study controls for the following factors influencing corporate green innovation: (1) Firm Size (*Size*): Measured by the natural logarithm of total assets to account for the impact of corporate comprehensive strength and market position on green innovation. (2) Leverage Ratio (*Lev*): Calculated as the ratio of total liabilities to total assets to control for the influence of debt repayment capacity on green innovation. (3) Return on Assets (*ROA*): Determined as annual net income divided by total assets to capture the effect of profitability levels on green innovation. (4) Asset Turnover Ratio (*ATO*): Computed as the ratio of net sales revenue to average total assets to control for the alignment between asset investment scale and sales performance in affecting green innovation. (5) Board Size (*Board*): Represented by the natural logarithm of the number of directors to account for governance structure impacts. (6) Cash Flow Ratio (*Cashflow*): Measured as the ratio of net cash flow to current liabilities at period-end to control for short-term liquidity constraints on green innovation. (7) Operating Revenue Growth Rate (*Growth*): Calculated as the year-over-year change in operating revenue

to capture the influence of corporate growth trajectories and developmental capacity on green innovation. Descriptive statistics for these variables are presented in Table 1.

3.3. Data sources

This study employs panel data of Chinese A-share listed enterprises from 2011 to 2023 to construct an econometric model for empirically examining the driving effects of FinTech on corporate green innovation behaviors. In terms of data collection, information on corporate green innovation patents was sourced from the State Intellectual Property Office's patent retrieval system, with manual coding ensuring precise matching of patent types to individual enterprises. Core variable data were consolidated from the CSMAR Database and the Wind Database. To ensure data integrity, samples with significant missing values and financially insolvent enterprises were excluded. Finally, continuous variables underwent Winsorization at the 1% and 99% percentiles to mitigate outlier effects. The final analysis encompassed 17,805 observational samples.

As indicated by the variance inflation factor (VIF) test results in Table 2, the VIF values for all variables range from 1.03 to 1.75, with all values below 5 and well below 10. This indicates that the model does not suffer from severe multicollinearity issues.

4. Empirical analysis

4.1. Baseline regression results and discussion

To control for potential confounding effects from temporal, entity-specific, and industry characteristics, this study constructs a multi-dimensional fixed-effects model. We first incorporate time and entity fixed effects while controlling for industry-level fixed differences. In terms of control variables, we include firm size (*Size*), financial leverage (*Lev*), profitability (*ROA*), operational efficiency (*ATO*), cash flow position (*Cashflow*), growth opportunities (*Growth*), and governance structure (*Board*) as explanatory variables.

The baseline regression results in Table 3 reveal: In Column (1) without control variables, the marginal effect of FinTech on corporate green innovation is 0.103; this coefficient decreases to 0.092 in Column (2) after incorporating micro-level controls. Taking Column (2) as an example, the economic interpretation indicates that a one-unit increase in FinTech development corresponds to a 0.092-unit increase in corporate green innovation. This finding theoretically aligns with Li et al. (2023), demonstrating the role of FinTech advancement. By restructuring market mechanisms and resource allocation logic, FinTech development significantly enhances firms' endogenous motivation for green innovation. On one hand, the positive externalities of green R&D create a disparity between private and social returns, discouraging spontaneous corporate investment. On the other hand, information asymmetry hinders financial institutions' accurate valuation of green projects' environmental value and technical risks, resulting in financing constraints and capital misallocation. FinTech reshapes the green innovation ecosystem through technological integration: it reduces financial institutions' risk perception biases toward green projects, facilitating lower-cost capital flows into clean technology R&D (Liu et al., 2023). Additionally, digital platforms aggregate fragmented market demand and supply, creating novel green financial instruments and service models. This internalizes environmental costs into corporate decision-making, incentivizing firms to pursue premium returns through technological innovation, thereby driving green innovation evolution from policy-driven to market-endogenous mechanisms.

Further analyzing structural differences in green innovation, Columns (3)–(4) of Table 3 show that a one-unit increase in FinTech development corresponds to a 0.076-unit increase in strategic green innovation and a 0.039-unit increase in substantive innovation. Strategic green innovation, distinguished by its tangible and standardized outputs, is more amenable to identification through FinTech's data-capture and validation systems. In contrast, substantive innovation hinges on long-term R&D efforts and profound transformations in production processes, with environmental benefits emerging only after substantial time lags. Even when FinTech helps to ease initial financing constraints, it faces challenges in accurately assessing the true value and risks associated with technological pathways (Huang and Ma, 2024; Wang et al., 2024). Consequently, the asymmetry between strategic and substantive innovation is exacerbated under technological enablement, objectively inducing firms to allocate resources toward domains with immediate financial returns (Yan et al., 2022). Market mechanisms' short-term profit pursuit and regulatory compliance orientations further amplify this structural bias, prompting managers to prioritize indicator compliance for tenure risk avoidance. Thus, FinTech development demonstrates a stronger promotional effect on strategic green innovation compared to substantive green innovation.

Table 1
Descriptive statistics.

Type of variable	Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent Variable	Greino	17,805	0.390	0.815	0	6.616
	Strino	17,805	0.276	0.682	0	6.159
	Subino	17,805	0.211	0.562	0	5.617
Independent Variable	Fintech	17,805	3.545	1.402	0	7.362
Control Variables	Size	17,805	22.268	1.249	19.629	27.370
	Lev	17,805	0.411	0.194	0.030	0.963
	ROA	17,805	0.039	0.069	−0.375	0.263
	ATO	17,805	0.642	0.404	0.052	2.991
	Board	17,805	2.112	0.196	1.561	2.880
	Cashflow	17,805	0.049	0.068	−0.220	2.665
	Growth	17,805	0.165	0.372	−0.665	3.869

4.2. Robustness analysis

4.2.1. Robustness test

To conduct robustness checks, this study first reconstructs the measurement methods for core variables. Given the multitude of alternative measurement approaches for dependent variables, which may introduce measurement biases, we modify the dependent variable's measurement strategy by using the proportion of annual green patent applications relative to total patent applications as the proxy for corporate green innovation (Table 4, Column (1)). For strategic green innovation, we employ the ratio of independently applied green utility model patents to total applications as an alternative indicator (Table 4, Column (2)). Finally, we revise the metric to the share of independently applied green invention patents relative to total applications as an alternative indicator for substantive innovation (Table 4, Column (3)). Regression results from these alternative measurement models demonstrate that the coefficient signs and significance levels associated with FinTech attention remain substantially unchanged, confirming the robustness of our baseline findings against measurement errors in variables.

In response to the potential impacts of the COVID-19 pandemic on corporate production and operational decisions, this study excludes data from 2019 onwards from the analytical scope. This adjustment is made because sudden public health emergencies may induce strategic shifts in corporate priorities, causing short-term distortions in environmental focus effects (Jain et al., 2024). By removing abnormal operational data during the pandemic period, we enhance the precision in identifying the net effect of FinTech development on corporate green technology behaviors under normal economic conditions. This exclusion also mitigates interference from emergency management policies on innovation decisions, thereby improving the generality and applicability of our results (Table 5, Columns (1)–(3)).

Second, we exclude samples from municipalities directly under the central government to control for distortions caused by administrative

Table 2
Covariance analysis.

	Fintech	Size	Lev	ROA	ATO	Board	Cashflow	Growth
VIF	1.03	1.53	1.75	1.61	1.14	1.08	1.24	1.13
1/VIF	0.972	0.654	0.571	0.621	0.879	0.922	0.806	0.883

Table 3
Benchmark regression results.

Variable	(1)	(2)	(3)	(4)
	Greino	Greino	Strino	Subino
Fintech	0.103***	0.092***	0.076***	0.039***
	(0.015)	(0.013)	(0.012)	(0.008)
Size		0.136***	0.134***	0.064***
		(0.015)	(0.0142)	(0.012)
Lev		0.252***	0.126**	0.189***
		(0.075)	(0.058)	(0.056)
ROA		0.487***	0.295**	0.290***
		(0.147)	(0.122)	(0.100)
ATO		−0.009	−0.001	−0.007
		(0.029)	(0.026)	(0.020)
Board		−0.100	−0.072	−0.042
		(0.166)	(0.162)	(0.090)
Cashflow		−0.050***	−0.049***	−0.018*
		(0.015)	(0.012)	(0.009)
Growth		0.134**	0.063	0.107**
		(0.059)	(0.056)	(0.047)
_cons	0.026	−3.357***	−3.162***	−1.664***
	(0.054)	(0.374)	(0.356)	(0.253)
Individual fixed	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes
Observation	17,805	17,805	17,805	17,805
Adj-R^2	0.101	0.162	0.147	0.128

Table 4
Robustness test A.

Variable	(1)	(2)	(3)
	New_Greino	New_Strino	New_Subino
Fintech	0.004*	0.004**	0.002*
	(0.002)	(0.002)	(0.001)
Control	Yes	Yes	Yes
_cons	−0.015	−0.065***	−0.022
	(0.046)	(0.025)	(0.025)
Individual fixed	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Observation	17,805	17,805	17,805
Adj-R^2	0.088	0.059	0.038

and market environmental differences (Table 5, Columns (4)–(6)). As provincial administrative units, municipal enterprises enjoy institutional advantages including central fiscal subsidies and tax exemptions, which may deviate green innovation behaviors from market-driven logic. Furthermore, the financial center agglomeration effects and research resource siphon phenomena in municipal regions endow local firms with disproportionately superior technological access capabilities compared to firms in ordinary regions, creating asymmetric competitive conditions. The results demonstrate that after excluding pandemic-affected data and municipal samples, FinTech continues to robustly promote corporate green innovation levels.

4.2.2. Discussion on endogeneity

To address potential endogeneity issues arising from omitted variables, this study employs additional control variables. First, we incorporate factors influencing corporate green innovation from both firm and city perspectives, augmenting the baseline model by controlling for variables such as firm listing duration and re-estimating the regressions (Table 6, Columns (1)–(3)). The results confirm that FinTech development maintains a significant positive promotive effect on corporate green innovation. Finally, considering the potential bidirectional causality between FinTech development and corporate green innovation, we implement a two-stage least squares (2SLS) instrumental variable approach (Table 6, Columns (4)–(6)). Specifically, we use the industry-year average of other firms' FinTech development levels within the same sector as the instrumental variable (Nguyen, 2022). Firms in the same industry confront comparable technological diffusion environments, policy frameworks, and market demand structures, leading to spatial correlations in their FinTech investments driven by sector-specific common factors. The instrumental variable captures these externally driven trends by aggregating industry-level data, establishing strong correlation with target firms' FinTech levels while isolating idiosyncratic firm characteristics. Moreover, since the industry-year mean is constructed from other firms' data, individual target firm behaviors cannot retroactively influence the sector-wide average, thereby mitigating reverse causality concerns. The under-identification and weak instrument tests confirm that after accounting for endogeneity, FinTech development continues to exhibit a significantly positive impact on corporate green innovation, further validating the robustness of our baseline regression results.

Table 5
Robustness test B.

Variable	Excluding the effect of epidemic			Excluding municipality samples		
	(1)	(2)	(3)	(4)	(5)	(6)
	Greino	Strino	Subino	Greino	Strino	Subino
Fintech	0.079***	0.066***	0.032***	0.102***	0.083***	0.049***
	(0.014)	(0.012)	(0.010)	(0.016)	(0.014)	(0.009)
Control	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−3.604***	−3.462***	−1.709***	−3.391***	−3.093***	−1.783***
	(0.365)	(0.373)	(0.248)	(0.439)	(0.383)	(0.313)
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes
Observation	10,788	10,788	10,788	14,286	14,286	14,286
Adj-R^2	0.171	0.156	0.135	0.171	0.157	0.127

Table 6
Endogeneity test.

Variable	Adding control variables			2SLS method		
	(1)	(2)	(3)	(4)	(5)	(6)
	Greino	Strino	Subino	Greino	Strino	Subino
Fintech	0.087***	0.073***	0.035***	0.081***	0.057***	0.047***
	(0.014)	(0.012)	(0.008)	(0.015)	(0.014)	(0.010)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap rk LM statistic				32.53*** [0.00]	32.53*** [0.00]	32.53*** [0.00]
Kleibergen-Paap rk Wald F statistic				407.948	407.948	407.948
				{16.38}	{16.38}	{16.38}
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes

4.3. Heterogeneity regression results and discussion

The preceding empirical analysis confirms that FinTech development exerts a statistically significant positive driving effect on corporate green innovation, with this relationship surviving multiple robustness checks. However, given the multidimensional complexities arising from managerial heterogeneity, industry-specific characteristics, and firms' strategic responses to internal operational constraints and exogenous environmental shocks, corporate entities may implement differentiated innovation adjustments. This section conducts heterogeneity analyses from the perspectives of managerial attribute differences, corporate typology variations, and ownership nature distinctions, aiming to provide theoretical and empirical support for localized policy formulation by regional governments and policymakers.

4.3.1. Heterogeneity in managerial characteristics

Columns (1) and (2) of Table 7 reveal significant heterogeneity in the driving effect of FinTech on green innovation based on managers' cognitive endowments. Specifically, when management's environmental cognitive endowment is high, the marginal effect of FinTech on overall corporate green innovation reaches 0.098 ($p<0.01$), compared to 0.087 ($p<0.01$) when cognitive endowment is low. This indicates that managers' environmental awareness amplifies the green innovation effect of FinTech. Senior executives with strong environmental cognitive capital exhibit superior capacity to allocate attention to environmental issues, enabling more precise identification of green solutions embedded in digital finance tools (Xie et al., 2021). Furthermore, high cognitive endowment enhances government-enterprise synergies, as managers can more effectively leverage policy benefits from digital finance initiatives.

Column (3) and (4) of Table 7 further shows that when managers possess higher green cognitive capabilities, FinTech's promotional effect on strategic green innovation becomes more pronounced. Managers with elevated environmental awareness demonstrate greater agility in recognizing the environmental value and application scenarios of FinTech tools. Their cognitive advantages enhance the conversion efficiency of FinTech resources: through digital means, they can simultaneously reduce compliance costs for strategic innovations and efficiently access green financing channels, swiftly transforming superficial regulatory compliance into market reputation gains and policy dividends. Conversely, managers with low green cognitive capacity may limit FinTech applications to routine operations, failing to unlock its targeted green potential.

4.3.2. Heterogeneity in corporate typology

We categorize the sample into high-pollution and low-pollution firms. As shown in Columns (1)–(2) of Table 8, FinTech development significantly enhances green innovation in non-heavy-polluting firms, while its promotive effect on heavy-polluting firms remains insignificant. Notably, Columns (3)–(6) of Table 8 reveal that FinTech exerts stronger promotive effects on both substantive and strategic green innovations among non-polluting firms. From a cost-benefit perspective, heavy-polluting firms face rigid marginal cost constraints for green innovation due to their high negative externalities. They must bear sunk costs from retrofitting pollution control facilities while confronting diseconomies of scale in clean technology R&D. Conversely, non-heavy-polluting firms, with relatively lower environmental compliance costs, can internalize green transition benefits through incremental technological innovations (Wang et al., 2024). Through the lens of dynamic capability theory, these firms demonstrate greater agility in converting public environmental concerns into strategic resources, constructing sustainable competitive advantages through substantive innovations like green product differentiation and environmental management certifications. This heterogeneity provides theoretical underpinnings for

Table 7
Results of the test for heterogeneity of managerial characteristics in enterprises.

Variable	Greino		Strino		Subino	
	(1)	(2)	(3)	(4)	(5)	(6)
	Low cognitive endowment	High cognitive endowment	Low cognitive endowment	High cognitive endowment	Low cognitive endowment	High cognitive endowment
Fintech	0.087***	0.098***	0.068***	0.081***	0.044***	0.039***
	(0.023)	(0.014)	(0.022)	(0.012)	(0.014)	(0.008)
Control	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−3.483***	−3.318***	−3.246***	−3.176***	−1.905***	−1.518***
	(0.577)	(0.573)	(0.544)	(0.560)	(0.429)	(0.296)
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes
Observation	5132	12,673	5132	12,673	5132	12,673
Adj-R^2	0.159	0.158	0.145	0.145	0.126	0.140
Permutation test	−0.011***		−0.013***		−0.005***	

Table 8
Results of the test for heterogeneity of pollution types in enterprises.

	Greino		Strino		Subino	
Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting enterprises	Non-polluting enterprises	Polluting enterprises	Non-polluting enterprises	Polluting enterprises	Non-polluting enterprises
Fintech	0.016	0.085***	0.001	0.078***	0.013	0.024**
	(0.014)	(0.017)	(0.013)	(0.014)	(0.010)	(0.010)
Control	Yes	Yes	Yes	Yes	Yes	Yes
_cons	2.146	0.977	1.288	−0.625	0.334	1.837
	(1.748)	(2.715)	(1.292)	(2.238)	(1.156)	(1.789)
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes
Observation	5528	12,277	5528	12,277	5528	12,277
Adj-R^2	0.076	0.174	0.053	0.162	0.050	0.137
Permutation test	−0.069***		−0.077***		−0.011***	

differentiated policy design, necessitating tailored environmental regulations and financial support frameworks aligned with firm-specific characteristics.

Finally, we differentiate samples based on corporate ownership structure, categorizing them into state-owned enterprises (SOEs) and non-state-owned enterprises (Non-SOEs), to examine the heterogeneous impacts of FinTech development on green innovation across ownership types. Columns (1)–(2) of Table 9 reveal that FinTech exerts a stronger promotive effect on green innovation in non-SOEs compared to SOEs. Furthermore, Columns (3)–(6) of Table 9 demonstrate that FinTech's positive influence on both substantive and strategic green innovations is significantly more pronounced among non-SOEs.

SOEs operate within governance paradigms dominated by administrative logic, characterized by hierarchical organizational structures and institutional resource dependencies. While this institutional framework grants SOEs preferential access to policy information and financial resources, entrenched path dependencies render their carbon-intensive production models resistant to transformation, with notable technological lock-in effects compared to non-SOEs. Additionally, multi-layered principal-agent chains exacerbate decision-making delays, and soft budget constraints diminish innovation efficiency incentives. Consequently, environmental investments in SOEs often prioritize high-visibility symbolic projects over foundational technological breakthroughs. In contrast, non-SOEs exhibit greater environmental strategic agility. Their flat organizational structures enable more rapid market signal processing, facilitating timely adjustments to production processes and efficient alignment with green technology trends.

5. Further analysis

5.1. Mechanism effects analyses

While prior analysis has only demonstrated the promotive effect of FinTech development on corporate green innovation, this section systematically investigates the underlying mechanisms by examining mediating variables such as managerial capability and financing constraints, while justifying their theoretical relevance. Specifically, we test the impact pathways through which FinTech development influences these mediating variables, while the causal relationships between mediating variables and green innovation are substantiated by integrating theoretical frameworks and citing existing authoritative empirical evidence. The econometric specification for mechanism validation is formulated as follows (Equation (2)):

$$Mech_{it} = \delta + \theta_1 Fintech_{it} + \sigma_i X_{it} + Firm_i + Year_t + Ind_s + \varepsilon_{it} \quad (2)$$

In Equation (2), $Mech_{it}$ represents the specific mediating variables, including managerial capability and financing constraints, with other variables consistent with Equation (1). Managerial capability, as an integrated competency encompassing strategic, decisional, organizational, coordinative, and control functions, plays a pivotal role in driving the implementation of corporate green development strategies. Academic quantification of managerial capability primarily employs two approaches: (1) the ratio of operating revenue to total assets, and (2) the proportion of administrative and selling expenses relative to total operating revenue. This study adopts the operating revenue-to-total assets ratio as the proxy for managerial capability.

Financing constraints, serving as a micro-foundation for coordinating economic and environmental development, make green innovation implementation critical for firms to sustain competitiveness and align with national green development strategies. Following Hadlock

Table 9
Results of the test for heterogeneity of ownership types in enterprises.

Variable	Greino		Strino		Subino	
	(1)	(2)	(3)	(4)	(5)	(6)
	SOE	Non-SOE	SOE	Non-SOE	SOE	Non-SOE
Fintech	0.082***	0.099***	0.075***	0.079***	0.025***	0.046***
	(0.018)	(0.014)	(0.018)	(0.011)	(0.009)	(0.010)
Control	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−4.086***	−2.774***	−3.954***	−2.529***	−1.846***	−1.593***
	(0.935)	(0.502)	(0.860)	(0.504)	(0.607)	(0.307)
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes
Observation	5770	12,035	5770	12,035	5770	12,035
Adj-R^2	0.220	0.161	0.215	0.136	0.169	0.135
Permutation test	−0.017***		−0.004		−0.021***	

and Pierce (2010), this chapter employs the widely adopted SA index as the proxy for financing constraints, calculated as:

$$Sa = -0.737 \times szie + 0.043 \times size^2 - 0.04 \times age \quad (3)$$

Columns (1)–(3) of Table 10 report the direct effects of FinTech on corporate green development, while Columns (4)–(5) reflect its indirect effects through mediating variables. Column (4) demonstrates that FinTech significantly elevates corporate managerial capability, thereby enhancing managerial capability to drive green development. As a critical enabler of green strategy formulation and execution, managerial capability is strengthened by FinTech through the provision of intelligent, customized management tools and services. These technologies improve information processing capacity and sharing efficiency, leading to optimized resource allocation, green product process innovation, and effective implementation of environmental strategies—ultimately elevating overall corporate green innovation levels.

Column (5) reveals that FinTech alleviates financing constraints to empower green development. Under traditional financing paradigms, green projects face credit rationing and cost premiums due to technological risks, long payback periods, and insufficient collateral. FinTech addresses these barriers by constructing dynamic green credit models using big data, incorporating non-financial information such as energy consumption data, carbon trading records, and supply chain environmental performance. This enables precise quantification of environmental benefits, reduces information verification costs for financial institutions, and facilitates credit enhancement for firms lacking tangible collateral but possessing emission reduction potential.

5.2. Moderating effects analyses

While the development of FinTech has accelerated the pace of financial supply-side reforms in China, significantly enhancing the efficiency of financial resource allocation, and thereby robustly promoting the advancement of regional green economic development, its inherent technological risks may amplify traditional financial risks and trigger severe contagion effects (Morris et al., 2008). As FinTech continues to evolve, the boundaries between finance and the real economy are becoming increasingly blurred, with the emergence of innovative financial formats such as equity crowdfunding and shadow banking that operate outside effective regulatory frameworks. In regions with weaker financial oversight, these financial activities exacerbate corporate financialization, diverting substantial capital flows from the formal financial system and constraining firms' green transition processes—ultimately posing significant obstacles to green economic development (Levine, 2012). In response, this study employs the ratio of financial regulatory expenditure to the value-added of the financial sector as a proxy for financial regulatory intensity, to further investigate the moderating role of regulatory stringency on the effects of FinTech development. The specific validation model is formulated as follows:

$$Greino_{it} = \delta + \theta_1 Fintech_{it} \times Finreg_{it} + \theta_2 Fintech_{it} + \sigma_i X_{it} + Firm_i + Year_t + Ind_s + \varepsilon_{it} \quad (4)$$

In Equation (4), *Finreg* denotes financial regulatory intensity, with other variables consistent with Equation (1). Table 11 reveals that financial regulation suppresses the promotive effect of FinTech on corporate green innovation, particularly exerting a negative moderating effect on FinTech's impact on substantive green innovation—a deviation from conventional understanding. This paradox stems from the inherent tension between institutional constraints and technological enablement. First, compliance costs crowd out innovation resources: stringent regulatory requirements compel firms to divert substantial resources toward short-term compliance optimizations rather than long-term R&D investments (Begenau and Landvoigt, 2022). Second, risk aversion constrains capital supply: heightened regulatory scrutiny intensifies financial institutions' risk aversion, leading to reduced credit support for high-uncertainty substantive innovations. The deeper conflict arises from regulatory-technological misalignment existing regulatory frameworks, designed for traditional financial instruments, struggle to accommodate FinTech's unique attributes. Ultimately, regulatory pressures may distort corporate innovation structures: strategically oriented innovations, with quantifiable outcomes, continue to attract resources, while substantive innovations characterized by long cycles and high risks—face systemic marginalization.

6. Conclusions and recommendations

This study constructs an econometric model using panel data from China's A-share listed enterprises (2011–2023) to empirically examine the driving effects of FinTech on corporate green innovation behaviors.

Table 11
Moderating effect test results.

Variable	Greino	Strino	Subino
	(1)	(2)	(3)
Fintech	0.092***	0.076***	0.039***
	(0.013)	(0.012)	(0.008)
Fintech×Finreg	−0.626*	−0.264	−0.614**
	(0.333)	(0.307)	(0.238)
Finreg	0.022	−0.086	0.076
	(0.401)	(0.283)	(0.240)
Control	Yes	Yes	Yes
_cons	−3.358***	−3.163***	−1.665***
	(0.374)	(0.357)	(0.253)
Individual fixed	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Observation	17,805	17,805	17,805
Adj-R^2	0.162	0.147	0.128

Table 10
Mechanism test results.

Variable	Greino	Strino	Subino	Man	SA
	(1)	(2)	(3)	(4)	(5)
Fintech	0.092***	0.076***	0.039***	0.005**	0.010**
	(0.013)	(0.012)	(0.008)	(0.003)	(0.004)
Control	Yes	Yes	Yes	Yes	Yes
_cons	−3.357***	−3.162***	−1.664***	−0.356***	−4.321***
	(0.374)	(0.356)	(0.253)	(0.074)	(0.383)
Individual fixed	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes	Yes	Yes
Observation	17,805	17,805	17,805	17,805	17,805
Adj-R^2	0.162	0.147	0.128	0.220	0.282

Key findings include: (1) FinTech significantly enhances overall corporate green innovation, with a stronger promotive effect on strategic innovations compared to substantive innovations. These conclusions remain robust across multiple specification tests. (2) Heterogeneity analyses reveal that FinTech's green innovation effects are more pronounced among enterprises with high managers' cognitive endowments, non-state-owned enterprises, and non-heavy-polluting enterprises. (3) Mechanism tests confirm that FinTech facilitates green innovation by enhancing corporate managerial capabilities and alleviating financing constraints. (4) Financial regulation negatively moderates the FinTech green innovation relationship, particularly suppressing substantive green innovation—a finding counter to conventional expectations. Based on these results, we propose the following policy recommendations:

First, prioritize FinTech advancement to comprehensively elevate corporate green innovation. This requires accelerating digital transformation of the financial system through deep integration of next-generation information technologies with financial infrastructure, thereby constructing a digital financial ecosystem that strengthens foundational technological support for green product development and service model innovation. Regional FinTech innovation ecosystems should be enhanced via specialized incubation platforms that aggregate innovation resources, with policy guidance and capital synergies fostering virtuous development cycles to expedite the conversion of technological outcomes into green finance applications.

Second, strengthen FinTech's catalytic effects on green innovation through targeted interventions. For firms with weak green cognitive capacities, implement digital green finance training programs to elevate managers' proficiency in deploying FinTech tools, facilitating the translation of technological enablement into strategic innovation decisions. Establish dedicated green FinTech funds to prioritize substantive innovation projects such as clean technology R&D and low-carbon process upgrades, utilizing smart contracts to align funding disbursements with emission reduction targets while curbing excessive incentives for superficial compliance-driven innovations. Develop multi-dimensional green rating frameworks incorporating environmental performance, patent quality, and technological commercialization potential to guide financial institutions in directing preferential low-interest loans or equity financing toward firms with substantive innovation profiles.

Third, design adaptive regulatory frameworks to balance risk management and innovation incentives. Implement flexible regulatory regimes for financial activities involving clean technology development, streamlining approval processes to reduce compliance costs that crowd out long-term R&D investments. Introduce risk-sharing mechanisms that provide regulatory capital relief for financial institutions supporting long-term high-risk technology projects, encouraging cross-cycle capital allocation. Finally, ensure dynamic alignment between regulatory rules and technological evolution, transitioning green innovation from policy-dependent adaptation to market-driven endogenous growth while maintaining financial stability.

Although this paper has endeavoured to comprehensively address the relevant issues, the study still has the following limitations: First, the word frequency measurement method for fintech has inherent flaws. While relying on annual report text to extract keywords is objective, it may not fully capture the actual depth of technology implementation. Additionally, companies may strategically disclose technical terminology to align with regulatory guidelines, leading to discrepancies between measurement values and actual technological capabilities. Second, the representativeness of the sample is limited. The study only covers listed companies and does not include small and medium-sized enterprises or non-listed financial institutions, which are precisely the key beneficiary groups of fintech's inclusive nature. This may weaken the generalisability of the conclusions to a broader range of economic entities. Third, the measurement of relevant variables is relatively simple, such as the ratio of operating revenue to total assets. These issues require improvement in future research.

CRediT authorship contribution statement

Chuhong Wang: Writing – review & editing, Writing – original draft, Visualization, Software, Data curation, Conceptualization. **Xin Yin:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources. **Fangkun Yu:** Writing – original draft, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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