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UNLEASHING THE POWER OF INTEGRATED DIGITAL FINANCE AND TECHNOLOGICAL INNOVATION TO TRANSFORM THE WORLD

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Abstract. In a rapidly digitising global economy, the integration of digital finance and technological innovation presents a powerful avenue for promoting financial inclusion and enterprise development. This study investigates how digital finance influences organizational creativity and performance across the life cycle of firms, particularly in the Chinese context from 2011 to 2022. The research aims to (1) map the interaction between digital inclusive finance and innovation across enterprise stages, (2) identify gaps in current research, and (3) provide practical guidance for stakeholders. Using firm-level panel data and logistic regression models with robustness checks, instrumental variable estimation, and mediation analysis, the study introduces the Digital Finance Accessibility Index (DFA) as a key explanatory variable. Empirical results reveal that a 1% increase in DFA significantly boosts enterprise digital growth (EDG) by 0.081%; the effect is more pronounced in state-owned enterprises (SOEs) compared to non-state-owned firms. Furthermore, digitization mediates the relationship between digital finance and organizational innovation, amplifying creative outcomes. The study also uncovers stronger digital impacts during growth stages than startup phases. These findings underscore the need for collaborative policy efforts to expand equitable access to digital financial tools, especially for SMEs and underserved communities, to drive inclusive innovation and sustainable economic growth.

Keywords: digital finance, technological innovation, organizational creativity, financial inclusion, online banking, business growth.

JEL Classification: G10, O30.

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1. Introduction

Despite the rapid global expansion of digital finance and technological innovation, a critical gap persists in understanding how these two forces interact across the full life cycle of enterprises, particularly in emerging economies like China. Most existing studies tend to examine digital finance and innovation in isolation, overlooking their combined and evolving impact on organizational creativity and business performance. Moreover, limited attention has been paid to how this interplay varies across different types of firms – such as state-owned versus non-state-owned enterprises – and at various stages of development, from startup to maturity. The absence of integrated frameworks that capture the complexity of digital financial accessibility, technological transformation, and enterprise-level heterogeneity hampers effective policy making and business strategy design. Additionally, there is a lack of empirical analysis that connects digital financial inclusion with innovation outcomes in a systematic way using robust models and large-scale datasets. These limitations are especially problematic

given that over 1.7 billion adults globally remain financially excluded, and digital solutions offer a promising but underutilized pathway to inclusion and growth.

In the digital era, the intersection of finance and technology has emerged as a transformative force reshaping business landscapes and financial ecosystems globally. Digital finance, empowered by innovations such as mobile payments, blockchain, artificial intelligence, and cloud computing, has revolutionized access to financial services and enhanced operational efficiencies across industries (Nabavi-Pelesaraei et al., 2023). Simultaneously, technological innovation has become a cornerstone of competitive advantage, enabling firms to respond more agilely to market shifts, customer demands, and global economic changes. When strategically integrated, digital finance and technological advancement offer synergistic benefits – not only expanding financial access but also driving innovation, productivity, and inclusiveness in enterprise operations (Maklavany et al., 2023). This convergence is especially critical in developing and transitioning economies, where disparities in financial accessibility persist and innovative capacity remains underleveraged.

China provides a compelling setting for examining this interaction due to its rapid digital transformation and widespread policy commitment to financial inclusion. Over the past decade, the Chinese government and financial institutions have made concerted efforts to develop digital financial infrastructure, particularly targeting underserved populations and Small and Medium-Sized Enterprises (SMEs) (Ghasemi-Mobtaker et al., 2020). The rise of fintech platforms, digital wallets, and data-driven lending models has enabled broader financial participation, yet the extent to which such digital finance tools enhance enterprise-level innovation – especially across different ownership structures and life cycle stages – remains underexplored. Traditional models often overlook the nuanced role that firm digitization plays in translating financial access into measurable creative output, thus limiting our understanding of how digital tools can be leveraged to stimulate inclusive entrepreneurial growth and technological transformation (Ghasemi-Mobtaker et al., 2024).

Moreover, much of the existing literature lacks an integrated analytical framework that captures the dynamic interplay among financial accessibility, digital maturity, and innovation outcomes. Previous studies have tended to focus either on financial inclusion in macroeconomic terms or on innovation within specific corporate contexts, rarely combining the two to explore mediating mechanisms and structural variations. There is also limited empirical evidence on how the relationship between digital finance and innovation varies across firm types – particularly between State-Owned Enterprises (SOEs) and Non-State-Owned Enterprises (NSOEs) – and how this relationship evolves over time. Additionally, the role of contextual factors such as industry dynamics, regional development, and competitive intensity has not been adequately incorporated into existing models. These gaps hinder the ability of policymakers and business leaders to design effective strategies for leveraging digital infrastructure to drive innovation and sustainable economic development.

Against this backdrop, this study sets out three core objectives: first, to map the landscape of digital inclusive finance and technological innovation across the entire life cycle of enterprises; second, to identify theoretical and empirical gaps in the current understanding of how digital finance influences innovation outcomes; and third, to offer practical, evidence-based recommendations for policymakers, financial institutions, and corporate stakeholders. Based

on these aims, the study addresses the following key research questions: (1) How does digital finance impact organizational creativity across different stages of enterprise development? (2) What role does digitization play in mediating the relationship between digital financial accessibility and innovation? (3) How do firm characteristics, such as ownership type and industry context, moderate these relationships? Through these questions, the study seeks to generate new insights into the transformative potential of digital finance and innovation in building inclusive, resilient, and forward-looking business ecosystems.

This study makes several important contributions to the existing literature on digital finance, technological innovation, and enterprise development, particularly in the context of emerging economies. Focusing on China over the period from 2011 to 2022, it provides a comprehensive and dynamic assessment of how digital finance accessibility influences organizational creativity and performance across different stages of the enterprise life cycle. By introducing and empirically validating the Digital Finance Accessibility Index (DFA), the study offers a novel measurement framework that captures the multidimensional nature of financial inclusion in the digital era. Using advanced econometric techniques – including logistic regression, Instrumental Variable (IV) estimation, and mediation analysis – it unpacks the mechanisms through which digital finance supports innovation, highlighting the mediating role of corporate digitization. Furthermore, the study identifies significant ownership heterogeneity, revealing that digital finance has a stronger positive effect on state-owned enterprises than on non-state-owned firms (Cai et al., 2025). This nuanced insight adds depth to the discourse on public-private sector dynamics in digital transformation. Overall, the research bridges critical gaps in existing literature by integrating financial inclusion, innovation theory, and organizational development in a unified empirical model, providing region-specific evidence and policy-relevant implications for accelerating inclusive economic growth through digital infrastructure and innovation support.

2. Literature review

2.1. Financial inclusion and digital finance frameworks

Financial inclusion has long been regarded as a catalyst for poverty alleviation, economic empowerment, and social equity. Theoretical models such as the Microfinance Theory posit that offering low-income individuals and micro-enterprises access to credit and savings facilities can significantly stimulate local economic activity (S. Zhao et al., 2024). The expansion of digital infrastructure has transformed this proposition, giving rise to *digital financial inclusion*, where services such as mobile banking, online credit scoring, and digital wallets are used to reach unbanked populations. The concept has evolved to include not only access but also the *quality*, *affordability*, *and usage* of financial services (Zhang et al., 2023). As such, the new frontier of financial inclusion hinges on leveraging technology to design accessible and secure financial ecosystems that empower marginalised communities.

Complementing this, the Exclusion Theory focuses on systemic and structural barriers that prevent equitable access to financial services. These include lack of physical infrastructure, rigid regulatory frameworks, low financial literacy, and digital divides, which are particularly acute in rural and underserved regions (Ren et al., 2024). In the context of digital finance,

these barriers are both mitigated and intensified – while fintech platforms reduce dependency on physical branches, the digital divide in skills and infrastructure can reinforce exclusion. Therefore, scholars argue that digital inclusion is not only a matter of technological availability but also of socioeconomic context, user capability, and policy environment (X. Li et al., 2024). The transition from access to effective usage necessitates policies that address affordability, literacy, and trust in digital financial platforms.

Another crucial conceptual lens is the Financial Capability Framework, which integrates financial literacy and behavioral economics to explain the usage of financial services. This framework emphasizes that providing access alone is insufficient; users must also possess the capability to make informed decisions and manage financial risks. In the digital context, this translates into the need for user-friendly platforms, intuitive financial tools, and widespread education on cybersecurity and digital literacy (Abbas et al., 2022). Especially for small enterprises, the ability to navigate digital banking systems, interpret financial dashboards, or apply for algorithm-driven credit products determines the success of financial inclusion efforts. Therefore, scholars advocate a demand-side approach to inclusion – focusing not just on the supply of digital finance but also on users' ability to benefit from it (Liu & Yu, 2025).

In sum, the financial inclusion literature has broadened from microcredit and rural banking to more comprehensive digital strategies. However, while access metrics and adoption statistics are well-documented, fewer studies investigate how these tools directly influence innovation, performance, or growth at the enterprise level. Moreover, the intersection of digital finance with technological innovation remains under-theorised, prompting the need for integrated analytical frameworks that explore these linkages within organisational settings.

2.2. Technological innovation and diffusion theories

Technological innovation has long been conceptualised as a key driver of economic development. Schumpeter's innovation theory proposes that "creative destruction" through innovation leads to productivity gains, firm competitiveness, and macroeconomic transformation (Pandey et al., 2024). This perspective is central to understanding how firms adopt and integrate technological tools to gain market advantage. In recent years, this theory has been extended to digital environments, where artificial intelligence, big data, and platform economies allow firms to restructure value chains, reduce costs, and accelerate product development. However, empirical studies still struggle to capture the full effect of digital transformation, especially when innovation metrics are not always directly observable.

The technology diffusion theory complements this by explaining how new technologies spread across sectors, firms, and geographies. Y. Feng et al. (2023) identifies five adoption categories – innovators, early adopters, early majority, late majority, and laggards – which reflect different capabilities and motivations among firms. In the context of digital finance, diffusion is affected by external factors such as regulatory incentives, technological infrastructure, and competitive pressures, as well as internal capabilities like digital readiness and leadership orientation (Nikkel, 2020). In emerging economies, these diffusion patterns are heterogeneous – some firms leapfrog into advanced fintech solutions while others lag due to financial or cognitive constraints.

Open innovation theory offers another perspective by highlighting the importance of collaborative networks in driving technological progress. This theory argues that innovation can come from both internal R&D and external partnerships, including those with universities, tech firms, or fintech platform. In digital finance, such collaborations are crucial for co-creating platforms, sharing data for credit risk modelling, or integrating APIs for seamless service delivery. Particularly for SMEs with limited internal resources, open innovation strategies enable access to cutting-edge tools without heavy capital investment. Nevertheless, the literature points to the need for trust, interoperability, and mutual value-sharing for these collaborations to be sustainable.

Taken together, these theories provide a robust foundation for examining the drivers and mechanisms of digital transformation. However, they often focus more on technology than finance, and few studies investigate how innovation diffusion interacts with digital financial tools to enhance organisational creativity. This study addresses this gap by linking innovation theories to financial inclusion, particularly examining how access to digital finance supports the development and scaling of innovative capabilities across enterprise stages.

2.3. Organisational theories and enterprise growth

The Resource-Based View (RBV) of the firm posits that internal resources – both tangible and intangible – are critical determinants of competitive advantage. From this lens, digital finance and technological tools can be viewed as strategic assets that enhance a firm's innovation potential, operational efficiency, and market responsiveness (Lee & Wang, 2022). Access to credit via digital platforms, data-driven decision tools, and cloud-based infrastructure are all resources that support enterprise development. However, firms must have complementary capabilities – such as digital literacy, absorptive capacity, and strategic foresight – to fully leverage these tools. The RBV thus encourages an assessment of how firms vary in their ability to transform digital access into meaningful business outcomes (X. Chen et al., 2024).

Organisational Life Cycle Theory further enriches this perspective by suggesting that enterprises face distinct opportunities and challenges at different stages – startup, growth, maturity, and potential decline (Y. Chen et al., 2021). Innovation requirements and financing needs evolve accordingly: while startups may focus on idea validation and initial capital, mature firms may prioritise process optimisation and digital transformation. This dynamic nature of innovation is seldom captured in static models of digital finance. Therefore, applying life cycle thinking to the analysis of digital finance impact allows for a more nuanced understanding of firm-level behaviour and outcomes.

Meanwhile, Institutional Theory focuses on how external structures – such as regulatory frameworks, market norms, and socio-political conditions – shape organisational practices. In the realm of digital finance, the role of regulators and financial authorities is especially pronounced. Their policies influence not only market entry for fintech providers but also determine the security, interoperability, and user protection mechanisms that affect trust and adoption. The degree of institutional support can significantly affect how firms internalise and act upon digital finance opportunities. In some contexts, overly rigid regulation may stifle innovation, whereas in others, flexible sandbox environments have enabled rapid experimentation and adoption.

These organisational theories collectively offer a framework to understand how internal capabilities and external conditions jointly influence the success of digital finance and technological integration. However, most literature addresses these frameworks in isolation, with limited empirical work tying them together through comprehensive, multi-level analyses. This study fills this gap by integrating RBV, life cycle, and institutional perspectives to explore how digital finance and innovation jointly influence enterprise performance across diverse organisational and regulatory contexts (J. Li et al., 2020).

3. Methodology

3.1. Theoretical framework

This study adopts a quantitative research approach grounded in econometric analysis to explore the impact of digital finance on enterprise innovation and performance across different stages of business development in China from 2011 to 2022. The core objective is to investigate how Digital Finance Accessibility (DFA) influences Organizational Creativity (IE), while also examining the mediating role of Corporate Digitization (DT) and the moderating effects of ownership structure and enterprise life cycle stages. The methodological design integrates multiple theoretical frameworks – including the Resource-Based View, Innovation Diffusion Theory, and Financial Inclusion Theory – to guide variable selection, model specification, and empirical interpretation.

The analysis is based on a panel dataset comprising firm-level observations merged with prefecture-level indices of digital finance. Digital finance is measured through the Digital Finance Accessibility Index (DFA), developed by aggregating multiple indicators such as digital payment usage, online lending penetration, and mobile banking services, following the methodological precedent of (Skare et al., 2023). The dependent variable, Organizational Creativity (IE), is operationalised as the natural logarithm of the number of patents filed plus one, a common proxy for innovation output in firm-level studies (Hunjra et al., 2023). In addition, Research and Development (R&D) investment as a ratio of total operating income is used as a robustness variable to validate innovation intensity across firms.

The study employs logistic regression models to estimate the baseline relationship between DFA and IE, controlling for firm characteristics such as age, ownership type, board independence, revenue growth, leadership structure, and market competition (measured by the Herfindahl-Hirschman Index), as outlined by (Ding et al., 2023). To mitigate potential endogeneity issues – arising from reverse causality or omitted variable bias – the analysis includes a lagged independent variable model and applies the Two-Stage Least Squares (2SLS) and Generalized Method of Moments (GMM) techniques. These methods ensure the robustness of the estimated coefficients and the reliability of causal interpretations.

To further refine the explanatory mechanisms, the study integrates a mediation analysis framework based on (Rowan, 2023) classical approach, estimating the indirect effect of DFA on IE through DT. DT is measured using text mining techniques on firms' annual reports, calculating the frequency of digital transformation-related keywords (e.g., AI, cloud computing,

blockchain) and applying a natural logarithm transformation to standardise the metric (R. Xu et al., 2023). The Sobel and Bootstrap tests are used to confirm the significance of the mediating effect. This allows for a more granular understanding of how digital finance enhances innovation through enabling digital capability development within firms.

In addressing structural heterogeneity, the dataset is disaggregated into State-Owned Enterprises (SOEs) and Non-State-Owned Enterprises (NSOEs) to evaluate whether the impact of digital finance varies by ownership type. Subgroup regressions reveal critical differences in the sensitivity and response of these enterprise categories to digital finance, thereby reflecting institutional dynamics and policy-induced asymmetries in digital adoption (Aziz & Naima, 2021). Additional robustness checks include alternate specifications of the dependent variable, incorporation of interaction terms, and fixed effects by year, region, and industry to control for unobserved heterogeneity.

Overall, this rigorous methodological framework allows the study to uncover nuanced insights into the relationship between digital finance and enterprise innovation, ensuring validity through triangulation of models, inclusion of contextual controls, and systematic robustness testing. The empirical strategy not only strengthens the reliability of causal claims but also contributes a replicable analytical structure for future research in the intersection of fintech, organizational performance, and inclusive innovation.

3.2. Basic logistic modeling

To investigate the relationship between digital finance and enterprise-level innovation, we constructed a basic econometric framework employing logistic regression analysis. The core objective of this model is to evaluate the extent to which digital financial development – represented by the Digital Finance Accessibility Index (DF) – impacts the efficiency of organizational innovation, denoted as IE_{it}. The model is specified as follows:

$$IE_{it} = \alpha_0 + \alpha_1 DF_{it} + \sum_{j=2}^{6} \alpha_j X_{it} + \varepsilon_{it}, \quad (1)$$

where IE_{it} measures the innovation efficiency of firm i at time t, operationalised through the logarithmic transformation of patent counts as a proxy for innovative output. The key explanatory variable DF_{it} captures the level of digital financial development, reflecting factors such as digital payment infrastructure, online lending accessibility, and the overall usage of digital finance services at the regional level. The vector X_{it} represents a set of control variables, including firm age, ownership structure, revenue growth, managerial orientation, board independence, and market competition (proxied by the Herfindahl-Hirschman Index). The constant term α_0 denotes the intercept, while ε_{it} is the error term capturing unobserved influences. Empirical estimation results indicate a statistically significant relationship at the 5% level, suggesting that improvements in digital finance accessibility are associated with increases in innovation efficiency, holding other factors constant.

To further explore the underlying mechanism through which digital finance affects innovation, a mediation framework is introduced to examine whether corporate digital transformation

(DT) serves as a transmission channel. Building on the baseline model, the following equations are specified:

$$DT_{it} = \beta_0 + \beta_1 DF_{it} + \sum_{j=2}^{6} \beta_j X_{it} + \varepsilon_{it}; \tag{2}$$

$$IE_{it} = \gamma_0 + \gamma_1 DT_{it} + \gamma_2 DF_{it} + \sum_{j=2}^{6} \gamma_j X_{it} + \varepsilon_{it}. \tag{3}$$

In the first equation, DT_{it} represents the level of digital transformation within firm i at time t, measured using the logarithmic frequency of digital technology-related terms (such as artificial intelligence, big data, and blockchain) in corporate disclosures, capturing firms' technological orientation and digital readiness. The coefficient β_1 reflects the impact of digital finance on digital transformation. In the second equation, innovation efficiency IE_{it} is regressed on both digital transformation and digital finance. The coefficient γ_1 captures the effect of digital transformation on innovation, while γ_2 measures the direct effect of digital finance after accounting for the mediating role of digital transformation. The inclusion of both equations allows for the identification of indirect (mediated) and direct effects.

At the regional level, the Digital Finance Accessibility Index (DFA) is constructed using standardised scores of three components – Coverage Breadth (CB), Usage Depth (UD), and Digitisation Level (DL) – as follows:

$$DFA_i = \frac{CB_i - \mu_{CB}}{\sigma_{CB}} + \frac{UD_i - \mu_{UD}}{\sigma_{UD}} + \frac{DL_i - \mu_{DL}}{\sigma_{DL}}, \tag{4}$$

where CB_i, UD_i, and DL_i represent the raw values of each component for region i, and μ and σ denote the corresponding sample mean and standard deviation. This standardisation ensures comparability across regions by normalising each indicator.

At the firm level, the Digital Finance Integration Level (DFIL) is measured as:

$$DFIL_i = \ln\left(1 + \frac{\sum_{k=1}^{K} Freq^{(k,i)}}{Total\ Words_i}\right), \tag{5}$$

where $Freq^{(k,i)}$ denotes the frequency of digital-related keyword k (e.g., "blockchain", "cloud computing", "big data") in firm i's annual report, K is the total number of keywords considered, and $Total\ Words_i$ is the total word count of the document. The logarithmic transformation helps normalise the distribution and reduce skewness.

Additionally, the Digital Finance Adoption Rate (DFAR) is defined as:

$$DFAR_i = \frac{Digital\ Transactions_i}{Total\ Financial\ Transactions_i}, \tag{6}$$

where $Digital\ Transactions_i$ refers to the number of financial transactions conducted through digital channels by firm i, and $Total\ Financial\ Transactions_i$ is the total number of financial transactions. This variable captures the intensity of digital finance usage within the firm.

Together, these models provide a comprehensive framework for analysing both the direct and indirect effects of digital finance on enterprise innovation, highlighting the important mediating role of digital transformation while controlling for firm-specific and regional characteristics.

3.3. Variables description

This study employs a comprehensive set of variables to empirically investigate the relationship between digital finance, technological innovation, and enterprise performance. The dependent variable, *Innovation Efficiency* (IE), serves as a proxy for organisational creativity and is measured using the natural logarithm of one plus the number of patents granted to each firm in a given year. This transformation helps normalise the data and account for firms with zero or low patent counts, a common approach in innovation studies (S. Chen & Zhang, 2021). In robustness checks, innovation efficiency is alternatively measured using the ratio of R&D investment to total operating revenue, providing a financial perspective on creative output.

The primary explanatory variable is the *Digital Finance Accessibility Index* (DFA), which captures the extent and depth of digital financial services available within each firm's regional context. This index is derived from prefecture-level data and includes subcomponents such as the breadth of digital financial service usage, depth of internet finance application, and degree of digital inclusion, following the framework of (Y. Sun & Tang, 2022). To reduce volatility and ensure data stability, the index undergoes exponential transformation. This variable reflects the institutional and infrastructural readiness of the digital financial environment in which a firm operates.

To explore the mediating mechanism**,** the study introduces *Corporate Digitization* (DT) as a mediating variable. This construct measures the internal digital maturity of firms by analysing the frequency of digital technology-related terms – such as "blockchain," "machine learning," "cloud computing," and "big data" – within annual and interim financial statements. The frequency is averaged and then log-transformed to capture both the intensity and relative presence of digital orientation across firms (Ji et al., 2022). Digitization is thus conceptualised as a strategic response to digital financial accessibility and a pathway through which innovation is enhanced.

A robust set of control variables is also incorporated to account for firm-specific heterogeneity. These include *firm age*, measured by the number of years since establishment; *ownership structure*, distinguishing between state-owned and non-state-owned enterprises; *board independence*, indicated by the ratio of independent directors; *revenue growth*; *merger activity*; *Leadership Digital Orientation* (LDO); and *market competition*, proxied by the Herfindahl-Hirschman Index (HHI). These variables help isolate the effects of digital finance and digitization on innovation while accounting for confounding influences. Additional variables such as *Enterprise Lifecycle Stage* (ELS), *Revenue Diversification* (RevDiv), *Enterprise Digital Growth* (EDG), and *Strategic Digital Alliances* (SDA) are included to provide further depth, particularly in robustness testing.

3.4. Data sources

The primary objective of this study is to examine how digital finance influences organizational innovation across different stages of the enterprise life cycle, with a particular focus on the mediating role of corporate digitization and the moderating effect of ownership structure. Specifically, the study aims to (1) assess the direct impact of digital finance accessibility on firm-level innovation efficiency, (2) explore whether internal digital transformation mediates this relationship, and (3) investigate how the effects differ between state-owned and non-state-owned enterprises. To support this analysis, a range of variables were constructed and sourced from credible datasets, as outlined in Table 1. The dependent variable, Innovation Efficiency (IE), is measured by the logarithm of patent counts, while the main explanatory variable,

Table 1. Variables description

Variable	Symbol	Description	Data Source
Innovation efficiency	IE	Logarithm of (1 + number of patents granted per firm per year); proxy for organisational creativity	CNRDS, State Intellectual Property Office
Digital Finance Accessibility Index	DFA	Composite index measuring access to digital financial services, including coverage, usage, and depth of fintech platforms at the prefecture level	Peking University Digital Finance Research Centre
Corporate digitization	DT	Logarithm of the average frequency of digital keywords (e.g., AI, blockchain, cloud computing) in annual/interim reports; reflects internal digital maturity	CSMAR, Text Mining of Annual Reports
Firm age	Age	Number of years since firm establishment	CSMAR
Ownership type	SOE/ NSOE	Dummy variable; 1 = State-Owned Enterprise, 0 = Non-State-Owned Enterprise	CSMAR
Board independence	BoardInd	Proportion of independent directors on the board	CSMAR
Revenue Growth	RevGrow	Annual revenue growth rate	CSMAR
Merger activity	Merger	Dummy variable indicating whether the firm was involved in a merger/acquisition during the year	CSMAR
Leadership Digital Orientation	LDO	Log-transformed frequency of digital terminology used by executives in official disclosures	Textual analysis of annual statements
Market Competition	HHI	Herfindahl-Hirschman Index; measures industry concentration at the 4-digit level	National Bureau of Statistics (NBS), CSMAR
Enterprise Lifecycle Stage	ELS	Composite index indicating stage of development (startup, growth, maturity) based on firm age, size, and revenue trends	Calculated from CSMAR financial data
Revenue Diversification	RevDiv	Revenue share across multiple product or regional lines; a higher value indicates more diversified income sources	CSMAR
Enterprise Digital Growth	EDG	Annual change in digital orientation metrics; indicates progress in digital transformation	CSMAR, Textual analysis
Strategic Digital Alliances	SDA	Number of partnerships or alliances formed with tech firms, digital platforms, or fintech providers	Company disclosures, CNRDS

Digital Finance Accessibility (DFA), captures regional-level fintech development. Corporate digitization (DT) is included as a mediating variable, based on keyword frequency analysis in firm disclosures. Control variables such as firm age, board independence, revenue growth, Market Competition (HHI), and Leadership Digital Orientation (LDO) are also integrated to account for firm heterogeneity. Table 1 summarises each variable, its symbol, description, and corresponding data source, providing a structured foundation for the empirical modeling and analysis that follow (Liu et al., 2022).

4. Results and discussion

Table 2 presents the summary statistics for the key variables used in the empirical analysis, based on 10,180 firm-year observations. The dependent variable, Technological Innovation Efficiency, has a mean of –0.408 and a standard deviation of 0.772, indicating moderate variation and some firms with significantly lower innovation outputs. The Digital Finance Accessibility Index (DFA), along with related variables such as DFAR and DFIL, shows mean values close to zero, suggesting balanced distribution around the average, but with substantial variation across regions, as seen in the wide min-max ranges (Xia et al., 2022). Digital Transformation Maturity (DTM) and Enterprise Lifecycle Stage (ELS) also display near-zero means, indicating symmetric distributions around the average level of digital development and business maturity. Innovation Investment (InnovInvest), Revenue Diversification (RevDiv), and Enterprise Digital Growth (EDG) show slightly negative means (Feng et al., 2022b), possibly reflecting cautious innovation behaviour or stagnation in growth among some firms. Leadership Digital Orientation (LDO) and Strategic Digital Alliances (SDA) exhibit wider dispersions, suggesting heterogeneous strategic orientations toward digitalisation. The Digital Market Competition Index (DMCI) has a negative mean and relatively high standard deviation, highlighting varying competitive pressures in digital markets. Overall, the data reflects considerable heterogeneity across firms, supporting the need for differentiated analysis based on ownership type, life cycle stage, and digital readiness (Qi, 2021).

Table 2. Summary of variables from statistics

Variable name	Obs	Mean	SD	Min	Max
Technological Innovation Efficiency	10180	–0.408	0.772	–4.795	0.835
Digital Finance Accessibility Index (DFA)	10180	0.003	0.98	–1.77	2.162
Digital Finance Adoption Rate (DFAR)	10180	0.004	0.987	–2.527	1.953
Digital Finance Integration Level (DFIL)	10180	0.001	0.973	–2.158	2.207
Digital Transformation Maturity (DTM)	10180	–0.002	1.002	–1.352	0.74
Enterprise Lifecycle Stage (ELS)	10180	–0.006	1.001	–2.758	1.744
Innovation Investment (InnovInvest)	10180	–0.005	0.981	–1.67	2.688
Leadership Digital Orientation (LDO)	10180	0.002	0.975	–1.735	3.358
Revenue Diversification (RevDiv)	10180	–0.048	0.174	–0.123	1.083
Enterprise Digital Growth (EDG)	10180	–0.019	0.05	–0.089	0.263
Strategic Digital Alliances (SDA)	10180	0.001	1.003	–0.641	1.559
Digital Market Competition Index (DMCI)	10180	–0.013	0.926	–0.786	4.323

Table 3 presents the baseline regression results examining the impact of digital finance accessibility on innovation efficiency across four model specifications. The Digital Finance Accessibility Index (DFA) shows a consistently positive and highly significant relationship with innovation efficiency across all models, with coefficients ranging from 0.038 to 0.081, indicating that increased access to digital financial services enhances firms' innovative capacity. This finding aligns with previous studies highlighting the enabling role of fintech in promoting innovation by improving access to credit and reducing financing constraints (Chen et al., 2024; Cao et al., 2021). The Enterprise Lifecycle Stage (ELS) variable also shows a robust and positive effect, suggesting that firms in more advanced developmental phases tend to achieve higher innovation output, consistent with the life-cycle theory of firm innovation (Q. Xu et al., 2024).

Table 3. Baseline regression result

	–1	–2	–3	–4
Digital Finance Accessibility Index (DFA)	0.081*** –0.006	0.074*** –0.007	0.038*** –0.012	0.040*** –0.012
Enterprise Lifecycle Stage (ELS)	0.177*** –0.007	0.138*** –0.009	0.156*** –0.009	0.157*** –0.009
Innovation Investment (InnovInvest)	–0.006 –0.007	0.002 –0.007	0.007 –0.007	0.012 –0.007
Revenue Diversification (RevDiv)	1.006*** –0.044	1.015*** –0.044	0.981*** –0.044	0.867*** –0.048
Enterprise Digital Growth (EDG)	0.321** –0.147	0.255* –0.147	0.326** –0.147	0.139 –0.157
Leadership Digital Orientation (LDO)	–0.002 –0.006	–0.003 –0.006	–0.007 –0.006	–0.011 –0.006
Strategic Digital Alliances (SDA)	–0.022*** –0.006	–0.026*** –0.006	–0.032*** –0.006	–0.033*** –0.006
Digital Market Competition Index (DMCI)	–0.037*** –0.007	–0.030*** –0.007	–0.033*** –0.007	–0.042** –0.018
Constant	–0.357*** –0.007	–0.537*** –0.026	–0.505*** –0.037	–0.507*** –0.102
Year	NO	YES	YES	YES
Province	NO	NO	YES	YES
Industry	NO	NO	NO	YES
N	10180	10180	10180	10180
Adjusted R^2	0.143	0.149	0.176	0.215

Note: Standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Revenue Diversification (RevDiv) shows the strongest positive effect among all predictors, confirming that firms with diversified income streams are better positioned to invest in innovative activities. Conversely, variables such as Strategic Digital Alliances (SDA) and the Digital Market Competition Index (DMCI) exhibit significant negative coefficients, suggesting that while external collaboration is vital, excessive reliance on partnerships or intensified digital market competition may dilute internal innovation capacity. These findings contrast with some earlier work (Y. Wu & Huang, 2022), which found strategic alliances to be positive drivers

of innovation, indicating possible contextual differences in how digital ecosystems function across industries or regions. Overall, the increasing adjusted R^2 across models (from 0.143 to 0.215) demonstrates improved explanatory power with the inclusion of year, province, and industry fixed effects, reinforcing the relevance of structural heterogeneity in understanding innovation outcomes in the digital finance landscape.

Table 4 presents the robustness check results assessing the consistency of the relationship between digital finance and innovation efficiency using alternative specifications and additional digital finance indicators. The results confirm that the Digital Finance Accessibility Index (DFA) maintains a statistically significant and positive impact on innovation outcomes across all models. In column (1), where innovation efficiency is proxied by innovation investment (IE_inv), a 1% increase in DFA leads to a 0.017% rise in IE, significant at the 5% level. This effect strengthens in column (2) under the original innovation efficiency measure, with DFA increasing to 0.037% at the 1% significance level. Additionally, the Digital Finance Adoption Rate (DFAR) and Digital Finance Integration Level (DFIL) also show positive and significant effects (0.056 and 0.040 respectively), reinforcing the argument that broader usage and deeper integration of digital financial services enhance innovation performance (B. Wu & Yang, 2022).

These findings are consistent with the conclusions of (Chang et al., 2022) and (Chu et al., 2023), who highlight the enabling role of digital finance in promoting enterprise innovation by easing credit access and facilitating capital allocation. However, in contrast to earlier studies such as (Liu et al., 2023), which emphasised the central role of internal firm capabilities, this study underscores the external digital finance environment as a critical driver of innovation outcomes. The consistently high adjusted R^2 values (ranging from 0.204 to 0.219) across models suggest the robustness and explanatory strength of the empirical framework applied in this study.

Table 4. Robustness checks

–1	–2 IE_inv	–3 IE	–4 IE	 IE
Digital Finance Accessibility Index (DFA)	0.017** –0.009			0.037*** –0.013
Digital Finance Adoption Rate (DFAR)		0.056*** –0.012		
Digital Finance Integration Level (DFIL) Empty Cell			0.040*** –0.013	
Constant	–0.314*** –0.103	–0.522*** –0.103	–0.512*** –0.103	–0.527*** –0.103
Regulate Variables	YES	YES	YES	YES
Year	YES	YES	YES	YES
Province	YES	YES	YES	YES
Industry	YES	YES	YES	YES
N	10,175	10,175	10,175	10,175
adj. R2	0.204	0.215	0.214	0.219

Note: Standard errors are reported in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.

Table 5 reports the results of endogeneity correction using Instrumental Variable (IV) estimation, specifically employing a Two-Stage Least Squares (2SLS) approach to assess the impact of digital finance accessibility on innovation efficiency. In Phase 1, the Digital Finance Accessibility Index (DFA) is regressed on the instrumental variable, which demonstrates a strong and statistically significant relationship, with a coefficient of 0.998 at the 1% level and a very high Shea's adjusted partial R^2 of 0.995. The robust F-statistic of 110,000 further confirms the strength of the instrument, well above the conventional threshold, indicating no weak instrument problem. In Phase 2, the predicted values of DFA from the first stage are used to explain Innovation Efficiency (IE). The results show a consistent and significant positive impact of DFA on IE across both specifications in columns (2) and (3), with coefficients of 0.075, significant at the 1% level. This implies that the original positive association between digital finance and innovation is not driven by endogeneity or omitted variable bias. The adjusted R^2 of 0.143 in both models suggests a modest but stable explanatory power. These findings reinforce the robustness of the earlier baseline and robustness results, confirming that increased accessibility to digital financial services has a causal and meaningful effect on enterprise innovation performance.

The results presented in Table 5, confirming a significant and causal relationship between digital finance accessibility and innovation efficiency, are broadly consistent with and extend findings from earlier studies. For instance, Ning and Zhang (2023) highlight how digital finance reduces financing constraints and fosters innovation by enhancing capital allocation and risk management capabilities, particularly for small and medium enterprises. Similarly, Lee et al. (2022) argue that regions with greater digital financial development experience stronger innovation spillovers due to better access to online credit, digital payments, and data-driven financial services. The present study corroborates these observations but goes a step further by addressing potential endogeneity issues, thus offering more robust causal evidence through

Table 5. Outcomes of estimating the measurement factor

–1	–2 Phase 1 DF	–3 Phase 2 IE	 IE
Digital Finance Accessibility Index (DFA)		0.075*** –0.007	0.075*** –0.007
Digital Finance Accessibility Index (DFA)	0.998*** –0.001		
Constant	0/002 –0.001	–0.350*** –0.007	–0.350*** –0.007
Control Variables	YES	YES	YES
Shea's adj. partial R2	0.995		
Robust F	110,000 [0.000]		
Minimum eigenvalue statistic	1,695,670		
N	10,175	10,175	10,175
adj. R2	0.995	0.143	0.143

Note: Standard errors are reported in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.

instrumental variable estimation. In contrast to studies that emphasise internal capabilities as the dominant innovation drivers – such as those by Jiang et al. (2022) – this study underscores the critical role of external digital financial infrastructure, particularly in the context of institutional and technological heterogeneity in China. Moreover, while previous literature has often focused on either macroeconomic effects or firm-level technology adoption in isolation, this research integrates both dimensions, showing that access to digital finance not only complements internal innovation strategies but also amplifies their effectiveness across varied ownership structures and life cycle stages.

Table 6 presents the heterogeneity analysis based on ownership structure, comparing the impact of digital finance accessibility on innovation efficiency between State-Owned Enterprises (SOEs) and Non-State-Owned Enterprises (NSOEs). The results indicate that the Digital Finance Accessibility Index (DFA) has a significantly stronger positive effect on innovation in SOEs, with a coefficient of 0.083, significant at the 1% level, compared to 0.021 for NSOEs, which is only marginally significant at the 10% level. The higher adjusted R^2 value for SOEs (0.256) relative to NSOEs (0.229) further suggests that digital finance plays a more prominent role in explaining innovation efficiency within publicly owned firms. This disparity may reflect structural advantages available to SOEs, such as greater institutional trust, access to government-supported platforms, and preferential treatment in the adoption of fintech solutions.

These findings align with Ding et al. (2023), who argue that SOEs benefit more from financial and technological reforms due to their embeddedness within policy-driven ecosystems. Similarly, studies by Yu et al. (2020) highlight that the responsiveness of SOEs to digital finance is often amplified by their regulatory compliance and strategic alignment with state-led innovation agendas. In contrast, the weaker impact observed in NSOEs may be attributed to resource constraints, risk aversion, or lack of digital readiness, which hinder their ability to capitalise on external financial innovations – findings that contrast with the resource-based view presented by Wang et al. (2023), which would suggest that privately owned firms should

Table 6. The analysis of various forms of possession

–1	–2 State-owned enterprises IE	 Non-state-owned enterprises IE
Digital Finance Accessibility Index (DFA)	0.083*** –0.026	0.021* –0.015
Constant	–0.527*** –0.201	–0.511*** –0.118
Control variables	YES	YES
Year	YES	YES
Province	YES	YES
Industry	YES	YES
N	2922	6889
adj. R2	0.256	0.229

Note: Standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

respond more efficiently to competitive innovations. This divergence underscores the importance of ownership-specific strategies when designing policies aimed at enhancing digital financial inclusion and innovation across heterogeneous enterprise types.

Table 7 presents the results of the mediating effect analysis, examining whether digital transformation maturity (DTM) serves as a transmission mechanism through which digital finance accessibility (DFA) enhances Innovation Efficiency (IE). In Model 1, DFA has a significant and positive impact on IE (coefficient = 0.039, $p < 0.01$). Model 2 shows that DFA also positively affects DTM (coefficient = 0.122, $p < 0.01$), suggesting that greater access to digital financial services promotes internal digital transformation. In Model 3, when both DFA and DTM are included as predictors of IE, the coefficient of DFA remains significant (0.071), and DTM itself also has a strong positive impact on IE (0.069, $p < 0.01$). These results confirm a partial mediation effect, which is statistically supported by the Sobel and Bootstrap tests (both $p = 0.000$), indicating that digital transformation is a significant pathway through which digital finance boosts innovation outcomes.

These findings reinforce the theoretical proposition of Ritter and Pedersen (2020), who emphasise the critical role of digital readiness in translating external technological advancements into internal innovation benefits. The results also align with Yang et al. (2022), who demonstrate that firms investing in digital transformation exhibit superior innovation performance. In contrast to earlier research that often treats digital finance and innovation as separate dimensions (e.g., Y. Feng et al., 2023), this study integrates them by empirically validating the digital transformation mechanism. Moreover, the relatively high adjusted R^2 values, especially in Models 1 and 3 (0.214 and 0.147 respectively), provide robust empirical support for the integrated model. Overall, this mediation analysis offers novel insights into the dynamic interplay between external digital finance accessibility and internal innovation capacity, contributing to a more holistic understanding of innovation ecosystems in digitally evolving economies.

Table 7. The results of the intervening effect's regression study

–1	–2 IE	–3 DT	 IE
Digital Finance Accessibility Index (DFA)	0.039*** –0.013	0.122*** –0.008	0.071*** –0.008
Digital Transformation Maturity (DTM)			0.069*** –0.009
Constant	–0.509*** –0.103	0.035*** –0.009	–0.361*** –0.103
Control variables	YES	YES	YES
N	10,175	10,175	10,175
adj. R2	0.214	0.073	0.147
Sobel Test		0.0084*** (p = 0.000 Z = 6.812)	
Bootstrap Test		0.0084*** (p = 0.000 Z = 10.23)	

Note: Standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.1. Discussion

The results of this study provide strong empirical evidence that digital finance plays a pivotal role in enhancing enterprise-level innovation efficiency. The significant positive coefficients of the Digital Finance Accessibility Index (DFA) across all model specifications underscore the transformative influence of digital financial infrastructure on firms' creative capabilities. These findings support the view that digital finance reduces traditional barriers to credit, accelerates access to capital, and encourages risk-taking, all of which are essential to fostering innovation. Consistent with studies by (Guo et al., 2023), the present analysis confirms that regions and firms with higher exposure to digital financial services exhibit improved innovation outcomes. However, this study contributes additional nuance by contextualising this effect within a firm's life cycle, revealing that innovation gains from digital finance are more pronounced in more mature enterprises, suggesting that the absorptive capacity and institutional readiness of firms play an important role in maximising the benefits of digital financial tools (H. Zhao et al., 2023).

A key advancement in this study is the empirical validation of a mediation mechanism through corporate digitisation. The Digital Transformation Maturity (DTM) variable is shown to significantly mediate the relationship between digital finance and innovation efficiency, indicating that digital financial tools alone are not sufficient to generate innovation gains unless firms concurrently develop internal digital competencies. This finding aligns with theoretical propositions in the innovation diffusion literature, particularly those of (Feng et al., 2022b), who emphasise the importance of digital infrastructure and absorptive capacity in leveraging external technological shocks. Furthermore, the positive coefficients and statistical significance of both the Sobel and Bootstrap mediation tests strengthen the causal narrative that financial technology catalyses innovation not just through liquidity or access but through organisational restructuring around digital processes. This bridges a major gap in the literature, as few studies have explicitly tested how financial tools reshape innovation pathways through internal firm transformation.

The ownership-based heterogeneity analysis further enriches the discussion. The data indicate that State-Owned Enterprises (SOEs) respond more robustly to digital finance in terms of innovation efficiency than Non-State-Owned Enterprises (NSOEs). While this may appear to contradict classical resource-based views – which posit that private firms are more efficient and innovative due to competitive pressure and flexible governance structures (Ji et al., 2022) – it reflects the specific institutional context of China. SOEs often benefit from privileged access to state-backed digital infrastructure, government-aligned fintech initiatives, and policy mandates that incentivise technological upgrading. Studies such as those by (Ma et al., 2024) similarly document that SOEs in China are increasingly being positioned as vehicles for state-led innovation and digital transformation, thus explaining their stronger innovation outcomes under digital finance expansion. By contrast, NSOEs may encounter financing frictions, lack the resources for comprehensive digital transformation, and operate in more volatile environments, which limits their capacity to fully leverage digital financial services.

The study also highlights the multidimensional nature of innovation performance, which depends not only on financial access but also on organisational capabilities, leadership orientation, competitive environment, and industry-specific dynamics. For instance, the negative

association between Strategic Digital Alliances (SDA) and innovation efficiency challenges some existing findings in open innovation literature, such as those by Chesbrough (2003), which advocate for collaborative innovation. This divergence could stem from over-reliance on external alliances at the expense of internal capability building, especially in resource-constrained firms. Similarly, the Digital Market Competition Index (DMCI) exhibits a negative relationship with innovation, suggesting that intense digital competition may deter firms from investing in long-term innovation due to heightened short-term market pressures. These insights contribute to a more grounded understanding of how firms navigate innovation decisions under evolving digital and financial environments.

The robustness checks and endogeneity controls used in this study further bolster the reliability of the findings. By employing multiple estimation strategies – including alternative dependent variables, fixed effects models, Instrumental Variable (IV) techniques, and mediation tests – the study ensures that the results are not artefacts of specific model assumptions. The 2SLS estimation confirms that the relationship between DFA and innovation is not driven by reverse causality or omitted variables. In contrast to earlier studies that relied solely on cross-sectional data or limited indicators of digital finance, this research uses a longitudinal panel from 2011 to 2022 and employs multidimensional measures (DFA, DFAR, DFIL) to reflect the full breadth and depth of digital finance. This comprehensive design strengthens the external validity of the findings and positions this study as a key reference in empirical research on digital innovation ecosystems (Soltani, 2024).

From a theoretical standpoint, this study extends and integrates multiple frameworks – namely, the financial capability approach, innovation diffusion theory, resource-based view, and institutional theory. By empirically linking these strands, it presents a unified model that captures both the supply-side (financial infrastructure) and demand-side (digital readiness) conditions necessary for innovation. The positive role of digital finance in levelling the innovation playing field, particularly for state-owned enterprises and firms in less developed regions, reaffirms the microfinance and inclusion-based perspectives discussed by G. Li et al. (2022). However, it also cautions against simplistic assumptions that digital finance alone can drive innovation, underscoring the need for complementary investments in digital literacy, internal capability building, and policy support tailored to firm-specific contexts.

In conclusion, this study contributes to a growing body of literature on the digital economy by providing rigorous empirical evidence on how digital financial accessibility and internal digital transformation jointly affect innovation outcomes. It demonstrates that digital finance is not just a financial tool but a strategic lever for organisational innovation, especially when integrated with broader digitalisation efforts. The findings carry significant implications for policymakers, suggesting that efforts to expand digital financial infrastructure must be accompanied by programmes that build firms' digital competencies, particularly among non-state and small-scale enterprises. Future research may extend this work by examining cross-country comparisons, sector-specific dynamics, or the role of other mediators such as organisational agility, data infrastructure, or ESG-oriented innovation strategies. Such inquiries would further illuminate the pathways through which digital finance contributes to inclusive and sustainable technological development in the digital age.

5. Conclusions

This study investigates the impact of digital finance on enterprise innovation efficiency in China over the period 2011 to 2022, using a robust panel dataset and a range of econometric models, including logistic regression, instrumental variable estimation, and mediation analysis. The empirical analysis confirms that improved access to digital financial services – measured through the Digital Finance Accessibility Index (DFA) – has a statistically significant and positive effect on firms' innovation performance. By employing firm-level data across multiple provinces and industries, the study reveals that the benefits of digital finance are not uniform but vary depending on enterprise characteristics such as ownership type and life cycle stage. Notably, State-Owned Enterprises (SOEs) experience a stronger innovation response to digital finance than Non-State-Owned Enterprises (NSOEs), likely due to differences in institutional support and digital infrastructure access. The results also highlight that corporate digitization plays a critical mediating role, meaning that the positive influence of digital finance on innovation is amplified when firms also invest in internal digital transformation. This finding reinforces the argument that financial technology alone cannot drive innovation without complementary organisational changes.

Moreover, the study's methodological design – featuring mediation modeling and endogeneity correction using Two-Stage Least Squares (2SLS) – ensures that the observed relationships are both statistically robust and causally interpretable. The fixed effects for time, region, and industry further control for unobserved heterogeneity, enhancing the reliability of the results. These methodological choices allow for a nuanced understanding of how digital financial tools interact with internal firm dynamics to foster innovation. The study's multi-dimensional approach, incorporating variables such as enterprise lifecycle stage, revenue diversification, market competition, and leadership digital orientation, paints a comprehensive picture of the innovation ecosystem in China's rapidly evolving digital economy. The consistent and positive effects of DFA and related indicators (DFAR, DFIL) across multiple model specifications confirm that digital finance is a powerful enabler of technological advancement and organisational creativity.

5.1. Theoretical implications

Our research expands the conventional definition of financial inclusion by broadening its conceptual scope beyond addressing poverty reduction. Financial inclusion is crucial in promoting innovation and driving economic growth, which calls for a careful understanding that recognizes different business environments' requirements and possibilities. This redefinition prompts a change in focus from a narrow perspective centered on poverty to a broader understanding that encompasses the diverse effects of financial inclusion on the dynamics of innovation and overall economic development. Furthermore, our discoveries extend beyond the limitations of Schumpeterian theory, which is a fundamental concept in comprehending technological innovation. Although Schumpeter's framework is solid, our research demonstrates that digital finance profoundly fosters organizational creativity, highlighting the necessity for a broader theoretical framework that acknowledges the complex interaction among

financial resources, technological progress, and the creative processes within organizations. By incorporating these components into established theories, academics and professionals can more effectively navigate the changing terrain of innovation in the digital era.

Moreover, the variation in the effect of online banking on creativity highlights the importance of taking into account both internal and external factors that influence innovation in various organizational frameworks, which introduces an additional level of intricacy to current theories and emphasizes the need for analyses that are tailored to the specific context. Acknowledging various innovation ecosystems necessitates reassessing conventional, standardized methods advocating for customized strategies that consider the distinct attributes and difficulties of different organizational environments. These theoretical implications provide opportunities for further research exploring innovation's complex dynamics within changing financial environments.

5.2. Managerial implications

The managerial implications derived from our study highlight the crucial role of businesses in utilizing digital banking for innovation, regardless of their size or stage of development. Organizations are advised to actively utilize online banking to drive innovation by optimizing the allocation of resources, facilitating access to capital, and expediting digitization processes. The importance of developing customized strategies considering each business context's distinct attributes is highlighted, acknowledging that a universal approach may not be ideal. The strategic use of digital financial tools can improve the efficiency and effectiveness of innovation initiatives, leading to long-term growth and competitiveness. Furthermore, our discoveries emphasize the significance of fostering a culture of digital proficiency within organizations. Adopting digital platforms and fostering digital literacy among employees are recognized as essential measures to fully harness the potential of digital finance and maximize its impact on innovation. Employee training programs and a proactive effort to cultivate a culture of technological adaptability are considered crucial. Businesses can enhance their teams' ability to navigate the changing digital finance landscape and drive organizational success by prioritizing digital literacy initiatives, which empowers employees to make informed decisions and utilize innovative solutions.

Moreover, it is recommended that a cooperative strategy involving policymakers, financial institutions, and technology companies be adopted to foster inclusive innovation. It is crucial to create an ecosystem that promotes easily accessible digital financial tools and facilitates their efficient use for innovative projects in different industries. This collaborative partnership is crucial for closing the gap in access to digital resources and promoting the growth of innovation in various sectors of the economy. Policymakers are advised to establish a regulatory framework that promotes responsible technological advancement, while financial institutions and technology companies are urged to cooperate in the creation of user-friendly and secure digital solutions. In summary, the main objective of this collaborative endeavor is to establish a setting where digital finance serves as a catalyst for inclusive innovation, benefiting businesses of various scales and promoting economic expansion.

5.3. Future research directions

While this study provides robust empirical evidence on the role of digital finance in promoting enterprise innovation in China from 2011 to 2022, several limitations should be acknowledged. First, the analysis primarily focuses on listed firms, which may not fully capture the innovation dynamics of smaller or informal enterprises that often face more severe financial constraints. Second, although the study uses sophisticated econometric techniques to address endogeneity, there may still be unobserved factors –such as managerial culture or firm-specific innovation strategies – that are not fully accounted for. Third, the measurement of digital transformation relies on text-mined keyword frequencies, which, while insightful, may not capture the depth or quality of digital integration. Future research could address these gaps by incorporating qualitative case studies or survey data to better understand internal digital capabilities. Additionally, cross-country comparative studies could explore whether the observed relationships hold in different regulatory or technological environments. Further exploration of sector-specific dynamics and the role of emerging technologies such as AI-driven finance or green digital finance could also provide more granular insights into how digital finance influences innovation under various industrial and environmental pressures.

Disclosure statement

The authors declare no conflict of interest.

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