Corporate Innovation Mechanisms in The Yangtze River Delta Catalyzed by Digital Finance: Research on The Impact of Financing Constraints and Corporate Digital Transformation

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Abstract. Taking the data of Shanghai and Shenzhen A-share enterprises in 41 cities in the Yangtze River Delta (YRD) region from 2012 to 2022 as research samples, we constructed two-way stationary models, mediation models, and carried out research on the impact of digital finance on enterprise innovation in YRD. The results of full-sample regression show that digital finance has a positive role in promoting enterprise innovation, and all three sub-dimensions of digital finance have a significant role in promoting enterprise innovation. The results analysed through the mediation effect show that digital finance can promote the motivation of enterprise innovation by alleviating the financing constraints and providing more financing channels for enterprises, so that enterprises can have wider access to financing funds. By providing financing support, data analysis tools, cooperation platforms and technological innovation, digital finance effectively promotes the digital transformation of enterprises, which in turn promotes the innovative development of enterprises.

Keywords: digital finance; corporate innovation; intermediary effect; financing constraints; corporate digital transformation.

1. Introduction

Technological innovation is considered the key engine for high-quality development of enterprises, as well as an essential factor in continuously enhancing the overall strength of a region[1]. In the Yangtze River Delta (YRD) region, enterprise innovation plays a vital role in economic development, not only by elevating the region's position in the global value chain but also by bolstering its competitiveness. With the rapid rise of digital finance, traditional financial services are experiencing transformative changes, offering enterprises in the YRD area more convenient funding options. The objective of this research is to examine how digital finance supports corporate innovation. It delves into the ways in which digital finance can enhance innovation by easing financial limitations and enabling digital transitions, with the ultimate goal of fostering high-quality business growth in the YRD area.

2. Theoretical analysis and hypothesis development

2.1. Digital finance and corporate innovation

Technological innovation within enterprises is critical for enhancing competitive strength, and the Y RD region, as one of China's most economically active areas, requires increased investment in technological innovation by its enterprises to be vital for national technological progress and product competitiveness. Digital finance, as a modern financial model that emphasizes inclusivity and services small and medium-sized enterprises, plays a positive role in fostering corporate innovation [2]. Drawing on the foregoing analysis, the study advances Hypothesis H1, which posits that the growth of digital finance exerts a beneficial influence on corporate innovation.

2.2. Digital Finance, Financing Constraints and Corporate Innovation

Extensive research shows that financing constraints hinder corporate innovation, as it necessitates significant, ongoing capital investment, often relying on internal cash flows. Obstacles like

information asymmetry and lack of collateral make it tough for businesses to access funding, potentially halting tech innovation[3]. However, digital finance has significantly eased these financing challenges. Consequently, Hypothesis H2 suggests that digital finance can alleviate financial constraints, fostering corporate innovation.

2.3. Digital finance, enterprise digital transformation and corporate innovation

In the digital economy, companies digitally transform to compete and sustain growth. Digital finance, merging IT and financial services, supports this transformation by providing not only funding but also tech and service backing. It increases enterprise digitalization, optimizes management and collaboration, expands innovation resources, strengthens R&D, and enhances product and service quality, boosting competitiveness and sustainability[4]. Hypothesis H3 posits that digital finance fosters business innovation through digitalization, facilitating innovative practices.

3. Data sources and research design

3.1. Sample data sources

This study uses a sample of 41 YRD cities with Shanghai and Shenzhen A-share listed companies from 2012 to 2022, creating a panel dataset by matching them with a digital financial index. To improve representativeness, it excludes finance, real estate, and ST-listed firms, retains samples with at least five years of data, excludes companies with key variable missing values, and winsorizes continuous variables at the 1% and 99% percentiles. This yields 7,085 valid samples. The enterprise data comes from the CSMAR database, and digital finance data is from the Peking University Digital Finance Research Center.

3.2. Variable selection

Corporate Innovation (Inn). In this article, the level of technological innovation in enterprises is assessed by the intensity of R&D investment. The proportion of R&D investment to net operating revenue is used as an indicator to measure corporate innovation [5].

This paper measures Digital Finance (DIF) using the Digital Inclusive Finance Index (2012-2022) from Peking University's Digital Finance Research Center, including its three sub-indices: Coverage Width (DIF_C), Usage Depth (DIF_D), and Degree of Digitalization (DIF_Di). These indicators offer a thorough evaluation of digital finance progress. Financial Constraints (SA) are represented by the SA index, used as a mediating variable.[6]. its calculation formula is as follows:

$$SA = -0.737 * Size + 0.043 * Size2 - 0.04 * Age \quad (1)$$

In Equation (1), Size denotes the firm's total assets at the end of the fiscal year, and Age represents the age of the firm from its inception up to the year of observation.

This paper assesses digital transformation (DT) through a frequency analysis of 76 keywords from five categories: AI, blockchain, cloud services, big data analytics, and other digital tech applications. These keywords, as listed in Fig 1[7], are used to search and match, and their frequencies are calculated. The data is then categorized by technology domain and aggregated to create an indicator framework for gauging corporate digital transformation. To correct the skewed frequency data, a plus-one operation is applied, followed by the calculation of the natural logarithm of the transformed data.

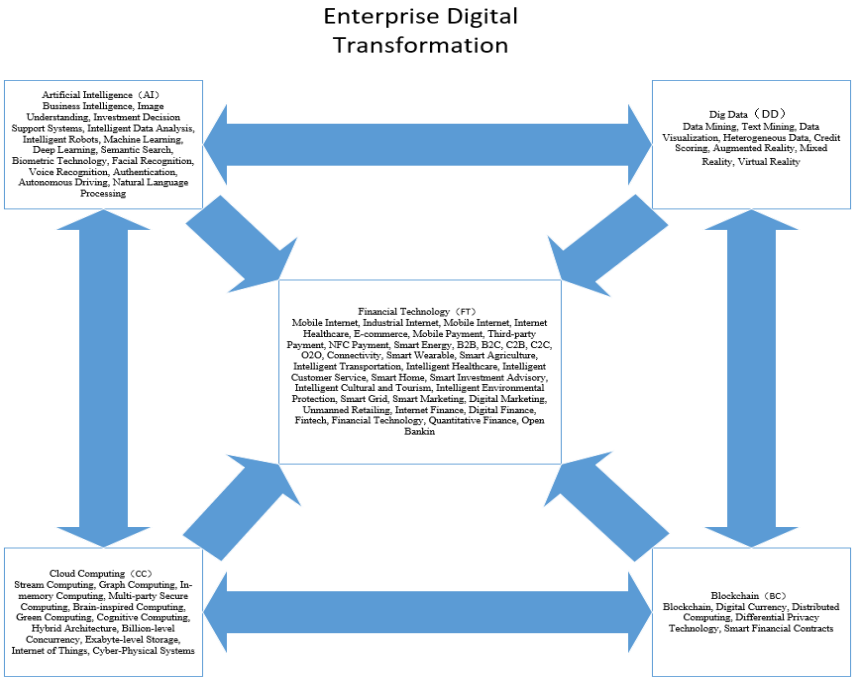

Fig 1. Feature Word Graph of Corporate Digital Transformation

This study selects Asset Sze (AS), Corporate Leverage (CL), Fixed Asset Ratio (FAR), Firm Age (FA), Corporate Net Profit (CNP), Director Ownership Ratio (DOR), and Equity Concentration (EC) as control variables to control for other confounding factors except for digital inclusive finance. The symbols and detailed construction methods of each variable are as shown in Table 1.

Table 1. Definition of Variables

Typology	Name	Variable Symbol	Hidden Meaning
Explanatory Variables	Corporate Innovation	CI	R&D Expenditure/Operating Revenue
Explanatory Variable	Digital Finance	DIF	Digital Finance/100
	Broad Coverage	DIF_C	Broad Coverage/100
	Depth of Use	DIF_D	Depth of Use/100
	Degree of Digitalization	DIF_Di	Degree of Digitalization/100
Mediating Variable	Financing Constraints	SA	SA Index
	Digital Transformation	DT	ln(AI+BC+CC+DTA+BD+1)
Control Variables	Asset Size	AS	Natural logarithm of total enterprise assets
	Fixed Asset Ratio	FAR	Total fixed assets/total assets at end of year
	Corporate Leverage	CL	Total liabilities at end of period/total assets at end of period
	Firm Age	FA	ln(year of observation - year of establishment)
	Corporate Net Profit	CNP	Net profit/average total assets
	Director Ownership Ratio	DOR	Percentage of independent directors
	Equity Concentration	EC	Number of shares held by the largest shareholder/total number of shares

3.3. Model Construction

Benchmark Model.Testing the Impact of Digital Finance on Corporate Innovation - Establishing a Model as Follows:

$$\text{Inn}_{\text{it}} = \alpha_0 + \alpha_1 \text{DIF}_{jt} + \alpha_n \text{controls}_{\text{it}} + \upsilon_i + \lambda_t + \varepsilon_{it} \tag{2}$$

In Equation (2), "i", "t" and "j" respectively denote firm, year, and city. "Inn_{it}"represents the firm innovation of firm i in year t, while"DIF_{jt}"signifies the level of digital financial development in city j during year t. "controls_{it}"refers to the selected control variables."υ_i"stands for the industry fixed effect, "λ_t"for the time fixed effect and "ε_{it}"indicates the random disturbance term.

Mediation Effect Model. Based on the benchmark regression, this paper further employs a mediation effect model to explore the transmission mechanism. The mediation effect test is conducted using the stepwise regression method. The model is constructed as follows:

$$\text{Inn}_{\text{it}} = \alpha_0 + \alpha_1 \text{DIF}_{\text{jt}} + \alpha_n \text{controls}_{\text{it}} + \upsilon_i + \lambda_t + \varepsilon_{it} \tag{3}$$

$$\text{ZJ}_{\text{it}} = \beta_0 + \beta_1 \text{DIF}_{\text{jt}} + \beta_n \text{controls}_{\text{it}} + \upsilon_i + \lambda_t + \varepsilon_{it} \tag{4}$$

$$\text{Inn}_{it} = \gamma_0 + \gamma_1 DIF_{\text{jt}} + \lambda_2 SA_{it} + \gamma_n controls_{it} + \upsilon_i + \lambda_t + \varepsilon_{it} \tag{5}$$

In Equation (3)-(5), "i", "t" and "j" respectively denote firm, year, and city.ZJ serves as a mediator, indicating the financing constraints and digital transformation of the firm."υ_i"stands for the industry fixed effect, "λ_t"for the time fixed effect and "ε_{it}"indicates the random disturbance term.

4. Empirical Results and Analysis

4.1. Full Sample Benchmark Regression Analysis

The two-way fixed effects model, presented in Table 3, controls for industry and time effects. Column (1) results show that digital finance (DIF) has a significant positive impact on corporate innovation (CI), with a coefficient of 0.025 at the 1% level, supporting Hypothesis H1. The adoption of digital finance technologies, such as online payment systems and blockchain, reduces transaction and capital movement costs, improving inter-firm transaction efficiency and encouraging innovative partnerships and business model experimentation. In Columns (2)-(4), the regression coefficients for the subsets of digital finance indicators - coverage breadth (DIF_C), usage depth (DIF_D), and digitalization extent (DIF_Di) - are 0.022, 0.016, and 0.014 respectively, with all coefficients reaching statistical significance at the 1% level. This indicates that growth in these three dimensions of digital finance positively influences corporate technological innovation.The regression analysis on corporate innovation shows that higher capital leverage, a higher fixed asset ratio, older firms, greater equity concentration, and lower directors' ownership ratio are negatively associated with innovation. Conversely, a higher directors' ownership ratio is positively linked to innovation, suggesting it enhances professional advice, risk avoidance, regulatory compliance, and long-term innovation strategies.

Table 3. Regression Results of Digital Finance on Corporate Innovation

	(1)	(2)	(3)	(4)
	CI	CI	CI	CI
DIF	0.025***			
	(9.127)			
DIF_C		0.022***		
		(9.857)		
DIF_D			0.016***	
			(6.787)	
DIF_Di				0.014***
				(4.007)
AS	-0.001***	-0.001***	-0.001***	-0.002***
	(-3.114)	(-2.917)	(-3.386)	(-3.477)
CL	-0.047***	-0.047***	-0.046***	-0.046***
	(-14.150)	(-14.204)	(-14.004)	(-13.927)
FAR	-0.028***	-0.028***	-0.030***	-0.033***
	(-6.873)	(-6.845)	(-7.291)	(-7.903)
FA	-0.011***	-0.011***	-0.011***	-0.011***
	(-7.575)	(-7.538)	(-7.606)	(-7.488)
CNP	-0.041***	-0.041***	-0.041***	-0.041***
	(-3.909)	(-3.973)	(-3.917)	(-3.902)
DOR	0.000**	0.000**	0.000**	0.000**
	(2.049)	(2.149)	(2.039)	(2.240)
EC	-0.000***	-0.000***	-0.000***	-0.000***
	(-9.531)	(-9.574)	(-9.208)	(-8.878)
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R2	0.357	0.358	0.355	0.351

Note: Figures in parentheses are robust standard errors, ***p<0.01, **p<0.05, *p<0.1; same below

4.2. Mediation Analysis of financing constraints

Table 4 of this study reveals that the absolute value of financing constraints (SA) is a measure of firms' severe financial restrictions, with higher values indicating greater constraints. The regression shows that digital finance (DIF) significantly reduces these constraints, as indicated by the highly significant negative coefficient of -0.029 in column (2). Additionally, column (3) finds that financing constraints negatively impact corporate innovation (CI), suggesting that when these constraints are alleviated by digital finance, firms gain easier access to funding, which fosters innovation investments and activities, ultimately enhancing innovation outcomes. This supports Hypothesis H2, showing that digital finance stimulates innovation by mitigating firms' financing constraints.

Table 4. Results of Mediation Analysis for SA

	(1)	(2)	(3)
	CI	CI	CI
DIF	0.025***	-0.029***	0.025***
	(9.127)	(-4.152)	(8.984)
SA			-0.014***
			(-3.707)
Control Variables	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adj. R^2	0.354	0.834	0.355

4.3. Mediation Analysis of Digital Transformation

As shown in Table 5, under the second column, digital finance (DIF) exhibits a substantial and positive correlation with digital transformation (DT), with a regression coefficient of 0.860 that is highly significant at the 1% significance level. This suggests that the growth of digital finance not only stimulates innovation directly but also facilitates it indirectly by encouraging digital advancements within companies. In the third column, the coefficient for the influence of digital transformation (DT) on corporate innovation (CI) is 0.004, also significant at the 1% level, which reinforces the idea that digital transformation serves as a mediator in the connection between digital finance and corporate innovation. These results align with Hypothesis H3, highlighting that digital finance fosters innovation in firms, in part, by propelling digital transformation within them.

Table 5. Results of Mediation Analysis for DT

	(1)	(2)	(3)
	CI	CI	CI
DIF	0.025***	0.860***	0.022***
	(9.127)	(10.110)	(7.827)
DT			0.004***
			(9.237)
Control Variables	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	0.357	0.409	0.368

4.4. Stability Test

Table 6 from this study conducts robustness tests by using patent applications (PA) as a proxy for firm innovation and by excluding data from enterprises in direct-administered municipalities. The results show a strong, statistically significant positive relationship between digital finance and firm innovation when patent applications are used (column 1). To account for the unique economic and policy environments of direct-administered municipalities like Shanghai, which differ from other cities, adjustments were made. Column 2 reveals that after removing these enterprises, the positive impact of digital finance on firm innovation remains significant at the 1% confidence level, confirming the robustness of the initial findings.

Table 6. Stability Test for Variable Replacement and Sample Exclusion

	(1)	(2)
	PA	CI
DIF	20.411***	0.033***
	(2.731)	(9.622)
Control Variables	Yes	Yes
Ind FE	Yes	Yes
Year FE	Yes	Yes
R^2	0.192	0.325

5. Conclusion

Using a panel dataset of 41 cities in the YRD region, this study examines the relationship between digital finance and firm innovation, controlling for financing constraints and digital transformation as mediating factors. It is found that there is a significant positive correlation between the digital finance composite index and its sub-indexes and enterprise innovation. This in turn suggests that the development of digital finance can promote technological innovation by firms. The study also shows that digital finance can promote innovation by improving the corporate financing environment and

alleviating financing constraints. Moreover, digital transformation is a key mediator, and digital finance can stimulate technological innovation by facilitating enterprises' digital transformation.The above conclusion provides valuable insights for enterprises, governments, and research institutions in the YRD region, aiding in the advancement of the relationship between digital finance and corporate innovation. This, in turn, facilitates sustainable development and high-quality growth of the regional economy.

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