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The Impact of Digital Finance on Corporate Operational Risk

— From the Perspectives of R&D Investment and Financing Constraints

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Abstract: The swift expansion of digital finance has profoundly influenced the operations of micro-enterprises and subsequently impacted macroeconomic stability and financial health. This study utilizes financial data from A-share listed companies from 2011 to 2020, alongside indicators of the macro digital economy, to assess how digital finance development influences business risks. It demonstrates that digital finance notably reduces these risks, with these findings holding steady even after addressing endogeneity concerns and performing various robustness tests. Analysis of the mechanisms shows that increased investments in R&D and alleviation of financing constraints are key ways digital finance reduces business risks. A heterogeneity analysis reveals that the impact of digital finance varies depending on the corporate structure and size, with state-owned and large-scale enterprises benefiting more, likely due to the digital divide. Furthermore, this study explores the effects of digital finance on reducing corporate fraud and litigation risks, discovering that it significantly lowers fraud risks, although it does not significantly affect litigation risks. This research provides important theoretical and practical insights, suggesting that digital finance can enhance risk management and contribute to superior economic and financial development.

Keywords: Digital Finance, Operational Risk, R&D Investment, Financing Constraints

1. Introduction

In recent years, despite facing a complex and challenging international environment and arduous tasks, China's economic and social development has achieved significant accomplishments. The economy showed signs of recovery and improvement in 2023, with substantial progress in high-quality development. However, it must be acknowledged that China's economic development still faces challenges and potential risks. The report of the 20th National Congress of the Communist Party of China and the Central Economic Work Conference of 2023 both emphasized the need to "continuously and effectively prevent and resolve risks in key areas," enhance risk prevention and mitigation capabilities, and stabilize the development of the real economy and finance, which has become crucial. The operations of micro-enterprises are directly related to the overall safety of the economy and the sustained healthy development of finance. In 2011, there were only 2,392 listed

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companies on the Shanghai and Shenzhen stock exchanges; by 2023, this number had grown to 5,335. While the increase in the number of enterprises brings development opportunities, it also intensifies market competition, leading to more complex and diverse risks for enterprises, particularly a significant increase in operational risks. This not only affects the enterprises themselves but may also have adverse impacts on social consumption and investment, employment, and financial markets. In 2023, a total of 3,820 companies faced operational risks and were shut down or went bankrupt due to market competition, financing difficulties, and other reasons. Therefore, it is urgent to study how to take effective measures to reduce operational risks, enhance enterprises' risk prevention and mitigation capabilities, and thereby promote high-quality economic development.

China places significant emphasis on the development of its digital economy, positioning it as a core national strategy. The Party and government have consistently highlighted the importance of the digital economy and digital finance in their reports and strategic discussions. The 2023 Central Financial Work Conference suggested a focus on 'technology finance, green finance, inclusive finance, pension finance, and digital finance.' Digital finance is considered pivotal in enhancing financial services and is fundamental to building a strong financial infrastructure. With comprehensive policy support, China's digital finance sector has experienced rapid and high-quality growth, which is crucial for macroeconomic and financial development, and has notably affected micro-enterprises. Digital finance drives enterprise digital transformation, boosts innovation, enhances operational efficiency, and influences investment strategies. Furthermore, it mitigates information asymmetry, making it easier for businesses to secure credit from formal financial institutions, thereby optimizing their financial structures. As companies improve their investment configurations and ease financing constraints, operational risks diminish. Consequently, digital finance is becoming increasingly essential in reducing business risks and bolstering risk prevention and mitigation efforts within enterprises.

Drawing on data from publicly listed companies in China spanning 2011 to 2020, this paper investigates the effects of digital finance development on corporate operational risks and their mechanisms of influence. It further explores how digital finance impacts corporate fraud risks and litigation risks. The findings reveal that digital finance helps decrease operational risks through enhanced R&D investments and eased financing restrictions, and it effectively lowers corporate fraud risks. The theoretical value of this research enhances our understanding of digital finance and corporate risk management, contributing to the broader discourse on enterprise risk. Practically, the study provides empirical support for the benefits of digital finance in mitigating corporate risks, which could inform policy recommendations for further promoting digital finance development, reducing corporate operational risks, enhancing risk prevention and resolution capabilities, and promoting economic and financial stability.

The potential marginal contributions of this paper are as follows:

1. Focus on Chinese Issues: This study advances the assessment of digital finance's impact on enterprise risk within China. It uses the entropy method to construct a regional digital finance development index. The findings suggest that digital finance significantly mitigates operational, fraud, and litigation risks across enterprises, providing micro-level evidence of the positive impact of digital finance on enterprise risk prevention and mitigation, offering new perspectives for related research.

2. Enterprise Investment and Financing Perspective: this paper supplements the micro-level quantitative analysis of the transmission mechanism through which digital finance impacts enterprise operational risk. It confirms that the development of digital finance reduces operational risks by increasing enterprise R&D investment and alleviating financing constraints, thereby broadening the research boundaries on the transmission channels through which digital finance affects enterprise operational risks.

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3. Enterprise Structure and Scale Perspective: this paper investigates the potential digital divide issue in the development of digital finance. It finds that digital finance has a stronger effect on reducing operational risks for state-owned and large-scale enterprises, while its impact is weaker for private and small-to-medium enterprises. This indicates the possible existence of a digital divide and digital barriers in the development of digital finance. The study's conclusions provide valuable insights for further promoting digital finance development, bridging the digital divide, and effectively reducing operational risks for enterprises, particularly private and small-to-medium enterprises.

2. Literature Review and Theoretical Analysis

2.1. Factors Influencing Corporate Operational Risk

The operational risks of enterprises have significant impacts on their stability, competitiveness, and future development, thereby affecting macroeconomic and financial stability. This issue has attracted widespread attention in academic circles. Hamada (1972) defined operational risk as the risk arising from uncertainties affecting enterprises during production and operation. Subsequent scholars have further refined this definition. Research has found that external factors such as regional financial activities and peer effects among enterprises may exacerbate operational risks by increasing corporate debt financing costs. In contrast, a favorable macroeconomic environment and policy certainty can mitigate financing constraints and improve operational conditions. The openness of financial markets can also reduce information asymmetry and financing constraints, thereby decreasing operational risks.

Regarding internal factors, the literature mainly focuses on the impact of corporate innovation behavior and financing constraints on operational risks. Some scholars believe that corporate innovation behavior may increase operational risks due to the uncertain returns associated with R&D expenditures [1,2,3,4]. However, more studies suggest that increasing R&D investment can enhance competitiveness and reduce operational risks [5,6,7,8]. The consensus in research is that increased financing constraints raise operational risks and hinder corporate development [9,10,11]. Additionally, a small number of studies have examined the effects of corporate social responsibility performance, tax reputation, cross-border mergers and acquisitions, international diversification behavior, and financialization [12,13,14,15,16], as well as non-economic factors such as ownership concentration, board diversity, and managerial experience [17,18,19] on operational risks.

2.2. Finance and Corporate Operational Risk

In recent years, as technological innovation has progressed, digital finance has emerged as a significant area of study for scholars worldwide [20,21]. Research has delved into how digital finance influences corporate financing constraints, innovation levels, TFP, and entrepreneurial behavior. Findings indicate that advancements in digital finance can relieve financing constraints, boost operational efficiency, and foster both innovation and entrepreneurship. [22,23,24,25,26,27,28,29,30].

Additionally, scholars have noted the potential impact of digital finance on corporate risk-taking. Studies found that digital finance, through resource and info effects, can increase risk-taking by alleviating financing constraints, raising the proportion of credit funds, and enhancing innovation capabilities, influencing innovation and digital transformation [7,31,32,33,34,35]. Further analysis on the causal relationship between digital finance development and operational risk reveals that digital transformation can reduce operational risks by enhancing internal control quality, increasing info transparency, and promoting innovation [5,36]. Additionally, digital inclusive finance impacts audit risks, including operational risks, through resource supply and info effects [37].

In summary, existing literature has recognized the impact of digital finance on operational risk and conducted preliminary research. However, gaps remain in understanding the mechanisms and effects.

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One gap is the potential endogeneity problem when using corporate digital transformation indicators to study their impact on operational risk, as corporate risk-taking can influence digital transformation. Another gap is that the digital inclusive finance index, though less endogenous, does not fully represent digital finance and differs significantly from other audit risks. Therefore, this paper constructs a provincial-level digital finance development index using the entropy method to comprehensively reflect regional digital finance levels and deeply analyze the causal relationship between digital finance and operational risk, providing micro-evidence of the benefits of digital finance development and offering valuable references for further promoting digital finance, reducing operational risk, and achieving high-quality economic and financial development.

3. Theoretical Analysis

3.1. The Impact of Digital Finance Development on Corporate Operational Risk

Corporate operational risk is influenced by various economic and non-economic factors. The development of digital finance changes the internal and external environment of enterprises, inevitably affecting their operational risk. Externally, digital finance has an information effect that can effectively mitigate information asymmetry, reduce corporate financing costs, improve financing structure, and thus reduce operational risk. Internally, digital finance changes corporate production, procurement, and investment decisions, promotes increased innovation investment, enhances efficiency, and drives high-quality development, thereby reducing operational risk [38]. Existing literature has found that digital inclusive finance development and corporate digital transformation can reduce operational risk by enhancing internal control quality, increasing information transparency, promoting innovation, and increasing resource supply [5,37]. Since digital finance development and corporate digital transformation are specific manifestations of continuous digital finance innovation, this paper hypothesizes that digital finance development can effectively reduce corporate operational risk.

Hypothesis 1: Digital finance development can effectively reduce corporate operational risk.

3.2. Mechanisms of Digital Finance Affecting Corporate Operational Risk

(1) R&D Investment Mechanism

Based on Hypothesis 1, this paper further analyzes the specific mechanisms through which digital finance affects corporate operational risk. The first mechanism is R&D investment. Existing literature suggests that while increasing R&D investment may temporarily occupy corporate cash flow and increase earnings uncertainty, it is an essential long-term strategy for enhancing corporate competitiveness, promoting high-quality development, and reducing operational risk [5,7]. Digital finance development can increase R&D investment by lowering financing costs, improving financing structures, and reducing information asymmetry [39]. Additionally, digital finance development can drive market competition intensity, forcing companies to adjust investment strategies and increase R&D investment to enhance competitiveness. Therefore, this paper hypothesizes that digital finance development increases R&D investment, reducing corporate operational risk.

Hypothesis 2: Increasing R&D investment is a possible mechanism through which digital finance reduces corporate operational risk.

(2) Financing Constraints Mechanism

The second mechanism is financing constraints. Existing theory and empirical evidence suggest that financing constraints are crucial factors affecting corporate risk-taking levels, and digital finance

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development influences corporate financing constraints and structures [7,40]. From the credit supply perspective, digital finance development changes traditional credit models, promoting digital operations in banks and financial institutions, solving information asymmetry, increasing credit supply, and alleviating financing constraints [35,41,42,43]. From the credit demand perspective, digital finance development increases information transparency, reduces credit thresholds, and enhances credit efficiency, making it easier for companies to seek credit from formal financial institutions. Additionally, digital finance development broadens financing channels, allowing companies to use equity financing, bond financing, crowdfunding, and other diversified financing methods. Thus, digital finance development can alleviate financing constraints from both supply and demand sides, reducing corporate operational risk.

Hypothesis 3: Alleviating financing constraints is a possible mechanism through which digital finance reduces corporate operational risk.

4. Research Design

(1) Data Sources and Processing

This paper selects A-share listed companies from 2011 to 2020 as the research sample to analyze the impact of digital finance development on corporate operational risk. Financial data regarding corporate operational risk is sourced from the CSMAR database, while relevant digital economic indicators are derived from the "China Statistical Yearbook."

Before conducting the empirical analysis, the data underwent certain processing steps. Samples with missing key variables and outliers were excluded, as were companies listed on the Beijing Stock Exchange, ST and ST* companies, and financial sector companies. Ultimately, the sample includes data from 3,032 companies, comprising 18,538 data points.

(2) Variable Selection

1. Dependent Variable

The primary independent variable in this study is the digital finance development index. Following the methodology established by Yu Yao et al. (2022), the ratio of credit loans to total bank loans is used to measure operational risk. A higher ratio indicates greater credit support for the company, representing stronger risk response capabilities and lower operational risk.

2. Independent Variable

The core independent variable is the digital finance development index. Drawing on the method of Zhao Tao et al. (2020), this index is constructed using five digital-related indicators: "number of internet users per 100 people," "proportion of employees in computer services and software," "per capita telecommunications business volume," "number of mobile phone users per 100 people," and the "digital inclusive finance index". To construct the regional digital finance development index, the entropy method is applied, and principal component analysis is utilized to consolidate these five indicators into a unified index for robustness testing.

3. Control Variables

To control for other factors that might influence corporate operational risk, several control variables are included in the model, such as company size (Size), return on assets (ROA), fixed asset ratio (Fix), operating cash flow (CFO), Tobin's Q (TobinQ), the shareholding ratio of the largest shareholder (Top1), dual roles (Dual), financing constraints (KZ), labor productivity (Labprod), ownership structure (SOE), and R&D investment (RD). Definitions of these variables are provided in Table 1.

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Table 1: Variable Definitions

Variable Name	Symbol	Definition Description
Operational Risk	Creloan	credit loans/total bank loans
Digital Economy Level (Entropy Method)	Dige2	Constructed using the entropy method
Company Size	Size	ln(total assets at the end of the period)
Return on Assets	Roa	Net profit / total assets
Labor Productivity	Labprod	ln(revenue per employee)
Ownership Structure	Soe	1 for state-owned enterprises, 0 otherwise
Fixed Asset Ratio	Fix	Fixed assets / total assets
Operating Cash Flow	Cfo	Net cash flow from operating activities / total assets
Tobin Q	Tobing q	Market value / total assets at the end of the period
Largest Shareholder	Top1	Shareholding ratio of the largest shareholder
Dual Roles	Dual	1 if the chairman also serves as the general manager, 0 otherwise
R&D Investment	RD	R&D investment / revenue * 100
Financing Constraints	KZ	KZ index
Year Dummy Variable	Year	Dummy variable for the year
Operational Risk	Ind	Dummy variable for the industry based on the CSRC industry classification

(3) Model Specification

This paper initially employs a panel data fixed effects model to analyze the impact of digital finance development on corporate operational risk. The model is specified as follows:

$$Y_{it} = \alpha + \beta_1 digital_{it} + \beta_2 X_{it} + \delta_b + \gamma_t + \mu_{it} \quad (1)$$

Where i denotes the individual company, t represents time, Y_{it} is the operational risk level of company i in year t, digital is the regional digital finance development level, X_{it} represents a series of control variables, δ_b represents industry fixed effects, $\gamma_t$represents year fixed effects, μ_{it} is the

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random error term, and β_1 is the coefficient of interest. A positive β_1 indicates that digital finance development reduces corporate risk, supporting Hypothesis 1.

Considering that corporate operational risk is a censored variable ranging from 0 to 1, this paper also constructs a Tobit model for robustness testing:

$$y_{it}^{*} = \beta_0 + \beta_1 digital_{it} + \beta_2 X_{it} + \gamma_t + \varepsilon_{it} \quad (2)$$

$$y_{it} = \max(0, y_{it}^{*}) \quad (3)$$

where y_{it} is the observed operational risk level, γ_t represents time fixed effects, ε_{it} follows a normal distribution, and other variables are defined as in the fixed effects model.

5. IV. Empirical Analysis

(1) Descriptive Statistics

Table 2 presents the descriptive statistics of the main variables. The results show that the maximum and minimum values of the Digital Economy Index are 0.998 and 0.052, respectively, with a mean of 0.377. This indicates that although the digital economy in China has developed rapidly and has great potential for growth, there are still significant regional disparities. The maximum value of operational risk is 1, the minimum value is 0, the mean is 0.34, and the standard deviation is 0.36, suggesting that Chinese enterprises may face considerable operational risks and that the levels of operational risk vary significantly among different companies. The descriptive statistics for other variables are all within reasonable ranges. The following sections will conduct an in-depth analysis of the causal relationship between digital finance and corporate operational risk.

Table 2: Descriptive Statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Creloan(%)	18538	34.24	36.11	0	100
Dige2	18538	0.377	0.254	0.0522	0.998
size	18538	22.47	1.306	17.88	28.64
Labprod	18538	13.90	0.909	9.629	18.93
Soe	18538	0.424	0.494	0	1
Roa	18538	0.0270	0.0884	-3.994	0.590
fix	18538	0.228	0.170	0	0.971
Cfo	18538	0.0435	0.0735	-1.938	0.876
Tobingq	18538	1.921	1.435	0.674	48.51
Top1	18538	34.51	14.91	0.290	89.99
Dual	18538	0.240	0.427	0	1
RD	18538	0.0111	0.0368	0	0.782
KZ	18538	1.485	2.182	-11.33	13.66

(2) Benchmark Regression: The Impact of the Digital Economy on Corporate Operational Risk

Using the data and models above, this section empirically examines the impact of digital finance on corporate operational risk. Table 3 presents the estimation results. Column (1) illustrates the regression analysis of the Digital Economy Index on corporate operational risk as a single variable. Columns (2) and (3) progressively add control variables related to corporate structure and operations. The estimated coefficients are significantly positive at the 1% level. The estimated coefficient in

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Column (3) indicates that after accounting for industry, year fixed effects, and other control variables, an increase of one unit in the Digital Economy Index reduces corporate operational risk by 4.55%, which is both economically and statistically significant.

Table 3: Benchmark Regression

	(1)	(2)	(3)
VARIABLES		Creloan	
Dige2	7.520***	5.580***	4.550***
	(1.084)	(1.049)	(1.050)
size		3.425***	3.858***
		(0.232)	(0.255)
Soe		17.12***	18.63***
		(0.604)	(0.605)
Dual		-0.536	-0.497
		(0.614)	(0.608)
Top1		0.165***	0.119***
		(0.0183)	(0.0183)
Labprod			-0.268
			(0.359)
Roa			19.34***
			(3.168)
fix			3.626*
			(2.099)
Cfo			-19.49***
			(4.530)
Tobingq			1.308***
			(0.203)
RD			6.140
			(8.113)
KZ			-2.214***
			(0.166)
Constant	31.42***	-57.63***	-62.12***
	(0.483)	(5.097)	(6.535)
Observations	18483	18483	18483
R-squared	0.075	0.152	0.168
ind FE	YES	YES	YES
Year FE	YES	YES	YES

(3) Endogeneity Analysis

The benchmark regression results suggest that digital finance can reduce corporate operational risk. However, the empirical model might suffer from endogeneity issues. First, measurement error might exist during the collection and input of corporate financial data, potentially affecting the estimation

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results. To address this, the dependent variable is adjusted, excluding samples with operational risk equal to 0 or 1, as such extreme samples are rare in the actual business environment. The results are shown in Column (1) of Table 4, and the estimated coefficient remains significantly positive.

Second, omitted variable bias might be present. Factors such as industry characteristics and industry development cycles, which are difficult to observe, might influence corporate operational risk, leading to inconsistent estimates. The benchmark regression includes industry and year fixed effects to absorb the impact of unobservable factors that vary across industries or years, minimizing the interference from omitted variable bias.

Third, there may be reverse causality between the development of digital finance and business risks. This paper addresses the potential reverse causality between digital finance development and enterprise operational risk by using the instrumental variable (IV) method. The number of fixed telephone users per 10,000 people in 1984 is selected as the instrument. This variable is related to the regional development of digital finance, satisfying the relevance assumption, and does not directly influence enterprise operational risk, meeting the exogeneity assumption. The IV estimation results indicate that the number of fixed telephone users has a significant positive impact on digital finance development. When the instrument is included, the direction and significance of the impact of digital finance development on enterprise operational risk remain consistent with the baseline regression results. The first-stage F-value is much greater than 10, passing the weak instrument test. This demonstrates that the conclusion remains valid after addressing endogeneity issues, thereby supporting Hypothesis 1.

Table 4: Endogeneity Analysis

VARIABLES	(1) Creloan	(2) shuzi	(3) Creloan
Dige2	3.575***		8.590***
	(1.127)		(1.406)
phone		47.37***	
		(0.312)	
Control	YES	YES	YES
Constant	-15.37**	0.0939***	
	(7.384)	(0.0308)	
C-D F-value			2.3e+04
Observations	11,669	18,483	18,483
R-squared	0.158	0.632	0.102
ind FE	YES	YES	YES
Year FE	YES	YES	YES

(4) Robustness Checks

1. Changing the Dependent Variable

To further enhance the accuracy of the study's conclusions, various strategies were employed for robustness checks. First, the measurement method of the Digital Finance Development Index was changed by using principal component analysis to reconstruct the digital finance development indicator. The regression results are shown in Column (1) of Table 5. The estimated coefficient remains significantly positive, and the results are comparable to the benchmark regression. Second, the logarithm of the Peking University Digital Inclusive Finance Index was used to measure the level

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of digital finance development in different regions. The results are shown in Column (2), where the estimated coefficient remains significantly positive at the 1% level.

2. Higher-Order Fixed Effects

Given that using two-way fixed effects for time and industry in the regression model may not fully address the issue of omitted variables and may not adequately consider endogeneity issues [37], this study adopts a higher-order joint fixed effects model controlling for "time × industry" as suggested by Moser and Voena (2012) and Tang Song et al. (2020). This approach involves introducing the interaction term "industry × year" based on controlling for industry and year effects separately. The results of this test are shown in Column (3) of Table 5, indicating that digital finance still significantly suppresses operational risk after adopting the higher-order fixed effects regression.

3. Changing the Estimation Model

Considering that corporate operational risk is a truncated variable with values ranging from 0 to 1, using ordinary least squares (OLS) estimation for such variables might lead to biased results. Therefore, an IVTobit model was used for estimation. Since adding industry fixed effects to the Tobit model would result in losing too many samples, only time fixed effects were included to reduce estimation bias. The results are shown in Column (4) of Table 5, with the estimated coefficient remaining significantly positive. The Wald test value is 16.36, passing the instrumental variable test, confirming that the conclusion still holds.

The results of robustness checks using different methods indicate that the direction and significance of the main explanatory variable regression coefficients remain unchanged, confirming that digital finance significantly reduces corporate operational risk.

Table 5: Robustness Checks

	(1)	(2)	(3)	(4)
VARIABLES	Creloan			
Dige (Principal Component)	21.67***			
	(5.626)			
Dige (Inclusive Finance)		6.319***		
		(1.712)		
Dige2			4.558***	0.104***
			(1.061)	(0.0207)
Control	YES	YES	YES	YES
Constant	-72.55***	-95.79***	-64.06***	-0.910***
	(6.890)	(10.81)	(6.654)	(0.0896)
Wald test				16.36
Observations	18,483	18,483	18,422	18,538
R-squared	0.168	0.168	0.185	
ind FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Ind*year	/	/	YES	/

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(5) Mechanism Analysis

The empirical results above indicate that the conclusion that digital finance reduces corporate operational risk remains valid after addressing endogeneity issues and conducting robustness checks. The following section will refer to Jiang Ting (2022) to examine the mechanisms through which digital finance affects corporate operational risk.

1. R&D Investment Mechanism

According to theoretical analysis, digital finance can reduce corporate operational risk by increasing R&D investment. The empirical analysis assesses the impact of digital finance on corporate R&D investment. Using R&D investment as the dependent variable, the results are shown in Column (1) of Table 6. The results show a significantly positive coefficient, indicating that digital finance significantly increases corporate R&D investment. Therefore, Hypothesis 2 is confirmed.

2. Financing Constraint Mechanism

Existing literature suggests that financing constraints also affect corporate operational risk. When financing constraints are high, companies may struggle to obtain credit funds, affecting cash flow in their operations. In this analysis, financing constraints are used as the dependent variable, with results shown in Column (2) of Table 6. The significantly negative coefficient indicates that digital finance can alleviate corporate financing constraints. Therefore, it is proposed that alleviating financing constraints is a possible mechanism through which digital finance reduces corporate operational risk, confirming Hypothesis 3.

Table 6: Mechanism Analysis

	(1)	(2)
VARIABLES	RD	KZ
Dige2	0.00376***	-0.312***
	(0.000958)	(0.0466)
Control	YES	YES
Constant	0.0742***	-2.990***
	(0.00594)	(0.290)
Observations	18,483	18,483
R-squared	0.333	0.549
ind FE	YES	YES
Year FE	YES	YES

(6) Heterogeneity Analysis

Corporate decisions are influenced by complex factors such as organizational structure and management strategies. Therefore, the impact of digital finance on operational risk may vary significantly among companies of different sizes and structures. This section analyzes the heterogeneity in the impact of digital finance on state-owned versus non-state-owned enterprises and large versus small-scale enterprises.

1. Enterprise Structure Heterogeneity

This paper categorizes enterprises into state-owned and non-state-owned groups, performing regression analysis for each. The findings indicate that digital finance significantly lowers operational risks for state-owned enterprises, while the effect on non-state-owned enterprises is minimal. This disparity can be attributed to two factors: state-owned enterprises generally receive more government

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financial and policy support, making it easier for them to secure funding and support within the digital finance landscape, thus enhancing R&D investment. Furthermore, financial institutions, such as banks, are more inclined to extend loans to state-owned enterprises. The advancement of digital finance facilitates credit support for state-owned enterprises, easing financing constraints and reducing operational risks. Conversely, although digital finance reduces information asymmetry for non-state-owned enterprises, they may still encounter financing challenges, resulting in a relatively minor impact on their operational risks.

Table 7: Heterogeneity Analysis by Corporate Structure

VARIABLES	(1)	(2)	(3)	(4)
	Creloan			
	Soe=1	Soe=0	Size<median	Size>=median
Dige2	4.420***	0.908	-0.455	6.974***
	(1.519)	(1.498)	(1.728)	(1.302)
Control	YES	YES	YES	YES
Constant	-106.0***	3.604	-49.18***	-58.75***
	(10.15)	(9.261)	(17.68)	(9.899)
Observations	7,791	10,635	9,102	9,313
R-squared	0.195	0.092	0.096	0.257
ind FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

2. Heterogeneity in Corporate Size

This paper utilizes grouped regression analysis based on the median size of enterprises and discovers that the development of digital finance significantly reduces operational risks for medium and large enterprises, while having no notable effect on small and medium enterprises. Further quantile regression analysis, which groups by enterprise size quartiles, shows that as enterprise size increases, the impact of digital finance transitions from negative to positive, becoming significant only for the largest 25% of enterprises. This can be explained by several factors: large enterprises often have stable cash flows and substantial assets, enabling them to increase R&D investment without facing severe financial risks, thereby making digital finance more effective in promoting their R&D activities. In contrast, small enterprises have limited funds, and high R&D investment proportions can pose significant financial burdens, resulting in minimal promotion effects from digital finance on their R&D investment. Additionally, small enterprises have weaker risk-bearing capabilities; even if digital finance increases their R&D investment, the associated risks may actually heighten their operational risks. Large enterprises face higher revenue uncertainty, with greater economic losses under uncertainty, leading to higher operational risks; thus, the marginal effect of digital finance development is stronger for them. Therefore, there is heterogeneity in how enterprises of different sizes utilize digital finance to improve operational performance. Large enterprises are more likely to benefit, achieving growth and risk reduction, while small enterprises may face more challenges and limitations, indicating the presence of a digital divide.

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Table 8: Heterogeneity Analysis by Corporate Size

VARIABLES	(1)	(2)	(3)	(4)
	Creloan			
	0-25%	25%- 50%	50%-75%	75%-100%
Dige2	-0.361	-0.842	2.735	9.165***
	(2.634)	(2.297)	(2.142)	(1.637)
Control	YES	YES	YES	YES
Constant	-59.49*	-73.35	-99.83**	-60.96***
	(32.80)	(55.32)	(43.48)	(14.66)
Observations	4,514	4,639	4,655	4,664
R-squared	0.104	0.121	0.196	0.343
ind FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

6. Further Analysis

Operational risk is crucial for enterprises as it directly relates to their daily operations and long-term survival. However, within the risk framework of an enterprise, in addition to operational risk, litigation risk and fraud risk also significantly impact corporate operations and development. Therefore, this paper further examines the impact of digital finance development on corporate fraud risk and litigation risk.

First, the impact of digital finance development on corporate fraud risk is analyzed, following the approach of Yin Changping et al. (2023). The ratio of other receivables to total assets, a proxy for the second type of agency cost, is used to measure corporate fraud risk. The estimation results using Model (1) are shown in Column (1) of Table 9. The estimated coefficient is significantly negative, indicating that digital finance development can effectively reduce corporate fraud risk. This may be because digital finance development promotes the digital transformation of enterprises, alleviating the information asymmetry caused by internal principal-agent problems and increasing the opportunity cost of fraudulent behavior, thus reducing the likelihood of fraud risk. Specifically, this progress weakens the ability of internal controllers to “whitewash” financial reports for personal gain.

Second, the impact of digital finance on corporate litigation risk is analyzed. The corporate litigation risk indicator is constructed based on whether the enterprise is involved in significant lawsuits or arbitrations, with a value of 1 if involved and 0 otherwise. Since this variable is a binary discrete variable, a panel data Probit model is used for estimation. The results are shown in Column (2) of Table 9. Although the estimated coefficient is negative, it is not significant, indicating that digital finance development does not significantly impact corporate litigation risk. This may be due to two reasons: first, the relatively small sample size of enterprises involved in significant litigation or arbitration may lead to estimation bias; second, the causes of litigation cases usually include not only economic factors but also various non-economic factors such as contract disputes, product liability, and intellectual property infringement. Digital finance development mainly affects the economic conditions of enterprises, while its impact on non-economic factors may be limited, ultimately failing to significantly reduce litigation risk.

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Table 9: Further Analysis

VARIABLES	(1) Tunnel	(2) Lmpliti
Dige2	-0.00510***	-0.0984
	(0.000939)	(0.145)
Control	Yes	Yes
Constant	0.0179***	-1.168
	(0.00584)	(0.821)
Observations	18,483	17,998
R-squared	0.145	
ind FE	YES	YES
Year FE	YES	YES

7. Conclusion and Recommendations

The swift development of digital finance has significantly influenced corporate operations. This paper empirically examines the effects and transmission mechanisms of digital finance development on corporate operational risk. The findings reveal that digital finance can lower corporate operational risk by boosting R&D investment and easing financing constraints. Heterogeneity analysis indicates that the beneficial impact of digital finance in mitigating operational risk is more pronounced for state-owned and large-scale enterprises, highlighting a potential digital divide in digital finance development. Further research suggests that while digital finance development can also decrease corporate fraud risk, it has no significant effect on litigation risk. To further advance digital finance and enhance corporate risk prevention capabilities, the following recommendations are proposed.

First, further promote the development of digital finance and facilitate the digital transformation of enterprises. This study finds that digital finance can effectively reduce corporate operational and fraud risks. Therefore, efforts should be accelerated to improve digital infrastructure, support corporate digital transformation, enhance the accessibility of digital financial services, and effectively promote corporate digital transformation. Enterprises should align with the trend of digital finance development, adopt targeted measures to improve the digital literacy of their management, increase the proportion of digital talent, improve the investment and financing structure, and optimize business models to effectively reduce corporate risk and enhance risk prevention and mitigation capabilities.

Second, pay attention to the transmission channels through which digital finance affects corporate operational risk. This study finds that corporate R&D investment and financing constraints are key channels through which digital finance affects operational risk. Therefore, the advantages of digital finance as a new financial format should be fully utilized to accelerate the integration of digital finance and the real economy, reduce the cost of information elements, alleviate information asymmetry issues, further lower the barriers and costs to corporate financing, and address the problems of difficult and expensive financing for enterprises. This will ensure that financial resources reach where they are needed, enhance corporate innovation vitality, reduce operational pressures, and improve the ability to bear risks, thereby promoting high-quality economic development.

Finally, focus on developing inclusive digital finance to enhance the inclusiveness and commercial sustainability of digital finance. This study finds that digital finance development more significantly reduces operational risk for state-owned enterprises and large-scale enterprises, indicating a potential digital divide in the process of digital finance development. Therefore, the inclusive characteristics of digital finance should be emphasized to further narrow the regional digital finance development

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gap, promote balanced development of digital finance, lower the barriers to digital finance usage, and provide high-quality and effective digital financial services to small and medium-sized enterprises. This will help alleviate the financing difficulties and high costs faced by private and small and medium-sized enterprises, thereby reducing their operational risks and supporting the high-quality development of the macroeconomy and finance.

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