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Digital Transformation and Corporate Financial Risk: Evidence from Listed Companies in China

Xuanhong Chen[1†], Jiannan Chen[2]

1. School of Accounting and Finance, The Hong Kong Polytechnic University, Hongkong, China

2. School of Economics, Guizhou University, Guizhou, China

[†]Email: xhchen2003@gmail.com

Abstract

As a core issue in enterprise operation management, corporate financial risk is directly related to the survival and development of enterprises, and digital transformation has brought new challenges to the control of corporate financial risk. Based on the data of The Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) from 2009 to 2022, this paper analyzes the impact of digital transformation on corporate financial risk and the impact mechanism. The empirical study finds that digital transformation significantly increases the financial risk of enterprises, and shows differences among different regions, different risk factors, and enterprise natures, and substantially increases the corporate financial risk in the East and West, non-state-owned enterprises, high-risk and low-risk enterprises. The mechanism analysis found that digital transformation would affect the financial risk of enterprises by increasing their R&D investment and reducing their debt level. The conclusion improves insights and guidance for analyzing and managing financial risks in enterprises under digital transformation.

Keywords: Digital Transformation; Financial Risk; Debt Level

1 INTRODUCTION

With the continuous development of digital technologies represented by computer information technology, the Internet, and artificial intelligence, the digital economy has become a new engine for promoting economic development. The Recommendations of the Central Committee of the Communist Party of China on the Fourteenth Five-Year Plan for the System of National Economic and Social Development and the Visionary Goals for the 23rd Five-Year Plan propose to continuously promote the industrialization of the digital industry and the digitization of industry and to combine traditional producers, production products and production objects digitally. "Accelerating digital development and building a digital China" has become the keynote of China's current economic development. Developing a digital economy, promoting innovation and growth, improving efficiency and competitiveness, and realizing sustainable development are the strategic goals of China's economic development. As an indispensable part of developing a digital economy, the digital transformation of enterprises not only improves their business efficiency and productivity but also improves the customer experience and promotes innovation and competitive advantages. Through digital technologies, enterprises can better understand and meet customer needs, improve the accuracy and speed of decision-making, and create sustainable business models. Digital transformation has become indispensable in driving high-quality business growth.

Today, digital transformation occupies an important position in the business environment and has become one of the key strategies for enterprises to enhance their competitiveness and adapt to the fast-changing market [1]. With the rapid development of technology, the opportunities and challenges faced by enterprises have become more and more complex. In the digital era, enterprises no longer rely solely on traditional business models and experiences but actively explore the application of digital technologies to achieve innovation, improve efficiency, and better meet changing market demands.

Corporate financial risk, as a core issue in business operations, is directly related to the survival and development of

enterprises, and digital transformation puts forward brand-new tests and opportunities for enterprise financial risk management. The development of digital transformation significantly increases the uncertainty of business activities, which in turn increases the financial risk of enterprises [2].

Based on the data of The Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) from 2009 to 2022, this paper empirically investigates the impact of digital transformation on financial risk by using a fixed effects model, which helps to better understand the new characteristics of enterprise financial risk in the digital era and provides insights for enterprises in the areas of analyzing risk sources and conducting risk management. The possible marginal contributions of this paper are: first, this paper analyzes the impact of digital transformation on enterprise financial risk from a digital perspective, enriching the existing relevant research on enterprise digital transformation; second, further clarifying the mechanism of the impact of digital-for-transformation on enterprise financial risk. Theoretical analysis shows that digital transformation will increase the enterprise's R&D investment, occupy the enterprise's limited funds, and lead to an increase in financial risk. At the same time, enterprises in the digital transformation will significantly reduce the enterprise asset-liability ratio, the reduction of liabilities makes enterprises tend to equity financing, and the negative information brought by equity financing exacerbates the enterprise's financial risk; What's more, combined with the mechanism of the impact of digital transformation on the enterprise's financial risk, put forward some policy insights by local conditions, which provides a reference for how enterprises can ensure financial stability while pursuing technological innovation.

2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

Facing the rapidly changing market, enterprises must fully grasp their risk factors to achieve high-quality development. One of the characteristics of financial risk is uncertainty, and the continuous development of digital transformation has further deepened this uncertainty. According to the theory of information asymmetry, when enterprises carry out digital transformation, they can grasp more information about themselves, but their customers, investors, and other stakeholders are in the information disadvantage party, which will lead to the use of some of the consumer's information to carry out differential pricing, which increases the consumer's distrust of the enterprise [3]. At the same time, digital transformation will reduce the production cost of enterprises, promote competition among enterprises [4], and aggravate the uncertainty factor of enterprise development. Digital transformation will alleviate the financing constraints of enterprises to a certain extent, and the ability of enterprises to obtain funds becomes stronger [5], on the one hand, abundant funds will lead enterprises to innovate [6], reduce the cost of financing, and enhance the ability of enterprises to withstand risks, on the other hand, the unconstrained funds may cause enterprises to accelerate the expansion or carry out high-risk investment, making enterprises face greater risks. At the same time, the digital transformation will make enterprises more dependent on the globalized supply chain [7,8], and global events (e.g., natural disasters, pandemics, etc.) may have a serious impact on this supply chain, which makes the enterprises may face supply chain disruptions, logistics, and other problems. This affects the production and daily operations of the firms and exacerbates the risk of the firms. Xin & Guo [9] argue that the development of digital transformation means that companies tend to diversify their business strategies, which leads to greater audit risk. The digital management approach may require changes in the organizational structure, business processes, and work styles of the firm, which may cause employee discomfort and resistance [10]. If an organization fails to adequately train and support its employees, employee productivity and job satisfaction will decrease and may even trigger employee turnover, which will have an impact on the organization's production operations. Digital transformation will not only increase the uncertainty of enterprise production and operation, but also have an impact on the capital market, and some scholars believe that digital transformation will exacerbate the fragmentation of ownership, which exacerbates the volatility of stock prices [11]. Behavioral finance theory emphasizes the impact of market psychology and feedback loops on share prices, and a fall in share prices may trigger negative feedback loops that increase risk aversion among market participants, leading to further capital outflows and share price declines [12]. This chain reaction not only affects a company's market capitalization but may also increase its financing costs and financial risks. Therefore, the direct impact of digital transformation of enterprises on financial risk is to increase the uncertainty of business operations. In summary, this paper proposes the following hypotheses:

Hypothesis 1: Digital transformation significantly increases the financial risks faced by enterprises.

The primary factor for digital transformation is to have the proper technology infrastructure and tools, which include hardware devices, network connectivity, software systems, data storage and processing capabilities, etc. Talents with appropriate capabilities are also needed to drive and maintain the infrastructure, which will undoubtedly increase the share of labor costs and labor income of the enterprise [13,14]. With the development of digital transformation, various legal and regulatory requirements are also evolving, which may expose enterprises to more legal compliance pressure. Due to the legal requirements related to data privacy, cybersecurity, and intellectual property rights [15], enterprises may need to invest more resources and efforts to ensure their compliance, or they may face consequences such as fines, lawsuits, and reputational damage. Digital transformation has led companies to favor digital management and increase their R&D investment funds [16]. Most enterprises have limited funds, and all of the above factors will occupy the enterprise's funds, on the one hand, the enterprise's limited funds invested in R&D or manpower for digital transformation will cause the enterprise to lose a certain amount of investment opportunities [17]. On the other hand, the occupation of the funds will lead to the enterprise facing a larger funding gap, and for the enterprise whose liquidity is tight in itself; the capital occupation will cause the enterprise to face a larger capital gap, for the enterprise itself is tight liquidity, will undoubtedly exacerbate the enterprise's capital gap, leading to the enterprise cannot fulfill the obligation to pay the capital and interest on time, and the possibility of financial crisis becomes larger.

Enterprises often require significant upfront investment in digital transformation, including but not limited to the purchase of software, hardware, cloud service subscriptions, and the transformation of existing IT infrastructure, and the lack of capital forces enterprises to recapitalize [18]. From the perspective of creditors, they tend to get stable returns, so creditors will carefully examine the industry and market conditions of the enterprise [19]. However, digital transformation increases the uncertainty of business operations, leading creditors to worry about the risk that companies will fail to repay principal and interest when due, thus reducing debt investment or increasing debt costs [20]. From the bank's point of view, the bank prefers that the funds can be lent to enterprises with stable operations and many fixed assets for collateral security [21]. Digital transformation makes enterprises tend to invest in intangible assets [22], the proportion of fixed assets decreases, and the assets available for collateralized security decreases, thus making it difficult for enterprises to obtain only enough funds from banks. Pecking order theory (also known as preferential financing theory) suggests [23] that in the presence of transaction costs and information asymmetry, firms will prioritize debt financing followed by equity financing in their external financing. In the process of digital transformation, it is difficult for enterprises to use debt financing to meet their capital needs, forcing them to choose equity financing. The negative effects of equity financing in terms of high cost, reduced control due to dilution of ownership, and fixed dividends [24] will exacerbate the risk of enterprises. Meanwhile, capital structure theory requires that the optimal capital structure must have a reasonable level of debt, and the tax shield effect of debt can increase the value of the enterprise [25]. Digital transformation reduces the debt capacity of enterprises, which leads to the difficulty of constructing an optimal capital structure and the inability to make full use of its resources to maximize profits when making capital structure adjustments. Credit rating agencies such as Moody's, Standard & Poor's, and Fitch give credit ratings to enterprises by comprehensively evaluating their financial status, industry position, market competitiveness, and other factors. A capital structure that is not optimal may lead to a lower credit rating, and a lower credit rating increases the cost of corporate finance because creditors and investors will demand higher interest rates to compensate for the increased risk [26]. This increased financing cost further increases the financial pressure on the firms, which may fall into a vicious cycle of debt. In summary, this paper proposes the following hypothesis:

Hypothesis 2: Digital transformation will exacerbate corporate financial risk by increasing corporate R&D investment.

Hypothesis 3: Digital transformation will increase enterprise financial risk by reducing the enterprise's debt level.

3 RESEARCH DESIGN

3.1 Model Construction

Referring to Qi et al. [27], this paper constructs the following fixed effect model to analyze the impact of digital

transformation on corporate financial analysis:

$$Z_{i,t} = \alpha_0 + \beta_1 Digital_{i,t} + \beta_2 controls_{i,t} + \gamma_i + \delta_i + \varepsilon_{i,t} \quad (1)$$

Where $Z_{i,t}$ denotes the level of financial risk in the firm i in period t, and eventually the coefficients are standardized. α_0 is the intercept term, which is also called the constant term. $\beta_1 \beta_2$ is the regression coefficient of the variable. $Digital_{i,t}$ denotes the level of digital transformation in the firm i in period t, which is obtained using word frequency statistics, and again the coefficients are standardized. $controls_{i,t}$ is the control variable, which mainly consists of several other characteristic variables that can have an impact on the financial risk of the firm, including seven control variables for the ratio of the first largest shareholder's shareholding (Top1), development capacity (growth), capital intensity (Cap_intensity), nature of the firm (Soe), number of boards of directors (Boardsize), solvency (Debt), and cash flow (Cfo). γ_i is the firm i's unobservable individual fixed effects. δ_i is a time-fixed effect. $\varepsilon_{i,t}$ is a random disturbance term.

3.2 Setting and Calculation of Key Variables

(1) Explained variables. Enterprise financial risk (Z): in this paper, the Z-Score model [28] is chosen to represent the level of financial risk of enterprises, and the Z-Score model is calculated as:

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5 \quad (2)$$

where X_1、X_2、X_3、X_5 is the firm's working capital, retained earnings, interest rate before interest and taxes (EBIT), and sales revenue divided by the firm's total assets, respectively. X_4 denotes the total market value of equity divided by the total book value of liabilities. The final calculated Z-value indicates the level of financial risk of the company, and the larger the Z-value, the smaller the likelihood that the enterprise will incur financial risk [$Z < 1.8$, bankruptcy zone; $1.8 \leq Z < 2.99$, gray zone; $2.99 < Z$, safety zone]. Considering the different magnitudes of each variable, the coefficients are standardized in this paper to remove the magnitude [29]. The sZ values after standardization are finally used for regression.

The standardized treatment is mainly to achieve comparability, which mainly includes three points: variable comparability [30], between-group comparability [31], and cross-period comparability [32]. The standardized score method used in this paper is the Standardization method, as follows:

$$x' = \frac{x - mean(x)}{\sigma} \quad (3)$$

where $mean(x)$ represents the mean of the variable and σ represents the standard deviation. After standardization, the data will conform to a distribution where the mean will be 0 and the standard deviation will be 1.

(2) Explanatory variables. Digital transformation level: for enterprises, digital transformation is a very cumbersome and systematic process, leading to the difficulty of portraying the degree of enterprise digitization at the micro level, and the existing studies mainly start from the enterprise's macro point of view and use the industry level or regional digital economy indexes instead of the level of digital transformation. Some studies measure the degree of digital transformation of enterprises from the micro level of information technology employees, information assets, and information technology system applications. Still, these methods cannot portray the full picture of the enterprise's digital transformation. For example, Qi et al. [33] used the intangible assets ratio to measure the level of enterprise's informationization investment, and this metric ignores the practical problem that the level of enterprise's informationization investment does not necessarily represent the level of enterprise's application of informationization. Another part of the literature adopts the method of questionnaire survey and applies the percentage of employees using computers to measure the degree of digitalization application by enterprises [34], which is limited by two aspects [13]: firstly, pure computer application is only the behavior of network application, and does not represent the degree of digitalization of the enterprise; secondly, the way of questionnaire survey often leads to poor representation due to the number of questionnaires. With the extensive use of text analysis in the field of economics and finance, more and more scholars have begun to use the method of text analysis to measure the degree of digital transformation of enterprises. For example, Wu et al. [35], Zhao et al. [36], Xu & Sheng [37], and Qi & Cai [38] use annual reports of listed companies to conduct text analysis, construct a dictionary of keywords, and then

portray the degree of digital transformation of enterprises through the number of word frequencies.

In this paper, we download all the annual reports of SSE and SZSE from the official website of CNINFO, referring to the dictionaries constructed by Wu et al. [35] and Zhao et al. [36]. Next, we build the lexicons from eight dimensions, such as big data technology, blockchain technology, AI technology, cloud computer technology, application of digital technology, internet business model, intelligent manufacturing, and modern information system, respectively. Then we use Python crawler technology to crawl the keyword dictionary while eliminating the existence of "no", "not", "did not" and other negative words in front of the keyword expression, to build enterprise Digital Transformation Indicators.

To verify that the lexicon constructed in this paper is reasonable, this paper uses the lexicon word frequency of Zhao et al. [36] and the digital transformation word frequency given by the CSMAR database alone to do a trend comparison. The results are shown in Figure 1, which shows that the number of the digital transformation word frequency of the CSMAR database is roughly the same as the number of the word frequency of Zhao et al. [36]. However, the number of digital transformation word frequencies constructed in this paper is higher than those of the CSMAR database and Zhao et al. [36], which is because the lexicon constructed in this paper is a synthesis of Zhao et al. [36] and Wu et al. [35], and thus the number of lexicons is higher than that of a single author. From the year trend, the three-word frequency quantities become more with time and remain largely consistent in the trend, which verifies the reasonableness of the lexicon constructed in this paper. To ensure the robustness of the results, this paper continues to use the number of word frequencies of CSMAR as the level of digital transformation to carry out the stability test.

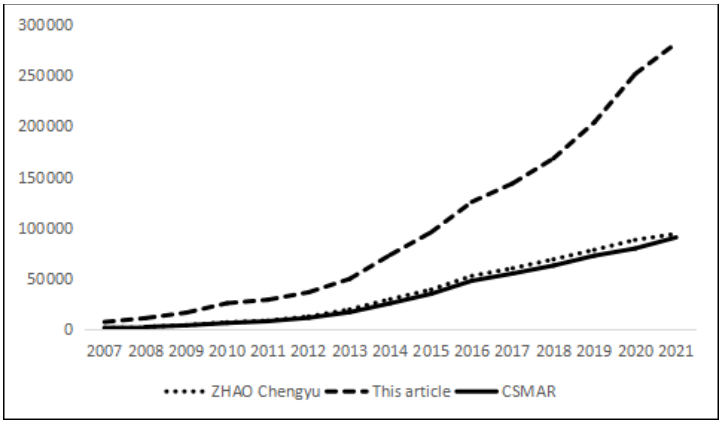

FIG. 1 DIGITAL TRANSFORMATION WORD FREQUENCY ANNUAL STATISTICS

(3) Other control variables: this paper refers to the existing literature [35,33,6] and uses seven control variables which are the ratio of the first largest shareholder's shareholding (Top1), development capacity (growth), capital intensity (Cap_intensity), nature of the firm (Soe), number of boards of directors (Boardsize), solvency (Debt), and cash flow (Cfo).

TABLE 1 DEFINITIONS OF KEY VARIABLES AND DATA SOURCES

Variable type	Variable symbol	Variable name	Unit	Variable definition	Data source
Explained variable	sZ	Financial risk		Z-Score model standardization	CSMAR
Explained variable	sDigital	Digital transformation level	Number of word frequency	Word frequency statistics standardization	CNINFO
Other control variables	Top1	Top1 Shareholding ratio of the first largest shareholder	%	Shareholding ratio of the first largest shareholder	CSMAR
	Growth	Growth capacity	%	Operating income growth rate	CSMAR
	Debt	Debt Solvency	%	Cash ratio	CSMAR

	Soe	Nature of enterprise		1 for SOEs, 0 for non-SOEs	CSMAR
	Boardsize	Boardsize	Number of people	Number of board members	CSMAR
	Cfo	Cash Flow		Net Cash Flow from Operating Activities / Total Assets	CSMAR
	Cap_intensity	Capital intensity	%	Capital intensity	CSMAR
Mechanism variable	RD	R&D investment	%	R&D expenditures taken as logarithmic plus 1	CSMAR
	Lev	Debt level	%	Gearing ratio	CSMAR

3.3 Data Source and Data Processing

The company basic information data selected for this paper comes from the database of CSMAR, and the information on digital transformation comes from the annual reports of listed companies on CNINFO. To make the sample data more representative, this paper refers to the existing literature [6] to do the following processing of the data: 1.Considering the specificity of the financial industry, this paper excludes the data of the financial sector according to the industry classification of the Securities and Exchange Commission (SEC); 2.excludes the data of listed companies that have been labeled as ST, ST*, and *ST during the listing period; 3.excludes all the missing values of the variables; 4. to avoid the influence of outliers on the final results, the article carries out the 1% shrinking treatment for continuous variables; 5. To achieve the comparability between the variables, this article does the standardization treatment for the explained variables and the explanatory variables respectively, and the standardization treatment method is shown in the above. After the above processing, 33527 data are obtained from 2009-2022.

3.4 Descriptive Statistics

Table 2 describes the basic characteristics of the main variables, in which Z and Digital indicate the data before standardization, respectively. From the table, the minimum value of Z is 0.3224, and the maximum value is 35.0733, which indicates that the degree of financial risk of different enterprises has a large difference, and the mean value of Z is 5.0243, which indicates that the degree of financial risk of the listed companies used in this paper is generally low. The mean value of Z value is 5.0243, which means that the financial risk level of listed companies used in this paper is generally low, and most of the enterprises do not have financial risk, which may be caused by the stricter management of listed companies in China. At the same time, the mean of the Z value is much larger than the median, which indicates that the method of standardizing the Z value in this paper and using the standardized sZ value to represent the financial risk of enterprises in the regression is reasonable. Table 3 also describes the digital transformation word frequency (Digital) which is not standardized, and the mean value of Digital is 35.2892, and the median is 14, which has serious right skewed characteristics, so it is reasonable for this paper to use sDigital after standardization of digital transformation word frequency (Digital) to represent the level of digital transformation of enterprises.

TABLE 2 DESCRIPTIVE STATISTICS OF MAJOR VARIABLES

Variable Name	Sample Size	Mean	Standard Deviation	Minimum	Median	Maximum
Z	33527	5.0246	5.4708	0.3224	3.3020	35.0733
Digital	33527	35.2892	57.1354	0.0000	14.0000	335.0000
sZ	33527	0.0000	1.0000	-0.8595	-0.3149	5.4926
sDigital	33527	-0.0000	1.0000	-0.6176	-0.3726	5.2456
Top1	33527	35.0714	14.7247	9.3900	33.1100	74.8200
Cfo	33527	9.88e+08	7.98e+09	-4.35e+10	1.33e+08	3.67e+11
Boardsize	33527	9.9162	2.5017	5.0000	9.0000	18.0000
Debt	33527	1.1443	2.8861	-0.0716	0.4453	167.5440
Cap_intensity	33526	6.1731	602.8090	0.0876	1.9077	1.10e+05
Soe	33527	0.3413	0.4741	0.0000	0.0000	1.0000
Growth	33527	0.1650	0.3378	-0.5106	0.1152	1.8749

Table 3 describes the trend of digital transformation word frequency (Digital) by year and region, and from the results, with the popularization and application of new generation of digital information technology such as digital technology, cloud computers, blockchain, artificial intelligence, and other digital information technologies, the level of development of digital transformation has shown a rising trend year by year. Through the horizontal comparison of different regions at the same time level, the number of listed companies in the sample period is higher in the eastern region, which has a higher number of occurrences of digital transformation word frequency than the eastern and western regions because of the high level of technological progress and economic development. This paper also finds that the number of listed companies in the central region has always been much higher than that in the western region, but the degree of digital transformation in the western region is gradually approaching that of the eastern region, which may be due to the following two factors: 1.Some more developed cities in the western region (such as Chengdu, Chongqing, Kunming, etc.) are gradually catching up with or even surpassing some cities in the central region due to the rapid development of their economic strength. These regions contribute most of the digital transformation word frequency, thus causing the western region to approach the central region. 2. in 2015, the first national data center - disaster recovery center and Huawei and other major Internet company's data centers settled in Guizhou, greatly enhancing the western region for the degree of attention to digital transformation, resulting in a substantial increase in the frequency of digital words in the western region.

TABLE 3 TRENDS IN DIGITAL TRANSFORMATION WORD FREQUENCIES BY YEAR AND REGION

Year	Eastern Region		Central Region		Western Region	
	Number of observations	Mean value	Number of observations	Mean value	Number of observations	Mean value
2009	729	7.7860	211	5.6730	162	5.5432
2010	959	9.7956	252	6.6389	188	6.2500
2011	1152	13.7743	290	9.2724	201	8.5274
2012	1253	14.5754	301	10.1063	213	8.5775
2013	1249	17.5653	299	11.5552	212	11.3443
2014	1317	22.1131	304	15.0033	220	16.1909
2015	1444	29.1454	330	20.4121	239	20.3305
1611	1611	34.2060	342	26.0731	268	24.5261
2017	1971	38.1882	380	29.0342	285	30.0561
2018	2059	43.0228	398	31.0904	301	32.5449
2019	2185	47.9089	413	34.4044	316	34.5063
2020	2444	52.7042	474	38.8333	338	37.6509
2021	2857	56.4008	553	43.6420	381	39.9449
2022	3150	58.5590	601	44.9401	423	43.6123

4 ANALYSIS OF EMPIRICAL RESULTS

4.1 Benchmark Regression Results

Table 4 depicts the regression results of the fixed effects model of digital transformation on corporate financial risk, column (1) indicates the regression results when no control variables are added, column (2) indicates the regression results after control variables are added, and columns (3) and (4) indicate the regression results after fixing the individuals and fixing the time. The empirical results show that the coefficient of digital transformation level is significantly negative in all four regressions. It indicates that the constructed coefficient of the effect of digital transformation on corporate financial risk is negative and significant at a 1% level, which indicates that digital transformation exacerbates corporate financial risk, i.e., Hypothesis 1 is verified. In terms of economic significance, for example, in column (4), when the level of digital transformation (sDigital) increases by one unit, the corresponding corporate financial risk (sZ) will decrease by 0.0826 units, i.e., corporate financial risk will increase. The possible reason for this is that when a company decides to undergo digital transformation, it will spend the company's limited funds on purchasing digital equipment and hiring digital professionals, which makes the company's funds tight and leads to financial risk as the company is unable to pay its debtors in full and on time.

The relationship between the control variables in the regression results and the financial risk of the enterprise also basically meets the theoretical expectations: the coefficient of the ratio of the first shareholder's shareholding (Top1) is also negative and significant at the 1% and 5% level, indicating that the more the ratio of the first shareholder's

shareholding, the greater the financial risk of the enterprise; the coefficient of the debt service capacity (Debt) is significantly positive at the 1% level, indicating that the stronger the debt service capacity of the enterprise, the lower the financial risk. The coefficient of debt serviceability (Debt) is significantly positive at a 1% level, indicating that the stronger the debt serviceability, the lower the financial risk.

TABLE 4 BENCHMARK REGRESSION RESULTS

	(1) sZ	(2) sZ	(3) sZ	(4) sZ
sDigital	-0.1088***	-0.0668***	-0.1073***	-0.0826***
	(-10.7355)	(-7.3676)	(-7.0931)	(-6.2317)
Top1		-0.0026***		-0.0025**
		(-4.0679)		(-2.5348)
Cfo		0.0000		0.0000***
		(0.4724)		(3.2677)
Boardsize		-0.0021		-0.0012
		(-1.0084)		(-0.5779)
Debt		0.0831***		0.0688***
		(6.8387)		(6.1712)
Cap intensity		-0.0000***		-0.0002**
		(-4.6255)		(-2.0268)
Soe		-0.2065***		-0.0715*
		(-8.8458)		(-1.6868)
Growth		0.0437***		0.0128
		(3.3934)		(0.9875)
Fixed Individual	N	N	Y	Y
Fixed year	N	N	Y	Y
Control Variables	N	Y	N	Y
Sample size	33,526	33,526	33,526	33,526
Within-R2	0.0158	0.0781	0.0858	0.1502

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, t-values in parentheses, same below

4.2 Endogeneity Test

Although the endogeneity problem has been avoided as much as possible in the selection of variables, the endogeneity problem will inevitably arise due to the omission of variables, selection bias, and so on. To further control the possible endogeneity problem, therefore, this paper uses the propensity score matching method and instrumental variable method to address endogeneity.

(1) Propensity score matching method. In this paper, with the help of the method of He Yanlin et al. [39], the digital transformation level of enterprises is grouped according to the median, and the samples with the level of digital-for-transformation higher than the median are defined as high digital transformation (treatment group) and the samples with the level of digital-for-transformation lower than the median are defined as low digital transformation (control group). The propensity score values were calculated using logit regression. The above control variables were used as covariates. Referring to He et al. [40], the propensity score value was selected using the nearest neighbor method, 1:1 no-return matching was performed between the two groups, and the regression was performed using the matched samples. The regression results are shown in column (1) of Table 5, the coefficient of digital transformation on corporate financial risk is significantly negative at the 1% level, which is consistent with the previous findings.

(2) Instrumental variable method. This paper refers to Huang et al. [41] who chose the product of the number of Internet broadband access ports and the number of post offices in 1984 as the instrumental variable, the number of

Internet broadband access ports reflects the level of digital infrastructure, which is directly associated with the enterprise's ability to carry out the digital transformation, while the number of post offices in 1984 serves as a measure of the level of the communication infrastructure and socio-economic development of the time, which indirectly affects the operating environment and technological adaptability of contemporary businesses. This combination reflects a region's long-term support system for technological and economic development and is closely related to digital transformation, thus satisfying the strong correlation condition that instrumental variables should have. The regression results after addressing endogeneity using instrumental variables are shown in column (2) of Table 5, and the regression results are significantly negative and significant at the 1% level, consistent with the previous findings and further validating the robustness of the paper's conclusions.

TABLE 5 ENDOGENEITY TEST

	（1）	（2）
	sZ	sZ
sDigital	-0.0453***	-0.2080***
	(-3.7450)	(-8.6039)
Top1	-0.0030***	-0.0034***
	(-2.6383)	(-4.5593)
cfo	0.0000***	0.0000***
	(2.8065)	(3.5921)
Boardsize	-0.0018	0.0026
	(-0.6726)	(1.3212)
Debt	0.0681***	0.0651***
	(5.5972)	(38.8284)
Cap_intensity	-0.0041***	-0.0002*
	(-6.0506)	(-1.6576)
Soe	-0.1276**	-0.1024***
	(-2.4760)	(-3.6048)
Growth	-0.0174	0.0243**
Top1	(-1.0930)	(2.2469)
Fixed Individual	Y	Y
Fixed time	Y	Y
Control Variables	Y	Y
Sample size	17,834	33,182
Within-R2	0.1596	0.0736

4.3 Robustness Test

(1) Excluding 2015 data. Considering that China had a stock market crash in 2015, which led to the risk faced by many enterprises becoming larger. Therefore, the data in 2015 may interfere with the regression results of this paper. In this paper, the 2015 data in the sample period is excluded to further enhance the credibility of the results of this paper. The regression results are shown in columns (1) and (2) of Table 6, after excluding the data in 2015, the coefficient of the digital-for-transformation level is negative and significant at the 1% level regardless of whether the time and individual are fixed or not, indicating that the digital transformation exacerbates the financial risk of the enterprise, which is consistent with the previous regression results.

(2) Replacement of explanatory variables. The word frequency used in this paper to measure the level of digital transformation is a synthesis of Wu et al. [35], Zhao et al. [36], and the statistical frequency of the word frequency is different from that of the two scholars' methods alone, and this paper continues to use the level of digital transformation given by Cathay Pacific (sDig) to conduct the robustness test. The results are shown in columns (3) and (4) of Table 6, and in column (4), for example, the coefficient of the impact of digital transformation on corporate financial risk is -0.0684, which is significant at the 1% level after fixing the time and individual. It is consistent with the previous findings.

TABLE 6 ROBUSTNESS TEST1

	(1)	(2)	(3)	(4)
	sZ	sZ	sZ	sZ
sDigital	-0.0569***	-0.0749***		

	(-6.3360)	(-5.6700)		
sDig			-0.0425***	-0.0684***
			(-3.7853)	(-4.2848)
Top1	-0.0030***	-0.0026***	-0.0003	-0.0001
	(-4.8801)	(-2.7585)	(-0.4202)	(-0.0946)
Cfo	0.0000	0.0000***	-0.0000	0.0000***
	(0.6125)	(3.0835)	(-0.5354)	(3.1340)
Boardsize	-0.0026	-0.0007	-0.0010	-0.0005
	(-1.2606)	(-0.3580)	(-0.3913)	(-0.1927)
Debt	0.0825***	0.0686***	0.0979***	0.0723***
	(6.9753)	(6.3234)	(3.8642)	(3.0365)
Cap_intensity	-0.0000***	-0.0002**	-0.0001**	-0.0002***
	(-4.7317)	(-2.0126)	(-2.1838)	(-6.6156)
Soe	-0.1736***	-0.0628	-0.2327***	-0.0551
	(-7.2696)	(-1.4559)	(-8.6131)	(-1.3298)
Growth	0.0637***	0.0186	0.0754***	0.0183
	(5.2661)	(1.5119)	(4.6325)	(1.0951)
Fixed Individual	N	Y	N	Y
Fixed time	N	Y	N	Y
Control Variables	Y	Y	Y	Y
Sample size	31,496	31,496	21,443	21,443
Within-R2	0.0920	0.1345	0.0640	0.1527

(3) Lagged explanatory variables. The level of digital transformation obtained in this paper is obtained through word frequency statistics of annual reports of listed companies, after standardization, since enterprises may only be laying out for the future when proposing relevant terms, and not currently carrying out work related to these terms. Using the current word frequency to represent the current level of digital transformation may interfere with the results. After considering this factor, this paper lags the explanatory variables by one period and two periods respectively to conduct robustness tests. The regression results are shown in columns (1) and (2) of Table 7, with column (1) representing the regression results with one lag. The results show that the coefficient on the level of digital transformation is -0.0958, which is significant at the 1% level. Column (2) represents the regression results with two periods lagged. The results show that the coefficient on the level of digital transformation is -0.0873, which is significant at the 1% level. The above results show that the level of digital-for-transformation significantly increases corporate financial risk, both in one-period lag and two-period lag, which is consistent with the previous findings.

(4) Reduction of sample size. Taking into account China's regional development imbalance, some regions are more economically developed, some regions are more economically backward, and the diversity of financing, business operations, and means of risk resistance of enterprises in economically developed places will affect the impact of digital transformation on enterprise financial risk; at the same time, the regional economy is more backward due to these constraints, and the enterprise's financial risk may not be due to digital transformation Therefore, this paper conducts a robustness test according to the regional GDP rankings released by China in 2022, excluding the top three and bottom three provinces in terms of GDP ranking [According to the China Statistical Yearbook, China's provincial GDP rankings in 2022, the top three are Guangdong Province, Jiangsu Province and Shandong Province, respectively. The bottom three rankings are Ningxia Hui Autonomous Region, Qinghai Province, and Tibet Autonomous Region respectively].

The test results are shown in columns (3) and (4) of Table 7. Column (3) is the result without fixing individuals and time, and column (4) is the regression result after fixing individuals and time. As can be seen from the results, the impact of digital transformation on the financial risk of enterprises is significantly negative at the 1% level regardless of whether individuals and time are fixed or not, indicating that digital transformation exacerbates the financial risk of enterprises based on considering the imbalance of regional economic development, which further validates the conclusions of this paper.

TABLE 7 ROBUSTNESS TEST2

	(1)	(2)	（3）	（4）
	sZ	sZ	sZ	sZ
L1.sDigital	-0.0958***			

	(-6.4293)			
L2.sDigital		-0.0873***		
		(-5.5175)		
sDigital			-0.0729***	-0.0862***
			(-6.5226)	(-5.3878)
Top1	-0.0023**	-0.0018	-0.0036***	-0.0039***
	(-2.2137)	(-1.5808)	(-4.5240)	(-3.2139)
Cfo	0.0000***	0.0000***	0.0000	0.0000***
	(3.2565)	(3.0082)	(0.5039)	(2.6066)
Boardsize	-0.0028	-0.0022	-0.0016	0.0002
	(-1.3890)	(-1.0651)	(-0.6084)	(0.0665)
Debt	0.0867***	0.1103***	0.0836***	0.0675***
	(4.3287)	(3.4960)	(4.8808)	(4.1315)
Cap_intensity	-0.0067**	-0.0065***	-0.0001**	-0.0002**
	(-2.5450)	(-2.6075)	(-2.1015)	(-1.9818)
Soe	-0.0644	-0.0627	-0.2125***	-0.0737
	(-1.4586)	(-1.4495)	(-7.1228)	(-1.3693)
Growth	-0.0034	-0.0122	0.0363**	0.0065
	(-0.2585)	(-0.8333)	(2.3285)	(0.4054)
Fixed Individual	N	Y	N	Y
Fixed time	N	Y	N	Y
Control Variables	Y	Y	Y	Y
Sample size	28,931	24,987	22,058	22,058
Within-R2	0.1706	0.1765	0.0723	0.1381

5 HETEROGENEITY ANALYSIS

5.1 Heterogeneity Analysis based on Regionality

Considering that China's large land area and uneven distribution of regional resources have led to large differences in the level of regional economic development in China, and there are also large differences in economic development conditions, policy factors, and industrial agglomeration between different regions, so to examine in depth the differences in the impact effect of digital transformation on the financial risk of the enterprise in different regions, this paper, by the province where the enterprise is located, divides the sample into East, Central and West for sub-sample study.

The regression results are shown in Table 8, the coefficient of digital transformation in the three regions is negative, indicating that whether in the eastern region, central region, or western region, digital transformation hurts enterprise financial risk, that is, with the deepening of the level of digital transformation, the financial risk of the enterprise will be higher and higher. From the coefficient, the coefficient of the level of digital transformation in the east is -0.0476, central -0.0151, and western -0.0812. From the coefficient alone, the level of digital transformation on the enterprise financial risk of the negative effect of the level of digital transformation in the western region is the largest, which may be due to the western region of some of the big data centers have settled in Guiyang and Chengdu, Chongqing, Kunming and other regions of rapid economic development, leading to the rapid growth of the level of digital transformation of enterprises, the enterprise financial risk of the rapid growth of the level of digital transformation. This has led to a rapid increase in the degree of digital transformation of enterprises, but other aspects of the enterprise such as operating income, net profit, and other factors to resist risk did not increase with the increase in digital transformation, resulting in the financial risk faced by enterprises in carrying out digital transformation has become greater. The negative effect of the level of digital transformation on the financial risk of enterprises in the central region is the smallest and insignificant, which may be because enterprises in the central region pay more attention to balanced development, and other aspects of the enterprise increase based on deepening the level of digitization, resulting in the impact of digitization on the financial risk of the enterprise becomes smaller.

TABLE 8 RESULTS OF HETEROGENEITY ANALYSIS BASED ON REGIONALITY

	Eastern	Central	Western
	sZ	sZ	sZ
sDigital	-0.0476***	-0.0151	-0.0812**
	(-3.8392)	(-0.5064)	(-2.4015)
Top1	-0.0022*	-0.0042**	-0.0018

	(-1.8740)	(-2.1175)	(-0.5099)
Cfo	0.0000***	0.0000***	0.0000***
	(2.6443)	(3.6171)	(2.6071)
Boardsize	-0.0025	-0.0019	0.0043
	(-1.0487)	(-0.3458)	(1.0442)
Debt	0.0644***	0.1110***	0.0872***
	(5.4089)	(6.8080)	(8.1810)
Cap_intensity	-0.0001*	-0.0053***	-0.0119**
	(-1.8907)	(-10.6991)	(-2.0281)
Soe	-0.0422	-0.0243	-0.3232***
	(-0.7778)	(-0.3394)	(-2.7190)
Growth	0.0152	-0.0324	-0.0216
	(0.9804)	(-1.1087)	(-0.6912)
Fixed Individual	Y	Y	Y
Fixed time	Y	Y	Y
Control Variables	Y	Y	Y
Sample size	24,379	5,148	3,744
Within-R2	0.1584	0.1495	0.1493

5.2 Heterogeneity Analysis based on the Nature of Equity

Enterprises in China can be divided into state-owned enterprises, private enterprises, foreign-controlled enterprises, etc., and different enterprises face different risks and have different desires to carry out digital transformation. Among them, most of the private enterprises and foreign-controlled enterprises are in pursuit of profit maximization, and they tend to carry out digital transformation if it can increase the income of the enterprise, and vice versa, they will not carry out digital transformation. Therefore, this paper analyzes the heterogeneity of all listed companies in China by dividing them into SOEs and non-SOEs (including private and foreign-controlled enterprises).

The regression results are shown in the first two columns of Table 9, and the coefficients are negative for both SOEs and non-SOEs, indicating that neither SOEs nor non-SOEs will increase the financial risk of the enterprise when undergoing digital transformation. It is worth noting that the coefficient for non-SOEs is significantly negative at the 1% level, but the coefficient for SOEs is negative but not significant. The possible reason for this is that SOEs bear more social responsibility, which leads SOEs not to maximize their profits and cause themselves to face greater risks and will pay more attention to the control of risks when undergoing digital transformation. Therefore, the impact of digital transformation on the financial risk of state-owned enterprises is not significant.

5.3 Heterogeneity Analysis based on Risk Factors

Considering that different enterprises face different risks, which may ultimately lead to different enterprises' digital transformation effect on financial risk is also different, this paper divides the enterprises into high-risk enterprises and low-risk enterprises for the heterogeneity analysis, and its division standard is the introduction of the variable of the social security fund's position, taking into account the special nature of the social security fund, so the social security fund is generally invested in the enterprises with lower risk [42], so this paper classifies enterprises with the record of social security fund positions as low-risk enterprises, and enterprises without social security fund positions as high-risk enterprises. This leads to the heterogeneity analysis of risk factors.

The regression results are shown in the last two columns of Table 9, where the coefficients of both low-risk and high-risk firms are significantly negative at the 1% level. Among them, the coefficient of low-risk enterprises is -0.0310, and the coefficient of high-risk enterprises is -0.0768. From the coefficients alone, the negative effect of digital transformation on high-risk enterprises is higher than that of low-risk enterprises, indicating that when low-risk enterprises are undergoing digital transformation, since such enterprises are risk averse themselves, they will not promote the digital transformation of enterprises at the cost of increasing their risks. However, high-risk enterprises are themselves risk-preferring and face higher risks than low-risk enterprises. Due to the complexity and intersectionality of risks, the financial risks brought by such enterprises when undergoing digital transformation will promote other risks, and other risks will in turn promote the growth of financial risks, leading to an increase in the financial risks they face when undergoing digital transformation.

TABLE 9 REGRESSION RESULTS OF HETEROGENEITY ANALYSIS BASED ON NATURE OF EQUITY AND RISK FACTORS

	SOEs	Non-SOEs	Low-risk firms	High-risk firms
	sZ	sZ	sZ	sZ
sDigital	-0.0300	-0.0908***	-0.0310***	-0.0768***
	(-1.4380)	(-6.0742)	(-2.9189)	(-4.9271)
Top1	-0.0046***	-0.0011	-0.0028***	-0.0027**
	(-3.8308)	(-0.6738)	(-2.9290)	(-2.4444)
Cfo	0.0000**	0.0000***	-0.0000**	0.0000***
	(2.1596)	(2.5981)	(-2.4758)	(3.3195)
Boardsize	0.0012	-0.0011	-0.0043	-0.0031
	(0.5375)	(-0.3515)	(-1.1841)	(-1.2942)
Debt	0.1311***	0.0636***	0.1089***	0.0642***
	(3.7128)	(5.6654)	(6.2433)	(5.0540)
Cap_intensity	-0.0059*	-0.0002**	-0.0000***	-0.0047**
	(-1.6743)	(-1.9793)	(-3.5131)	(-2.2007)
Soe			-0.1451***	-0.1017*
			(-3.9899)	(-1.8211)
Growth	-0.0288**	0.0184	0.0021	0.0244
	(-2.0399)	(1.0201)	(0.0881)	(1.6251)
Fixed Individual	Y	Y	Y	Y
Fixed time	Y	Y	Y	Y
Control Variables	Y	Y	Y	Y
Sample size	11,442	22,084	26,850	6,638
Within-R2	0.1378	0.1706	0.2112	0.2343

6 MECHANISM ANALYSIS

The conclusions of the previous study show that enterprises undergoing digital transformation will significantly increase the financial risk faced by enterprises. To further discuss the mechanism of digital transformation on enterprise financial risk, this paper starts from two perspectives of R & D investment and debt level and refers to Wen et al. [43] using stepwise regression to carry out mechanism analysis.

6.1 Mechanism Analysis based on R&D Input

For most enterprises, the funds available to the enterprise are generally limited, and when the enterprise undergoes digital transformation, due to the purchase of digital equipment, hiring digital talents, digital R&D, etc., it will lead to the transfer of funds originally used by the enterprise for daily business activities. Therefore, enterprises with insufficient funds face a larger funding gap when they carry out digital switching transformation, and with the development of enterprise digital transformation, the R&D of digital transformation tends to increase the enterprise's demand for highly skilled labor talents [13], thus increasing the enterprise's salary expenditure, further deepening the enterprise's funding gap, affecting the enterprise's solvency, and leading to the enterprise facing a greater financial risk.

To examine the mechanism of the role of R&D investment costs on digital transformation and corporate financial risk, this paper refers to Ye et al. [44] to conduct a regression by adding 1 to the logarithmic measure of the enterprise's R&D expenditures to measure the enterprise's research and development (RD), and the regression results are shown in the first three columns of Table 10. The regression results in column (1) show that the coefficient of digital transformation on firms' R&D investment is significantly positive and significant at the 1% level, indicating that digital transformation can increase firms' R&D investment. The results in column (2) show that the expenditure on R&D investment on enterprise financial risk is significantly negative at the 1% level, indicating that the increase in R&D investment will, to a certain extent, take up the enterprise's working capital and debt servicing funds, exacerbate the enterprise's need for financing, and thus make the enterprise's financial risk larger. Column (3), after adding R&D investment, the coefficient of digital transformation and enterprise financial risk is no longer significant, which further verifies a mechanism of R&D investment's role in the relationship between digital transformation and enterprise financial risk, i.e., hypothesis 2 is verified.

6.2 Mechanism Analysis based on Debt Level

Reasonable debt level has multiple benefits for the company. First, debt financing can be utilized for its tax advantages by offsetting taxes through interest. Second, the cost of debt financing is usually lower than that of equity financing, which helps to improve the cost efficiency of capital. Through the moderate use of debt, a company can expand its total assets and use financial leverage to increase earnings per share and shareholder return. Reasonable debt levels also help optimize the capital structure, balance risk and return, minimize the cost of capital, and maximize firm value.

To examine the mechanism of the role of debt level in digital transformation and corporate financial risk, this paper uses the ratio of total liabilities to total assets to measure the debt level of enterprises (Lev). The empirical results are shown in the last three columns of Table 10, from the regression results in column (4), it can be concluded that the digital transformation significantly reduces the level of corporate liabilities, and at the same time, there are regression results in columns (5) and (6), which can be seen that the level of liabilities is positively correlated with sZ, which indicates that the higher the level of liabilities, the greater the sZ, and at the same time, the lower the financial risk of the enterprise. After adding the mediator variable, the regression coefficient of digital transformation on enterprise financial risk is still significantly negatively correlated, and the coefficient becomes smaller, indicating that the level of indebtedness plays a mediating role in it. Hypothesis 3 is verified.

TABLE 10 MECHANISM ANALYSIS RESULTS

	(1)	(2)	(3)	（4）	（5）	（6）
	RD	sZ	sZ	Lev	sZ	sZ
sDigital	0.0738***		-0.0188	-0.2403***		-0.0401***
	(4.4578)		(-1.5342)	(-4.5851)		(-3.7175)
RD		-0.0270***	-0.0263***			
		(-2.6794)	(-2.6269)			
Lev					0.1784***	0.1776***
					(26.6185)	(26.4287)
Top1	0.0074**	-0.0021	-0.0021	0.0098***	-0.0040***	-0.0042***
	(2.5101)	(-1.5984)	(-1.6216)	(3.0531)	(-4.9413)	(-5.2045)
cfo	0.0000**	0.0000***	0.0000***	0.0000***	0.0000**	0.0000**
	(2.0257)	(2.9348)	(2.9369)	(4.1901)	(2.0044)	(2.0098)
sum	0.0100***	0.0034	0.0034	0.0034	-0.0021	-0.0018
	(3.9297)	(1.3331)	(1.3435)	(0.6110)	(-1.1662)	(-1.0103)
Debt	-0.0206***	0.1050***	0.1048***	0.4602***	-0.0129	-0.0131
	(-5.0354)	(6.2946)	(6.2831)	(5.6241)	(-1.4706)	(-1.4785)
Cap_intensity	0.0001***	-0.0001	-0.0001	0.0002	-0.0002	-0.0002*
	(4.9132)	(-1.4020)	(-1.4047)	(0.6212)	(-1.6387)	(-1.6474)
Soe	-0.2310***	0.0032	0.0009	-0.2503	-0.0251	-0.0273
	(-4.4616)	(0.0644)	(0.0180)	(-1.6239)	(-0.8315)	(-0.9070)
Growth	0.2005***	0.0671***	0.0674***	-0.4169***	0.0868***	0.0869***
	(8.8003)	(3.6885)	(3.7042)	-0.4169***	0.0868***	0.0869***
Fixed Individual	Y	Y	Y	Y	Y	Y
Fixed time	Y	Y	Y	Y	Y	Y
Control Variables	Y	Y	Y	Y	Y	Y
Sample size	15,920	15,920	15,920	33,484	33,484	33,484
Within-R2	0.2295	0.0934	0.0936	0.3825	0.3415	0.3423

7 CONCLUSION AND POLICY RECOMMENDATIONS

Enterprises, as an important component of the economic system, in digital transformation, seizing digital opportunities, avoiding the negative effects of digitization, managing corporate financial risks, and promoting high-quality development of enterprises are important measures to promote high-quality development of the economy. This paper uses the data of listed companies from 2009-2022 to measure the digital transformation of enterprises by identifying the keyword frequency of digital transformation. The results find that digital transformation significantly increases corporate financial risk, and the conclusion still holds after considering a series of robustness tests and endogeneity tests. Heterogeneity analysis finds that the effect of digital transformation on corporate financial risk is significantly negative in East and West regions, non-state-owned enterprises, and high-risk

and low-risk enterprises. The mechanism analysis shows that digital transformation increases firms' financial risk by increasing firms' R&D investment and decreasing firms' debt level. Enterprises will increase their financial risks when undergoing digital transformation, but digital transformation will also significantly increase the competitiveness and efficiency of enterprises, so it is particularly important to strengthen the management of financial risks in the process of digitalization. Combined with the above conclusions, this paper proposes the following recommendations from the government and enterprise perspectives:

(1) Increase government support and strengthen the construction of infrastructure: first, the government should formulate differentiated support policies according to the specific conditions of the region, especially in the western region where the risk is higher, and the transformation cost of enterprises can be reduced by providing measures such as financial subsidies and tax incentives. Second, strengthening investment in infrastructure is key, improving access to the Internet and related technologies to provide the necessary physical foundation for the digital transformation of enterprises. In addition, establishing a risk monitoring and early warning system to provide enterprises with real-time risk assessment and coping strategies, especially in times of economic fluctuations or market changes, this mechanism can play an important role.

(2) Establish a sound mechanism to cope with risks: Given that digital transformation may increase the risk of enterprises relying on a globalized supply chain, enterprises should establish a plan to cope with unforeseen events, such as data leakage and supply chain disruption. This includes strengthening coordination and cooperation with suppliers to ensure a diversified and timely response capability of the supply chain; at the same time, increasing investment in cybersecurity and data protection to ensure the security and privacy protection of business data and reduce potential legal and financial risks. Make full use of the advantages of digital transformation, while avoiding the disadvantages of digital transformation as much as possible, to promote the high-quality development of the enterprise.

(3) Optimize liability structure and fund management: When making digital investments, enterprises need to rationally plan and optimize the use of funds, especially in the optimization of liability structure to achieve fine management. Enterprises should enhance their internal capital flow monitoring and liability level assessment mechanisms to ensure that normal financial health is not affected by excessive digital investment. Enterprises may consider multi-channel financing and prioritize lower-cost financing methods that can be stable in the long term, such as equity financing combined with government subsidies and tax incentives, to reduce the risks arising from the use of funds and an excessively low level of indebtedness.

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