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Digital transformation and the cost of bank loans in China

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Abstract

Purpose – This study aimed to analyze the impact of enterprise digital transformation on bank loan contracting from 2007 to 2021.

Design/methodology/approach – This study used an empirical approach to examine the impact of digital transformation on bank loan interest rates and the possible mechanisms. The digital transformation data of firms were obtained by Python, and the bank loan contracting information of Chinese listed firms was hand-collected from the notes of the annual report.

Findings – The results show that digital transformation can significantly reduce the bank loan interest rate and show heterogeneity in the nature of property rights, industry type and firm size. The above results remain significant after conducting a series of robustness tests. Channel tests suggest that digital transformation can promote total factor productivity, improve firms' information environment and reduce the risk of financial distress, thus helping them reduce their loan interest rate. In addition, banks' digital transformation can also affect the link between enterprise digital transformation and bank loan interest rates.

Originality/value – First, this paper deeply investigates the relationship between enterprise digital transformation and bank loan contracting, and the mechanisms behind it which expands the research on economic consequences of digitalization. Developing digitalization society has been a top priority in China as it is an urgent task to survive in the competitive global economic environment as a developing country. Second, in developed countries, the evidence relating to bank loan contracting is plentiful. However, the Chinese studies are still very limited as it has no database like Dealscan in US.

Keywords Digital transformation, Bank loan interest rate, Python text recognition, Mechanism analysis

Paper type Research paper

1. Introduction

In recent years, with the booming development of digital technologies such as big data and cloud computing, the digital economy has become the hot spot of the times. In this wave, China has made significant strides in technological innovation, particularly in areas of artificial intelligence, big data, cloud computing, and the Internet of Things (IoT). As one of the largest world economies, China is still a developing country with less developed industries than many developed countries. To sustain economic growth and enhance competitiveness, the Chinese government has been actively promoting digitalization as part of its national agenda. For example, "Made in China (2025)" and "Internet Plus" emphasize the importance of integrating digital technologies into traditional industries to upgrade the economy. Therefore, a growing number of scholars have begun to focus on digital transformation in the Chinese market.

Archival studies have found that the digital transformation of enterprises plays a positive role in innovating business models (Li, 2020), reducing stock crash risk (Wu *et al.*, 2022), and

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improving risk-taking ability (Tian *et al.*, 2022). It is conducive to enhancing the competitive advantage of enterprises and promoting the high-quality development of enterprises. However, few studies explore the impacts of digital transformation on corporate financing activities. Our study aims to fill this void and investigate the relationship between digital transformation and bank loan costs.

China's financial system is different from that of other countries. First, in a highly developed capital market, direct debt financing through the bond market can satisfy a large portion of borrowers' funding incentives (Rajan and Zingales, 1998). However, this is not the case in China. Until 2020, the security regulation just liberalized the bond market of China. The uneven development of China's debt market has led Chinese firms to rely heavily on indirect bank loan borrowing (Firth *et al.*, 2009; Allen *et al.*, 2005). Second, the legal environment and investor protection are relatively poor compared with other developed countries or areas like the US, Hong Kong, or the UK (La Porta *et al.*, 1998, 2000). Djankov *et al.* (2007) document that creditor protection in China is only 2 on a scale of between 0 (poor creditor rights) and 4 (strong creditor rights). Furthermore, Allen *et al.* (2005) also state that China's financial system is dominated by a large but undeveloped banking system, mainly controlled by the four largest state-owned banks, thus leading to Chinese listed firms' excessive dependence on bank loans. Therefore, exploring whether and how the new digitalization influences the bank loan contracting process would evaluate the effectiveness of China's banking system.

Following the previous literature, bank loan providers need to make lending decisions based on various information channels and make suitable decisions. Among the bank loan contract items, the most important one is the interest rate which represents the price of debt financing. Studying what factors will influence banks when deciding loan interest rates is of wide concern in both academic research and business practice around the world (Graham *et al.*, 2008; Lin *et al.*, 2011; Ge *et al.*, 2012; Kim *et al.*, 2015; Cen *et al.*, 2016). Studies of bank loan contracting determinants in China are limited due to the data limitation (Cui *et al.*, 2022; Chen *et al.*, 2022a). In the US, Dealscan provides scholars with a structural database to ascertain the loan term. In China, there is no such database and we have to collect the loan-level data manually. As a comprehensive change in the process of enterprise development (Verhoef *et al.*, 2021), digital transformation will affect the ability of enterprises to obtain resources by promoting better innovation output and business performance (Niu *et al.*, 2023; Llopis-Albert *et al.*, 2021; Peng and Tao, 2022), which will be reflected in the capital market. However, from the existing literature, few studies have included digital transformation and bank loans in the same framework for analysis.

Based on the above argument, this study used the Chinese A-share listed companies from 2007 to 2021 as the research object, using the manually collected corporate bank loan interest rate and the word frequency of digital transformation in corporate annual reports obtained by Python crawlers as the research data. The relationship between the digital transformation of the industry and the bank loan interest rate and its mechanism were empirically tested. The study found that the higher the degree of digital transformation of enterprises, the lower the interest rate of bank loans obtained. Furthermore, digital transformation works through the channels of promoting total factor productivity, improving the quality of the information environment, and reducing the risk of financial distress of enterprises, and the effect is more significant in non-state-owned enterprises, high-tech industries, and large-scale enterprises. The influence of digital transformation on the interest cost of bank loans is more pronounced when the lending banks have not engaged in digital transformation. After a series of robustness tests and endogeneity tests, the findings of this study still hold.

The marginal contributions of this study are mainly reflected in the following aspects. First, this study deeply investigated the relationship between enterprise digital transformation and bank loan contracting, and the mechanisms behind it to expand the research on the economic consequences of digitalization. Developing a digitalization society has been a top priority in China as it is an urgent task to survive in the competitive global economic environment as a developing country. Even though there has been a large amount of input into enterprise digital transformation, the outcomes for firms are still under-explored. Using the Python approach, we provide supplementary evidence in regard to this branch of study.

Second, it enriches the research on the factors influencing bank loan contracting. In developed countries, the evidence relating to bank loan contracting is plentiful. However, the Chinese studies are still very limited as China has no database like Dealscan in the US. In this study, we manually collected the interest rates of bank loans instead of using indirect and less precise proxies such as financial expense and borrowing amount to impute the cost of the loan approximately.

The rest of the paper is organized as follows: Section 2 formulates the research hypothesis based on the previous literature; Section 3 presents the data, main variables, and the research model; Section 4 shows the descriptive statistics and empirical regression results; finally, we conclude in the last section.

2. Institutional background and hypothesis development

2.1 Institutional background

In the Report of the State Council on the Development of the Digital Economy, it is pointed out that China's digital infrastructure has achieved leapfrog development and the innovation capacity of the digital industry has been accelerated. In 2021, the scale of China's core industry of the industrial Internet exceeded 1 trillion yuan, the scale of the big data industry reached 1.3 trillion yuan, and China will become one of the fastest-growing cloud computing markets in the world. In 2022, the report of the 20th National Congress of the Communist Party of China proposed that the development of China's digital economy had achieved remarkable results. Overall, the Chinese government has proposed various policies to stimulate the digitalization pace (see Table A1 in Appendix 1). In the future, it is necessary to "accelerate the development of digital economy, promote the deep integration of digital economy and the real economy, build digital industrial clusters with international competitiveness".

From the standpoint of micro-firms, enterprises also actively participate in digitalized reforms. For example, the famous firm, China National Petroleum Corporation (CNPC), is keeping pace with the times, deeply exploring and implementing the application of digital technology. CNPC has made significant achievements in the operation of the firm. Another typical example is Beijing CTJ Information Technology Co. Ltd. Following the advocations of government digitalized policies, the company became deeply involved in digital transformation and successfully conducted its IPO in 2022. Engagement in digital transformation also further helps firms sustain their continuous competitiveness in the market. The detailed information and description are documented in Appendix 2.

2.2 Literature review and hypothesis development

2.2.1 Literature on digital transformation. With the booming digital economy, digital transformation has become one of the key strategies for business development. This transformation fundamentally empowers businesses to streamline their operations, reach broader markets, and adapt quickly to market changes through data-driven insights and agile practices (Gong and Ribiere, 2021). Hinings *et al*. (2018) also state that digital transformation is a comprehensive change in the participants, structure, and culture of a business organization brought about by digital technology.

In academics, digital transformation reflects various spillover benefits and redefines its value proposition to stakeholders (Amit and Zott, 2001). The most straightforward effect of digital transformation is that it enables firms to modernize their operations, enhance their efficiency, and generate superior performance. For example, Porter and Heppelmann (2014) argue that digital transformation can help companies to have real-time data on product performance, which allows more effective marketing strategies and timely after-sales service, thus contributing to their operational efficiency. It has also been found that digital transformation can improve the total factor productivity of enterprises (Yu *et al.*, 2024). In addition, because digital transformation drives innovation in the business model of an enterprise, i.e. the way an enterprise interacts with its customers and suppliers, the enterprise is also better able to achieve higher performance (Llopis-Albert *et al.*, 2021; Peng and Tao, 2022). And, digital transformation can improve business performance by reducing costs, for example, by facilitating the information exchange within or outside the enterprise, digital transformation can reduce the information cost (Zhai *et al.*, 2022). Lyytinen *et al.* (2016) propose that new organizational forms brought about by digital transformation can strengthen process and task transparency, which also leads to cost reductions.

In addition, digital transformation can also enhance a firm's information environment by integrating its systems for better data accessibility and integration across departments. Jiang *et al.* (2022) found that digital transformation improves the quality of internal control. Chen *et al.* (2022b) document that digital transformation can improve the information environment and enhance the accuracy of firms' information disclosure. Wang and He (2024) found that digital transformation can mitigate the information asymmetry among different departments and increase the quality of financial statements. Such a transparent information environment helps firms improve their financing efficiency and alleviate their financing constraints significantly (Wei and Li, 2024; Cui and Wang, 2023).

Another branch of study has found that digital transformation can also help firms improve their financing efficiency and alleviate their financing constraints. For example, Wei and Li (2024) found that digital transformation can reduce the cost of both debt financing and equity financing. In addition, due to digital transformation meeting national policies and becoming a social consensus, it is easier for enterprises with a higher degree of digital transformation to access financing resources (Cui and Wang, 2023).

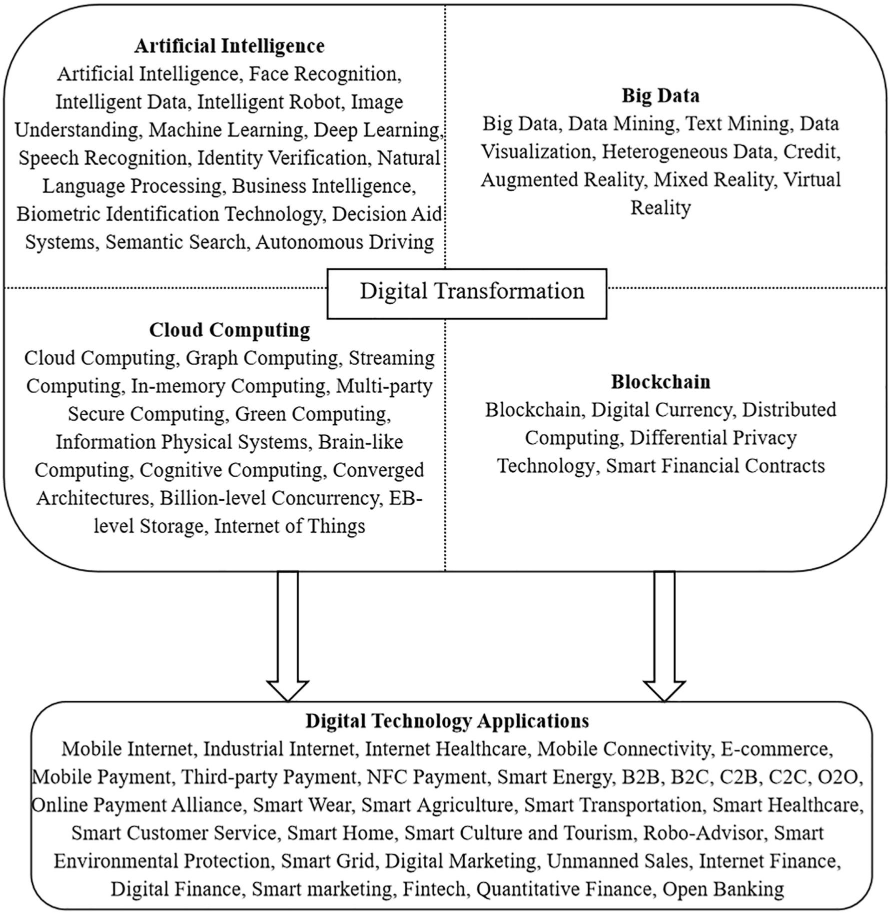
2.2.2 Literature on bank loans. As one of the main debt financing approaches, bank loans have attracted lots of academic interest. When carrying out bank loan contracting, banks need to collect efficient information to balance the creditworthiness of borrowing firms. Prior studies reveal that a bank's assessment of credit risk heavily relies on a firm's financial statements. Thus, the quality of accounting information is crucial to determining the loan terms (Bharath *et al.*, 2008). For example, misreporting, restatements, and real earnings management amplify information asymmetry, which will result in higher loan spreads (Graham *et al.*, 2008; Pappas *et al.*, 2019). Conversely, Kim *et al.* (2011c) found that adopters of IFRS can obtain lower loan interest rates because adopting IFRS can increase the information disclosure quality. In addition, external financial information, like audit information, also plays an important role in bank loan contracting (Francis *et al.*, 2017; Kim *et al.*, 2011a). Porumb *et al.* (2021) used the mandatory regulation of an expanded auditor's report as an external shock and found that the introduction of the expanded auditor's report is associated with a reduced loan spread.

Furthermore, non-financial information, such as corporate governance also plays a vital role in bank loan contracting. Empirical evidence indicates that shareholder-friendly firms receive higher loan spreads, as such structures represent higher credit risks (Chava *et al.*, 2009). Additionally, Lin *et al.* (2011) highlighted that disparities between control rights and cash flow rights amplify agency costs, thus leading to increased interest rates. In addition, some scholars have further explored the impact of the quality of corporate governance. For example, firms with weaker internal controls typically face harsher lending terms, while firms with good internal governance receive favorable interest rates (Kim *et al.*, 2011b; Ge *et al.*, 2012).

Recently, a lot of research has begun to focus on many new emergent issues that are influencing the design of bank loan contracting. Becchetti and Manfredonia (2022) found that negative media attention can increase bank loan costs. Macro-level factors such as a firm's exposure to climate risk could also affect its financing terms in relation to bank loans. Huang *et al.* (2022) summarize that climate risk results in unfavorable corporate financing terms related to bank loans. In the era of digitalization, we expect that there exists a significant impact on decision-making regarding bank loan agreements.

2.2.3 Hypothesis development. The most tangible impact of digital transformation on firms is its ability to streamline operations, reduce costs, and enhance efficiency through the integration of advanced technologies. By integrating advanced technologies into business operations, organizations can optimize their resource allocation, enhance their processing efficiency, and accelerate innovation cycles. Additionally, digital tools facilitate collaboration and communication, fostering a more agile and responsive organizational structure. Yu *et al.* (2024) document that digital transformation has the potential to enhance firms' total factor productivity by increasing the efficiency of the division of labor, cutting down labor costs, and optimizing the structure of human capital. Thus, firms with digital transformation, who own higher total factor productivity, will certainly have easier access to resources including bank loans.

When making a loan contract, the collection of information is the main consideration for banks (Healy and Palepu, 2001). When banks are unable to obtain sufficient information, then



Source(s): Authors' own creation/work, refer to Wu *et al.* (2021)

Figure 1. Digital transformation keywords

the bank will impose higher interest rates as compensation for the information risk. Enabled by digital technology, not only traditional financial information but also a large amount of production data can be recorded and disclosed to investors. Therefore, the scope and amount of information disclosed can be expanded, thus enhancing information transparency. Moreover, according to signaling theory, in the process of digital transformation, enterprises will voluntarily improve their information transparency to obtain the support of investors for their transformation (Jiang *et al.*, 2022). Therefore, digital technology can enable enterprises to release the information dividend fully, pass more high-quality information to the bank, and thus lower the loan interest rates.

On the other hand, digital transformation can inhibit earnings management. According to the principal–agent theory, there are multiple agency relationships between shareholders and managers, creditors, and large and small shareholders in a company (Jensen and Meckling, 1976). Due to the conflicting interests, each party may employ immoral means to benefit themselves, and earnings management is one of the common methods. Earnings management impairs the quality of firms' information, exacerbates the information asymmetry between banks and firms, and leads banks to raise interest rates as a risk premium. The real-time data monitoring enabled by digital technology limits the power of managers and employees. In sum, the wide adoption of digitalization can help optimize the information environment between firms and banks, thus contributing to a lower borrowing cost.

Finally, digital transformation can help firms improve their financing efficiency and guarantee their financial stability. The stability of future performance is an important factor for creditors to assess default risk (Bonsall *et al.*, 2017). With lower financial distress risk, the firm's future performance is usually more stable and its default risk is lower. Digital transformation can alleviate the financial distress risk of firms by reducing their business risks and easing their financial constraints (Cui and Wang, 2023). Therefore, digital transformation can create a favorable financial environment for businesses, which can lead to lower loan interest rates. Accordingly, we propose our main hypothesis as follows:

H1. The digital transformation of firms is negatively associated with bank loan interest rates.

Table 1. Descriptive statistics

Variables	*N*	Mean	Median	Sd	Min	Max
Interest	9,824	0.059	0.059	0.015	0.017	0.121
DT	9,824	0.571	0	0.967	0	4.828
Shareholding	9,824	0.363	0.346	0.159	0.093	0.748
SOE	9,824	0.615	1	0.487	0	1
Tangibility	9,824	0.246	0.218	0.189	0.000	0.920
ROE	9,824	0.073	0.079	0.117	−0.950	0.341
Leverage	9,824	0.584	0.598	0.162	0.067	0.973
MTB	9,824	1.625	1.387	0.775	0.865	9.548
Bank4	9,824	0.406	0	0.491	0	1
Z_score	9,824	1.099	1.016	0.664	−1.580	9.411
Cash_Volatility	9,824	0.053	0.041	0.045	0.003	0.240
SA	9,824	−3.762	−3.752	0.259	−4.468	−2.781
ABSDA	9,824	0.068	0.046	0.075	0.001	0.388

Note(s): Table 1 reports the descriptive statistics on dependent, independent, and control variables in our main regression. To alleviate the impacts of outliers, we winsorize all continuous variables at the 1st and 99th percentiles. See Table A2 in Appendix 3 for variable definitions
Source(s): Authors' own creation/work

Table 2. Pearson correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)Interest	1												
(2)DT	−0.152***	1											
(3)Shareholding	0.015	−0.072***	1										
(4)SOE	−0.056***	−0.101***	0.172***	1									
(5)Tangibility	−0.165***	−0.073***	−0.007	0.087***	1								
(6)ROE	−0.007	−0.027***	0.111***	−0.008	−0.119***	1							
(7)Leverage	0.148***	−0.065***	0.127***	0.212***	−0.191***	−0.101***	1						
(8)MTB	−0.103***	−0.016	−0.144***	−0.149***	0.071***	0.078***	−0.306***	1					
(9)Bank4	−0.056***	−0.015	−0.059***	0.011	0.082***	0.011	−0.032***	0.015	1				
(10)Z_score	−0.074***	0.022**	0.099***	−0.049***	−0.167***	0.351***	−0.224***	0.135***	−0.013	1			
(11)Cash_ volatility	0.065***	−0.086***	0.021**	−0.005	−0.340***	0.063***	0.153***	0.011	0.028***	0.091***	1		
(12)SA	0.045***	−0.288***	0.240***	0.074***	0.194***	0.074***	−0.089***	0.080***	0.005	0.070***	−0.127***	1	
(13)ABSDA	0.010	−0.045***	−0.003	0.001	−0.280***	0.041***	0.149***	−0.004	0.045***	0.023**	0.493***	−0.109***	1

Note(s): This table represents the correlation matrix for the main variables. Correlations between variables are all less than 0.5, implying that there is not strong multicollinearity problem. Here, *, ** and *** indicate 10%, 5% and 1% levels of significance respectively
Source(s): Authors' own creation/work

3. Research design

3.1 Sample selection

This study used a sample of loan contracts initiated between 2007 and 2021 by Chinese A-share listed firms. The loan interest rate information was collected manually from the footnotes of annual reports. The data of enterprise digital transformation were crawled from the annual reports through Python. The rest of the company data are from the China Stock Market and Accounting Research (CSMAR) database. We applied the following criteria: (1) deleting the financial industry; (2) dropping ST, *ST firms; (3) deleting observations with missing data. We winsorized all continuous variables at the 1st and 99th percentile to alleviate the impacts of outliers. Finally, we obtained 9,824 observations.

3.2 Variable definition

3.2.1 Dependent variable. Bank loan interest rate (*Interest*). This study used the annual interest rate on bank loans extracted from the financial statement notes in the annual reports. Thus, the final observations are concentrated on each single bank loan of the enterprises.

3.2.2 Independent variable. The degree of enterprise digital transformation (*DT*). We used the text recognition of enterprise annual reports method. Quantifying enterprise digital

Table 3. Main regression

Dep.Var. =	(1) Interest
DT	−0.001***
	(−3.394)
Shareholding	−0.001
	(−0.774)
SOE	−0.002***
	(−8.938)
Tangibility	−0.004***
	(−4.220)
ROE	−0.001
	(−1.030)
Leverage	0.007***
	(7.691)
MTB	0.001***
	(2.887)
Bank4	−0.001***
	(−3.182)
Z_score	−0.002***
	(−9.258)
Cash_volatility	−0.006*
	(−1.659)
SA	−0.001*
	(−1.958)
ABSDA	−0.004**
	(−2.126)
Constant	0.068***
	(23.896)
Year and Ind	Yes
Observations	9,824
Adjusted R^2	0.347

Note(s): This table represents the main result of the impact of digital transformation on bank loan interest rates. All variables are defined in Table A2 in Appendix 3. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

transformation is an ununified issue in both academic research and practical sectors. It is not merely about digitizing corporate data, but leveraging advanced digital technologies and hardware systems to digitize enterprise production resources and processes, thereby achieving the crucial goals of improving enterprises' quality and efficiency. To realize digital transformation, firms rely on the deployment and development of key core technologies such as artificial intelligence, blockchain, cloud computing, and big data. Therefore, embedding digital technology into internal corporate production operations and management modes, and engaging technological transformations and upgrades are the main reflections of digital transformation. The burgeoning digital transformation information is more likely to be reflected in firms' annual reports, which serve as summaries and guides for enterprise operations and future development. As a result, scholars widely use the textual analysis of enterprise annual reports to represent digital transformation. The specific implementation method was the use of Python to crawl the annual reports of Chinese A-listed companies from 2007 to 2021 for textual analysis. Next, we counted the frequency of the keywords related to digital transformation in them to obtain

Table 4. Channel test

Dep.Var. =	(1) TFP	(2) Transparency	(3) EM	(4) O_Score
DT	0.098***	0.041***	−0.005**	−0.062***
	(12.406)	(4.054)	(−2.246)	(−7.092)
Shareholding	0.477***	0.051	−0.058***	−0.318***
	(10.982)	(0.881)	(−4.994)	(−6.784)
SOE	0.194***	0.264***	−0.050***	−0.093***
	(14.660)	(14.373)	(−13.803)	(−6.301)
Tangibility	−0.137***	0.263***	−0.408***	0.128***
	(−3.267)	(4.303)	(−34.931)	(2.698)
ROE	−0.034	0.901***	0.065***	−3.481***
	(−0.572)	(10.943)	(4.264)	(−55.640)
Leverage	2.701***	−0.235***	0.060***	7.161***
	(60.089)	(−3.722)	(4.931)	(145.558)
MTB	−0.252***	−0.056***	0.013***	0.059***
	(−29.030)	(−4.421)	(5.383)	(6.035)
Bank4	−0.053***	0.038**	−0.009***	0.037***
	(−4.403)	(2.263)	(−2.827)	(2.744)
Z_score	0.904***	0.215***	0.026***	−0.326***
	(67.475)	(10.446)	(8.800)	(−27.124)
Cash_volatility	−0.448***	−0.750***	0.210***	0.938***
	(−2.662)	(−3.201)	(4.688)	(5.175)
SA	0.259***	0.521***	0.013	−0.446***
	(7.455)	(12.158)	(1.520)	(−12.665)
ABSDA	−0.439***	−0.158	−0.273***	−0.057
	(−4.388)	(−1.257)	(−10.620)	(−0.547)
Constant	6.185***	2.940***	0.017	−11.949***
	(42.891)	(16.160)	(0.453)	(−79.212)
Year and Ind	Yes	Yes	Yes	Yes
Observations	8,591	4,922	9,541	9,824
Adjusted R^2	0.658	0.266	0.410	0.809

Note(s): This table presents the possible channels through which the digital transformation of firms affects bank loan interest rates. We test four possible channels including total factor productivity (*TFP*), information transparency (*Transparency*), earnings management (*EM*), and financial risk (*O_Score*). All variables are defined in Table A2 in Appendix 3. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

the text intensity in relation to digital transformation and used them as the main independent variable. Since the digital transformation data have right-skewed characteristics, they were logarithmically processed.

The steps of keyword construction were as follows: we referred to a series of classical literature in the field of digital transformation to summarize the keywords. Specifically, this included word sets such as artificial intelligence, blockchain, cloud computing, and big data, as well as the application of these technologies in specific scenarios, ultimately forming the keyword list shown in Figure 1.

3.3 Research model

To test the relationship between digital transformation and bank loan interest rates, we set up the following regression model. We added a set of control variables including firm-level characteristics, year, and industry fixed effects. All the detailed definitions can be found in Table A2 in Appendix 3.

Table 5. Heterogeneity of property rights

Dep.Var. =	(1) SOE = 1 Interest	(2) SOE = 0 Interest
DT	−0.000	−0.001***
	(−1.242)	(−3.672)
Shareholding	−0.000	−0.003*
	(−0.185)	(−1.712)
Tangibility	−0.001	−0.011***
	(−0.801)	(−5.841)
ROE	−0.001	0.000
	(−0.495)	(0.164)
Leverage	0.006***	0.007***
	(5.561)	(4.150)
MTB	0.001***	0.001*
	(4.113)	(1.691)
Bank4	0.000	−0.002***
	(0.172)	(−4.865)
Z_score	−0.002***	−0.004***
	(−6.340)	(−7.254)
Cash_volatility	−0.007*	0.003
	(−1.821)	(0.485)
SA	−0.001	−0.003**
	(−0.704)	(−2.261)
ABSDA	−0.002	−0.011***
	(−0.719)	(−3.127)
Constant	0.068***	0.067***
	(18.858)	(13.351)
Year and Ind	Yes	Yes
Observations	6,046	3,778
Adjusted R^2	0.362	0.350
ChowTest		
F-Value	40.210	
Prob > *F*	0.000	

Note(s): This table presents the results by distinguishing property rights. We classify our sample into the non-state-owned enterprises group and state-owned enterprises group. *SOE* is a dummy variable, which equals 1 if the enterprise is state-owned and 0 otherwise. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

$$Interest_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \sum \alpha_i Controls_{i,t} + Industry\, fixed\, effect + Year\, fixed\, effect + \varepsilon_{i,t}$$

4. Empirical results

4.1 Descriptive statistics

Table 1 shows the descriptive statistics of the main variables. The mean value of the bank loan interest rate was 5.9%. The mean of *DT* was 0.571, and there was a certain right skewness of this variable. The mean (median) of *Cash_volatility* was 0.053 (0.041). On average, the total debt and net fixed assets were 58.4 and 24.6% of total assets, respectively. *ROE* had the mean

Table 6. Heterogeneity of industry

Dep.var. =	(1) High_tech = 1 Interest	(2) High_tech = 0 Interest
DT	−0.001***	−0.000*
	(−2.674)	(−1.778)
Shareholding	−0.006*	−0.001
	(−1.714)	(−0.698)
SOE	−0.001	−0.003***
	(−1.225)	(−8.910)
Tangibility	−0.013***	−0.004***
	(−3.912)	(−4.095)
ROE	0.000	−0.002
	(0.046)	(−1.321)
leverage	−0.012***	0.009***
	(−3.959)	(8.919)
MTB	0.001	0.001***
	(1.540)	(3.157)
Bank4	0.002**	−0.001***
	(2.176)	(−3.814)
Z_score	−0.005***	−0.002***
	(−3.949)	(−8.921)
Cash_volatility	0.014	−0.007**
	(0.931)	(−2.064)
SA	−0.003	−0.001
	(−1.634)	(−1.567)
ABSDA	−0.007	−0.003*
	(−1.060)	(−1.699)
Constant	0.079***	0.067***
	(10.883)	(21.905)
Year and Ind	Yes	Yes
Observations	1,118	8,706
Adjusted R^2	0.238	0.372
ChowTest		
F-Value	9.290	
Prob > *F*	0.000	

Note(s): This table presents the results by distinguishing industries. We classify our sample into the high-tech industries group and the non-high-tech industries group. *High_tech* is a dummy variable with a value of 1 for high-tech industries and a value of 0 for non-high-tech industries. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

and median of 0.073 and 0.079 and 61.5% of the sample were state-owned enterprises. The means (median) of *MTB*, *Shareholding*, and *Z_score* were 1.625 (1.387), 0.363 (0.346), and 1.099 (1.016), respectively. The percentage of whether the lending bank belonged to the "Big Four" state-owned banks was 40.6%. The means (median) of *SA* and *ABSDA* were −3.762 (−3.752) and 0.068 (0.046), respectively. The other firm characteristics were also within a reasonable range.

4.2 Pearson correlations

Table 2 presents the Pearson correlations. The results show that the correlation coefficient between digital transformation and bank loan interest rate was −0.152, which passed the 1% significance test, implying that digital transformation is negatively correlated with bank loan interest rate. However, the Pearson Correlation Test just preliminarily tested the linear

Table 7. Heterogeneity of size

Dep.Var. =	(1) Size = 1 Interest	(2) Size = 0 Interest
DT	−0.001***	0.000
	(−3.830)	(0.612)
Shareholding	0.003**	−0.003***
	(2.035)	(−2.896)
SOE	−0.004***	−0.001***
	(−9.085)	(−3.216)
Tangibility	0.003*	−0.007***
	(1.958)	(−6.472)
ROE	−0.001	0.004**
	(−0.467)	(2.136)
Leverage	0.011***	0.006***
	(6.413)	(4.831)
MTB	−0.000	0.001***
	(−0.502)	(3.006)
Bank4	−0.001***	−0.000
	(−3.270)	(−1.148)
Z_score	−0.001***	−0.004***
	(−3.428)	(−9.854)
Cash_volatility	−0.015***	0.009**
	(−2.754)	(2.133)
SA	−0.004***	0.000
	(−3.858)	(0.489)
ABSDA	−0.002	−0.005
	(−0.765)	(−1.627)
Constant	0.057***	0.077***
	(10.300)	(21.466)
Year and Ind	Yes	Yes
Observations	4,915	4,909
Adjusted R^2	0.394	0.317
ChowTest		
F-Value	14.670	
Prob > *F*	0.000	

Note(s): This table presents the results by distinguishing the size of firms. We divide the sample into two groups of large-scale and small-scale firms. *Size* is a dummy variable, which equals 1 if the size of the firm is larger than the median and 0 otherwise. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

Table 8. Robustness tests: instrumental variable test

Panel A: The first stage	
Dep.Var. =	(1) DT
Expenditure	0.070***
	(8.313)
Shareholding	0.032
	(0.603)
SOE	−0.027
	(−1.574)
Tangibility	−0.538***
	(−9.871)
ROE	0.443***
	(6.188)
Leverage	0.278***
	(4.937)
MTB	0.020*
	(1.814)
Bank4	−0.024
	(−1.558)
Z_score	−0.016
	(−1.156)
Cash_volatility	−0.660***
	(−3.179)
SA	0.192***
	(4.738)
ABSDA	−0.276**
	(−2.304)
Constant	0.615***
	(3.545)
Year and Ind	Yes
Observations	9,824
Adjusted R^2	0.416

Panel B: The second stage	
Dep.Var. =	(1) Interest
DT	−0.006**
	(−2.440)
Shareholding	−0.000
	(−0.491)
SOE	−0.003***
	(−8.172)
Tangibility	−0.007***
	(−4.155)
ROE	0.001
	(0.693)
Leverage	0.008***
	(7.319)
MTB	0.001***
	(2.716)
Bank4	−0.001***
	(−3.720)
Z_score	−0.002***
	(−8.981)

(*continued*)

Table 8. Continued

Panel B: The second stage	
Dep.Var. =	(1) Interest
Cash_volatility	−0.009**
	(−2.371)
SA	−0.000
	(−0.527)
ABSDA	−0.006***
	(−2.761)
Constant	0.072***
	(19.945)
Year and Ind	Yes
Observations	9,824
Adjusted R^2	0.286
Underidentification test	
Kleibergen-Paap rk LM statistic	51.427
p-value	0.000
Weak instrument tests	
Cragg-Donald Wald *F* statistic	69.104
Kleibergen-Paap rk Wald *F* statistic	51.211

Note(s): This table reports the 2-stage least regressions of the instrumental variable test. Panel A presents the results for the first stage and Panel B reports the second-stage result and the tests investigating the validity of instrumental variables. We select government finance expenditure on science and technology as an instrumental variable. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

relationship between digital transformation and bank loan interest rate and did not include the control variables, so it needed to be further investigated through the OLS model. In addition, the correlation coefficients of the variables were less than 0.5, so there was no serious multicollinearity problem.

4.3 Regression results

Table 3 reports the results of the main regression model. From Table 3, we find that there is a significantly negative relationship between digital transformation and bank loan interest rate (−0.001, *t*-value = −3.394, significant at the 1% level), i.e. the higher the degree of enterprise digital transformation, the more favorable the bank loan interest rate available. In other words, firms with a higher degree of digital transformation have access to a more favorable bank loan interest rate. All else being equal, a one-standard-deviation increase in digital transformation is associated with a 1.64%[1] reduction in interest rate relative to the mean, implying that a reduction of interest rate is economically significant. Therefore, the hypothesis of this paper is supported by the empirical results.

4.4 Channel tests

In this section, we test the possible channels through which digital transformation affects the interest rate. Bank loan interest rate, which is the central element of loan contracting, serves as an indication of a bank's assessment of a firm's creditworthiness. We argue that digital transformation can reduce loan interest rates by increasing the total factor productivity. Higher total factor productivity represents higher efficiency, which is a positive signal for banks.

Table 9. Robustness tests: Heckman test

Panel A: The first stage

Dep.Var. =	(1) DT
Shareholding	−0.019
	(−0.184)
SOE	0.025
	(0.757)
Tangibility	−0.531***
	(−5.064)
ROE	0.999***
	(6.830)
Leverage	0.237**
	(2.169)
MTB	−0.003
	(−0.141)
Bank4	0.031
	(1.011)
Z_score	−0.000
	(−0.001)
Cash_volatility	−1.215***
	(−2.919)
SA	0.305***
	(3.869)
ABSDA	0.279
	(1.176)
Constant	−0.224
	(−0.659)
Year and Ind	Yes
Observations	9,690
Pseudo R^2	0.224

Panel B: The second stage

Dep.Var. =	(1) Interest
DT	−0.001***
	(−3.334)
Imr	−0.001
	(−0.504)
Shareholding	−0.001
	(−0.713)
SOE	−0.003***
	(−8.834)
Tangibility	−0.003***
	(−3.197)
ROE	−0.002
	(−1.076)
Leverage	0.007***
	(7.277)
MTB	0.001***
	(2.853)
Bank4	−0.001***
	(−3.227)
Z_score	−0.002***
	(−9.208)

(*continued*)

Table 9. Continued

Panel B: The second stage	
Dep.Var. =	(1) Interest
Cash_volatility	−0.005
	(−1.351)
SA	−0.002*
	(−1.917)
ABSDA	−0.004**
	(−2.157)
Constant	0.069***
	(20.995)
Year and Ind	Yes
Observations	9,690
Adjusted R^2	0.343

Note(s): This table reports the results of the Heckman test. All the variables are defined in the Table A2 in Appendix 3. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In Panel A, in parentheses are *z*-statistics. In Panel B, in parentheses are *t*-statistics
Source(s): Authors' own creation/work

Therefore, we tested whether digital transformation can reduce loan interest rates by increasing the total factor productivity.

Furthermore, we also inferred that digital transformation can improve the information quality of a firm, thus reducing bank loan interest rates. Specifically, we measured information quality in terms of both information transparency and earnings management. The increased information transparency and decreased earnings management indicate a lower level of information risk; therefore, banks are more willing to give favorable loan interest rates (Qian *et al.*, 2023; Pappas *et al.*, 2019). For information transparency, we selected the rating of the Shanghai Stock Exchange and Shenzhen Stock Exchange. We used sequence indicators, assigning three points to firms rated A, two points to firms rated B, one point to firms rated C, and zero points to firms rated D. For earnings management, following Bhattacharya *et al.* (2003), we selected earnings aggressiveness as the indicative variable. The greater the earnings aggressiveness, the worse the information quality.

In addition, a decreased financial distress risk indicates a lower level of credit risk, hence banks will grant lower interest rates. As a result, we tested whether financial distress risk is a possible channel. Following Ohlson (1980), we chose the O-Score to measure the risk. The higher the O-Score, the greater the financial distress risk.

We report the result of the channel tests in Table 4. We regressed the above four variables on digital transformation (*DT*), respectively. Column (1) of Table 4 shows that the coefficient of digital transformation (*DT*) is significantly positive (0.098, *t*-value = 12.406), suggesting that digital transformation is positively associated with total factor productivity. Columns (2) and (3) of Table 4 show that digital transformation is significantly positive with regard to information transparency (0.041, *t*-value = 4.054) at the 1% level and significantly negative with regard to earnings management (−0.005, *t*-value = −2.246) at the 5% level, implying that firms with a higher degree of digital transformation tend to achieve better information quality. In column (4) of Table 4, we demonstrate that the coefficient of *DT* on *O_Score* is significantly negative (−0.062, *t*-value = −7.092), indicating that digital transformation can effectively reduce financial distress risk.

Overall, the evidence above supports that digital transformation helps firms to obtain favorable interest rates by increasing the total factor productivity, optimizing the information quality, and reducing the financial distress risk.

4.5 Heterogeneity tests

4.5.1 Property rights. In China, due to their political relationships, state-owned enterprises (SOEs) are more likely to obtain loans because the predominant entities within the Chinese banking system are state-owned banks (Fan *et al.*, 2021). Therefore, digital transformation has a limited impact on SOEs, while non-SOEs, facing stronger financing constraints (Tian *et al.*, 2022), are more willing to drive digital transformation to access bank credit support. Hence, we infer that the decrease in bank loan interest rates resulting from digital transformation is more significant in non-SOEs than in SOEs.

Table 5 presents the result of the subgroup test. We define SOE as 1 if the enterprise is state-owned, and 0 otherwise. By comparing Column (1) and Column (2) of Table 5, we find that the coefficient of *DT* is merely significantly negative (−0.001, *t*-value = −3.672) in the non-SOEs group, indicating that the effect of digital transformation is more pronounced in non-SOEs.

4.5.2 Industry heterogeneity. The high-tech industry has more technical resources to better empower digital transformation (Niu *et al.*, 2023). Non-high-tech industries often exhibit lower sensitivity in seizing the opportunities presented by the digital economy, mainly due to their relatively weak technological base and lack of innovative firm culture. Therefore, we predict that the impact of digital transformation is more significant in high-tech industries.

Table 10. Robustness tests: consider different maturities

Dep.Var. =	(1) Short_term Interest	(2) Long_term Interest
DT	0.001	−0.001***
	(0.874)	(−3.844)
Shareholding	0.005	−0.001
	(1.585)	(−1.424)
SOE	0.000	−0.003***
	(0.430)	(−9.543)
Tangibility	−0.007**	−0.003***
	(−2.489)	(−3.499)
ROE	−0.002	−0.001
	(−0.477)	(−0.774)
Leverage	0.005	0.007***
	(1.491)	(7.463)
MTB	0.002***	0.000**
	(3.190)	(2.099)
Bank4	−0.002**	−0.001***
	(−2.109)	(−2.903)
Z_score	−0.003***	−0.002***
	(−3.062)	(−8.683)
Cash_volatility	0.002	−0.005
	(0.194)	(−1.284)
SA	−0.006**	−0.001
	(−2.429)	(−0.921)
ABSDA	−0.021***	−0.003
	(−2.720)	(−1.639)
Constant	0.045***	0.072***
	(4.548)	(23.245)
Year and Ind	Yes	Yes
Observations	936	8,888
Adjusted R^2	0.463	0.334

Note(s): This table presents the results by distinguishing loan maturity. We divide the sample into two groups short-term loans and long-term loans. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

We divided all the samples into two groups according to industry heterogeneity. Table 6 presents the result. From Column (1) of Table 6, we can find that the coefficient of *DT* is significantly negative at the 1% level (−0.001, *t*-value = −2.674) and the Chow test is significant at the 1% level, suggesting that the effect of digital transformation is more pronounced in high-tech industries than in non-high-tech industries.

4.5.3 Firm size. Due to the complicated governance levels, the information flow is usually more complex in large-scale firms. Therefore, the acceleration of information flow and increased transparency brought about by digital transformation will benefit large-scale firms more. Additionally, large-scale firms are better governed than small-scale firms (Jiang *et al.*, 2022), so they can design and conduct digital transformation better. Therefore, we predict that digital transformation works better in large-scale firms and has a greater impact on bank loan interest rates.

Column (1) and (2) of Table 7 show the results of large-scale firms and small-scale firms, respectively. Comparing Columns (1) and (2) of Table 7, we can find that the coefficient of *DT* is only significantly negative at the 1% level (−0.001, *t*-value = −3.830) in large-scale firms,

Table 11. Robustness tests: add control variables

Dep.Var. =	(1) Interest
DT	-0.001^{***}
	(−3.402)
Loanamount	-0.001^{***}
	(−6.479)
Maturity	0.001^{***}
	(4.131)
Shareholding	−0.001
	(−0.923)
SOE	-0.002^{***}
	(−8.914)
Tangibility	-0.003^{***}
	(−3.514)
ROE	−0.001
	(−0.684)
Leverage	0.008^{***}
	(8.951)
MTB	0.000^{**}
	(2.392)
Bank4	-0.001^{***}
	(−3.809)
Z_score	-0.002^{***}
	(−9.535)
Cash_volatility	−0.005
	(−1.451)
SA	-0.001^{*}
	(−1.767)
ABSDA	-0.004^{**}
	(−2.257)
Constant	0.072^{***}
	(21.247)
Year and Ind	Yes
Observations	9,711
Adjusted R^2	0.356

Note(s): In this table, we add two loan characteristics into control variables. Year-fixed effects and industry-fixed effects are also included. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

implying that the decrease in bank loan interest rate caused by digital transformation is greater in large-scale firms than in small-scale firms.

4.6 Robustness tests

4.6.1 Instrumental variable test. Sufficient capital is the guarantee for firms to carry out digital transformation. As one of the most important sources of financing for firms, bank loans will directly affect the implementation of digital transformation. To solve this reverse causality problem, we applied an instrumental variable test. Government finance expenditure on science and technology guides the digital transformation of firms by improving the digital transformation infrastructure, but it has no relation to firm-specific bank loan contracting. Therefore, we used government finance expenditure on science and technology as an instrumental variable.

In the first stage, we tested the relationship between government finance expenditure on science and technology and the digital transformation of firms. Panel A of Table 8 shows that government finance expenditure on science and technology is significantly positive with regard to the digital transformation of firms at the 1% level (0.070, *t*-value = 8.313). Therefore, the instrumental variable meets the requirement of relevance. Panel B of Table 8

Table 12. Robustness tests: change sample interval

Dep.Var. =	(1) Interest	(2) Interest
DT	−0.001***	−0.001***
	(−4.189)	(−4.722)
Shareholding	−0.002**	−0.002*
	(−2.310)	(−1.782)
SOE	−0.003***	−0.003***
	(−8.040)	(−8.005)
Tangibility	−0.006***	−0.007***
	(−5.794)	(−6.028)
ROE	−0.002	−0.002
	(−1.506)	(−1.321)
Leverage	0.007***	0.007***
	(6.167)	(6.182)
MTB	0.001***	0.001***
	(2.585)	(2.816)
Bank4	−0.001***	−0.001***
	(−4.042)	(−3.768)
Z_score	−0.002***	−0.002***
	(−7.614)	(−7.084)
Cash_volatility	−0.006	−0.007
	(−1.379)	(−1.629)
SA	−0.002***	−0.002***
	(−3.060)	(−2.773)
ABSDA	−0.002	−0.002
	(−0.768)	(−0.699)
Constant	0.068***	0.069***
	(20.411)	(20.207)
Year and Ind	Yes	Yes
Observations	7,642	7,271
Adjusted R^2	0.357	0.350

Note(s): In this table, we exclude the effects of the 2008 economic crisis and the 2015 Chinese stock market crash. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

presents the result of the second stage. The coefficient of *DT* is still significantly negative at the 5% level (−0.006, *t*-value = −2.440). In addition, we conducted a series of tests to examine the validity of instrumental variables. The results are presented at the bottom of Panel B of Table 8. In particular, the Kleibergen-Paap rk LM statistic was significant at the 1% level, rejecting the null hypothesis of under-identification. In the weak instrument test, the Cragg-Donald Wald F statistic and Kleibergen-Paap rk Wald F statistic were 69.104 and 51.211, respectively, and both were larger than the 10% Stock Yogo (16.38), implying that the result does not suffer the problem of the weak instrument. Therefore, the instrumental variable is reasonable and valid. In sum, to the extent that our instrument variable is valid, increased digital transformation can lead to a more favorable bank loan interest rate.

4.6.2 Heckman test. Digital transformation arises from both the strategic considerations of firms and the influence of a mix of external factors, which may also affect loan interest rates. To mitigate the possible self-selection issues, we adopted the Heckman two-stage approach. Firstly, we estimated a probit model for digital transformation. Secondly, we added *Imr* calculated in the first stage to the control variables. Panel A of Table 9 presents the result of the first stage and Panel B presents the result of the second stage. The result of Panel B shows that

Table 13. Robustness tests: extend time window

Dep.Var. =	(1) Interest	(2) Interest
Lag_dt	−0.001***	
	(−5.442)	
Lag_dt2		−0.001***
		(−5.599)
Shareholding	−0.001	−0.001
	(−1.175)	(−1.382)
SOE	−0.002***	−0.003***
	(−8.672)	(−8.730)
Tangibility	−0.004***	−0.004***
	(−4.091)	(−4.158)
ROE	−0.001	−0.003**
	(−1.023)	(−2.306)
Leverage	0.008***	0.008***
	(8.539)	(7.607)
MTB	0.001***	0.000**
	(2.988)	(2.393)
Bank4	−0.001***	−0.001***
	(−2.865)	(−2.641)
Z_score	−0.002***	−0.002***
	(−8.675)	(−7.995)
Cash_volatility	−0.004	−0.002
	(−1.035)	(−0.544)
SA	−0.001	−0.001
	(−1.312)	(−1.540)
ABSDA	−0.005**	−0.005**
	(−2.190)	(−2.162)
Constant	0.071***	0.053***
	(23.875)	(17.692)
Yearand Ind	Yes	Yes
Observations	9,307	8,786
Adjusted R^2	0.344	0.326

Note(s): This table presents the result of the impact of lagging digital transformation on bank loan interest rates. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

after adding *Imr* to control variables, the coefficient of *DT* was still significantly negative at the 1% level (−0.001, *t*-value = −3.334), suggesting that the result of the main regression did not change after considering the self-selection problem [2].

4.6.3 The impact of digital transformation on loans of different maturities. Considering the differences in the interest rates for loans of different maturities, this study conducted subgroup regressions for long-term loans with a loan maturity of more than one year and short-term loans with a maturity of less than one year. The results are shown in Table 10. Columns (1) and (2) show that the coefficient of *DT* in the short-term group was not significant but significantly negative (−0.001, *t*-value = −3.844) at the 1% level in the long-term group. In other words, when making long-term loan decisions, banks consider digital transformation more.

4.6.4 Adding additional control variables. According to Bharath *et al.* (2011), loan characteristics, i.e. the amount and maturity, will also affect loan interest rates. Therefore, we added loan amount and maturity into the control variables to strengthen the persuasiveness, and the result is presented in Table 11. The coefficient of *DT* was still significantly negative (−0.001, *t*-value = −3.402) at the 1% level.

4.6.5 Changing sample interval. The bank loan rate is also affected by the macroeconomic environment, and major adverse financial events will impact the external financing

Table 14. Robustness tests: use a dummy variable to measure *DT*

Dep.Var. =	(1) Interest
DT	−0.001**
	(−2.451)
Shareholding	−0.001
	(−0.828)
SOE	−0.002***
	(−8.830)
Tangibility	−0.004***
	(−3.994)
ROE	−0.001
	(−1.090)
Leverage	0.007***
	(7.577)
MTB	0.001***
	(2.837)
Bank4	−0.001***
	(−3.103)
Z_score	−0.002***
	(−9.218)
Cash_volatility	−0.006
	(−1.625)
SA	−0.001**
	(−2.007)
ABSDA	−0.004**
	(−2.004)
Constant	0.068***
	(23.847)
Year and Ind	Yes
Observations	9,824
Adjusted R^2	0.347

Note(s): This table presents the results by changing the way *DT* is measured. We use a dummy variable, which equals 1 if the firm has undergone a digital transformation and 0 otherwise. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

environment of firms. Therefore, this study excluded the 2008–2009, and 2015–2016 data and re-ran the regression to exclude the effects of the 2008 financial crisis and the 2015 China stock market crash and their subsequent effects. Column (1) of Table 12 presents the result after excluding the 2008 financial crisis, while Column (2) shows the results further excluding the influence of the 2015 stock market crash. The coefficients of *DT* in Columns (1) and (2) were both significantly negative (−0.001, *t*-value = −4.189; −0.001, *t*-value = −4.722) at the 1% level, implying that the result is robust.

4.6.6 Extending the time window. Due to the possibility of a lag in the impact of digital transformation, we lagged the digital transformation variable (*DT*) by one and two years, respectively, and performed the regression again. Columns (1) and (2) of Table 13 show that after lagging by one and two years, respectively, digital transformation was still significantly negative (−0.001, *t*-value = −5.442; −0.001, *t*-value = −5.599) with regard to the loan interest rate at the 1% level, suggesting that the impact of digital transformation does not weaken with the extension of the time window.

4.6.7 Using a dummy variable to measure DT. To enhance the robustness, we changed the way *DT* is measured. We calculated the independent variable according to whether the firm had undergone digital transformation. If the firm had undergone digital transformation, *DT*

Table 15. Robustness tests: use digital patents to measure *DT*

Dep. Var. =	(1) Interest
DT	−0.000***
	(−7.635)
Shareholding	−0.001
	(−0.800)
SOE	−0.003***
	(−6.288)
Tangibility	−0.002
	(−1.200)
ROE	−0.003
	(−1.600)
Leverage	0.006***
	(4.103)
MTB	0.001**
	(2.543)
Bank4	0.001***
	(3.946)
Z_score	−0.002***
	(−5.053)
Cash_volatility	−0.003
	(−0.510)
SA	0.001
	(0.971)
ABSDA	−0.003
	(−0.940)
Constant	0.071***
	(14.681)
Year and Ind	Yes
Observations	4,693
Adjusted R^2	0.279

Note(s): This table presents the results by using digital patents to measure *DT*. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

equaled 1, and otherwise, *DT* equaled 0. Table 14 shows the results. The coefficient of *DT* was still significantly negative (−0.001, *t*-value = −2.451).

4.6.8 Using digital patents to measure DT. To further enrich the measurement of digital transformation, we used digital patents granted in the current year to measure the digital transformation. The result is shown in Table 15. Digital transformation was still negatively associated with interest rates (−0.000, *t*-value = −7.635).

4.6.9 Deleting samples with a high interest rate. To exclude the effect of high interest rates on the results, we deleted samples with interest rates greater than 10%. Table 16 shows the results. The coefficient of *DT* was still significantly negative (−0.0003, *t*-value = −2.441).

4.7 Additional test

In the previous section, this paper suggested that banks will take the digital transformation of firms as a positive signal and grant favorable interest rates to firms with a high degree of digital transformation. Under the digital economy, commercial banks are also actively undergoing digital transformation for better loan management. Therefore, this paper further explores whether commercial banks' digital transformation affects their assessment of firms' digital transformation as well as their loan pricing.

Table 16. Robustness tests: delete samples with high interest rate

Dep.Var. =	(1) Interest
DT	−0.0003**
	(−2.441)
Shareholding	−0.001
	(−1.375)
SOE	−0.002***
	(−7.588)
Tangibility	−0.003***
	(−3.863)
ROE	−0.001
	(−1.348)
Leverage	0.005***
	(6.208)
MTB	0.000***
	(2.994)
Bank4	0.000
	(1.370)
Z_score	−0.002***
	(−10.171)
Cash_volatility	−0.000
	(−0.123)
SA	−0.002***
	(−3.081)
ABSDA	−0.003
	(−1.536)
Constant	0.066***
	(26.977)
Year and Ind	Yes
Observations	9,620
Adjusted R^2	0.356

Note(s): This table presents the results by deleting samples with high interest rates. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

Digital transformation can help banks gather more comprehensive information about firms from the Internet and thus assess default risk more accurately. Banks that have not undergone digital transformation, will place more emphasis on information that firms voluntarily disclose due to their limited capacity for information collection and processing. In the channel tests section, we have shown that one of the mechanisms through which firms' digital transformation affects loan interest rates is by improving the quality of information. Therefore, when the bank's digital transformation allows the bank to collect sufficient information, the impact of corporate digital transformation on loan interest rates will be weakened. Accordingly, we infer that the impact of firms' digital transformation on bank loan rates is more significant in banks that have not undergone digital transformation.

We designed *Bank_dt* as 0 if there were no words about digital transformation in the bank's annual report and 1 otherwise. The results are shown in Table 17. Comparing the result of Columns (1) and (2) of Table 17, the coefficient was only significantly negative (−0.003, *t*-value = −5.277) when *Bank_dt* equaled 0, indicating that the impact of digital transformation of firms is greater if the lending bank is not digitally transformed. In other words, commercial

Table 17. Impact of bank digital transformation

Dep.Var. =	(1) Bank_dt = 1 Interest	(2) Bank_dt = 0 Interest
DT	−0.000	−0.003***
	(−0.811)	(−5.277)
Shareholding	−0.000	−0.002
	(−0.226)	(−0.895)
SOE	−0.001***	−0.003***
	(−4.359)	(−3.447)
Tangibility	−0.001	0.000
	(−1.468)	(0.021)
ROE	−0.003**	0.003
	(−2.531)	(0.800)
Leverage	0.004***	0.003
	(4.219)	(1.121)
MTB	0.000*	−0.000
	(1.662)	(−0.882)
Bank4	−0.002***	0.001
	(−8.625)	(0.660)
Z_score	−0.001***	−0.001
	(−4.394)	(−1.450)
Cash_volatility	−0.002	0.001
	(−0.664)	(0.181)
SA	−0.001**	−0.001
	(−2.019)	(−0.819)
ABSDA	−0.003*	0.005
	(−1.742)	(1.028)
Constant	0.065***	0.064***
	(22.140)	(8.723)
Year and Ind	Yes	Yes
Observations	5,501	526
Adjusted R^2	0.442	0.612

Note(s): This table presents the results by distinguishing the digital transformation of banks. *Bank_dt* is a dummy variable, which equals 1 if the bank has undergone a digital transformation and 0 otherwise. Year-fixed effects and industry-fixed effects are also included. Here, *, **, and *** indicate 10%, 5%, and 1% levels of significance respectively. In parentheses are *t*-statistics
Source(s): Authors' own creation/work

banks that have not undergone digital transformation place greater emphasis on the positive impacts brought about by the digital transformation of firms.

5. Conclusion

Using the data from Chinese A-share listed companies from 2007 to 2021, this paper examined the impact of digital transformation on bank loan interest rates. Our findings show that digital transformation can significantly reduce firm-level loan interest rates, and the results remained consistent after conducting a series of robustness checks. Using the channel test, we found that increasing the total factor productivity, enhancing the information quality, and reducing the financial distress risk are three possible channels of the main relationship. Further heterogeneity analysis showed that the effect of digital transformation on firms' bank loan rates is larger in non-state-owned enterprises, high-tech industries, and large-scale enterprises.

This study has important implications for different parties. From the perspective of bank sectors, they can use a firm's digital transformation as a tool to adjust loan terms more accurately. This enables banks to offer more competitive interest rates tailored to the specific needs and risk profiles of different firms. From the perspective of firms, they can potentially access lower-cost financing by improving their digital capabilities. This finding underscores the strategic importance of investing in digital transformation not only for operational efficiency but also for financial advantage through reduced borrowing costs. From the perspective of policymakers, they can consider promoting digital transformation initiatives as a tool to enhance the competitiveness of enterprises, particularly those in sectors where technological advancement plays a crucial role. Future research could delve deeper into the digital transformation role within firms or explore more precise proxies for transformation measurement.

Notes

1. The economic significance was calculated as the coefficient of *DT* in the main regression times the standard deviation of *DT*, and then adjusted by the mean value of bank loan interest.
2. In a response letter, we further overcome the possible self-selection problem by using a propensity score match test based on whether the loan interest rate is disclosed for three consecutive years. We define firms that disclose for three consecutive years as the treatment group and apply 1:1 matching. The results are robust.

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Further reading

Wu, F., Hu, H.Z., Lin, H.Y. and Ren, X.Y. (2021), "Enterprise digital transformation and capital market performance: evidence from stock liquidity", *Management World*, Vol. 37 No. 7, pp. 130-144+10, (In Chinese).

Appendix 1

Table A1. The key digitalized policies proposed by the Chinese government

Time	File name
2015.08	Action Plan for Promoting Big Data Development
2016.12	13th Five-Year National Informatization Plan
2017.07	Plan for the Development of the Next-Generation Artificial Intelligence
2019.10	Implementation Plan for National Pilot Zones for Innovation and Development of Digital Economy
2020.03	Special Action Plan for Digitally Empowering Small and Medium-sized Enterprises
2020.04	Implementation Plan for Promoting the "Cloud Computing and Big Data Empowering Intelligence" to Cultivate New Economic Development
2020.09	Notice on Accelerating the Digital Transformation of State-owned Enterprises
2021.11	14th Five-Year Plan for the Development of the Big Data Industry
2021.12	14th Five-Year Plan for Digital Economic Development
2022.11	Guidelines for Digital Transformation of Small and Medium-sized Enterprises
2023.02	Overall Plan for Digital China Construction

Source(s): Authors' own creation/work

Appendix 2
Cases of micro-firms' digital transformation

(1) China National Petroleum Corporation (CNPC)

In the era of the digital economy, China National Petroleum Corporation (CNPC) is keeping pace with the times, deeply exploring and implementing the application of digital technology, to promote comprehensive reform of management and business models, injecting strong vitality into the transformation and upgrading of the traditional oil and gas industry.

From a management perspective, CNPC, starting from the strategic height of the group, has established a unified office management platform. This platform not only realizes cross-departmental business collaboration but also greatly promotes real-time information sharing, making internal communication more efficient and significantly improving management efficiency.

In terms of business models, CNPC actively uses digital tools to promote the construction of intelligent sales. By strengthening information technology construction, CNPC can capture customer needs more accurately, thus formulating marketing strategies that are more in line with market realities.

CNPC's digital transformation has made great achievements. Its four subsidiaries were successfully selected as "100 Typical Cases of Digital Transformation of State-owned Enterprises in 2020". Among them, PetroChina Xinjiang Oilfield Company achieved real-time monitoring and refined management of the production process through the application of IoT technology, not only improving production efficiency but also directly creating economic benefits of 887 million yuan.

Resources: http://news.cnpc.com.cn/system/2021/03/18/030027153.shtml
http://news.cnpc.com.cn/cms_udf/2021/szh1019/index.shtml.

(2) Beijing CTJ Information Technology Co., Ltd

Beijing CTJ Information Technology Co., Ltd, specializing in smart finance, intelligent medical insurance, and other digital government fields, successfully listed on the Growth Enterprise Market in 2022. The company has always adhered to the goal of being a "builder of digital economic infrastructure," focusing on the field of digital government, especially in fiscal information construction. The company continues to promote the deep integration of big data, blockchain, artificial intelligence, and other cutting-edge technologies with government information and digitalization, innovatively applies information technology to all aspects of digital government, and has launched digital government products and solutions covering fiscal, finance, government big data, medical insurance, electronic license, and electronic signature. As of December 2022, the company has signed contracts totaling more than 600 million yuan. In 2023, the company's integrated fiscal budget management system project based on microservices architecture won the outstanding case of digital transformation of listed companies 2023 selected by the China Association of Listed Companies, fully demonstrating the company's outstanding achievements in the field of digital transformation.

Resource: https://soft.zhiding.cn/software_zone/2023/0906/3152092.shtml.

Appendix 3

Table A2. Variable definitions

Variable	Definition and calculation
Dependent variable	
Interest	Bank loan interest rate from annual reports
Independent variable	
DT	ln (1+ frequency of digital keywords in annual reports)
Control variables	
Shareholding	The proportion of shares of the first largest shareholder
SOE	The dummy variable, equals 1 if the enterprise is state-owned, and otherwise, the SOE will equal 0
Tangibility	Net fixed assets/total assets
ROE	Net profit/equity
Leverage	Total debt/total assets
MTB	Market value/book value
Bank4	Dummy variable, if the lending bank is one of China's four largest state-owned banks, the variable equals to 1 and 0 otherwise
Z_score	Modified Altman's (1968) Z-Score = (1.2*working capital+1.4*retained earnings+3.3*EBIT+0.999*sales)/total assets. This model does not include "0.6*(market value of equity/book value of total debt)" because *MTB*, a similar term enters regressions as a control variable

(*continued*)

Table A2. Continued

Variable	Definition and calculation
Cash_ volatility	The standard deviation of cash flows over the 3 years and scaled by total asset
SA	$SA = -0.737^{*}size+0.043^{*}size^{2}-0.040^{*}age$
ABSDA	The absolute value of the residuals calculated by the modified Jones model
Other variables	
Loanamount	ln (loan size (RMB))
Maturity	ln (loan maturity (days))
Expenditure	ln (government finance expenditure on science and technology (RMB))
Transparency	According to the information transparency rating of the Shanghai and Shenzhen Stock Exchanges, A takes 3, B takes 2, C takes 1 and D takes 0
EM	Earnings aggressiveness, the accruals of the enterprise/total assets at the end of the previous year
TFP	Total factor productivity, calculated according to LP methodology
O_Score	O_Score = −1.32-0.407ln(total assets)+6.03(total debt/total assets)−1.43(working capital/total assets)+0.0757(current debt/current asset)−2.37(net income/total asset)−1.83 (operating cash flow/total debt)+0.285INTWO−1.72OENEG−0.521CHIN, INTWO equals to 1 if net income of the past two years <0, and 0 otherwise; OENEG equals to 1 if total debt > total asset, and 0 otherwise; $CHIN=(NI_t-NI_{t-1}-1)/(\lvert NI_t\rvert+\lvert NI_{t-1}\rvert)$, NI refers to net income
High_tech	The dummy variable equals 1 if the firm belongs to a high-tech industry, and 0 otherwise
Size	The dummy variable equals 1 if the size of the firm is larger than the median, and 0 otherwise
Bank_dt	The dummy variable equals 1 if the word frequency of digital transformation in annual reports is greater than 0 and 0 otherwise

Source(s): Authors' own creation/work

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