The impact of digital finance on SMEs financialization: Evidence from thirty million Chinese enterprise registrations

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A R T I C L E   I N F O

A B S T R A C T

Based on the registration information of 30 million Chinese enterprises, this study innovatively constructs a financialization index based on the text information of enterprise business scope. Then, the impact of digital finance on small and medium-sized enterprise (SME) financialization is examined. Specifically, this study screens out SMEs involved in financial transactions by counting the keyword information in their business scope. The level of SME financialization is measured at the provincial level, based on a large number of registration samples. Empirical results based on panel fixed effects show that digital finance significantly inhibits SME financialization. On average, for each standard deviation increase in digital finance, SME financialization decreases by 0.087 standard deviations. This conclusion remains valid after a series of robustness analyses. A mechanism analysis shows that digital finance inhibits SME financialization by alleviating financing constraints, especially by providing liquidity to SMEs with relatively high financing constraints. In addition, the risk consequences of SME financialization are further examined, and SME financialization is found to significantly increase bankruptcy risk, while digital finance alleviates financing constraints and thus reduces bankruptcy risk. This study provides a new perspective for the governance of SME financialization and the optimization of the survival environment for SMEs in the context of the digital economy.

1. Introduction

In recent years, the issue of financialization in the global entity economy, including China, has been receiving widespread attention [1]. Financialization of the entity economy not only squeezes out real investment, further reducing the return on real investment [2,3], but also may lead to an increase in financial systemic risk. This can cause a systemic impact on the financial system and even the economy as a whole [4]. As the micro foundation of the entity economy, enterprises' financialization problem is one of the important sources of macroeconomic disengagement from the real economy. Existing research has examined the consequences of enterprise financialization from many aspects, including innovation [5], investment risk [6], and risk taking [7,8]. However, there is currently no unified conclusion on how to effectively solve the problem of enterprise financialization.

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Looking back at the causes of financialization, existing research has summarized three different motivations for enterprise financialization, namely the "reservoir" theory [9], the "investment substitution" theory [10], and the "entity intermediary" theory [11]. Of the three, the "investment substitution" theory and the "entity intermediary" theory have more empirical evidence support in existing literature. The former argues that, in the context of relatively low profitability, entity enterprises tend to engage in more profitable financial activities for profit-seeking purposes. The latter suggests that information asymmetry leads to financing discrimination and credit allocation problems between banks and enterprises. This causes providers of surplus funds in the real economy to be motivated to engage in credit activities similar to financial intermediaries. Therefore, in terms of causes, the problem of enterprise financialization is closely related to the high returns (as well as high risks) of financial markets, compared to the real economy, as well as the information asymmetry problem in credit markets.

How can the problem of corporate financialization be effectively solved, and how can its potential risks be curbed? This study argues that the rapid development in recent years of digital finance in China could provide an effective solution. Digital finance is an emerging type of financial service that combines information technology, such as the Internet, big data, and cloud computing, with traditional finance. Digital finance can construct a big data credit system that traditional financial institutions find difficult to establish through digital technology and can also make financial services more accessible to small and micro groups through mobile devices. On the one hand, the construction of a comprehensive and accurate credit system, combined with traditional commercial banks and other formal financial institutions, helps to fundamentally alleviate or even solve the problem of information asymmetry between the supply and demand of funds. This reduces the financialization tendency of entity enterprises, away from the "entity intermediary" motive. On the other hand, as an emerging type of financial service, digital finance may also compete with traditional financial markets and squeeze the profit space of traditional financial industries. Digital finance narrows the gap between finance and the real economy and reduces the financialization tendency of entity enterprises away from the "investment substitution" motive.

Against this background, a research area that is of practical value and has been less thoroughly explored in existing literature is financialization and its risks to SMEs. Existing literature on corporate risk and financialization in China has typically focused on large entities, represented by thousands of listed companies. However, rarely have scholars delved into the issue with regard to small and medium-sized enterprises (SMEs) found among the tens of millions of non-listed companies. In China, SMEs contribute over 50% of the country's tax revenues, over 60% of GDP, over 70% of technological innovation, over 80% of urban employment, and over 90% of the total number of enterprises. These figures highlight the significance of researching this segment of the economy. Moreover, theoretically, large-scale enterprises, as surplus fund providers, and SMEs, as fund demanders, not only face different financing constraints in terms of financial credit, but they also exhibit obvious differences in resource allocation. For example, under the asymmetric information conditions that arise from bank credit allocation, large-scale entities form "entity intermediaries", which cause some financialized large entities to become suppliers of funds. Meanwhile, SMEs become fund demanders, leading to differentiation among enterprise groups with different financing constraints and different scales. This differentiation creates different financialization motives for enterprise groups with different financing constraints. This is particularly true for SMEs facing relatively higher financing constraints, a situation which creates even greater urgency for research on SME financialization.

Based on the above analysis, this study mainly examines the impact of digital finance on SME financialization. First, a theoretical model is constructed to explain the causes of entity financialization, as well as how digital finance helps SMEs alleviate their financing constraints. This shows how digital finance increases the likelihood of success for the SMEs' real investment projects and suppresses their financialization tendencies. On this basis, considering that most SMEs are non-listed companies and that financial information is usually difficult to obtain, the business scope text from China's enterprise business registration is used as the corpus for measuring financialization. The business registration information is a full sample database that covers all registered legal entities disclosed by the State Administration for Industry and Commerce in recent years. The mixed segmentation model in the Jieba engine is used to segment the business scope text information, and the term frequency-inverse document frequency (TF-IDF) algorithm to screen out industry-specific keywords. On this basis, the proportion of entity SMEs participating in financial services in each province is calculated, in order to measure the level of SME financialization.

On the basis of financialization indicators construction, this study empirically examines the impact of digital finance on SME financialization, using a panel fixed effects model. The benchmark regression results show a significant inhibitory effect of digital finance on SME financialization. On average, for each standard deviation increase in digital finance, SME financialization decreases by 0.087 standard deviations. A series of robustness checks are conducted, including changing the selection criteria for SMEs, changing the standards for extracting financial industry keywords, adding industry * year fixed effects, and using instrumental variables to address endogeneity. After the checks, the results are similar to the benchmark regression. In a further mechanism analysis, digital finance is found to mainly inhibit SME financialization by alleviating financing constraints for SMEs. Also, this inhibitory effect is stronger for SMEs with higher financing constraints. In addition, the risk effects of digital finance and SME financialization are further examined, and SME financialization is found to significantly increase bankruptcy risk. This finding indicates that financialization behavior is not conducive to the survival of a large number of SMEs. However, digital finance significantly inhibits the bankruptcy risk of SMEs, and this inhibitory effect exhibits relatively good persistence.

This study makes the following contributions: First, the impact of digital finance on SME financialization is explored from an entirely new perspective, and the study further examines digital finance's positive effects on reducing SME bankruptcy risk and optimizing their survival environment. This not only contributes to the relevant research on enterprise risk management but also provides a new perspective on digital finance for the risk management of entity enterprises. Second, the shortcomings of research on SME financialization are addressed. Empirically, existing literature has typically focused more on large entities (such as listed companies) with sound information disclosure and comprehensive data. Far less attention has been paid to existing SMEs, in spite of their much greater numbers. Investigating a large number of SMEs not only improves the theoretical mechanism of enterprise

financialization and risk formation under credit allocation; doing so also alleviates sample selection bias in studies on the impact of digital finance. Third, this study proposes a measurement method for SME financialization that is based on natural language processing (NLP) and unstructured text information under the condition of missing structured financial data. Based on the business scope text information of 30 million enterprises and using relevant NLP techniques, this paper provides a novel method of measuring SME financialization. This approach not only makes the research on SME financialization and its risks feasible but also provides data support and a reference point for subsequent research on SMEs.

The remainder of this paper is arranged as follows: Section 2 provides a literature review. Section 3 presents a concise theoretical model. Section 4 provides the empirical model and data. Section 5 conducts baseline regression analysis, robustness checks, and mechanism analysis. Section 6 further examines the impact of digital finance and SME financialization on SME bankruptcy risk, and Section 7 concludes the paper and provides corresponding policy implications.

2. Literature review

2.1. Causes of entity enterprise financialization

Existing research has shown that entity enterprise financialization has both macro and micro-level factors. Macro factors that are commonly believed to contribute to entity enterprise financialization include economic downturns, macroeconomic instability, and policy environment. For example [12], studied SME financialization in the U.S. and pointed out that the fierce international competition faced by the U.S. after the 1970s led to a continuous decline in their domestic SMEs' investment return rate. This caused SMEs to withdraw funds from the real economy and invest in the financial industry, with the expectation of higher returns. In addition, based on the research on non-listed companies in China [13], found a U-shaped relationship between economic policy uncertainty (EPU) and corporate financialization. The finding suggests that, when EPU levels are too high, firms are more willing to invest in financial assets.

The micro-level causes of financialization in non-financial firms are also complex, and this issue has also been extensively explored. As discussed above, three theories are widely accepted: the "reservoir" theory [9], the "investment substitution" theory [10,14], and the "entity intermediary" theory [11]. The "reservoir" theory suggests that non-financial firms hold financial assets as liquidity reserves, mainly because financial assets have greater liquidity and marketability than other assets (such as fixed assets). Therefore, when faced with financing constraints, non-financial firms are more willing to hold financial assets. In contrast to the "reservoir" motive, the "investment substitution" motive explains why firms prefer to hold financial assets or engage in financial activities from a profit-maximizing perspective. The "entity intermediary" motive is mainly related to non-financial firms' participation in credit business in the financial market. The "entity intermediary" theory was first proposed by Ref. [11] and is mainly used to explain the credit allocation phenomenon in emerging economies. Due to credit allocation restrictions, many SMEs cannot obtain credit from banks, while others can obtain excessive credit from banks. The latter, as a surplus provider of funds, will form the so-called "entity intermediary". They will provide SMEs that are short of funds with relatively high-interest loans. In addition, a large amount of research has examined the impact of factors, such as CEO personal traits [15,16,17], on financialization in non-financial firms.

2.2. Impacts of entity enterprises financialization

Existing literature has generally maintained that the financialization of real enterprises will have a comprehensive impact on various aspects of those enterprises, including enterprise performance, value, innovation, efficiency, and so on. Regarding the impact of financialization on enterprise value or performance [18], pointed out that a real enterprise participating in various businesses can essentially be regarded as an investment portfolio. In such portfolios, assets can simultaneously include real assets and financial assets. For example [19], empirically showed that, the higher the proportion of profits obtained through financial channels is, the lower the economic value added (EVA) of entity enterprises will be. In terms of enterprise efficiency, [20,21]; and [22] all showed that the financialization of entity enterprises has an impact on production efficiency. However, there is controversy regarding the specific impact direction. Regarding enterprise innovation, studies have also supported the conclusion that the financialization of real enterprises inhibits innovation. For example [23], found that financialization has a restraining effect on enterprise innovation, but this effect has a threshold effect. Also, heterogeneity exists among enterprises with different ownership structures and different financing constraints.

There is also some evidence regarding the impact of entity-level financialization on corporate risk. For instance, Li (2019) found that, as the degree of financialization in the non-financial corporate sector deepens, the level of risk undertaken by the firms significantly decreases. In addition, researchers have examined the influence of entity-level financialization on corporate financial risk. For example [14], found that the increase in financing constraints caused by financialization will enhance the relevant companies' financial risk. However, due to the ample amount of supporting data, such studies have typically focused on listed companies, while neglecting research on SMEs.

2.3. Impacts of digital finance

Numerous studies have indicated that digital finance has significant impacts on macro-society, economy, and micro-enterprises. Research on the macro-social and economic impacts of digital finance has mainly focused on income inequality [24,25,26,27], industrial upgrading or regional innovation [28,29,30], economic growth [31,32], consumption [33,34], and other related aspects.

Regarding micro-enterprises, many studies have suggested that digital finance helps to alleviate information asymmetry and thereby mitigate financing constraints [35,36,37,38]. In addition, numerous studies have indicated that digital finance can help improve firms' innovation capacity by various mechanisms, such as alleviating financing constraints (Huiyuan & Xiaomin, 2021; [39, 40,41,42,43].

However, relatively few studies have analyzed how digital finance affects the financialization of physical enterprises. Of the few studies that have, although [44] used data from listed companies in China's A-share market and found that digital finance helps to reduce enterprises' level of financialization and thereby enhance their business performance, no targeted research has been found specifically related to SMEs.

3. Theoretical model

This study focuses on analyzing the mechanism of financialization of SMEs under credit allocation conditions, and the potential impact of digital finance is further discussed.

3.1. Basic model setting

Assuming that a series of consecutive investment projects exists in the market, the success rate p of each investment project follows a uniform distribution; that is, $p \sim U(0, 1)$. The smaller p is, the smaller is the success rate of the project. The company needs to obtain financing from the bank to invest in a certain project. Without a loss of generality, it is assumed that the funds required for all projects are 1. If the project succeeds, the company can obtain a return of i ($i > 1$); otherwise, the company's return is 0. To simplify matters, this study assumes that the expected returns of all projects are a constant, $E = p * i$. When the success rate p of the project is low, the return rate i of the successful project is high. This can be regarded as a high-risk, high-yield financial investment. When p is relatively large, i is relatively small, and the project can be considered to be a more stable industrial investment than a financial investment. In general, the risk of industrial investment is lower than that of financial investment. Therefore, this study uses $1 - p$ to measure the degree of financialization of the company's investment in a project. The larger $1 - p$ is, the more the project tends to be a high-risk, high-yield investment, which in turn means that the degree of financialization of the project is higher.

The enterprise obtains the necessary funds for the project through a loan from the bank. This not only requires paying a certain amount of interest to the bank but also obtaining guarantees from a guarantee company. In this process, the enterprise needs to provide a guarantee fee a ($a < 1$) to the guarantee company and offer collateral b ($b < 1$). Only when the successful project's return i exceeds the sum of the guarantee fee a and collateral b will the enterprise choose to take out a loan for project investment, i.e., if $i > a + b$. In addition, in the absence of credit rationing, the bank determines the loan interest rate. Assuming that the loan interest rate set by the bank is dependent on the enterprise's creditworthiness and collateral situation, the higher the collateral is, the lower the loan interest rate will be. That is:

$$r = g(c, b) \#$$ (1)

where r is the loan interest rate provided by the bank, c is the enterprise's credit level, and g is a decreasing function of c and collateral b.

In the above setup, the expected profit ($\pi^{(e)}$) the firm makes from financing and investing in a project can be expressed as follows:

$$\pi^{(e)} = p(i - 1 - r - a) + (1 - p)(0 - a - b) \#$$ (2)

Equation (2) represents the expected profit ($\pi^{(e)}$) of the enterprise that is financing and investing in a project under the given assumptions. When the investment project succeeds with probability p, the enterprise will receive an investment return of i, pay a principal plus interest of $1 + r$ to the bank, and pay a guarantee fee of a to the guarantor. When the investment project fails with probability $1 - p$, the enterprise's investment return is 0, and the enterprise defaults. The enterprise no longer pays the principal and interest to the bank, but the guarantor will confiscate the collateral submitted by the enterprise and also deduct the guarantee fee a. Since the expected return for all projects is a constant $E = p * i$, Equation (2) can be further simplified as follows:

$$\pi^{(e)} = -a - b - (1 + r - b - i)p \#$$ (3)

When the expected returns of all projects are constant E, Equation (3) can be further simplified as follows:

$$\pi^{(e)} = E - a - b - (1 + r - b)p \#$$ (4)

where $1 + r - b > 0$. Therefore, the enterprise's expected profit is a decreasing function of p. That is, under the condition that other factors (such as interest rates and collateral) remain unchanged, the enterprise will tend to choose projects that have smaller success rates, i.e., higher risks. Therefore the enterprise tends to engage in financial investments to obtain higher expected profits but will face greater risks at the same time.

The fundamental reason for this phenomenon is that the contracts agreed upon by all parties involved in the credit transaction are essentially similar to a call option. That is, when the project succeeds, the enterprise's profit depends on the success return i, which has no upper limit, while when the project fails, the enterprise at most only needs to pay the cost of $a + b$, while the risk of project failure is backed by the guarantee company. Therefore, once the enterprise obtains a loan, it will strive to the greatest extent possible to pursue financial investment projects with higher i, lower p and higher risks. Under the condition of the projects' equal expected returns E, the

smaller p, i.e., the higher the risk is, the larger i will be, i.e., the successful return of financial investment is higher than that of industrial investment. Therefore, presented with the temptation of high returns, profit-seeking enterprises will always have a motive for financialization.

3.2. Entity enterprise financialization from the financing perspective

Assuming no credit rationing, the bank is willing to provide loans to all types of enterprises (including large and small enterprises), but only as long as the guarantee company is willing to provide guarantees. However, due to the differences in the creditworthiness and collateral of different enterprises, the bank will set different interest rates for different enterprises. Intuitively, the bank will clearly prefer enterprises with higher creditworthiness and more collateral. Therefore, the interest rate offered by the bank should be a decreasing function of the enterprise's creditworthiness c and collateral b, as shown in Equation (1). At this point, the guarantee company bears the enterprise's default risk, and the expected profit $\pi^{(s)}$ of the enterprise is shown as Equation (5):

$$\pi^{(s)} = p * a + (1 - p)(a + b - 1 - r) \# \tag{5}$$

That is, if the project in which the enterprise invests is successful (with probability p), the guarantee company returns the collateral submitted by the enterprise and earns a guarantee fee of a. If the project in which the enterprise invests fails (with probability $1 - p$), the guarantee company not only charges a guarantee fee of a but also does not return the collateral b provided by the enterprise. However, the guarantee company needs to pay loan interest of $1 + r$ to the bank.

Under the above assumptions, the guarantee company and the enterprise, respectively, receive uncertain profits with probability p, while the bank receives a deterministic profit in addition to interest r. Under the condition that the guarantee company bears the risk of project failure, the guarantee company will only provide a guarantee to the enterprise if it can ensure that the expected profit $\pi^{(s)}$ is greater than 0. Therefore, we have:

$$p > 1 - \frac{a}{1 + r - b} = p_l \# \tag{6}$$

where the sum of the guarantee fee and the collateral should be less than the loan amount of 1; otherwise, the enterprise can invest in the project using its own funds without borrowing from the bank, i.e. $1 + r > a + b$. After a simple transformation, we have $a / (1 + r - b) \in (0, 1)$. Therefore, for their own profit considerations, the guarantee company will impose certain restrictions on the enterprise's choice of investment projects, thereby avoiding unrestricted investment in high-risk projects.

However, one should note that the above restriction only stops enterprises from investing in some extremely high-risk projects; since $1 - a / (1 + r - b)$ is a decreasing function of a and b, this baseline will also continue to decrease as a and b increase. Next, a further analysis of the enterprise's project investment decision can more clearly obtain the upper limit of the success probability of the enterprise's project selection.

According to Equation (4), an enterprise will only choose to finance and invest in projects if the expected profit is greater than 0 ($\pi^{(e)} > 0$). Based on the previous analysis, since $\pi^{(e)}$ is a decreasing function of p, there exists an upper probability limit p_u to ensure that $\pi^{(e)} > 0$ holds. Solving for $\pi^{(e)} > 0$ yields Equation (7):

$$p < \frac{E - a - b}{1 + r - b} = p_u \# \tag{7}$$

where $E > 1$, and $a + b < 1$, then we have $E - a - b > 0$, and

$$1 - \frac{a}{1 + r - b} < p < \frac{E - a - b}{1 + r - b} \# \tag{8}$$

Assuming that p follows a uniform distribution between 0 and 1 without loss of generality, the conditional expectation of the probability of project success for the firm under the condition in Equation (8) can be expressed as Equation (9) [1]:

$$\overline{p} = \frac{1}{2} + \frac{E - 2a - b}{2(1 + r - b)} \# \tag{9}$$

The trend of $\overline{p}$ with respect to the guarantee fee rate a and interest rate level r is related to the collateral b. When b is small, $E - 2a - b$ may be a positive value, further leading to a negative correlation between $\overline{p}$ and the guarantee fee rate a and interest rate level r, i.e., a tendency towards financialization, with $1 - \overline{p}$ positively correlated with the guarantee fee rate a and interest rate level r. Specifically, when $b < E - 2a$, $E - 2a - b > 0$. In reality, the National Development and Reform Commission of China has specified that the benchmark guarantee fee rate can be collected at 50% of the bank's loan interest rate for the same period. In addition, the specific guarantee fee rate can fluctuate between 30% and 50%, based on the risk level of the project. This means that a is generally relatively small and usually not more than 10%. Since $E > 1$, $E - 2a$ is generally not less than 80%. In contrast, the collateral asset (mortgage

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[1] Assuming a variable x follows a specific probability distribution between m and n, with probability density function $f(x)$. Given $m < m_1 < n_1 < n$, the conditional expectation of x given that $m_1 < x < n_1$ is: $\overline{x} = \frac{\int_{m_1}^{n_1} x f(x) dx}{P(m_1 < x < n_1)}$

rate) b generally does not exceed 70%. This means that $E - 2a - b > 0$ usually holds. The above results imply that, especially for SMEs, if enterprises' collateral assets are insufficient, in addition to the tendency towards financialization due to low investment returns, the rise in enterprise financing costs will also lead to a greater tendency for enterprises to choose financial investment projects with lower success rates and higher risks. This phenomenon drives the financialization of real enterprises.

Based on the above reasoning, combined with the current situation of SMEs facing difficulties and high financing costs, if banks offer higher interest rates to SMEs than they offer to large enterprises, then the expected probability of success for the investment projects available to SMEs will be lower than that for investment projects available to large enterprises. This implies that the tendency towards financialization, i.e., $1 - p$, will be greater for SMEs.

3.3. Credit rationing and SME financialization

The aforementioned model assumptions are all based on the absence of credit rationing. In reality, credit rationing on the part of banks towards SMEs is a common phenomenon and is fundamentally caused by information asymmetry. Due to the moral hazard that is more likely to arise in lower-quality firms after obtaining financing, banks just raising interest rates is not enough to effectively exclude these lower-quality firms. Rather, this raising of interest rates is more likely to exclude higher-quality firms from the financing range, thus forming a credit rationing problem. In this case, banks will no longer lend to credit-impaired and collateral-poor SMEs through high interest rates. Instead, the banks will provide funds to larger entities with higher credit levels and more collateral, resulting in a financing mismatch, whereby there are excess funds for larger entities and insufficient funds for SMEs. At this point, in addition to investing in their main industrial projects, larger entities can still obtain credit from banks and lend those funds to SMEs at higher interest rates to earn (for the larger entities) interest spreads. This forms yet another financialization mechanism that focuses on financial credit business. Therefore, this study will further consider credit rationing based on the aforementioned model to examine how the financialization of larger entities that occurs through participating in credit business affects the financialization of SMEs.

The market is divided into large entities with strong financing capabilities and SMEs with weak financing capabilities. Large entities not only participate in normal project investments through financing but also profit by providing credit services to SMEs. This model is essentially equivalent to large entities replacing SMEs in financing, thereby helping them complete their investment projects. In return, the large entities take a share of the returns on investment from SMEs. Assuming that the financing scale is still 1 unit, the expected profit of the large entity $\pi^{(e_1)})$ is expressed as follows:

$$\pi^{(e_1)} = p^{(e_2)}(r_m - r - a) + \left(1 - p^{(e_2)}\right)(0 - a - b)\#$$

(10)

where $p^{(e_2)}$ represents the success probability of investment projects for SMEs, and $1 - p^{(e_2)}$ reflects the tendency of SME financialization. The expected profit of SMEs ($p^{(e_2)}$) is expressed as follows:

$$\pi^{(e_2)} = E - p^{(e_2)}(1 + r_m)\#$$

(11)

Compared to Equation (2), in Equation (10), in order for large-scale entity enterprises to choose to participate in financial credit business, they need to ensure that their profits from the financial credit business will be higher than the profits from other project investments; that is, $1 + r_m > i^{(e_1)}$. Under this condition, in order for SMEs to obtain positive profits from project investment, they must ensure that their investment returns $i^{(e_2)}$ are higher than the financing cost of $1 + r_m$. Therefore, the following inequality is obtained:

$$i^{(e_1)} < 1 + r_m < i^{(e_2)}\#$$

(12)

Under credit allocation, SMEs must pursue financial investment projects with higher returns and higher risks, as their financing costs (r_m) are higher. Consequently, the SMEs need to seek higher investment returns ($i^{(e_2)}$), and they will have lower success rates ($p^{(e_2)}$), leading to higher risk (1-$p^{(e_2)}$) in their financial investment projects. This, in turn, further lowers the upper limit of the success rate that SMEs can pursue and forces them to become more financially-oriented.

Similar to the logic in Section 3.2, since the profit function of the guarantee company remains unchanged, the lower bound of $p^{(e_2)}$ is still as shown in Equation (6). Meanwhile, according to Equation (11), one can see that the upper bound of $p^{(e_2)}$ is:

$$p^{(e_2)} < \frac{E}{1 + r_m}\#$$

(13)

Combining Equations (6) and (13), the conditional expectation for the feasible range of $p^{(e_2)}$ is shown in Equation (14):

$$\overline{p}^{(e_2)} = \frac{1}{2} - \frac{a}{2(1 + r - b)} + \frac{E}{2(1 + r_m)}\#$$

(14)

The SMEs' probability of success through project investment decreases in line with the increase of r_m, indicating that the financial inclination $1 - \overline{p}^{(e_2)}$ increases in line with the increase of r_m. In other words, if large entities participating in credit business increase the loan interest rate to increase profits, this will cause SMEs to prefer financial projects with lower success rates but higher profits, thereby directly promoting the financialization of SMEs.

3.4. The role of digital finance

The main advantage of digital finance is that it can accurately and comprehensively grasp the transaction history, financing history, and operating situation of enterprises, all through big data information. This effectively avoids the adverse selection problem of enterprise financing. At the same time, digital finance can fully grasp an enterprise's future business situation through digital technology, such as sales contracts and accounts receivable, and can make reasonable predictions based on past operating and credit conditions. This information can form the credit capital of enterprises and can help avoid the moral hazard behavior of enterprises after obtaining financing. Internalizing this logic into theoretical models essentially provides enterprises with an element of additional credit capital. In addition, digital finance can more accurately obtain the past operating information of enterprises through big data and other technologies. In this case, future sales contracts and accounts receivable signed by enterprises can become important collateral, and indeed can form new collateral capital. The formation of the above credit capital and collateral capital helps change banks' judgment on the creditworthiness of enterprises, thereby reducing the interest rate level for high-quality enterprises.

Assuming that the new credit capital and collateral capital brought by digital finance to enterprises are Δc and Δb, respectively, the interest rate determination of the bank can be expressed as Equation (15):

$$r = g(c + \Delta c, b + \Delta b)\#$$ (15)

Whereas, since $\Delta c > 0$, and $\Delta b > 0$, the new interest rate level is lower than the interest rate level without digital finance, as given in Equation (1).

Based on the credit collateral capital Δb obtained through digital finance, the capital can also be used to provide collateral to the guarantee company to alleviate financing constraints. Therefore, the expected profit of the enterprise is as follows:

$$\pi^{(e)} = p(i - 1 - r - a) + (1 - p)(0 - a - b - \Delta b)\#$$ (16)

The expected profit of the guarantee company is as follows:

$$\pi^{(s)} = p * a + (1 - p)(a + b + \Delta b - 1 - r)\#$$ (17)

Based on Equations (16) and (17), we have:

$$\bar{p} = \frac{1}{2} + \frac{E - 2a - b - \Delta b}{2(1 + r - b - \Delta b)}\#$$ (18)

The conditional expectation of the project selection success probability $\bar{p}$ depends not only on the physical collateral asset b but also on the impact of the credit collateral asset Δb. When the level of digital finance is sufficiently high, enough credit collateral assets can be provided for high-quality SMEs, so that $E - 2a - b - \Delta b < 0$ is established. At this time, $\bar{p}$ will rise in line with the increase of the interest rate level; that is, the financialization tendency $1 - \bar{p}$ will decrease in line with the increase of the interest rate level. This means that the decrease in information asymmetry and the increase in credit capital caused by digital finance will enable high-quality enterprises to obtain more, sufficient, and low-cost financing. These enterprises can then invest in industrial projects with higher success rates, which will reduce the level of enterprise financialization and reduce the risk of enterprise project investment.

When credit rationing exists, large corporate entities have the motivation to use their financing advantages to obtain additional credit and participate in shadow banking activities, i.e., by lending to SMEs. At this point, the impact of digital finance can be further divided into two scenarios. Firstly, digital finance mainly serves commercial banks. Then, by improving the credit level and credit collateral of SMEs, digital finance reduces interest rates and solves the problem of credit rationing. At this time, SMEs can directly obtain financing from commercial banks at lower interest rates, without borrowing from large corporate entities. This undermines the foundation upon which large corporate entities participate in credit business and thus financialization from the source. In addition, digital finance also helps SMEs invest in higher-success-rate industrial projects at lower interest rates, thereby easing the financialization trend of SMEs. The specific mechanism can be referred to in the discussion of Equation (18). Secondly, digital finance is mainly utilized by shadow banking, entity intermediaries, and other informal financing channels. At this time, large corporate entities may have a full grasp of the financial status, credit level, and operational situation of SMEs. The result is more severe interest exploitation and the promotion of the financialization of large corporate entities and passive financialization of SMEs. The second scenario is reflected in the model, where large corporate entities, as entity intermediaries, adjust the interest rate r_m more flexibly, based on the information they have. The aim of the large entities is to maximize their expected profits. Due to the restrictions of the guarantee company, there is a lower limit for the success rate of projects available to SMEs, as shown in Equation (12). Therefore, the increase in interest rate r_m will approach this lower limit as closely as possible; that is:

$$\frac{E}{1 + r_m} = 1 - \frac{a}{1 + r - b}\#$$ (19)

Based on Equation (19), we have:

$$r_m = \frac{E(1 + r - b)}{1 + r - a - b} - 1\#$$ (20)

As entity intermediaries, large enterprises are pursuing profit maximization and will raise the interest rate as closely as possible to the upper limit in Equation (20). This will greatly compress the investment project selection space of SMEs, thereby promoting the

financialization of SMEs. From this perspective, the impact of digital finance, as an emerging financial format, on the financialization of entity enterprises has a double-edged sword effect. From the perspective of enterprise investment and financing, financialization largely stems from various problems, such as financing difficulties, high financing costs, and credit rationing. Only by using digital finance to effectively optimize and transform the business model of commercial banks, rather than pursuing profit maximization in entity intermediaries and private financial sectors, can the promotion of enterprise real investment and the reduction of entity enterprise financialization be effectively achieved.

4. Empirical model and data

The panel fixed effects model is constructed in Equation (21) as the baseline model to examine the impact of digital finance on SME financialization:

$$SMEF_{i,t} = \alpha + \beta DF_{i,t-1} + \gamma' Control_{i,t-1} + \mu_i + \tau_t + \varepsilon_{i,t} \# \tag{21}$$

where $SMEF_{i,t}$ denotes the SME financialization of province i at time t; $DF_{i,t-1}$ denotes the digital finance of province i at year $t-1$; *Control* denotes a series of control variables; μ_i and τ_t are province and year fixed effects, respectively, and β measures the impact of digital finance on SMEF.

(1) SMEs financialization (SMEF)

This paper focuses on SMEs, which are generally not obligated to publicly disclose their financial information. Therefore, it is difficult to measure the financialization level of a specific SME based on its asset composition, as can be done with large entities such as publicly traded companies. To address this issue, this paper proposes a method that relies on text analysis of information related to SMEs, including the main products or services in a particular province or industry. This information is used to determine the extent to which the industry is involved in financial market activities and thus, its level of financialization. The selection of the corpus is a critical basis for the accurate measurement of SME financialization, and it should be comprehensive enough to cover a wide range of industries, in order to avoid potential sampling biases. In addition, the information contained in the corpus must be precise enough and should not include too much additional noise, in order to avoid interfering with the final measurement results.

Based on the aforementioned considerations, this paper chooses to use the scope of business information of enterprises in the full sample of Chinese enterprise registration information as the basis corpus for measuring SME financialization. This vast database contains information on approximately 30 million Chinese enterprises, and this database resource can fully guarantee the accuracy of the subsequent measurement results.

Based on existing data, this study uses registered capital as the criterion for selecting SMEs. According to calculations, from 2011 to 2017, an average of approximately 53.1% of enterprises in China had registered capital of less than 1 million yuan; about 20.16% of enterprises had registered capital of 5 million yuan or more. Based on this proportion, this study defines enterprises with registered capital of below 1 million yuan as SMEs. To ensure the reliability of the subsequent empirical results, for robustness, the financialization levels of enterprises with registered capital below 1.5 million yuan are also analyzed. The specific algorithm is as follows.

① The MixSegment model in the Jieba segmentation engine, which is commonly used in the Chinese segmentation field, is employed to segment the enterprises' business scope.
② Remove the 1893 most commonly-used Chinese stop words to eliminate the noise caused by these high-frequency but meaningless words. This results in approximately 4.59 billion words, of which there are about 155,000 non-repeated words.
③ The TF-IDF algorithm is used to measure the importance of each word in a specific industry and to calculate the TF-IDF value of each keyword.
④ Finance and real estate industries are designated as finance-related industries. The top *N* keywords with high TF-IDF values are selected as the financial keyword library.
⑤ The presence of financialization in each enterprise is determined by comparing the enterprise's business scope keywords with the financial keywords library.
⑥ Based on the above calculation, the proportion of financially-oriented enterprises is determined as the financialization level of the province, industry, and year.

In the above calculation process, 200 financial keywords are set as the benchmark for measuring financialization. In addition, the financialization level calculated with 100 financial keywords is used for robustness analysis.

(2) Digital finance (DF)

[45] constructed a digital inclusive finance development index based on billions of transactional data from Ant Financial, covering 24 detailed indicators. In addition to the overall index, the index is further divided into three directions: breadth of usage, depth of usage, and digitization level. Considering that Ant Financial is the largest fintech company in China, and its transactional data is highly representative nationwide and more accurate than keyword searches, this study adopts this index to measure the level of digital financial development.

Table 1

Descriptive statistics of variables.

Variables	Obs.	Mean	S.D.	Min	Median	Max	Skewness	Kurtosis
SMEF	18,980	0.232	0.245	0.000	0.036	0.144	0.355	1.000
DF	18,980	2.172	0.714	0.213	2.311	3.345	−0.569	2.403
EG	18,980	8.853	5.193	−28.870	6.760	8.725	10.840	20.830
GC	18,980	0.488	0.348	0.195	0.325	0.403	0.522	2.450
DO	18,980	0.265	0.302	0.0168	0.084	0.141	0.300	1.548
IS	18,980	45.320	9.033	29.700	39.100	44.500	49.530	80.980
WL	18,980	10.930	0.292	10.350	10.720	10.920	11.120	11.890
AS	18,980	0.099	0.0217	0.0482	0.084	0.097	0.113	0.152

Notes: Obs. denotes the number of observations, and S.D. denotes the standard deviation of variables.

Table 2

Impact of digital finance on the financialization of SMEs.

	(1)	(2)	(3)	(4)
D.V.	SMEF	SMEF	SMEF	SMEF
DF	−0.0209*			
	(0.0115)			
DF width		−0.0328**		
		(0.0150)		
DF depth			−0.0086	
			(0.0060)	
Digitization				−0.0006
				(0.0034)
EG	0.0004**	0.0005***	0.0004**	0.0004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
GC	0.1494***	0.1550***	0.1531***	0.1542***
	(0.0191)	(0.0188)	(0.0189)	(0.0193)
DO	0.0461***	0.0505***	0.0451***	0.0498***
	(0.0095)	(0.0093)	(0.0099)	(0.0093)
IS	0.0021***	0.0020***	0.0022***	0.0022***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
WL	0.0069	0.0059	0.0077	0.0039
	(0.0161)	(0.0160)	(0.0162)	(0.0160)
AS	−0.3380***	−0.3779***	−0.3446***	−0.3444***
	(0.0875)	(0.0884)	(0.0873)	(0.0892)
Year FE	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
N	12,992	12,992	12,992	12,992
Adj. R^2	0.5951	0.5951	0.5950	0.5949

Notes: DF width, DF depth and digitization denote breadth of usage, depth of usage, and digitization level of digital finance, respectively. Parentheses indicate the standard deviation of parameter estimates; *, **, and *** denote the significance levels of 10%, 5%, and 1%, respectively.

(3) Other control variables

As both digital finance and SME financialization are provincial-level variables, this study chose some provincial-level control variables, with all data sourced from the CSMAR database. The rationale for selecting these variables is as follows:

Economic growth (EG): Since provincial economic growth reflects the state of the economic environment, enterprises are expected to have more motivation to participate in industrial operations when the economic environment is good. Additionally, as a component of the national economy, digital finance is also expected to be related to macroeconomic conditions. Therefore, the GDP growth rate at the provincial level is used as a control variable.

Government capacity (GC): Government capacity not only reflects the influence of local governments on the economy but also reflects their ability to provide public goods, such as infrastructure construction. Thus, government capacity is expected to have an impact on both digital finance and physical enterprise operations. This study measures government capacity using the ratio of local government fiscal expenditure to GDP.

Degree of openness (DO): To some extent, the degree of provincial openness to the outside world can reflect a province's economic vitality. The stronger the provincial economic vitality is, the better the development environment for digital finance, and the better the survival and operational environment for enterprises. This study measures the degree of openness using the ratio of total imports and exports to provincial GDP.

Industrial structure (IS): A province's industrial structure can reflect the level of advanced or reasonable economic development in that province. The more reasonable the industrial structure and the higher the level of industrial upgrading in a province is, the greater is the possibility of new technologies and business models emerging. This study measures the level of industrial structure using the proportion of the tertiary industry to GDP.

Table 3
Robustness: changing the criteria for SMEs.

	(1)	(2)	(3)	(4)
D.V.	SMEF	SMEF	SMEF	SMEF
DF	−0.0236**			
	(0.0114)			
DF width		−0.0369**		
		(0.0148)		
DF depth			−0.0077	
			(0.0060)	
Digitization				−0.0019
				(0.0034)
Year FE	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
N	13,014	13,014	13,014	13,014
Adj. R^2	0.6013	0.6013	0.6012	0.6011

Notes: Parentheses indicate the standard deviation of parameter estimates, and ** denotes the significance levels of 5%.

Wage level (WL): The level of employee wages reflects the income level and purchasing power of consumers in the employees' province. The higher the average wage level in a province is, the stronger is the purchasing power of consumers, and the better the survival environment for enterprises and the development environment for digital finance. This study measures the wage level using the natural logarithm of the average annual wage of employees at the provincial level.

Age structure (AS): The higher the proportion of young people in a province is, the higher will be the young people's ability to accept new things, their economic vitality, and innovation capability. These factors are also expected to affect the development of digital finance and the survival and operation of enterprises. This study measures the age structure using the proportion of the population aged 65 and above at the provincial level.

Table 1 presents the descriptive statistics of the variables. Among SMEs with registered capital of no more than RMB 1 million, up to 14.4% of those enterprises participate in financial activities. The skewness of SMEs financialization is 0.355, indicating that the majority of SMEs have relatively low levels of financialization. In addition, the minimum and maximum values of the digital finance index are 0.213 and 3.345, respectively, with quite a large range. This finding suggests there is an uneven distribution of digital finance development across cities in China. However, the mean value shows that the overall level of digital finance development in the country is relatively high, at around 2.172.

5. Empirical analysis

5.1. Baseline regression

According to Table 1, SMEs exhibit a right-skewed distribution, indicating the presence of some relatively large outliers. Therefore, subsequent regressions exclude excessively high samples of SMEs, thus avoiding the bias caused by outliers on the estimation results. Table 2 reports the results of the baseline regression; all regressions control for year fixed effects and provincial fixed effects. As can be seen, all four types of digital finance indices have negative impacts on SME financialization. This finding suggests that digital finance has a restraining effect on SME financialization.

A further observation of the results of various types of digital finance indices in Table 2 reveals that the impact of the digital finance composite index on SME financialization in Column (1) is −0.0209, significant at the 10% level. Meanwhile, the impact of digital finance coverage breadth on SME financialization in Column (2) is −0.0328, significant at the 5% level. The effects of digital finance usage depth and digitization degree in Columns (3) and (4) are not significant. Their coefficients are also much smaller than those of the composite index and coverage breadth index. These results suggest that digital finance mainly exerts a significant inhibitory effect on SME financialization through digital finance's coverage breadth. Subsequently, a robustness analysis will be conducted to further address potential endogeneity issues and examine the effects of the three sub-indices.

The present study further calculates the standardized coefficients of the baseline regression mentioned above and finds that an increase of one standard deviation in the comprehensive index and coverage breadth of digital finance would lead to a decrease of 0.087 and 0.099 standard deviations in the financialization of SMEs, respectively. These impacts are significantly greater than those of economic growth, degree of openness, industrial structure, wage level, and age structure. The findings indicate a strong economic significance of the inhibitory effect of digital finance on the financialization of SMEs. However, this study also discovers that an increase of one standard deviation in government capacity would lead to an increase of approximately 0.22 standard deviations in the financialization of SMEs. This increase is much higher than the effect of digital finance. As government capacity to a certain extent reflects the level of government intervention in the market and inversely reflects the degree of marketization in the province, improving provincial marketization and reducing government intervention in the market could help to reduce the financialization of SMEs. The main reason for this phenomenon could be that governments engaging in higher levels of market intervention may result in resources being more biased toward state-owned enterprises or large entities supported by local governments. This situation worsens the investment environment for SMEs and ultimately leads to their financialization.

Table 4
Robustness: changing the extraction criteria for financial industry keywords.

	(1)	(2)	(3)	(4)
D.V.	SMEF	SMEF	SMEF	SMEF
DF	−0.0145*			
	(0.0087)			
DF width		−0.0138		
		(0.0115)		
DF depth			−0.0089*	
			(0.0045)	
Digitization				−0.0003
				(0.0026)
Year FE	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
N	13,014	13,014	13,014	13,014
Adj. R^2	0.6013	0.6013	0.6012	0.6011

Notes: Parentheses indicate the standard deviation of parameter estimates, and * denotes significance levels of 10%.

Table 5
Robustness: adding industry * year fixed effects.

	(1)	(2)	(3)	(4)
D.V.	SMEF	SMEF	SMEF	SMEF
DF	−0.0237**			
	(0.0111)			
DF width		−0.0236		
		(0.0145)		
DF depth			−0.0095	
			(0.0058)	
Digitization				−0.0033
				(0.0033)
Year FE	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
Industry & year FE	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
N	13,014	13,014	13,014	13,014
Adj. R^2	0.6013	0.6013	0.6012	0.6011

Notes: Parentheses indicate the standard deviation of parameter estimates, and ** denotes significance levels of 5%.

5.2. Robustness tests

(1) Change the criteria for SMEs.

Combining the analysis in Section 4, the criterion for judging SMEs is changed, from not exceeding RMB 1 million to not exceeding RMB 1.5 million. The regression results are shown in Table 3. As can be seen, the regression results are very similar to those in Table 2, indicating that changing the measurement standard for SMEs does not cause significant interference to the regression results. To further demonstrate the robustness of the results, this paper also attempts to change the judgment standard of SMEs to not exceeding RMB 500,000, 750,000, 1.25 million and 2 million, respectively, and the results show no significant differences. The inhibitory effect of digital finance on SMEs' financialization always exists.

(2) Change the extraction criteria for financial industry keywords.

In the previous analysis, the main approach was to use the top 200 vocabulary of TF-IDF values in the financial industry over the years as financial industry keywords. Inevitable errors in the NLP process, such as relatively less important vocabulary being included in the top 200, can lead to an overestimation of SME financialization. Therefore, the top 100 vocabulary of TF-IDF values in the financial industry over the years are selected to recalculate SME financialization. The regression results are shown in Table 4.

As can be seen, the overall regression results from Tables 2 and 3 still do not show significant differences, and the impact of digital finance on SME financialization is still negative. After adding control variables, the impact of the digital finance composite index and the use of depth is more significant. This is slightly different from Tables 2 and 3 However, in terms of economic significance, that is, the size of the standardized coefficients, the impact of the digital finance composite index and coverage breadth on SME financialization is still the largest. Considering the potential problem of multicollinearity, this paper pays more attention to the economic significance of the impact of digital finance.

Table 6
Influence mechanism of digital finance on SMEs financialization.

	Full-sample	Low cons.	High cons.
	(1)	(2)	(3)
D.V.	SA	SA	SA
DF	−0.0040	0.0208***	0.0918***
	(0.0053)	(0.0059)	(0.0127)
Year FE	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Control variables	Yes	Yes	Yes
N	11,141	9428	1509
Adj. R^2	0.9366	0.8926	0.9385

Notes: Parentheses indicate the standard deviation of parameter estimates, and *** denotes significance levels of 1%.

(3) Adding time-varying fixed effects

The previous regressions all controlled for year fixed effects and provincial fixed effects. To further eliminate the endogeneity issues caused by some heterogeneity factors that vary by industry, industry * year fixed effects are further controlled in the following regression. The results are shown in Table 5. As one can see, the results remain relatively robust, mainly indicating that the comprehensive index and coverage breadth of digital finance have the strongest inhibitory effect on SME financialization.

(4) Instrumental variables regression

Finally, this paper has controlled for some potential confounding factors that may cause endogeneity issues by controlling provincial-level covariates, adding fixed effects, and using the lagged independent variable to avoid reverse causality. However, there may still be unquantifiable or unobservable confounding factors that cannot be fully controlled for in the limited sample size and degrees of freedom, and this could lead to additional endogeneity issues. Therefore, next, instrumental variable regression is used to further examine the robustness of the digital financial coefficient in affecting SMEs financialization in the benchmark regression. The internet penetration rate is used as the instrumental variable in two-stage least squares regression. The results show that the negative impact of the digital financial index on SMEs financialization remains significant at the 10% level. Thus, endogeneity issues are also unlikely to significantly interfere with the empirical results of the benchmark regression.

5.3. Mechanism analysis

This section mainly considers whether digital finance can suppress SMEs' financialization by easing their financing constraints. The commonly-used SA index is employed to measure SMEs' financing constraints. According to Ref. [46]; the SA index is generally negative, and the smaller the absolute value is, the stronger is the financing constraint.

Table 6 reports the corresponding results. Column (1) reports the impact of digital finance on SMEs' financing constraints in the full sample. As can be seen, from a full-sample perspective, the impact of digital finance on financing constraints is not significant. Financing constraints are not a macro-level mechanism; they reflect SMEs' own characteristics. Considering the strong theoretical relationship between financing constraints, credit rationing, and SMEs' financialization, and considering that only when SMEs face high financing constraints will they participate in financial market activities to maintain their survival, this study groups SMEs according to the size of their financing constraints. Then, we examine whether significant differences exist between the high financing constraint group and the low financing constraint group. Based on the data characteristics, the group with an SA index less than 0.4 is defined as the high financing constraint group; the remaining sample is the low financing constraint group. The regression results of the grouped analysis are shown in Columns (2) and (3) of Table 6. The results of the grouped regression show that digital finance significantly eases the financing constraints of enterprises in the high financing constraint group. In contrast, although digital finance can also ease the financing constraints of the enterprises in the low financing constraint group, the effect of easing their financing constraints is weaker. This is because the financing constraints of the low group are relatively minimal. Overall, the mechanism analysis results show that digital finance mainly suppresses SMEs' financialization by easing their financing constraints, especially by providing liquidity to enterprises with relatively high financing constraints.

6. Further research

Section 3 shows that a deterioration of credit allocation or the investment environment may lead SMEs to engage in higher-risk financial investment activities, thereby increasing their risk. Therefore, this section further examines how digital finance and SME financialization affect SMEs' bankruptcy risk (BR). The reason for examining SMEs' bankruptcy risk is twofold. First, for SMEs, survival is a more prominent risk concern, and second, data availability issues need to be considered.

This study uses the available enterprise business registration information to calculate the SMEs' mortality rate by industry, province, and year. Also, a bankruptcy risk indicator for SMEs is designed, based on external environmental information. The indicator is defined as follows:

Table 7
Impact of digital finance on insolvency risk of entity SMEs.

D.V.	(1)	(2)	(3)	(4)	(5)	(6)
	F1.BR	F2.BR	F3.BR	F4.BR	F5.BR	F1.BR
SMEF						0.0046*
						(0.0026)
DF	−0.0521***	0.0046	0.0460***	0.0777***	−0.0377***	−0.0448***
	(0.0041)	(0.0053)	(0.0062)	(0.0077)	(0.0101)	(0.0052)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
N	18,979	16,138	13,834	11,485	9114	13,179
Adj. R^2	0.5995	0.6287	0.6126	0.5938	0.5437	0.5667

Notes: Parentheses indicate the standard deviation of parameter estimates, and ** and *** denote significance levels of 5% and 1%, respectively.

$$BR_{i,j,t} = \frac{Dead_{i,j,t}}{Sum_{i,j,t}} \# \tag{22}$$

where $BR_{i,j,t}$ represents the bankruptcy risk of industry j in province i at year t; $Dead$ represents the number of SMEs' deaths, and Sum represents the number of registered and non-dead SMEs.

Table 7 reports the overall impact of digital finance on SMEs' bankruptcy risk. As can be seen, digital finance has a significant inhibitory effect on the bankruptcy risk (Column (1)). In addition, a dynamic test is conducted by lagging the DF by more periods (two to five periods) in Columns (2) to (5). The results show that this inhibitory effect has good persistence under different lag periods.

To further examine the role of SME financialization in reducing bankruptcy risk through digital finance, Column (6) in Table 7 adds SME financialization as an independent variable, based on Column (1). As can be seen, when controlling for the confounding effect of digital finance, SME financialization significantly increases bankruptcy risk. This finding indicates that digital finance helps reduce SME bankruptcy risk by suppressing SME financialization.

7. Conclusions

This study innovatively uses business registration information from 30 million companies and measures the financialization level of SMEs, based on their business scope text information. On this basis, this study finds that digital finance has a significant inhibitory effect on SME financialization. In further mechanistic analysis, digital finance is found to mainly inhibit SME financialization by easing financing constraints; this inhibitory effect is also stronger for SMEs with higher financing constraints. In addition, this study finds that SME financialization significantly increases the SMEs' bankruptcy risk, reflecting that financialization behavior is not conducive to the survival of a large number of SMEs. However, digital finance can reduce SME financialization and thereby reduce that bankruptcy risk. This highlights the positive role of digital finance in optimizing the environment in which SMEs can survive.

The results of this study provide a valuable supplement to existing research, which has mainly focused on listed companies. This study offers solid empirical evidence for the risk management of SMEs, based on digital finance. On the one hand, the development of digital finance must be continually promoted and its advantages fully leveraged, in order to provide a more stable survival environment for SMEs. This can be achieved by increasing efforts to promote digital finance, cultivating digital finance awareness, and enhancing the convenience of the use of digital finance use, among other dimensions. This should be done to ensure that digital finance effectively serves the survival and development needs of SMEs.

On the other hand, the significant effect of digital finance in easing SMEs' financing constraints and reducing their bankruptcy risk implies that commercial banks, while actively developing digital finance businesses, need to abandon the traditional credit thinking mode based on collateral. Commercial banks must fully utilize digital platforms and digital credit systems to explore financial services for the long-tail customer group, including a large number of SMEs. From the perspectives of quantity, employment, and output value, SMEs still account for a significant proportion of China's industrial economy, and their credit market space is vast. With the help of digital finance technology, commercial banks should actively promote the use and development of digital finance. Corresponding financial products should be developed, as well as services targeted at the long-tail group. Only by fully combining the technological advantages of digital finance with the financing needs of the existing and extensive long-tail group can a broad market space be opened up for the further development of digital finance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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