

Research on the Impact Mechanism of Digital Finance on Total Factor Productivity of Enterprises: A Case Study of Shanghai and Shenzhen A-share Listed Companies

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Abstract: The improvement of total factor productivity (TFP) of enterprises is the key to achieving high-quality economic development. Digital finance, as a new form of financial services, has a significant impact on the total factor productivity of enterprises. Therefore, this article searched for data on A-share listed companies in Shanghai and Shenzhen from 2010 to 2021, and used a fixed effects model and instrumental variable method to empirically analyze the impact and mechanism of digital finance on TFP. Research has found that: (1) digital finance and its sub dimensions (especially the degree of digitization) significantly improve enterprise TFP;(2)Digital finance has a stronger TFP promotion effect on small-scale enterprises, non-state-owned enterprises, high-tech enterprises, and enterprises in western regions; (3) Digital finance promotes TFP growth through mechanisms such as increasing research and development investment, enhancing human capital, improving resource allocation, improving information disclosure quality, strengthening risk-taking ability, and optimizing corporate governance. Based on this, this article proposes policy recommendations to promote the healthy development of digital finance and enhance the TFP of enterprises.

Keywords: Digital finance; Enterprise total factor productivity; Impact mechanism.

1. Introduction

1.1. Research Background

With the rapid development of digital technology, digital finance, as an emerging financial service model, is profoundly changing the operation of the traditional financial system. Through the application of technologies such as big data, cloud computing, and blockchain, digital finance not only improves the efficiency and coverage of financial services, but also injects new vitality into the real economy. In this context, total factor productivity (TFP) of enterprises, as a core indicator for measuring comprehensive efficiency and technological progress, has received widespread attention. Improving enterprise TFP is not only an important way to achieve high-quality economic development, but also a key factor in enhancing enterprise competitiveness.

In recent years, China's digital finance has developed rapidly, especially in areas such as mobile payments, online lending, and intelligent investment advisory, which have provided more convenient and low-cost financing channels for small and medium-sized enterprises. However, the long-standing problems of credit discrimination and information asymmetry in the traditional financial system have led many enterprises, especially non-state-owned enterprises and small and medium-sized enterprises, to face difficulties and high financing costs. The rise of digital finance provides a new path to address these issues. By optimizing resource allocation, reducing financing costs, and enhancing information transparency, digital finance has created favorable conditions for enterprise technological innovation and production efficiency improvement.

Although the development of digital finance has brought many opportunities for enterprises, its specific impact

mechanism on enterprise TFP has not been fully studied. Existing literature mostly focuses on the impact of digital finance on economic growth or financial inclusion, while there is relatively little research on how it affects corporate TFP through different channels. Whether there is heterogeneity in the role of digital finance, especially for enterprises of different ownerships, scales, and industries, still needs further exploration.

Based on this, this article takes A-share listed companies in Shanghai and Shenzhen as the research object, and explores the impact mechanism of digital finance on corporate TFP. By analyzing the role of digital finance in fund financing, resource allocation, information disclosure, and risk-taking, this article aims to reveal how digital finance can enhance enterprise TFP through various channels, and provide theoretical basis and policy recommendations for promoting the healthy development of digital finance and high-quality development of enterprises.

2. Literature Review

2.1. Research on Total Factor Productivity of Enterprises

2.1.1. Research on Measuring Total Factor Productivity of Enterprises

Since Solow (1957) proposed the concept of total factor productivity, scholars have regarded how to accurately measure total factor productivity as a new key research direction. During this period, many methods for measuring total factor productivity emerged, such as the Solow model method (Chen Chaofan, 2016) [2], the stochastic frontier analysis method (Li Xuesong and Gong Xiaoqian, 2021) [3], the data envelopment analysis method (DEA), and the

directional distance function method evolved from it (Sun Huashu and Lv Yiqing, 2019 [4]; Zhou Xiaohui et al., 2021 [5]). In addition, with the development of Internet technology, we have more and more convenient access to enterprise data, and the reliability of data has been greatly improved. Therefore, scholars began their journey to explore how to measure enterprise total factor productivity, and what methods can be used to measure total factor productivity. The methods we are familiar with mainly include OLS method, OP method, LP method, FE method, and generalized estimation method.

2.1.2. Factors affecting total factor productivity of enterprises

Zhai Shuping and Gu Qun (2013) found that the development of the financial industry can release the financing pressure of domestic high-tech enterprises, thereby promoting the total factor productivity of enterprises. Luo Liangwen and Sun Xiaoning (2020) studied Chinese industrial enterprises and explored the impact of financial development on enterprise TFP from two dimensions: the scale and efficiency of financial development. The study found that the development of the financial industry, especially in recent years, has provided domestic enterprises with a large amount of funds, allowing them to vigorously promote their own technological improvements and resource allocation, effectively utilizing resources and promoting the rapid growth of enterprise TFP.

2.2. Research on Total Factor Productivity of Digital Finance

2.2.1. Research on the Impact of Digital Finance on Macroeconomics

Wang Yongcang and Wen Tao (2020) found based on provincial level data from 2011 to 2017 that the positive correlation between digital inclusive finance and economic growth gradually deepens over time, and in China, compared to other regions, this positive effect is stronger in the central and western regions [8]. Cheng et al. (2021) studied 72 countries from 2000 to 2015 and used principal component analysis to verify that the application of information technology in the financial industry greatly weakened the negative effects of finance, thereby promoting economic growth [9].

2.2.2. Research on the Impact of Digital Finance on Micro Enterprises

Zhao Rui and Cao Tinggui (2022) found that digital finance can improve corporate leverage by reducing financing costs and operational risks, and has a more significant deleveraging effect on state-owned and large-scale enterprises [10]. Li Bin et al. (2021) studied the relationship between digital finance and the financial sustainability of small and medium-sized enterprises, and found that digital finance has a positive impact on the financial sustainability of enterprises, mainly through the bridging effect of financing constraints [11].

3. Theoretical Analysis and Research Hypotheses

3.1. Financial Intermediary Theory

Throughout history, the theory of financial intermediation has been able to be analyzed and elaborated from multiple perspectives. With the development of the times, transaction costs, information asymmetry, and agency have become the

main aspects of analyzing the necessity of the theory of financial intermediation.

3.1.1. Transaction Cost Theory

In the financial market, any trading behavior incurs certain costs, and individual investors often need to bear higher fees. In contrast, financial intermediaries, with their scale advantage and advanced technological capabilities, can collect, process, and analyze information more efficiently, thereby significantly reducing the cost burden of individual investors in information acquisition and processing.

3.1.2. Asymmetric Information Theory

The emergence of information asymmetry mainly stems from the following three reasons. Firstly, the existence of information acquisition costs makes some market participants choose to give up information search in the decision-making process due to the inability to afford the high cost of information collection or the cost exceeding expected benefits, resulting in information gaps among participants. Secondly, the differences in information held by different economic entities gradually widen with changes in social division of labor, and their abilities to discern and process information also gradually differentiate, further exacerbating the problem of information asymmetry. Finally, the market mechanism itself may have flaws, such as inadequate systems or regulatory frameworks, where some participants exploit regulatory loopholes to spread false information, exacerbating the problem of information asymmetry.

3.1.3. Principal Agent Theory

When ownership and management rights of a company are separated, conflicts of interest between owners and operators may lead to agency problems. Taking controlling shareholders and small and medium-sized shareholders as examples, the agency problem between the two mainly stems from differences in equity structure. The controlling shareholder holds a dominant position and decision-making power in the board of directors through their control over the company's equity, while small and medium-sized shareholders, due to their lower shareholding ratio, can usually only express their opinions through "voting with their feet". This power imbalance may lead to controlling shareholders engaging in improper behaviors such as manipulating stock prices and financial fraud in pursuit of their own interests, damaging the rights and interests of small and medium-sized shareholders, and ultimately having a negative impact on the overall interests of the company.

3.2. Financial Function Theory

Merton and Bodie proposed six basic functions of finance, including risk management, information transmission, incentive mechanisms, clearing and payment, resource transfer, and resource accumulation. Subsequently, Levine (1997; 2004) classified financial functions into five categories: promoting savings, managing risks, facilitating transactions, optimizing resource allocation, and improving corporate governance. Domestic scholars have also extensively explored the functions of finance, and some scholars believe that the core functions of finance include resource allocation, risk avoidance, and consumption guidance. Although there are some differences in the expression of these functions, this is mainly due to differences in research perspectives and research objects, and their essential connotations are consistent.

Based on the research direction of this article, it mainly

analyzes the following six functions: fund financing, information transmission, resource allocation, corporate governance, risk management, and human capital accumulation.

3.3. Analysis of the Impact of Digital Finance on Total Factor Productivity of Enterprises

The popularity of the Internet and the 5G upgrade have promoted the rapid development of digital finance, effectively solved the problems of credit discrimination and information asymmetry in traditional financial services, and alleviated the financing difficulties of enterprises. Digital finance breaks the limitations of time and space through online services, gathers idle funds, reduces financing costs, and uses big data to accurately assess corporate credit risks, lowering financing thresholds. At the same time, digital finance develops diversified financial products, enriches financing channels, and strengthens risk control through artificial intelligence and blockchain technology, improving enterprise resource utilization and total factor productivity. Based on this, the following hypothesis is proposed:

Assumption 1: Digital finance promotes the total factor productivity of enterprises.

3.4. Analysis of the Impact Mechanism of Digital Finance on Total Factor Productivity of Enterprises

3.4.1. R&D investment channels

Digital finance combines advanced technologies such as big data and machine learning with financial services, further enhancing the function of fund financing and providing necessary financial support for enterprises to increase research and development investment. The increase in research and development investment can promote technological progress and improve production efficiency, thereby laying the foundation for the growth of total factor productivity. Based on this, the following hypothesis is proposed:

Assumption 2: Digital finance drives the growth of total factor productivity by increasing research and development investment in enterprises.

3.4.2. Human Capital Channels

The promotion effect of digital finance on human capital accumulation is mainly reflected in two aspects: the increase of human capital stock and the improvement of human capital quality, among which the latter is particularly crucial (Sun Yanlin et al., 2022) [13]. Nelson and Phelps (1966) pointed out through model analysis that human capital mainly drives the growth of total factor productivity by improving the technological level of enterprises. Based on this, the following hypothesis is proposed:

Assumption 3: Digital finance promotes the growth of total factor productivity by enhancing the human capital level of enterprises.

3.4.3. Resource allocation channels

The development of digital finance helps optimize the efficiency of resource allocation for enterprises. The improvement of resource allocation efficiency means that enterprises can choose, allocate, and combine resources more reasonably, thereby achieving maximum efficiency, improving investment efficiency, and value creation ability. This not only enhances the investment of enterprises in the

research and development of new technologies and products, but also promotes the improvement of production efficiency and technological level, ultimately having a positive impact on the total factor productivity (TFP) of enterprises. Based on this, the following hypothesis is proposed:

Assumption 4: Digital finance promotes the growth of total factor productivity by optimizing the efficiency of enterprise resource allocation.

3.4.4. Information Disclosure Channels

The development of digital finance has prompted enterprises to improve the quality of information disclosure. In order to increase the likelihood of successful financing, companies need to enhance the transparency of information disclosure. On the one hand, high-quality information disclosure promotes the improvement of total factor productivity of enterprises through incentive effects; On the other hand, the supervisory effect of information disclosure has also promoted the growth of total factor productivity of enterprises. High quality information disclosure has formed an effective internal and external supervision mechanism, which encourages management to actively promote technological upgrading and innovative research and development, alleviates the problem of insufficient investment in research and development innovation, and thus benefits the growth of total factor productivity of the enterprise. Based on this, the following hypothesis is proposed:

Assumption 5: Digital finance promotes the growth of total factor productivity by improving the quality of information disclosure of enterprises.

3.4.5. Risk bearing channels

The development of digital finance has enhanced the risk-taking ability of enterprises. The increase in risk-taking level means that enterprises are more capable of investing in high-risk, high-yield projects, which helps to develop new products and upgrade production technology, thereby improving production efficiency and technological level, and having a positive effect on the growth of total factor productivity of enterprises. Based on this, the following hypothesis is proposed:

Assumption 6: Digital finance promotes the growth of total factor productivity by increasing the risk-taking level of enterprises.

3.4.6. Corporate Governance Channels

The core feature of digital finance lies in the use of digital technology tools such as big data and artificial intelligence, which not only play a role in credit services but also have significant implications in financial regulation. Therefore, digital finance may have a positive impact on the internal and external governance of enterprises, thereby promoting their total factor productivity. Based on this, the following hypothesis is proposed:

Assumption 7: Digital finance promotes the growth of total factor productivity by enhancing corporate governance.

4. Empirical Analysis

4.1. Research Design

4.1.1. Model Setting

The fixed effects model is suitable for eliminating the impact of heterogeneous factors on empirical results. Based on the empirical object and data in this article, the fixed effects model was selected for benchmark regression analysis,

and industry and year were fixed. The set model is as follows:

$$TFP_{i,t} = \alpha_0 + \alpha_1 Difi_{m,t} + \alpha_2 \sum Control_{i,t} + \theta_j + \mu_t + \varepsilon_{i,t}$$

Where, $Difi_{m,t}$ represents the level of digital finance development in province m where company i is located in year t , $Control$ is the control variable, θ_j and μ_t represent industry fixed and time fixed effects, respectively, and $\varepsilon_{i,t}$ is the random error term.

4.1.2. Variable Description

(1) Dependent variable. Total factor productivity (TFP) of enterprises: TFP is an indicator that measures the comprehensive efficiency of enterprises in the production process, reflecting the output level that enterprises can achieve under given inputs (such as capital, labor, and other production factors). Nowadays, the OP method, which has better accuracy, is generally used to measure the total factor productivity of micro enterprises. The OP method is more suitable for solving the problems of simultaneity bias and sample selection bias.

(2) Explanatory variables. Digital Finance (Difi): This article selects the provincial-level Peking University Digital Inclusive Finance Index as the explanatory variable and

matches it with sample enterprise data. The Digital Inclusive Finance Index (Difi) is a weighted index of three dimensions: digital finance coverage, usage depth, and digitalization level. It clearly reflects the status and evolving trends of digital finance development at the provincial, municipal, and county levels in China.

(3) Control variables. Referring to existing literature, this article comprehensively considers multiple aspects of a company's profitability, debt paying ability, growth ability, etc. It selects return on assets (Roa), debt to asset ratio (Lev), revenue growth rate (Growth), cash ratio (Cash), and independent director ratio (Indep) as control variables. In addition, the age and size of the company are also included as control variables.

(4) Intermediary variable. Based on existing research, R&D investment intensity (R&D), human capital level (Human), resource allocation efficiency (Effic), risk-taking level (Risk), information disclosure quality (KV), and corporate governance level (Maga) are selected as mediating variables. The specific variable definitions are shown in Table 1.

Table 1. Related Variables Table

Variable type	Variable name	Variable symbol	Measurement method
Explained Variable	Total factor productivity of enterprises	Tfp-op	OP method
Explanatory variable	Digital Finance Index	Difi	Refer to the Digital Financial Inclusion Index released by Peking University
	Breadth of digital finance coverage	Coverage	
	Depth of use of digital finance	Usage	
	The degree of digitalization in digital finance	Digi	
Intermediary variable	R&D investment intensity	R&D	R&D expenditure
	Human capital level	Human	Proportion of employees with a bachelor's degree or above
	Allocative efficiency	Effic	Standard deviation of total factor productivity in the industry
	Quality of information disclosure	Kv	KV method
	Risk bearing level	Risk	Three year profit volatility
	Corporate governance level	Magn	Principal Component Analysis
Control variable	Return on assets	Roa	Profit/Total Assets
	Asset liability ratio	Lev	Total liabilities/total assets
	Revenue growth rate	Growth	Revenue growth/previous year's revenue
	Cash ratio	Cash	Net cash flow generated from operating activities/total assets
	Proportion of independent directors	Indep	Proportion of independent directors in the board of directors
	Enterprise size	Size	Logarithmic ratio of total assets of the enterprise
	Enterprise age	Age	Long term existence of the enterprise

4.1.3. Sample selection and data sources

Based on the research content and direction of this article, relevant data of A-share listed companies in Shanghai and Shenzhen from 2010 to 2021 are selected as the experimental data. The data in this article mainly comes from Guotai Junan Financial Database and Wind Database.

4.1.4. Descriptive statistics

After performing simple filtering, exclusion, and other processing on the data, we first use descriptive statistical methods to perform simple descriptive statistics on the processed data, observe the patterns of enterprise data, and draw some simple conclusions from it.

Table 2 shows the descriptive statistical results of data

related to A-share listed companies from 2010 to 2021. From the results in the table, the average total factor productivity of A-share listed companies is 16.123, with a maximum value of 19.789 and a minimum value of 12.778, indicating that there is a certain gap in total factor productivity between companies. The maximum value of the Digital Finance Index (Difi) is 4.321 and the minimum value is 0.243, indicating that the degree of influence of digital finance varies among enterprises. The mean of the digital finance index is 2.541, with a median of 2.662, indicating that the digital finance index in most provinces of China is above the mean. The maximum value of revenue growth rate is 2.531 and the minimum value is -0.373, indicating that there is a gap in the

growth ability of A-share listed companies in China, with an average of 0.171 and a standard deviation of 0.377. This

suggests that the overall growth ability of Chinese companies still needs to be improved.

Table 2. describes the statistical results

Variable name	Sample size	Mean	Median	Standard deviation	Min	Max
Tfp-op	24943	16.121	16.0241	1.304	12.774	19.784
Difi	24943	2.546	2.6718	1.016	0.245	4.319
Coverage	24943	2.354	2.4392	0.988	0.129	3.97
Usage	24943	2.596	2.6374	1.071	0.236	4.887
Digi	24943	3.086	3.3031	1.192	0.076	4.537
Roa	24943	0.039	0.0379	0.069	-0.277	0.231
Growth	24943	0.171	0.0791	0.377	-0.373	2.531
Size	24943	21.754	21.5673	1.432	18.998	26.701
Lev	24943	0.447	0.4366	0.218	0.052	1.035
Age	24943	2.859	2.8904	0.345	1.792	3.497
Cash	24943	1.191	0.5649	1.854	0.033	12.033
Indep	24943	0.353	0.3333	0.091	0	0.571

4.2. Benchmark Regression Test

After conducting descriptive statistical analysis, perform

benchmark regression tests to estimate the potential impact of digital finance on total factor productivity of enterprises.

Table 3. Benchmark Regression Results

Variable	1	2	3	4
	Tfp-op	Tfp-op	Tfp-op	Tfp-op
Difi	0.0553*** (-3.5361)	0.0440***		
Coverage		(-3.0572)		
Usage			0.0404*** (-3.6415)	
Digi				0.0514** (-2.0652)
Roa	3.0694*** (-36.1046)	3.0695*** (-36.1077)	3.0691*** (-36.1)	3.0684*** (-36.1038)
Growth	-0.1921*** (-13.5817)	-0.1921*** (-13.5826)	-0.1921*** (-13.5819)	-0.1918*** (-13.5627)
Size	0.7398*** (-170.1598)	0.7398*** (-170.1367)	0.7399*** (-170.1895)	0.7398*** (-170.168)
Lev	0.6507*** (-21.9835)	0.6509*** (-21.9936)	0.6506*** (-21.9763)	0.6516*** (-22.0083)
Age	-0.0061 (-0.4324)	-0.0065 (-0.4577)	-0.006 (-0.4257)	-0.0095 (-0.6694)
Cash	0.0195*** (-8.3049)	0.0195*** (-8.3044)	0.0195*** (-8.3389)	0.0198*** (-8.4528)
Indep	0.2589*** (-5.5236)	0.2595... (-5.5335)	0.2585*** (-5.5146)	0.2610*** (-5.5705)
Constant	-0.5426*** (-5.2349)	-0.5362*** (-5.1747)	-0.5385*** (-5.2021)	-0.535*** (-5.1499)
Industry fixed	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes
N	24943	24943	24943	24943
adj.R ²	0.734	0.734	0.734	0.734

Note: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively. The t-statistic is in parentheses, the same applies below.

The first to fourth columns of Table 3 show the regression results of the impact of the total digital finance index, coverage breadth, usage depth, and digitalization degree on the total factor productivity (TFP) of enterprises. Overall, the coefficients of digital finance and its sub dimensions are significantly positive, indicating that various aspects of digital finance development have a significant driving effect

on the growth of enterprise TFP, thus verifying hypothesis 1. Specifically, column (1) displays the regression results of the Digital Finance Index, with a coefficient of 0.0553 and a significant positive value at the 1% level. This means that for every unit increase in the digital finance index, the TFP of enterprises will increase by 0.055 units.

The regression results for coverage breadth and usage depth are shown in columns (2) and (3), respectively, with coefficients of 0.0440 and 0.0404, both significant at the 1% level. This indicates that the breadth of coverage and depth of

use of digital finance have a positive effect on improving the TFP of enterprises. The fourth column shows the regression results of the degree of digitization, with a coefficient of 0.0514, which is significant at the 5% level. This indicates that the increase in digitalization contributes to the growth of total factor productivity in enterprises.

4.3. Robustness and Endogeneity Tests

In order to examine the impact of different measurement

methods for total factor productivity of enterprises on research conclusions, this paper re estimated the total factor productivity of enterprises using LP method, FE method, and GMM method, and used the results as the dependent variable for benchmark regression again. The robustness results are shown in Table 4. The results show that the digital financial coefficients have passed the significance test, and the reliability of the benchmark regression results in the previous section has been verified.

Table 4. Results of robustness test

Variable	1	2	3	4
	Tfp-op	Tfp-lp	Tfp-fe	Tfp-gmm
Difi	0.0553*** (-3.5361)	0.0119* (-1.9585)	0.0248** (-2.3415)	0.0413** (-2.5067)
Roa	3.0694*** (-36.1046)	1.1898*** (-35.4758)	1.4788*** (-23.355)	2.1113*** (-25.2396)
Growth	-0.1921*** (-13.5817)	-0.0555*** (-10.1346)	-0.0680*** (-6.7337)	0.0472*** (-3.3676)
Size	0.7398*** (-170.1598)	0.2464*** (-144.5769)	0.1584*** (-51.7008)	0.0960*** (-22.3018)
Lev	0.6507*** (-21.9835)	0.2932*** (-24.892)	-0.3740*** (-18.9787)	0.8970*** (-30.0785)
Age	-0.0061 (-0.4324)	0.0150*** (-2.7084)	-0.0244* (-2.5264)	0.0932*** (-6.2761)
Cash	0.0195*** (-8.3049)	0 (-0.0452)	-0.002 (-1.2829)	-0.0003 (-0.1326)
Indep	0.2589*** (-5.5236)	-0.0367** (-1.9808)	0.2402*** (-7.4535)	-0.9045*** (-18.2288)
Constant	-0.5426*** (-5.2349)	3.4626*** (-85.4685)	0.3802*** (-5.0774)	1.3138*** (-12.6192)
Industry fixed	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes
N	24943	24943	24943	24943
adj.R ²	0.734	0.677	0.206	0.146

4.4. Heterogeneity Test

Table 5. Heterogeneity test results

Variable	State-owned	Non-state
	Tfp-op	Tfp-op
Difi	0.0216 (-0.8558)	0.0732*** (-3.5522)
Roa	2.9942*** (-22.1079)	3.0985*** (-28.1796)
Growth	-0.1272*** (-4.9158)	-0.2203*** (-12.9641)
Size	0.7322*** (-100.3996)	0.7422*** (-136.4207)
Lev	0.5896*** (-12.0278)	0.6867*** (-18.3535)
Age	0.0128 (-0.4058)	0.0005 (-0.0271)
Cash	0.0210*** (-3.4386)	0.0188*** (-7.2584)
Indep	0.3067*** (-4.3945)	0.1814*** (-2.8024)
Constant	-0.2984* (-1.6518)	-0.6714*** (-5.2364)
Industry fixed	Yes	Yes
Fixed year	Yes	Yes
N	9198	15745
adj.R ²	0.722	0.739

All enterprises face external financing difficulties when improving total factor productivity (TFP). State owned

enterprises have limited financing constraints due to national credit guarantees and government support, and the marginal contribution of digital finance to them is limited. In contrast, non-state-owned enterprises have weak resource accumulation and rely on external financing. However, they often face credit discrimination and severe financing difficulties in traditional financial markets, which is not conducive to innovation and total factor productivity growth. Digital finance aims to counteract credit discrimination against non-state enterprises through digital means, alleviate financing restrictions, and may have a positive impact on the total factor productivity of enterprises. This article explores the differences in the impact of digital finance on TFP of enterprises with different ownership types by examining information related to state-owned and non-state-owned enterprises. The results are shown in Table 5.

The grouped regression results in Table 5 indicate that the positive relationship between digital finance and TFP of state-owned enterprises is not significant, but it shows a positive correlation with TFP of non-state-owned enterprises at the 1% significance level, with a coefficient of 0.0732. This indicates that digital finance has a more significant driving effect on the TFP of non-state-owned enterprises. The main reason is that digital finance supports diversified financing channels through technologies such as cloud computing and blockchain, optimizes the credit evaluation system, and thus improves the financing success rate of non-state-owned enterprises. In addition, the application of big data technology effectively alleviates the problem of information asymmetry,

enabling investors to more scientifically evaluate the investment value of non-state-owned enterprises and further promoting their financing capabilities. Non state-owned enterprises have fully utilized the opportunities brought by digital finance, increased equipment updates and research and development investment, significantly improved production efficiency and technological level, and thus promoted the growth of TFP. In contrast, state-owned enterprises have relatively limited promotion effect of digital finance on their TFP due to smaller financing constraints and insufficient

motivation for technological upgrading.

4.5. Impact Mechanism Testing

This article adopts a mediation effect test step to further analyze the path through which digital finance affects the total factor productivity of enterprises. It introduces R&D investment intensity, human capital level, resource allocation efficiency, information disclosure quality, risk-taking level, and corporate governance level as mediating variables, and constructs the following model:

$$Tfp_{i,t} = \alpha_0 + \alpha_1 Difi_{m,t} + \alpha_2 Controls_{i,t} + \theta_j + \mu_t + \varepsilon_{i,t}$$

$$Mediator_{i,t} = \beta_0 + \beta_1 Difi_{m,t} + \beta_1 Controls_{i,t} + \mu_t + \varepsilon_{i,t}$$

$$Tfp_{i,t} = \gamma_0 + \gamma_1 Difi_{m,t} + \gamma_2 Mediator_{i,t} + \gamma_3 Controls_{i,t} + \theta_j + \mu_t + \varepsilon_{i,t}$$

Among them, $Mediator_{i,t}$ mainly includes R&D investment intensity, human capital level, resource allocation efficiency, information disclosure quality, risk-taking level, and corporate governance level. The judgment criteria for the existence of intermediary effect: α_1 is significant, indicating that digital finance has an impact on the total factor productivity of enterprises; β_1 is significant, indicating that digital finance has an impact on intermediary variables; γ_1 and γ_2 are both significant, indicating that intermediary variables have a partial intermediary effect on the total factor productivity of enterprises.

4.5.1. R&D investment channels

This article first analyzes whether digital finance has had a positive impact on corporate TFP by increasing R&D investment. Empirical analysis was conducted on models 1, 2, and 3 in sequence, and the regression results are shown in Table 6.

Table 6. Estimated Results of R&D Investment Channels

Variable	1	2	3
	Tfp-op	R&D	Tfp-op
Difi	0.0553*** (-3.5361)	1.5486*** (-13.7367)	0.0491*** (-3.2361)
R&D			0.0040*** (-2.9594)
Constant	-0.5426*** (-5.2349)	1.9030*** (-3.3668)	-0.4915*** (-3.8859)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.29	0.734

In the regression results of column (2), the coefficient of digital finance is 1.5486, which is significant at the 1% level, indicating that digital finance can significantly enhance the R&D investment intensity of enterprises. This is mainly due to the optimization of the loan evaluation system through new technologies in digital finance, which reduces financing costs, improves the success rate of enterprise financing, and enhances the willingness and ability of enterprises to increase research and development expenditures. The results in column (3) show that after adding R&D investment as a

mediator variable, the coefficient of digital finance is 0.0491 and the coefficient of R&D investment is 0.004, both significant at the 1% level, indicating that R&D investment plays a partial mediating role in the impact of digital finance on firm TFP, with a mediation effect accounting for 11.20%. This indicates that digital finance promotes the increase of research and development investment by enterprises, drives the development of new products and the improvement of technological level, and ultimately assists in the growth of total factor productivity of enterprises.

4.5.2. Human Capital Channels

This article explores whether digital finance has a positive impact on the TFP of enterprises by improving their human capital level. The estimated results are shown in Table 7.

Table 7. Estimated Results of Human Capital Channels

Variable	1	2	3
	Tfp-op	Human	Tfp-op
Difi	0.0553*** (-3.5361)	5.3760*** (-12.8035)	0.0505*** (-3.3709)
Human			0.0009*** (-3.668)
Constant	-0.5426*** (-5.2349)	8.7370*** (-4.0397)	-0.5611*** (-5.3555)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.328	0.734

The results in column (2) show that the coefficient of digital finance is 5.3760, indicating a significant improvement in human capital level. The development of digital finance may indirectly promote the improvement of the education level of enterprise employees by improving the overall education level of regions or industries, providing low-cost credit services, and promoting the application of digital technology. Therefore, enterprises are more capable of providing training for employees and attracting high-quality talents. At the same time, employees actively learn due to technical needs, further enhancing their human capital.

After adding the mediating variable of human capital in column (3), the coefficients of digital finance and human capital are 0.0505 and 0.0009, respectively, both significantly positive, indicating that human capital plays a partial

mediating role in the impact of digital finance on enterprise TFP, with a mediating effect accounting for 8.75%. A higher level of human capital provides knowledge reserves for technological innovation, improves production efficiency, and thus has a positive impact on the growth of enterprise TFP.

4.5.3. Resource allocation channels

This article analyzes whether digital finance has had a positive impact on enterprise TFP by improving the efficiency of resource allocation. The estimated results are shown in Table 8.

Table 8. Estimated Results of Resource Allocation Channels

Variable	1	2	3
	Tfp-op	Human	Tfp-op
Difi	0.0553*** (3.5361)	-0.0364*** (-2.8936)	0.0645*** 3.3709
Human			-0.0109*** (-3.568)
Constant	-0.5426*** (-5.2349)	0.7370*** (24.0397)	-0.5611*** (-4.3555)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.308	0.734

The results in column (2) show that the coefficient of digital finance is -0.0364, which is significant at the 1% level, indicating that digital finance can significantly improve the efficiency of enterprise resource allocation. This is mainly because digital finance alleviates the financing difficulties of enterprises, and analyzes and supervises enterprise information through Internet, artificial intelligence and other technologies, so as to promote the inclination of resources to high productivity sectors, thus optimizing the efficiency of resource allocation. The results in column (3) show that the coefficient of digital finance is 0.0645, and the coefficient of resource allocation efficiency is -0.0109, both significant at the 1% level, indicating that resource allocation efficiency plays a partial mediating role in the impact of digital finance on enterprise TFP, with a mediating effect accounting for 1.45%. This indicates that digital finance has improved the R&D capabilities of enterprises by optimizing resource allocation efficiency, but its incentive effect on R&D enthusiasm is limited, so its promotion effect on TFP growth of enterprises is relatively small.

4.5.4. Information Disclosure Channels

This article analyzes whether digital finance has had a positive impact on corporate TFP by improving the quality of information disclosure. The estimated results are shown in Table 9.

The results in column (2) show that the coefficient of digital finance is -0.1364, which is significant at the 10% level, indicating that digital finance can improve the quality of information disclosure for enterprises. This is mainly due to: on the one hand, the information disclosed by enterprises is the foundation of big data analysis, and investors evaluate the value of enterprises through data, prompting enterprises to improve the quality of information disclosure to increase the success rate of financing; On the other hand, the dynamic risk monitoring and big data analysis of digital finance have increased the cost of false information disclosure, forcing

companies to improve the quality of information disclosure. The results in column (3) show that the coefficient of digital finance is 0.0545, and the coefficient of information disclosure quality is significantly negative, indicating that information disclosure quality plays a partial mediating role in the impact of digital finance on enterprise TFP, with the mediating effect accounting for 13.92%. High quality information disclosure not only increases the probability of corporate financing, provides financial support for expanding production scale and technological innovation, but also sends positive signals to investors, enhances corporate value, and thus has a positive impact on the growth of corporate TFP.

Table 9. Estimated Results of Information Disclosure Channels

Variable	1	2	3
	Tfp-op	Human	Tfp-op
Difi	0.0553*** (3.5361)	-0.1364*** (-1.7412)	0.0545*** 4.3709
Human			-0.0609*** (-3.468)
Constant	-0.5426*** (-5.2349)	0.8370*** (15.0397)	-0.7611*** (-8.3555)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.108	0.734

4.5.5. Risk bearing channels

This article explores whether digital finance has promoted the growth of total factor productivity of enterprises by increasing their risk-taking level. The estimated results are shown in Table 10.

Table 10. Estimated Results of Risk Bearing Channels

Variable	1	2	3
	Tfp-op	Human	Tfp-op
Difi	0.0553*** (3.5361)	0.1364*** (8.8936)	0.0345*** 3.6709
Human			0.1509*** (3.868)
Constant	-0.5426*** (-5.2349)	0.0570*** (7.0397)	-11.5611*** (-19.3555)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.118	0.734

The results in column (2) show that the coefficient of digital finance is 0.1364, which is significant at the 1% level, indicating that digital finance can significantly improve the risk-taking level of enterprises. This is mainly due to the relief of financing constraints for enterprises by digital finance, providing low-cost financial support, and building risk control and information sharing platforms through intelligent technology, reducing information asymmetry and agency problems, and enhancing enterprises' confidence in high-risk investments. The results in column (3) show that the coefficient of digital finance is 0.0345 and the coefficient of risk-taking level is 0.1509, both of which pass the 1%

significance test, indicating that risk-taking level plays a partial mediating role in the impact of digital finance on enterprise TFP, with the mediating effect accounting for 31.69%. Digital finance improves the risk-taking level of enterprises, optimizes investment efficiency, increases investment in technological innovation, and thus promotes the growth of total factor productivity of enterprises.

4.5.6. Corporate Governance Channels

This article explores whether digital finance has a promoting effect on corporate TFP by improving corporate governance. The estimated results are shown in Table 11.

Table 11. Estimated Results of Corporate Governance Channels

Variable	1	2	3
	Tfp-op	Human	Tfp-op
Difi	0.0553*** (3.5361)	0.3264*** (15.8936)	0.0445*** 3.0409
Human			0.0309*** (6.568)
Constant	-0.5426*** (-5.2349)	0.6870*** (5.0397)	-0.5611*** (-5.3555)
Control variable	Yes	Yes	Yes
Industry fixed	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes
N	24943	24943	24943
adj.R ²	0.734	0.196	0.734

The results in column (2) show that the coefficient of digital finance is 0.3264, indicating that it significantly improves the level of corporate governance. This is mainly due to the fact that digital finance has improved governance efficiency by enhancing the external and internal governance environment. On the one hand, digital finance provides regulators with digital regulatory tools, improves regulatory quality, constrains improper behavior of management, and optimizes decision-making levels; On the other hand, the intelligent analysis system of digital finance alleviates information asymmetry, encourages investors to pay more attention to the overall risk of the enterprise rather than the value of collateral, and motivates management to actively improve internal governance. The results in column (3) show that the coefficients of corporate governance level and digital finance are 0.0309 and 0.0445, respectively, both significantly positive, indicating that corporate governance plays a partial mediating role in the impact of digital finance on enterprise TFP, with a mediating effect accounting for 19.20%. Digital finance has improved corporate governance, reduced information asymmetry and management conflicts, stimulated technological innovation enthusiasm, and thus had a positive impact on the TFP growth of enterprises.

5. Conclusion and Suggestions

5.1. Conclusion

This article is based on data from A-share listed companies in Shanghai and Shenzhen from 2010 to 2021, using a fixed effects model to study the impact and mechanism of digital finance on total factor productivity (TFP) of enterprises. The specific impact paths are analyzed from six channels: R&D investment, human capital, resource allocation, information disclosure, risk-taking, and corporate governance. Meanwhile, through group comparison, the heterogeneous impact of

digital finance on different types of enterprises was explored, and the following conclusions were drawn:

(1) Digital finance significantly promotes the growth of enterprise TFP. The robustness and endogeneity tests were conducted by replacing the TFP measurement method, lagged the explanatory variable by one period, and using the instrumental variable method, and the results all supported this conclusion.

(2) Heterogeneity of ownership nature: The promotion effect of digital finance on the TFP of non-state-owned enterprises is stronger than that of state-owned enterprises, mainly because non-state-owned enterprises have greater financing constraints, and digital finance provides them with more financing opportunities.

(3) Scale heterogeneity: Digital finance has a more significant promoting effect on TFP of small-scale enterprises, as they face greater financing difficulties in traditional financial markets, and digital finance effectively alleviates their financing constraints.

(4) Regional heterogeneity: The promotion effect of digital finance on TFP of enterprises in the western region is stronger than that in the eastern and central regions. Due to the relative scarcity of financial resources in the western region, digital finance has made up for the shortcomings of traditional financial services.

(5) Industry Heterogeneity: Digital finance has a more significant promoting effect on TFP of high-tech enterprises, as it has higher demands for research and development innovation and funding. Digital finance provides them with more financing channels and technological support.

(6) Mechanism of action: Digital finance promotes the growth of enterprise TFP through six channels: increasing research and development investment, enhancing human capital, optimizing resource allocation, improving information disclosure quality, enhancing risk-taking ability, and improving corporate governance level.

5.2. Suggestions

(1) Improve the construction of digital financial infrastructure. Digital finance relies on the Internet and intelligent equipment. The government should increase investment in network infrastructure, promote 5G and 6G construction, and narrow the "digital divide" between the eastern, central and western regions. The central and western regions should seize the dividends of the digital economy and deepen the penetration rate of financial services; Developed regions should promote the digital transformation of traditional financial institutions to provide a better investment and financing environment for enterprises.

(2) Strengthening the cultivation of digital finance talents. Talents are the core driving force for the development of digital finance. The government should encourage universities to strengthen financial technology education and develop preferential policies for talent introduction in the central and western regions. At the same time, promoting digital finance knowledge through exhibitions, lectures, and other means can increase public and corporate awareness and participation in digital finance.

(3) Improve the regulatory system for digital finance. Digital finance has a wide coverage and complex technology, requiring the construction of a dynamic risk management platform combined with blockchain and other technologies, and implementing real-time supervision through models such as "sandbox supervision". At the same time, we will

accelerate the construction of the legal system for digital finance, formulate normative guidance, and ensure the healthy development of digital finance.

(4) Enterprises should seize the opportunities of digital finance and strengthen their own construction. Enterprises should actively utilize digital financial resources, increase research and development investment, introduce advanced equipment, and enhance innovation capabilities; Value human capital and enhance digital capabilities through training and talent introduction; Optimize resource allocation to avoid wastage of resources; Timely disclosure of information to reduce information asymmetry; Applying machine learning and other technologies to optimize decision-making and enhance corporate governance.

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