Financing Constraints and Firm's Productivity Under the COVID-19 Epidemic Shock: Evidence of A-Shared Chinese Companies

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Accepted: 29 November 2021 / Published online: 16 February 2022

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Abstract

Focusing on the financing barriers to firm productivity improvement under the influence of external shocks, we empirically analyze the data of A-share listed companies from 2007–2018 to determine the impact of financing constraints on total factor productivity (TFP) in the context of COVID-19 pandemic and the paths of factor use efficiency and R&D innovation efficiency on this impact using ordinary least-squares (OLS) method. We find that financing constraints are an important factor inhibiting the TFP of firms. This inhibitory effect is more serious in small-scale firms, non-state firms, and non-energy firms. Further investigation shows that the inhibitory effect of financing constraints on firms' TFP is more pronounced when firms are located in the Yangtze River Delta city cluster, the Pearl River Delta city cluster, non-port cities, and provincial capitals. The mechanism test finds that improving the efficiency of capital use and labor use can alleviate the suppressive effect of financing constraints on TFP. The alleviating impact is more significant when capital use efficiency is improved. However, increasing the efficiency of R&D innovation further strengthens the inhibitory effect of financing constraints, and this effect is more pronounced under positive external shocks.

Keywords Financing constraints · TFP · COVID-19 · R&D innovation efficiency · Factor use efficiency

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Résumé

Nous nous concentrons sur les obstacles liés au financement qui entravent l'amélioration de la productivité des entreprises lorsqu'il y a des chocs externes, et nous analysons de façon empirique l'impact des contraintes de financement sur la productivité globale des facteurs des entreprises dans le contexte de la COVID-19, ainsi que les voies permettant l'efficacité d'utilisation des facteurs et l'efficacité de l'innovation en R&D sur cet impact. Pour ce faire, nous utilisons la méthode des moindres carrés ordinaires en nous basant sur les données de sociétés cotées en bourse de 2007 à 2018. Nous constatons que les contraintes de financement représentent un facteur important qui inhibe la productivité globale des facteurs des entreprises. Cet effet inhibiteur est plus prononcé au sein des petites entreprises, des entreprises non gouvernementales et des entreprises non énergétiques. Une autre étude révèle que l'effet inhibiteur des contraintes de financement sur la productivité globale des facteurs des entreprises est plus prononcé lorsque les entreprises sont situées dans le groupe de villes du delta du fleuve Yangtze, dans le groupe de villes du delta de la rivière des Perles, dans les villes non portuaires et dans les capitales provinciales. Le test du mécanisme révèle que l'amélioration de l'efficacité de l'utilisation du capital et de la main-d'œuvre des entreprises peut atténuer l'effet suppressif des contraintes de financement sur la productivité globale des facteurs. L'impact d'atténuation est plus important lorsque l'efficacité d'utilisation du capital est améliorée. Cependant, l'augmentation de l'efficacité de l'innovation en R&D renforce encore l'effet inhibiteur des contraintes de financement, et il est plus prononcé en cas de chocs externes positifs.

Introduction

China's economy has shifted from a high growth stage to a high-quality development stage since 2017. This shift in economic priorities indicates that China is starting to give greater attention to the quality, efficiency, and effectiveness of its economic development (Kong et al. 2021a; Wong et al. 2021a). Therefore, how to effectively improve the productivity of enterprises has become a primary concern (Kong et al. 2021e). Over the past four decades of reform and opening up, along with rapid industrialization and urbanization, China has achieved a rapid accumulation of economic aggregates and has become the world's top developing country in terms of regional gross domestic product (GDP) growth rate (Kong et al. 2021d). However, behind these impressive achievements lie problems in the development process. First of all, the extensiveness and roughness of the traditional development model have led to an increasing prominence of environmental problems. In 2019, China's fossil fuel consumption accounted for more than 80% of its total energy consumption. In 2020, coal consumption accounted for 56.8% of total energy consumption, and natural gas and other clean energy consumption accounted for 24.3%. Faced with multiple constraints of available resources, environment management, and sustainable development, how to improve China's total factor productivity through green development and transformation is a real problem that needs to be solved (Kong et al. 2021g; Zhang et al. 2021a). A second problem pertains to China's insufficient

financial development. Many Chinese enterprises face more serious financing constraints, since banks tend to prioritize state-owned enterprises in granting loans. Moreover, private enterprises and SMEs face more serious financing constraints due to lack of collateral and opaque financial information (Allen et al. 2005; Cheng et al. 2020; Kong et al. 2021b). This creates a hindrance to corporate investment activities and production activities (Kong et al. 2020, 2021i). Therefore, given the need to promote open and high-quality economic development, how to improve the total factor productivity of enterprises to effectively allocate financial resources has become a major research question.

Scholars have conducted rich research on corporate financing constraints, financing costs, and lease financing (Arora 2014; Kim and Yoo 2019). For example, Jiang et al. (2016) has studied the impact and transmission mechanism of executives' financial experiences on corporate financing constraints. Pan et al. (2019) has explored the impact of clan power on financing constraints from the perspective that historical events produce long-term effects, whereas Shi et al. (2021) has focused on the impact of corporate lease financing on technological innovation. Some other scholars have compared leasing and debt financing, examining why firms adopt lease financing and the impact of financial leasing (Schallheim et al. 1987; Lin et al. 2013; Gavazza 2010). In terms of firm development, financing constraints are an important factor affecting the long-term growth of a firm (Friesen and Wacker 2019). Firms with high financing efficiency (exogenous and endogenous financing) or stable access to financing have a significant positive impact on firm productivity. The prevalence of information asymmetry and principal-agent problems in the financial market, and the resulting financing constraints, make it too costly for enterprises to raise finance; hence, they often do not get enough financial support and miss the opportunity to grow effectively. It is commonly believed that financing constraints are uncondusive to improving firm productivity (Zhang and Vigne 2021). Too strong financing constraints will inhibit firms' capital investment in R&D innovation and technology upgrading, significantly inhibiting productivity improvement. When firms face financial constraints and greater uncertainty, they may be more motivated to innovate, having greater incentive to increase productivity and gain greater returns.

Both firm size expansion and technological innovation contribute to total factor productivity (Kong et al. 2021c). However, many firms suffer from financing constraints for their R&D and investment activities, resulting in generally low total factor productivity. For capital market investors, the ability of firms to raise debt financing under the global pandemic of COVID-19 is likely to be an important factor influencing firm productivity. Considering the suddenness and urgency of the pandemic outbreak, debt financing has obvious advantages in helping firms to alleviate short-term cash flow constraints and safely survive the crisis (Cassimon et al. 2014). This paper uses the COVID-19 pandemic in China during the month of January 2020 as a research context to explore the impact of financing constraints on firms' total factor productivity from the perspective of external shocks. The study has implications for sustainable corporate development and the role of capital markets during crisis periods.

Compared with existing studies, the contribution of this paper lies in its ability to provide research findings that are directly applicable to achieving China's economic recovery. This contribution is outlined as follows. First, since macro data cannot portray the exact relationship between micro-enterprise financing constraints and total factor productivity, this paper uses data from A-share listed companies from 2007 to 2018 to achieve these findings. This data allows for observations of firm characteristics that are direct and accurate, which is more informative for economic analysis. Second, this paper analyzes heterogeneity from two perspectives: firm level and regional level. At the firm level, this study introduces heterogeneity analysis in terms of firm size, nature of ownership, and industry attributes (whether it is an energy firm or not). At the regional level, it examines how the characteristics of the cities in which firms are located and geographical location differences affect the relationship between financing constraints and a firm's total factor productivity. The results of the heterogeneity analysis can help to improve the research framework of financial policy, financing efficiency, and firm production by specific and detailed findings and practical policy implications. Third, the improvement of enterprise total factor productivity is mainly manifested in the efficiency of factor use and the efficiency of enterprise R&D and innovation. However, the sudden COVID-19 pandemic significantly impacted macroeconomics and firm production (Wu et al. 2021; Wong et al. 2022). On the one hand, the epidemic disrupted the flow of productive resources such as labor and capital, which caused an immediate reduction in production capacity, consumption, investment, and exports, along with price increases. On the other hand, the epidemic hit firms in transportation, retail, tourism, restaurants, real estate, and construction. The disruption of income due to rigid cost payments such as rent and production stagnation has also caused firms to double shock. Therefore, this paper introduces the negative external shock of the COVID-19 pandemic to examine the path of financing constraints affecting total factor productivity in terms of "factor use efficiency" and "R&D innovation efficiency."

The remainder of this paper is organized as follows: Sect. 2 presents the theoretical analysis and research hypothesis; Sect. 3 explains the research design; Sect. 4 presents and discusses the empirical test results and heterogeneity analysis findings; and Sect. 5 explains the findings of the mechanism test. Finally, Sect. 6 presents the research conclusion and implication.

Theoretical Analysis and Hypothesis Development

Total Factor Productivity is one of the key indicators reflecting the quality of economic development. Improving the total factor productivity of enterprises is of great significance in driving the transformation and upgrading of their economic structure. Existing studies have conducted extensive research at the macro and micro levels in an attempt to determine how total factor productivity is improved. At the macro level, Liu and Hu (2010), Tao et al. (2017), and Zhang et al. (2019a, b, c) have analyzed total factor productivity from the aspects of industrial policy, financial development, and market environment. At the micro-level, scholars have focused on technological innovation, enterprise management, and other

firm aspects (Schoar 2002). Notably, a study by Hsieh and Klenow (2009) reveals that 49% of the total factor productivity difference between Chinese and U.S. firms is caused by differences in resource allocation efficiency. While increasing firm productivity is a systemic project, it is difficult for firms without the support of financial markets to increase the productivity of their factors of production to achieve sustainable and endogenous growth (Kostov et al. 2012; Wong et al. 2021b).

The sound development of financial markets is an important path for improving the productivity of enterprises. Theoretically, financial markets promote capital accumulation and technological progress through risk management, capital allocation, supervision, and control functions, increasing firm productivity. However, China's stock market has been in the doldrums for a long time, and securities regulators have set high thresholds for stock IPOs, rights issues and share placements, making it difficult for enterprises to obtain direct financing from the capital market. As a result, bank loans have become the main channel for corporate financing. Banks and other financial institutions are granting credit to enterprises based on profit and risk. For enterprises, while considering the interest rate cost is important, they also need to evaluate various default risks and other additional loan conditions. Given these deferents, only a small number of enterprises can obtain bank loans to alleviate the financing constraint dilemma. In addition, due to the immature development of direct financing and the existence of information asymmetry in the market, the Chinese capital market finds it difficult to reduce moral hazard and adverse selection problems through information aggregation, collation and disclosure. This raises the cost of corporate financing and reduces the funds firms allocate to R&D innovation and improved process links, which inhibits firm productivity (Pástor and Veronesi 2009; He and Yang 2012; Zhang et al. 2019a, b). Based on these observations, this study proposes the following hypothesis.

Hypothesis 1 Financing constraints may inhibit an increase in total factor productivity of firms.

The capital allocation ability of enterprises is a key factor restricting total factor productivity improvement. Enhancing an enterprise's total factor productivity requires the support of capital. China's capital market is still immature: market effectiveness is insufficient, the level of financial development is backward, and the degree of information asymmetry is higher than that of developed countries. This environment poses a very serious financial constraint to enterprises (Luo and Gong 2014; Kong et al. 2021f, h). Considering the growing problem of financing constraints in Chinese firms, several scholars have used Chinese firms as a research sample to study the impacts of financing constraints. The findings indicate a negative effect on firm innovation efficiency and productivity (Zhang et al. 2012; Yan and Jiang 2019; Zhang and Guo 2019). Higher financing constraints are not conducive to optimal decisions in their business activities. They affect the R&D investment and resource allocation efficiency of firms, which in

turn negatively affects firms' total factor productivity (He and Yang 2012). In a perfect capital market, where information is completely symmetric and there are no transaction costs or financing costs, firms can easily raise the required funds from the capital market. However, real capital markets often have difficulty satisfying the assumptions of a perfect market, and external financing costs are higher than internal financing costs; hence, many firms face financing constraints (Kaplan and Zingales 1997). Since firms are often unable to afford expensive external financing, the required funds are not available, resulting in delayed or shelved process improvements, R&D innovation activities, or employee training programs that could have been implemented, and these setbacks ultimately inhibit productivity improvements. Based on the foregoing observations, this paper proposes two additional hypotheses:

Hypothesis 2a Financing constraints may inhibit production efficiency improvement by affecting capital use and labor use efficiency.

Hypothesis 2b Excessive financing constraints may inhibit firms' capital investment in R&D and innovation, thus inhibiting production efficiency improvement.

Research Design

Data Sources and Variable Descriptions

Sample Data Selection and Sources

This paper uses A-share listed companies from 2007 to 2018 as the empirical sample. The firm-level data used in this paper are mainly from the Cathay United (CSMAR) database and the RESSET database. Considering the validity of the sample data, this paper excludes from the original sample the following enterprises: (i) those with incomplete key information and missing key data; (ii) enterprises of ST, ST*, and PT types; (iii) enterprises belonging to financial industries such as securities, funds, insurance, trusts and banks. In order to avoid the influence of outliers, this paper further carries out the tailing process of 1% quantile for continuous type variables. After the above processing, 30,494 firm-annual observations of 3,707 firms are finally screened out. To supplement the missing data of some enterprises, this paper adopts the linear interpolation and mean value methods.

Explained Variables

The explanatory variable in this paper is the total factor productivity of firms. We refer to the methods of Levinsohn and Petrin (2003) and Olley and Pakes (1996) to measure total factor productivity, and borrow the improved methods proposed by Akerberg et al. (2015) and Wooldridge (2009) to modify the total factor productivity obtained by the LP and OP methods. The LP method and OP method estimation model is shown in Eq. (1).

$$\log Y_{it} = \alpha_0 + \alpha_1 \log K_{it} + \alpha_2 \log L_{it} + \delta_{it} + \varepsilon_{it}. \quad (1)$$

In Eq. (1), i denotes the firm and t denotes the year; Y_{it} denotes the firm's total output, K_{it} denotes capital input, L_{it} denotes labor input, δ_{it} is the observed and unobserved productivity to be estimated, and ε_{it} represents the other factors affecting the firm's productivity. Capital inputs are measured using the net fixed assets of the firm, and labor inputs are measured using the number of employees of the firm. Intermediate inputs are measured using the cash paid by the firm to purchase goods as well as to receive services, as indicated by Hu et al. (2021). The measurement of total firm output is mainly based on Lin et al. (2018) and Hu et al. (2020). Under the LP method, we use the sum of the firm's fixed asset depreciation, tax expense, employee compensation, and operating profit to obtain measurements. Under the OP method, the level of investment is a proxy variable for productivity, and we use capital expenditure as a proxy variable for corporate investment.

Explanatory Variables

This paper draws on the research method of Kaplan and Zingales (1997) to construct the KZ index with a sample of Chinese listed companies to measure financing constraints. The formula of KZ index is $KZ = kz1 + kz2 + kz3 + kz4 + kz5$. The specific calculation process is as follows: the full sample is classified for each year by the ratio of net cash flow from operations to total assets in the previous period (X1), the ratio of cash dividends to total assets in the previous period (X2), the ratio of cash holdings to total assets in the previous period (X3), the gearing ratio (X4), and the Tobin's Q value (X5). If the ratio of net cash flow from operations to total assets in the previous period is less than the median, then $kz1$ is taken as 1; otherwise it is taken as 0. If the ratio of cash dividends to total assets in the previous period is less than the median, then $kz2$ takes 1; otherwise it takes 0. If the ratio of cash holdings to total assets in the previous period is less than the median, then $kz3$ takes 1; otherwise it takes 0. If the gearing ratio is greater than the median, $kz4$ takes 1; otherwise it takes 0. If Tobin's Q is greater than the median, $kz5$ takes 1; otherwise it takes 0. Then KZ index is regressed as the dependent variable on X1, X2, X3, X4, and X5, and the regression coefficients of each variable are estimated. Finally, we estimate the KZ index of the degree of financing constraints for each listed company by drawing on the method of Wei et al. (2014). The greater the KZ index is, the higher the degree of financing constraint faced by the listed company.

Control Variables

The control variables include firm size (size), firm cash flow (cash), firm age (age), firm growth capacity (growth), firm equity nature (soe), firm asset structure (stru), and firm equity concentration (herf). Among them, firm size is measured by taking the natural logarithm of total assets. Firm age is the year of the firm minus the year the firm went public. Firm growth capacity is measured as the ratio of the difference between the current year's quarterly revenue minus the previous quarter's revenue and the previous quarter's revenue. The nature of firm equity is classified according

Table 1 Definition of main variables and descriptive statistics

Variables	Definition	Obs	Mean	SD	Min	Max
Explained variables						
lpacf	ACF amended LP	30,494	1.229	0.215	0.567	1.725
opacf	ACF amended OP	30,494	0.858	0.304	− 0.127	1.542
wrdg	Wooldridge Index	30,494	2.023	0.138	1.581	2.346
labor	Labor productivity	29,378	1.495	0.205	0.919	2.007
Explanatory variables						
sa	Financing constraints	28,842	0.155	0.226	− 0.649	0.645
Control variables						
soe	Nature of firm ownership	31,241	0.401	0.49	0.000	1.000
cash	Firm cash flow	30,535	21.418	2.188	0.000	23.419
size	Firm size	30,571	3.092	0.059	2.948	3.259
age	Firm age	29,469	2.016	0.897	0.000	3.219
growth	Firm growth capacity	31,241	0.184	0.508	− 1.398	2.452
herf	Firm equity concentration	29,460	2.476	1.254	− 1.060	4.212
stru	Firm asset structure	30,380	− 0.969	0.472	− 2.122	− 0.093

to the nature of the property rights of the controlling shareholders of the enterprise, including state owned and non-state owned enterprises. Firm asset structure is expressed using the sum of net fixed assets and net inventories over total assets. Firm equity concentration is expressed using the percentage of shares held by the company's largest shareholder.

Methodology

To investigate the effect of financing constraints on a firm's total factor productivity, the following regression model is constructed.

$$\text{lpacf}_{ijt} = \rho_0 + \rho_1 \text{se}_{ijt} + \rho_2 \text{controls}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (2)$$

where lpacf_{ijt} denotes the firm's total factor productivity; se_{ijt} denotes the degree of financing constraints of the firm. We focus on the regression coefficient ρ_1 in the model. If the regression result of ρ_1 is significantly positive, it indicates that the financing constraint inhibits the increase of the firm's total factor productivity. controls is the set of all control variables in this paper, whereas u_i denotes regional fixed effects; γ_j denotes industry fixed effects; λ_t denotes time fixed effects; and ε_{ijt} is the error term. The definitions of all variables in the empirical study of this paper are shown in Table 1.

The last four columns of Table 1 report the descriptive statistical analysis of the main variables in this paper. The results in Table 1 show that the mean value of total factor productivity of firms calculated by the ACF modified LP method is 1.229; the mean value of total factor productivity of firms calculated by the ACF modified OP method is 0.858; the mean value of Wooldridge index is 2.023; the mean value

of labor productivity is 1.495; and the mean value of firm financing constraints is 0.155. In terms of control variables, the nature of property rights according to the firm's controlling shareholders indicates that state-controlled firms account for 40.1%. The mean value of firm cash flow is 21.418; the mean value of firm size is 3.092; the mean value of firm age is 2.016; the mean value of firm growth capacity is 0.184; the mean value of firm equity concentration is 2.476; and the mean value of firm asset structure is -0.969.

In this paper, the Pearson tests were performed on the study variables as indicated by hypothesis 1. Table 2 reports the Pearson correlation coefficients between the research variables in this paper. Among the explanatory variables, the total factor productivity of firms calculated by the ACF modified LP method is mainly used. As shown in Table 2, the correlation coefficient between financing constraint (sa) and firms' total factor productivity (lpacf) is -0.029, indicating a negative relationship between financing constraint and total factor productivity. In other words, the financing constraint inhibits the increase of firm productivity, which is consistent with hypothesis 1. In addition, the results of Pearson tests of control variables and explanatory variables show that firm size (size), firm age (age), firm growth capacity (growth), nature of equity (soe), asset structure (stru), and equity concentration (herf) are positively related to firm total factor productivity (TFP), while firm cash flow (crash) has a negative relationship with total factor productivity (TFP).

Empirical Results and Discussion

Baseline Regression Results

Based on the ordinary least squares (OLS) method, this paper conducts an empirical analysis of the impact of financing constraints on a firm's total factor productivity. The results are shown in Table 3. In columns (1)–(4), the coefficient estimates of sa are negative and pass the 5% significance level test, indicating that financing constraints have a significant inhibitory effect on the increase of a firm's total factor productivity. In terms of economics, after controlling for fixed effects, financing constraints decrease the total factor productivity by 3.72% and by 12.52%. After adding the control variables, the financing constraint decreases the total factor productivity of firms by 7.26% and by 11.28%. In columns (5)–(8), the Wooldridge index and labor productivity are included as explanatory variables for the negative effect on total factor productivity. Overall, financing constraints significantly inhibit a firm's total factor productivity increase, verifying the validity of hypothesis 1. The possible reason is that higher financing constraints make external financing too costly for firms, leading them to rely on endogenous financing. However, supporting several business activities is difficult with endogenous financing, and firms are unable to make necessary investments in activities such as R&D innovation, technological improvement, and employee

Table 2 Pearson correlation coefficient test

Variables	lpacf	sa	size	cash	age	growth	soe	stru	herf
lpacf	1.000								
sa	− 0.029***	1.000							
size	0.460***	− 0.143***	1.000						
cash	− 0.081***	− 0.015**	− 0.098***	1.000					
age	0.148***	− 0.367***	0.299***	− 0.034***	1.000				
growth	0.010*	− 0.017***	0.013**	− 0.079***	0.027***	1.000			
soe	0.129***	− 0.002	0.284***	− 0.021***	0.388***	0.014**	1.000		
stru	0.076***	0.051***	0.096***	− 0.042***	0.144***	− 0.022***	0.170***	1.000	
herf	0.094***	− 0.205***	0.318***	− 0.013**	0.385***	− 0.011*	0.220***	0.046***	1.000

*, **, ***Represent 10%, 5%, and 1 % significance levels, respectively; t-values are reported in parentheses

Table 3 Baseline regression results of financing constraints and TFP

Variables	lpacf	opacf		wrldg		labor	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
sa	-0.0372** (-2.30)	-0.0726*** (-5.55)	-0.1252*** (-4.39)	-0.1128*** (-5.88)	-0.0825*** (-5.56)	-0.0429*** (-5.24)	-0.0657** (-2.41)
size		1.9279*** (32.97)		1.9892*** (21.34)		1.8404*** (63.54)	1.4404*** (15.90)
cash		-0.0032*** (-4.58)		-0.0069*** (-6.54)		-0.0008** (-2.05)	-0.0040*** (-5.25)
age		0.0001 (0.04)		0.0014 (0.27)		-0.0087*** (-4.61)	0.0040 (0.68)
growth		0.0024 (0.55)		0.0186** (2.71)		-0.0040** (-2.22)	0.0203*** (4.29)
soe		-0.0389*** (-4.76)		-0.0668*** (-5.51)		-0.0023 (-0.44)	0.0011 (0.13)
stru		-0.0014 (-0.34)		-0.0181*** (-2.88)		-0.0198*** (-7.70)	-0.0106 (-1.67)
herf		0.0024 (1.00)		0.0018 (0.48)		0.0035*** (3.16)	0.0033 (1.17)
constant	1.2340*** (130.94)	-4.6441*** (-26.81)	0.8765*** (89.01)	-5.1288*** (-18.57)	2.0356*** (126.82)	-3.6528*** (-41.99)	1.5044*** (154.57)
N	28,776	28,563	28,776	28,563	28,776	28,563	28,535
adj. R ²	0.020	0.271	0.031	0.162	0.052	0.596	0.206

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

training, which leads to distorted resource allocation and lower productivity (Liu and Wu 2009; Xiao et al. 2020).

Robustness Tests

Substitution of Explanatory Variable Measures

The previous section uses financing constraints as the core explanatory variable in this paper. Although the financing constraint indicator is comprehensive, covering a wide range of information, the choice of calculation method and different parameter settings may significantly impact the empirical results. In order to ensure the robustness of the empirical test, this paper substitutes the measure of financing constraint by using the KZ index and WW index variables and then uses OLS re-regression to measure the degree of financing constraint. The results are shown in Table 4 (Panel A).

The coefficient estimates of the KZ index in columns (1)–(4) are all negative and pass the 5% significance level test. This indicates that financing constraints measured by the KZ index significantly inhibit the total factor productivity improvement of firms. In columns (5)–(6), the coefficient estimates of the WW index are all negative and pass the 1% significance level test. It indicates that the degree of financing constraint measured by the WW index still significantly inhibits a firm's total factor productivity increase. Overall, the findings of this paper remain unchanged after the financing constraint measure is replaced. This illustrates the robustness of the benchmark regression results.

PPML Method

The influence of unobservable factors may lead to bias in the regression results. Therefore, this paper replaces the model estimation method and uses Poisson's pseudo-maximum likelihood estimation method (PPML) for robustness testing. Table 4 (Panel B) reports the test results of PPML. Among them, columns (9) and (10) are the regression results based on the LP method, and columns (11) and (12) are the regression results based on the OP method. No control variables were included in the odd columns, whereas control variables were included in the even columns. As can be seen from Table 4 (Panel B), the coefficient estimates of α are negative with or without the inclusion of control variables and pass the 1% significance level test. This indicates that after changing the estimation method of the model, the financing constraint still significantly inhibits the total factor productivity of firms. This result is consistent with the results of the benchmark regression, reflecting the correctness of the chosen estimation method and the robustness of the underlying findings.

Table 4 Robustness tests (1)

Variables	Panel A: Substitution of explanatory variable measures					Panel B: PPML method					
	lpacf	opacf	wrdg	labor	tfp_lp	tfp_op					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	(12)										
kz	−0.0109*** (−3.88)	−0.0072** (−2.59)	−0.0219*** (−4.99)	−0.0128*** (−3.08)							
ww					−0.3679*** (−9.59)	−0.0777*** (−8.82)	−0.3321*** (−7.07)	−0.1099*** (−8.45)			
sa									−0.0351*** (−17.96)	−0.0122*** (−9.49)	−0.0266*** (−5.68)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
constant	1.2937*** (275.64)	−1.1802** (−2.57)	0.9452*** (128.50)	−0.5405 (−0.78)	1.2542*** (229.31)	−3.0194*** (−8.10)	0.8867*** (116.08)	−3.3177*** (−5.95)	0.7094*** (1663.41)	−1.9899*** (−122.96)	0.2232*** (187.83)
N	12,000	11,958	12,000	11,958	21,723	21,201	21,723	21,201	28,776	28,563	28,776
adj. R ²	0.863	0.871	0.850	0.859	0.059	0.767	0.039	0.738	0.014	0.584	0.001

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

Exclusion of Exogenous Events

If other changes occurred during the sample period, the estimation results may be mixed with the effects of exogenous events. During 2007–2019, the interference of exogenous events such as the 2008 financial crisis and the 2013 financial reform, may have had an inconsistent impact on the total factor productivity of firms, thus leading to biased estimation results. To address this issue, this paper excludes the samples of 2008 and 2013 and divides the sample interval into 2009–2012 and 2014–2019. The results are shown in Table 5 (Panel C). As can be seen, the coefficient estimates of sa in both sample intervals are significantly negative, indicating that financing constraints have a negative inhibitory effect on the total factor productivity of firms. This result indicates that the benchmark regression results are not affected by policy reforms or sudden crises and the empirical results are robust.

Instrumental Variable Method

This paper uses the instrumental variables approach for robustness testing to reduce the endogeneity estimation bias caused by two-way causality and omitted variables. In this paper, one-period lag of financing constraint is used as the instrumental variable and the model is estimated using two-stage least-squares (2SLS) method. Theoretically, it is reasonable to choose financing constraints lagged by one period as the instrumental variable because (i) in terms of correlation, financing constraints lagged by one period have a high correlation with current financing constraints; and (ii) In terms of exclusivity, the degree of impact that financing constraints have on a firm's total factor productivity is not directly affected by the lagged one-period financing constraints.

Table 5 (Panel D) reports the test results for the instrumental variables. Column (9) shows the regression results for the first stage. The coefficient estimate of L_sa is positive and passes the 1% significance test, indicating that a significant positive relationship between financing constraints and lagged-period financing constraints. Columns (10)–(11) report the regression results of the second stage. The coefficient of sa , which is the focus of this paper, remains significantly negative. The above results suggest that financing constraints significantly inhibit the total factor productivity improvement of firms, and this finding remains robust after further addressing the endogeneity of treatment group selection.

Heterogeneity Analysis

Business Type Differences

Considering that the total factor productivity of enterprises may be affected by their size and the nature of their property rights, we divide the total sample into large-scale and small-scale enterprises and state-owned and non-state-owned enterprises. The regression results are shown in Table 6 (Panel A and Panel B). Columns (1)–(4) show the heterogeneous regression results grouped by firm size. The regression

Table 5 Robustness tests (2)

Variables	Panel C: Excluded the impact of exogenous events are								Panel D: Instrumental Variables Method			
	2009–2012				2014–2019				Stage 1		Stage 2	
	lpacf	opacf	opacf	lpacf	lpacf	opacf	opacf	sa	lpacf	opacf	opacf	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
sa	– 0.1632*** (–4.95)	– 0.1013*** (–4.07)	– 0.2085*** (–5.50)	– 0.1549*** (–4.30)	– 0.0549* (–1.81)	– 0.0672*** (–6.49)	– 0.0841** (–2.56)	– 0.1050*** (–6.43)	– 0.0250*** (–7.58)	– 0.0129* (–1.81)		
l_sa									0.7418*** (108.94)			
controls												
constant	1.2993*** (97.40)	– 4.2096*** (–20.40)	0.9629*** (55.39)	– 4.4825*** (–14.34)	1.2133*** (228.94)	– 4.8983*** (–24.93)	0.8289*** (110.92)	– 5.5169*** (–17.95)	0.5718*** (11.47)	– 3.4635*** (–106.03)	– 3.8642*** (–56.95)	
N	6983	6971	6983	6971	16,873	16,714	16,873	16,714	28,215	28,215	28,215	
Adj. R ²	0.023	0.252	0.021	0.141	0.005	0.27	0.006	0.147	0.695	0.587	0.220	

*, **, ***Represent 10%, 5%, and 1 % significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

Table 6 Results for differences in business type

Variables	Panel A: Firm size				Panel B: Nature of ownership				Panel C: Industry Properties			
	Large-scale firms		Small-scale firms		State-owned firms		Non-State-owned firms		Energy firms		Non-energy firms	
	lpacf	opacf	lpacf	opacf	lpacf	opacf	lpacf	opacf	lpacf	opacf	lpacf	opacf
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(1)	(2)	(3)	(4)
sa	-0.0278*	-0.0579**	-0.0384*	-0.0745**	-0.0569***	-0.0967***	-0.0606***	-0.0901***	-0.0320	-0.0388	-0.0785***	-0.1225***
	(-1.79)	(-2.53)	(-2.04)	(-2.48)	(-3.05)	(-3.29)	(-3.34)	(-3.59)	(-1.13)	(-0.91)	(-4.73)	(-4.98)
con-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
trols												
con-	-1.6770***	-1.0431***	-4.2630***	-4.6910***	-4.2988***	-4.6894***	-5.2176***	-5.9419***	-4.1224***	-4.3722***	-4.8977***	-5.5714***
stant												
	(-7.31)	(-2.99)	(-15.36)	(-11.39)	(-17.00)	(-11.95)	(-25.02)	(-18.20)	(-13.52)	(-9.40)	(-21.30)	(-15.53)
N	11,160	11,160	10,029	10,029	11,992	11,992	16,571	16,571	7255	7255	20,113	20,113
Adj. R ²	0.106	0.064	0.187	0.111	0.261	0.155	0.261	0.168	0.265	0.148	0.287	0.186

*, **, ***Represent 10%, 5%, and 1 % significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

coefficient estimates of *sa* are all significantly negative, indicating that financing constraints have a significant negative impact on total factor productivity for both large-scale and small-scale firms. The negative effect of financing constraints on the total factor productivity of small-scale firms is greater than that on the total factor productivity of large-scale firms. Possible reasons for this are information asymmetry and the lack of collateralized assets in financing among small-scale firms. Banks are more inclined to lend to large firms for credit security reasons. Small-scale enterprises are unable to obtain sufficient funds for project investment, and resources cannot be allocated effectively, when the productivity of enterprises is inevitably affected.

Columns (5)–(8) show the results of heterogeneity regressions grouped by the nature of firm ownership. The estimated regression coefficients of *sa* are negative and pass the 1% significance level test. This indicates that financing constraints inhibit total factor productivity improvement for both SOEs and non-SOEs. The negative effect of financing constraints on the total factor productivity of non-SOEs is greater than that on the total factor productivity of SOEs. Due to government guarantees and policy support, SOEs have easier access to government subsidies and exogenous financing, which can partially offset the negative impact of financing constraints on productivity (Sun and Ding 2021). Non-SOEs are discriminated against in terms of exogenous financing, making it difficult for them to engage in technological innovation and expand their production scale, which is detrimental to total factor productivity (Fan and Li 2017).

Considering the possible differential impact of financing constraints on firms with different industry attributes, the paper proceeds to divide the total sample into energy and non-energy firms. The regression results are shown in Table 6 (Panel C). Columns (9) and (10) are heterogeneous regression results for energy firms. The estimated regression coefficient of *sa* is negative but insignificant, indicating that the suppressive effect of financing constraints on the total factor productivity of energy firms is not significant. Columns (11) and (12) are heterogeneous regression results for non-energy firms. The estimated regression coefficients of *sa* are negative and pass the 1% significance level test, indicating that financing constraints have a significant inhibitory effect on the total factor productivity increase of non-energy firms. The above results suggest that financing constraints have a greater negative impact on total factor productivity of non-energy firms as compared to energy firms. The possible reason is that in economic transformation and development, the rate of transformation of old and new kinetic energy has increased, and the development prospect of the new energy industry is huge. Compared with non-energy enterprises, new energy enterprises have a good external foundation for financing, abundant financing channels, a perfect financing information communication mechanism, and higher market attention (Geng et al. 2018), all of which can accelerate technological industrial R&D and optimize structural layout, and thus mitigate the negative impact of financing constraints.

Table 7 Results for firms located in different urban clusters

Variables	Beijing–Tianjin–Hebei		Yangtze river delta		Pearl river delta	
	lpacf	opacf	lpacf	opacf	lpacf	opacf
	(1)	(2)	(3)	(4)	(5)	(6)
sa	− 0.0419 (−0.97)	− 0.0755 (−1.18)	− 0.0775*** (−5.83)	− 0.1230*** (−6.69)	− 0.1048*** (−12.29)	− 0.1604*** (−12.44)
controls	Yes	Yes	Yes	Yes	Yes	Yes
constant	− 4.3097*** (−12.45)	− 4.5330*** (−8.91)	− 4.4480*** (−18.12)	− 4.8990*** (−12.55)	− 4.5137*** (−38.85)	− 4.8060*** (−20.66)
N	3275	3275	7540	7540	3702	3702
Adj. R ²	0.330	0.180	0.263	0.167	0.275	0.162

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

Differences in the Geographical Location of Firms

There may be significant differences in the role of financing constraints on total factor productivity depending on the city cluster in which the firm is located. Due to space limitation, this paper only examines the heterogeneity regression results of firms located in three city cluster: Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Pearl River Delta. The results are shown in Table 7. Compared with the Beijing-Tianjin-Hebei city cluster, the negative effect of financing constraints on total factor productivity is greater in the Yangtze River Delta city cluster and the Pearl River Delta city cluster. Therefore, this paper concludes that there are differences in the effects of financing constraints on firm total factor productivity in these three city cluster.

This paper proceeds to discuss the impact of financing constraints on total factor productivity of firms in terms of both city location and administrative rank. We divide the sample into port cities and non-port cities, and into provincial capital cities and non-capital cities. The estimation results are shown in Table 8. The results show that the financing constraint has a stronger inhibitory effect on total factor productivity in non-port cities than in port cities. The financing constraint has a stronger inhibitory effect on total factor productivity in provincial capitals than in non-capital cities. The possible reason is the relatively higher level of economic development and market openness in port cities and provincial capitals. Capital market openness can help firms obtain more credit financing and equity financing, alleviate their financing difficulties, and reduce the problem of insufficient R&D conducted by firms under a financing constraint (Ma et al. 2021). The economic development of non-port and non-capital cities is relatively backward, and openness to the outside world and informationization is low. Enterprise managers in these cities will reduce various investment activities due to a lack of financial support, thus inhibiting the total factor productivity improvement.

Table 8 Results of firms in different urban locations and urban classes

Variables	Port Cities		Non-Port Cities		Provincial Capital Cities		Non-Capital Cities	
	lpacf	opacf	lpacf	opacf	lpacf	opacf	lpacf	opacf
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
sa	-0.0654*** (-6.21)	-0.1031*** (-6.36)	-0.0808** (-2.56)	-0.1192** (-2.47)	-0.0866*** (-3.32)	-0.1331*** (-3.26)	-0.0592*** (-2.84)	-0.0951*** (-3.04)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
constant	-4.4519*** (-21.25)	-4.8544*** (-15.43)	-4.8979*** (-14.77)	-5.4752*** (-10.39)	-4.9595*** (-17.92)	-5.5976*** (-12.95)	-4.3906*** (-16.00)	-4.7316*** (-11.08)
N	17,227	17,227	11,336	11,336	13,386	13,386	15,177	15,177
Adj. R ²	0.262	0.161	0.286	0.165	0.302	0.185	0.246	0.145

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, herf

Mechanism Test: the Impact of External Shocks

Considering the impact of COVID-19 on economic growth, this section introduces external shocks and further examines the path of financing constraints on the total factor productivity of firms, using “factor use efficiency” and “R&D innovation efficiency” as indicators. In measuring external shocks, this paper refers to Aghion et al. (2012) and Sun et al. (2020) who measure the impact of shocks in terms of their outcomes. This paper distinguishes between positive and negative exogenous shocks using the growth rate of the firm’s operating income. A positive exogenous shock is defined as a positive exogenous shock if the firm’s current operating income rises, while it is defined as a negative exogenous shock if the opposite is true.

Test of Factor Use Efficiency

Theoretically, the impact of financing constraints on total factor productivity may come from factor use efficiency. Under the influence of financing constraints, the capital use efficiency and labor use efficiency is limited (Zhang et al. 2021a b). In this paper, drawing on the study of Hu et al. (2021), we select firm capital use efficiency (kef) and firm labor use efficiency (lef) as mediating variables and use the most commonly used stepwise test (Baron and Kenny 1986) to develop the mediating effect test. The mediating effect model decomposes the effect of the core explanatory variable, financing constraint (se), on the total factor productivity (lpacf) of the explained variable in (2) into: (i) the direct effect of financing constraint on a firm’s total factor productivity; and (ii) the indirect effect on a firm’s total factor productivity through the mediating variables of capital efficiency (kef) and labor efficiency (lef). The specific model is set as follows.

$$\text{kef}_{ijt} = a_0 + a_1 \text{se}_{ijt} + a_2 \text{controls}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (3)$$

$$\text{lef}_{ijt} = b_0 + b_1 \text{se}_{ijt} + b_2 \text{controls}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (4)$$

$$\text{lpacf}_{ijt} = c_0 + c_1 \text{se}_{ijt} + c_2 \text{kef}_{ijt} + c_3 \text{controls}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (5)$$

$$\text{lpacf}_{ijt} = d_0 + d_1 \text{se}_{ijt} + d_2 \text{lef}_{ijt} + d_3 \text{controls}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (6)$$

where kef_{ijt} denotes capital use efficiency, lef_{ijt} denotes labor use efficiency, and all other variables are consistent with Eq. (2). Regarding the mediating effect test, this paper first conducted a regression analysis using the model in Eq. (2) to examine the total effect of financing constraints on a firm’s total factor productivity when no mediating variables are included. Second, regressions are conducted on Eqs. (3) and (4) to examine the effects of financing constraints on a firm’s capital use efficiency (kef) and labor use efficiency (lef), respectively. Finally, based on Eq. (5) and Eq. (6), the effects of a firm’s capital use efficiency (kef) and labor use efficiency (lef) on its total factor productivity are examined. For Eq. (3) and Eq. (5), a

mediating effect exists if both coefficient a_1 and c_2 are significantly non-zero. At this point, if c_1 is significantly non-zero, there is a partial intermediation effect. If c_1 is not significant, there is a full mediation effect. For Eq. (4) and Eq. (6), the mediating effect exists if both coefficient b_1 and coefficient d_2 are significantly non-zero. At this point, if d_1 is significantly non-zero, there is a partial mediation effect. If d_1 is not significant, there is a full mediation effect. In addition, if at least one of coefficients a_1 and c_2 and coefficients b_1 and d_2 is insignificant, the Sobel test can be used to determine whether there is a mediating effect. A significant Sobel coefficient means that factor use efficiency has a mediating effect; otherwise the mediating effect is not valid.

Table 9 reports the results of the mechanism test for factor use efficiency. Among them, regression results are presented in (1)–(4) for the full sample, (5)–(8) for positive shocks, and (9)–(12) for negative shocks. First, the regression coefficients of sa are both significantly negative at the 1% level, and the coefficients of kef and lef are significantly positive at the 1% level. This result indicates that both capital efficiency and labor efficiency have partial mediating effects on the total factor productivity of the firm. The improvement of a firm's capital use efficiency and labor use efficiency will alleviate the inhibitory effect of financing constraints on its total factor productivity, which verifies hypothesis 2a. Second, under the full sample, the size of the mediating effects of capital use efficiency and labor use efficiency are -0.012 ($-0.407*0.029$) and -0.009 ($-0.144*0.062$), respectively. Under positive external shocks, the size of the mediating effects of capital use efficiency and labor use efficiency are -0.011 ($-0.375*0.030$) and -0.009 ($-0.126*0.069$), respectively. Under negative external shocks, the size of the mediating effects of capital use efficiency and labor use efficiency are -0.013 ($-0.523*0.025$) and -0.009 ($-0.198*0.047$), respectively. Finally, the mediating effect of capital use efficiency is larger than that of labor use efficiency. The possible reason for this phenomenon is that financing constraints are highly inhibitory to capital use efficiency. Firms facing financing constraints have more difficulty carrying out activities such as technological innovation (Fan et al. 2020), which is detrimental to their total factor productivity. In addition, under negative external environmental shocks, firms face greater sustainability challenges and tend to have greater incentives to improve the efficiency of capital and labor use to enhance market competitiveness owing to the economic uncertainty.

Test of R&D Innovation Efficiency

Corporate technological innovation is one of the important factors that contribute to the total factor productivity of a firm. However, firms relying on internal financing alone often find it difficult to meet the demand for high-quality R&D innovation; indeed, financing constraints can be closely related to the R&D innovation activities carried out by firms (Liu et al. 2021; Huang et al. 2021; Li et al. 2021). Based on this observation, this section further discusses the impact of financing constraints

Table 9 Path test of factor use efficiency

Variables	Full sample				Positive shocks sample				Negative shocks sample			
	Capital use efficiency		Labor use efficiency		Capital use efficiency		Labor use efficiency		Capital use efficiency		Labor use efficiency	
	kef	lpacf	lef	lpacf	kef	lpacf	lef	lpacf	kef	lpacf	lef	lpacf
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
sa	− 0.4069*** (−11.60)	− 0.0499*** (−3.89)	− 0.1444*** (−3.07)	− 0.0545*** (−4.27)	− 0.3754*** (−14.31)	− 0.0440*** (−3.45)	− 0.1256** (−2.65)	− 0.0478*** (−3.61)	− 0.5232*** (−5.19)	− 0.0657** (−2.24)	− 0.1976*** (−2.95)	− 0.0728** (−2.74)
kef		0.0288*** (13.46)				0.0296*** (12.07)				0.0249*** (8.27)		
lef				0.0624*** (15.51)				0.0690*** (14.66)				0.0467*** (9.19)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
constant	− 3.3401*** (−5.63)	− 4.2306*** (−28.06)	− 12.6660*** (−19.72)	− 3.5716*** (−21.20)	− 3.8511*** (−6.20)	− 4.0172*** (−27.50)	− 12.7584*** (−20.80)	− 3.2925*** (−20.06)	0.0286 (0.04)	− 4.4614*** (−23.91)	− 11.3523*** (−11.06)	− 3.9540*** (−19.46)
N	26,297	26,288	26,296	26,288	19,822	19,822	19,823	19,822	6475	6466	6473	6466
Adj. R ²	0.181	0.298	0.092	0.345	0.195	0.307	0.096	0.364	0.149	0.268	0.077	0.294

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; t-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

Table 10 Path test of R&D innovation efficiency

Variables	Full sample		Positive shocks sample		Negative shocks sample	
	R&D	lpacf	R&D	lpacf	R&D	lpacf
	(1)	(2)	(3)	(4)	(5)	(6)
sa	0.1439*** (7.37)	-0.0193** (-2.63)	0.2039*** (5.04)	-0.0246*** (-4.09)	0.0205 (0.22)	-0.0358** (-2.58)
R&D		-0.0436*** (-33.66)		-0.0490*** (-35.58)		-0.0307*** (-10.87)
controls	Yes	Yes	Yes	Yes	Yes	Yes
constant	-34.6001*** (-78.32)	-6.1891*** (-85.61)	-32.9599*** (-125.69)	-5.9918*** (-71.04)	-35.2535*** (-30.56)	-6.0234*** (-25.87)
N	12,145	12,145	8929	8929	3215	3215
Adj. R ²	0.312	0.329	0.302	0.351	0.311	0.279

*, **, ***Represent 10%, 5%, and 1% significance levels, respectively; *t*-values are reported in parentheses. Controls include size, cash, age, growth, soe, stru, and herf

on a firm's total factor productivity by examining the efficiency of R&D innovation using a stepwise test. The model is set up as follows:

$$\text{R\&D}_{ijt} = \delta_0 + \delta_1 \text{sa}_{ijt} + \delta_2 \text{ontrols}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (7)$$

$$\text{lpacf}_{ijt} = \varphi_0 + \varphi_1 \text{sa}_{ijt} + \varphi_2 \text{R\&D}_{ijt} + \varphi_3 \text{ontrols}_{ijt} + u_i + \gamma_j + \lambda_t + \varepsilon_{ijt}, \quad (8)$$

where rd_{ijt} denotes the efficiency of corporate R&D innovation, which is measured using the number of R&D personnel. In Eqs. (7) and (8), if the coefficients δ_1 and φ_2 are both significant and non-zero, it indicates that a mediating effect exists. If the coefficient φ_1 in Eq. (8) is insignificant, it indicates that the mediating variable has a full mediating effect. If the coefficient φ_1 is significantly non-zero, it indicates that the mediating variable has a partial mediation effect. In addition, when at least one of the coefficients δ_1 and φ_2 is insignificant, the Sobel test is conducted to further test the possible mediating effect. The regression results are shown in Table 10.

The results in columns (1)–(2) show that firm R&D innovation efficiency has a partial mediating effect on firm total factor productivity, and the size of the mediating effect is -0.006 (0.144*–0.044). The financing constraint inhibits the increase of total factor productivity through a firm's R&D innovation efficiency, which verifies hypothesis 2b. The results in columns (3)–(4) show that the mediating effect size of R&D innovation efficiency is -0.010 (0.204*–0.049). The results in columns (5)–(6) show that the mediating effect of R&D innovation efficiency on financing constraints and total factor productivity does not exist under negative external shocks. The reason for the above results is that China is currently shifting toward high-quality development, and there is a significant gap between internal spending on R&D in China's high-tech industries and that in developed countries. State otherwise, China's R&D investment is not strong enough. At the same time,

Table 11 Results of intermediate effect test

Paths	Sobel test (coefficient multi- plication)			Bootstrapping test			
	SE	Z	$P > Z $	Bias—corrected 95% CI		Percentile 95% CI	
				Lower limit	Upper limit	Lower limit	Upper limit
sa → kef → tfp	0.0012	− 12.31	0.0000	− 0.0168	− 0.0119	− 0.0166	− 0.0117
sa → lef → tfp	0.0019	4.626	0.0000	0.0045	0.0124	0.0049	0.0128
sa → R&D → tfp	0.0020	− 2.128	0.0333	− 0.0082	− 0.00023	− 0.00837	− 0.0003

The bootstrap sampling count is 1000 times

many enterprises fail to organize their R&D priorities effectively, which lessens the probability of R&D success and its contribution to total factor productivity (Zhao 2014). Therefore, under the influence of a negative shock, such as COVID-19 pandemic, firms affected by financing constraints will face greater challenges in improving corporate productivity through R&D innovation activities.

Considering the limitations of the stepwise test method, this paper continues to use the Sobel and Bootstrapping method to test the mediating effect R&D innovation efficiency and factor use efficiency. Table 11 reports the results of the mediation effect tests. First, the results of the Sobel test show that the absolute values of Z-statistics for capital efficiency, labor efficiency, and R&D innovation efficiency are all greater than 1.96, and the corresponding P-values are all less than 0.05. This indicates that there are significant mediating effects of capital efficiency, labor efficiency, and R&D innovation efficiency on financing constraints and total factor productivity of enterprises. Second, the results of Bootstrapping method test show that the Bias-Corrected and Percentile path coefficients corresponding to capital use efficiency, labor use efficiency, and R&D innovation efficiency do not contain 0 at the 95% level of confidence interval. This again verifies the significant mediating effect of factor use efficiency and R&D innovation efficiency. Therefore, the findings in Tables 9 and 10 are relatively reliable. The mediation effects are significantly present under the three paths considered in this paper, $sa \rightarrow kef \rightarrow tfp$, $sa \rightarrow lef \rightarrow tfp$, and $sa \rightarrow R\&D \rightarrow tfp$.

Conclusion and Policy Implications

With changes in the domestic and international economic environment, China's economy has entered a new era, shifting from high speed growth to high-quality development. The past crude economic growth model driven by factor inputs is no longer applicable. China now urgently needs to find new dynamics of economic growth to achieve a power shift in global economic balance. This requires quality improvement, efficiency improvement, and especially total factor productivity

(Wang and Yao 2021; He and Shen 2018). Indeed, total factor productivity improvement is the necessary condition of high-quality economic development (Sun and Zhang 2020). Give these observations, this paper focuses on the micro-level, using A-share listed companies from 2007 to 2018 as an empirical sample to examine the impact of financing constraints on the total factor productivity of enterprises. It also compares and investigates the effect of financing constraints on total factor productivity taking into account differences in firm type and geographic location, and it examines the path of the effect of financing constraints on the total factor productivity of enterprises using “factor use efficiency” and “R&D innovation efficiency” as indicators.

The empirical results of this paper indicate that financing constraints have an overall significantly inhibit effect on the total factor productivity of firms. This finding is found to be robust through various robustness tests related to replacing explanatory variables, the PPML method, excluding the effect of exogenous events, and the instrumental variables method. Heterogeneity analysis shows that differences in the type of firm and its geographic location influence the effect of renewable energy policies on firm total factor productivity. At the firm level, the negative effect of financing constraints on the total factor productivity of small-scale firms is greater relative to large-scale firms. With respect to ownership, the negative effect of financing constraints on total factor productivity is greater for non-state-owned firms. The negative impact of financing constraints on total factor productivity of non-energy firms is greater relative to energy firms. In terms of the geographical location, the negative impact of financing constraints on the total factor productivity of firms is greater in the Yangtze River Delta and Pearl River Delta city clusters than in the Beijing-Tianjin-Hebei city cluster. In addition, financing constraints have a stronger inhibitory effect on firms' total factor productivity in non-port cities than in port cities, and a stronger inhibitory effect in provincial capitals than in non-capital cities. Finally, the mechanism test finds that improving a firm's capital use efficiency and labor use efficiency will alleviate the inhibitory effect of financing constraints on total factor productivity, and that the mediating effect of capital use efficiency is larger than that of labor use efficiency. However, financing constraint will inhibit the increase of firm's total factor productivity through firm's R&D innovation efficiency. The mediating effect of R&D innovation efficiency is relatively larger under positive external shocks, while it is not present in the negative external shock environment.

Based on this study, this paper proposes several recommendations on how to alleviate the financing constraints of enterprises and promote their total factor productivity. First, coordinate the differences in financial development among regions. Local governments should formulate financial support policies that correspond the characteristics of regional development to narrow the differences in financial development between regions and promote the gradual balancing of financial development levels in each region, thus driving the overall improvement of enterprise productivity. Second, optimize the structure of the capital market. This will require, optimizing the credit structure of the banking industry, eliminating the credit discrimination between private enterprises and state-owned enterprises, broadening the financing channels of private enterprises, and solving the financing difficulties of private

enterprises. It will also require improving the situation that have been dominated by the banking industry, and establishing a multi-level capital market structure to meet the diversified financing needs of enterprises. The third recommendation pertains to financial institutions. Carrying out financial innovation for technology innovation projects will improve total factor productivity. Financial institutions can launch more financial products and provide more effective financial intermediary services for technology innovation through financial innovation activities. Finally, give full play to the guiding effects of new industries on enterprise innovation and innovation funds. The government should give full play to these effects, continue to promote the policy of strategic new industries, and guide the financial support of third-party financial institutions for new industries, so that enterprises can have sufficient funds to invest in R&D innovation activities to enhance their total factor productivity.

This paper still leaves room for research expansion. First, based on the empirical results, it is inferred that financing constraints inhibit the total factor productivity increase of enterprises, but this conclusion has not been tested using a relevant causality identification method. Therefore, in a subsequent study, we will further test this causality. Second, the heterogeneity discussion regarding the path of the effects of financing constraints on total factor productivity is not carried out in this paper. For example, are there differences in the mediating effects of factor use efficiency and R&D innovation efficiency on the effects of financing constraints on total factor productivity across industries and firms with different property rights and external environment? This question will provide the direction for our future research.

Acknowledgements We gratefully thank the anonymous reviewers and the editors for their suggestions.

Funding Funding was provided by the National Natural Science Foundation of China (Grant Numbers 71303105 and 72074107), National Planning Office of Philosophy and Social Science (Grant Number 19FJYB039), Jiangsu Provincial Department of Education (Grant Numbers KYCX21_1430 and KYCX21_1431), and Nanjing University (Grant Number CXYJ21-03).

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