COVID-19, Financing Constraints and Total Factor Productivity of Enerprises

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ABSTRACT

As the COVID-19 epidemic swept the world in early 2020, it is worth watching how it affects the total factor productivity of enterprises. Based on the theory of information asymmetry and the data of A-share listed companies from 2014 to 2021, this paper conducts an empirical study on the relationship between COVID-19 and the total factor productivity of enterprises. The results show that the impact of the COVID-19 epidemic can significantly reduce the total factor productivity of enterprises, and the conclusion is still true after a series of robustness tests. Taking the financing constraint as an intervening variable, it clearly reveals a transmission mechanism, that is to say, the impact of the COVID-19 epidemic exacerbates the financing constraint of the enterprise, thus it makes the total factor productivity of the enterprise reduce. It is further found that the above effects are more obvious for small and medium-sized enterprises and non-intelligent enterprises. Based on this, the government should implement some active economic development policies to create a free, relaxed and orderly market environment for enterprise financing. At the same time, enterprises should not only pay attention to digital and intelligent development, and transform into technology-intensive enterprises, but also strengthen the awareness of worry. Enterprises should store "more grain" for preparing for the cold winter.
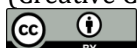
KEYWORDS

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1. Introduction

At the beginning of 2020, the COVID-19 epidemic, as a public health emergency, seriously affected China and even the global economy. Since the first meltdown of the U.S. stock market in 1997, there have been four meltdowns in the ten days from March 9 to 18, 2020, which has directly led to panic among global investors. The world economy is facing great downward pressure and foreign-funded enterprises in China have also suffered from it. According to the Bureau of Statistics of China, GDP exceeded 101 trillion yuan in 2020.The growth rate in 2020 was only 2.3% higher than that in 2019, which was much lower than the growth rate of 6.0% last year. The epidemic not only has a devastating impact on the macro economy, but also a fatal impact on microeconomic subjects. The external environment is the cornerstone of the survival and development of enterprises and has a decisive impact on the production and operation of enterprises. In view of epidemic prevention and control, China has adopted a series of measures such as restricting the flow of people, home isolation, canceling or delaying large-scale gatherings and delaying the resumption of work and production. These measures undoubtedly hinders the flow of production factors. And these also lead to a sharp decline in input and output, the accumulation of orders, insufficient supply of raw materials and the rupture of the capital chain. According to the China Association of Small and Medium-sized Enterprises, small and medium-sized enterprises directly lost 100,000 to 5 million. With the accelerated spread of the epidemic, the ideal capital market environment has been seriously damaged, the problem of information asymmetry and principal agency have been further highlighted. The enterprise financing environment has intensified and deteriorated Therefore, it has made the external financing cost of enterprises higher than the internal financing cost and been even difficult to enter the capital market to raise funds. The internal and external environmental risks faced by enterprises have intensified. And financial risks and business risks have been challenged unprecedentedly.

The report of the 19th National Congress of the Communist Party of China pointed out that "We should promote the quality change, efficiency change and power change of economic development. It will improve total factor productivity." At the end of 2019, the China Macroeconomic Management Academic Annual Conference regarded improving total factor productivity as the key to achieving high-quality economic development. All of them reflect the important position of total factor productivity. Total factor productivity refers to the contribution of factors other than capital and labour factors to production. It is the driving force of the high-quality development of the current economy and also an important indicator to measure the production efficiency level of enterprises. Enterprises are the micro-subject of the macro economy and the most active individuals in the market. In the post-epidemic era, it is crucial to resume normal production and operation, promote economic recovery and improve total factor productivity. Based on this, from the perspective of the public health emergency of COVID-19, this paper conducts an empirical study on the COVID-19 epidemic and the total factor productivity of enterprises. And Taking the financing constraint as an intervening variable, we explores the impact mechanism of COVID-19 on corporate TFP. We discover that the impact of the COVID-19 epidemic exacerbates the financing constraint of the enterprise, thus it makes the total factor productivity of the enterprise reduce. This helps to clarify the impact and mechanism of the COVID-19 epidemic on corporate TFP. In addition, we analyse the impact of the epidemic on total factor productivity from the differences in enterprise size and main business types, which is helpful for enterprises to cope with the impact of the epidemic or other turbulence. This helps to clarify the impact and mechanism of COVID-19 on enterprises' total factor productivity. In addition, we analyze the impact of the epidemic on TFP from the perspective of enterprise size and main business types, which is helpful to provide thinking for enterprises to cope with the impact of the epidemic or other turbulence.

2. Literature Review

The outbreak and continuous impact of the COVID-19 pandemic have caused the global economy to fall in a state of free fall. The impact is far greater than the 2008 financial crisis and the economic development is sluggish. Generally speaking, the current impact of the COVID-19 epidemic on the economy is mainly explained from both supply and demand.

In terms of supply, the supply of labour and products have been studied. In view of the labour supply situation, the more people confirmed cases of the epidemic is, the stricter the epidemic prevention measures are and the more individuals feel panicked. So It has a hard hit to labor supply. According to a study by Aum, Lee and Shin (2021), if the number of infected people in South Korea increases by one thousand, the number of local employees will drop by two to three percentage points. At the same time, the impact of the epidemic on different labour groups is different. The groups with low education, low salaries and temporary employees are the most negative impacted by the epidemic. According to the survey of Barrero, Bloom, Davis and Meyer (2021), the COVID-19 epidemic has less impact on employees with telecommuting capabilities. In view of the supply of products, in the early stage of the epidemic, there was a shortage of medical protective materials in China (Wang et al,2020). When the world entered a health emergency, drug supply became a key issue, and foreign countries relied heavily on China for supplies of raw materials(Vinci et al,2020). At the same time, Barua (2020) found that at the beginning of the epidemic, many factories and enterprises had no choice but to stop work and production, resulting in a significant decline in product production. The supply of market products exceeded demand and the output of industry and service industries fell the most.

In terms of demand, the dynamic outbreak of the epidemic has reduced the consumption income of residents. The uncertainty caused by this directly leads to poor future expectations of residents, weakened enthusiasm for consumption and sluggish market demand. Baker, Farrokhnia, Meyer, Baker and Yannelis (2020) used family financial data to study and found that with the spread of epidemic news, consumers first hoard goods resulting in a sharp increase in consumption, and then a sharp decline due to home quarantine. Clark, Lusardi and Mitchell (2021) conducted a survey on groups between the ages of 45 and 75. The results showed that about one in five people are in poor economic condition and use insufficient spare funds in the face of emergencies such as the epidemic. Among them, the income level is low or Groups with more family members are more likely to face the impact of the epidemic and have economic risks. In addition, the epidemic has also intensified investors' preference for risk avoidance, curbing investment activity and activity in the market.

Throughout the existing research on the factors affecting the total factor productivity of enterprises, we mainly explore the impact on the total factor productivity of enterprises from the macro level and the enterprise. From the macro perspective, industrial policy, financial development, capital market and other aspects affect the total factor productivity of enterprises.

Research on how industrial policies affect the total factor productivity of enterprises can be divided into two opposite conclusions: on the one hand, industrial policies can significantly improve the total factor productivity of enterprises. Aghion et al. (2015) found that national industrial policies can effectively improve the total factor productivity of enterprises, especially the allocation of resources to competitive enterprises or the introduction of industrial policies to promote enterprise competition which can improve the total factor productivity of enterprises. On the other hand, industrial policies can inhibit the improvement of the total factor productivity of enterprises. In terms of financial development, the sound development of the financial market can bring more funds to enterprises, alleviate the financing constraints of enterprises, and increase the R&D of enterprises. At the same time, it will also optimize the efficiency of resource allocation and guide resources to flow to high-efficiency projects, thus promoting the improvement of total factor productivity of enterprises. Han and Shen (2015) showed that Chinese financial development plays a significant role in promoting TFP growth. The faster the financial development takes place, the

better it could correct the mismatch of resource allocation, thus promoting TFP growth. In terms of the degree of capital market, there is no doubt about the impact of the capital market on the total factor productivity of enterprises, as the "blood of modern economic operation" and the link between the real economy. Larrain and Stumpner (2017) took Eastern European countries as an example to study the impact of capital market openness on corporate TFP, and found that capital market opening can effectively cover the efficiency of resource allocation, thus promoting the growth of TFP. At the same time, some scholars also analyzed the taxation reform (Guo & Li ,2023), environmental regulation (Wang, Ma, Song & Zhang ,2023), flow-carbon city pilot policy (Chen et al,2021) and other changes in the macro environment affect the total factor productivity of enterprises. Many valuable research conclusions have been obtained.

In terms of enterprises' own factors, technological innovation, resource allocation, financing constraints and other factors have a certain impact on the total factor productivity of enterprises.

From the perspective of technological progress, the existing literature basically supports that technological innovation can improve TFP of enterprises. Schmöller and Spitzer (2021) believed that the decline in R&D efficiency and innovation is the key to explain the slowdown in the total factor productivity of euro area countries before the crisis, and that the improvement of total factor productivity caused by technological progress is insufficient. Junior, Faria, Montenegro, Bahia and Gonçalves (2020) explored the economics effects of public R&D investment funding in Brazil and demonstrated that technological innovation input played a key role in promoting productivity improvement and economic growth. From the perspective of resource allocation, China has long belonged to the extensive economic growth model, and there are serious problems in resource allocation distortion. Therefore, optimizing the efficiency of resource allocation is conducive to tilting the scarce resources to the projects with high returns, reducing the phenomenon of resource misallocation, ensuring investment efficiency, and helping to boost the total factor productivity of enterprises. Hsieh and Klenow (2009) measured the total factor productivity based on the data of enterprises in the United States, China and India. They found that if Chinese and Indian enterprises could improve the efficiency of allocating capital and labor factors and make factors flow to high-productivity enterprises in the same way as the U.S. market, the total factor productivity of Chinese and Indian enterprises would increase by 40% and 50% respectively on average. From the perspective of financial constraints, most of the current research results support that financial constraints have a significantly negative impact on the total productivity of enterprises. Ferrando and Ruggieri (2018) found that financing constraints have a more significant inhibitory effect on corporate TFP among European private firms with small scale or short establishment year. Wang and Kong (2019) empirical findings suggested that non-listed companies in China face strong financial constraints that strangle their total factor productivity. Some scholars also reflect that the easing of financing constraints can relax the pressure of enterprises, which can lead to the behavior of "reckless investment," which can reduce the total factor productivity of enterprises.

It can be seen that in terms of the impact of COVID-19, the existing literature focuses on the impact of the epidemic on the economy from the perspectives of supply and demand, but there are few studies that comprehensively analyze the impact of the epidemic on the total factor productivity of enterprises. Enterprises are important carriers of microeconomic activities, and analyzing the impact of COVID-19 on TFP is helpful to better understand the economic consequences caused by the epidemic. In terms of TFP, the existing literature also explores the impact of TFP on macro and enterprises' own conditions, but there are few studies on exogenous shocks such as COVID-19. So it can be seen that at the present stage, there is a relatively lack of literature to study China's TFP from the COVID-19 epidemic. This article will take the COVID-19 epidemic, financing constraints and enterprise total factor productivity as the research subjects, further analyse the mechanism of the COVID-19 epidemic on the total productivity of enterprises and enrich the research on COVID-19 and total factor productivity at the enterprise level. At the same time, in the context of the epidemic, how to alleviate China's financing constraints and promote

the improvement of the total factor productivity of enterprises is of great significance for Chinese enterprises to break the quagmire of the epidemic and realise the high-quality development of enterprises.

3. Theoretical Analysis

Since the outbreak of COVID-19, enterprises have been facing great pressure to survive. According to statistics, affected by the epidemic, it is expected that the operating income of 59.1% of enterprises decline by more than 20% in 2020 and 31.9% of enterprises decline by more than 50%. The smaller the scale of the enterprise, the greater the impact of the epidemic. At the same time, the continuous spread of the epidemic has made isolated a large number of labour groups and the short-term absence of enterprise employees is serious. Moreover, the epidemic prevention measures have spatially blocked the flow of labour and the complicated procedures for applying for returning to work have made it difficult for employees to resume work. Many enterprises are facing the problem of breaking the labour chain and capital chain. Even if employees return to work normally, they will face a series of problems such as asynchronous resumption time of upstream and downstream enterprises, logistics control or long recovery time, which will lead to a series of problems such as order accumulation, raw material supply rupture, cost surge and capital flow difficulties. So the expected profit of enterprises will decline. In addition, home isolation will lead to changes in the type and quantity of market demand, which increases the uncertainty of the market. The emotionalisation of investors is serious, the stock price fluctuates frequently, and the value of enterprises declines.

Therefore, the impact of COVID-19 has made enterprises basically unable to make ends meet, affecting their production, operation, profit and other aspects. It leads to the deterioration of their internal production and operation, cash flow shortage, investment project stagnation and so on. Based on this, the following hypothesis is proposed:

Hypothesis H1: The impact of COVID-19 has led to a decline in the total factor productivity of enterprises.

TFP is not only affected by enterprises' technological innovation ability (Dai, Zhang & Luo, 2022) and resource allocation (Comin & Hobijn, 2010), but also depends on enterprises' financing constraints. Marx said in the theory of labor production that enterprises first raise funds, then put them into production, distribute the surplus of production and finally use it to expand and reinvest in production and so on to achieve the development and growth of enterprises. Therefore, from the perspective of production process, capital is the blood of enterprise development. Only smooth and stable capital can ensure the normal production and operation of enterprises and achieve long-term and stable development. However, financing constraints are the "stumbling block" for enterprises to carry out normal financing. The existence of financing constraints inhibits enterprise performance. It is closely related to the growth of corporate total factor productivity (Levine & Warusawitharana, 2021). At the same time, increasing R&D innovation investment is the only way to improve the total factor productivity of enterprises, but the R&D activities of enterprises are characterized by long cycle, high cost, high uncertainty and high risk. Therefore, stable, sufficient and flexible funds are essential for enterprise R&D activities. At present, Chinese enterprises mainly rely on internal financing and external financing. According to pecking order theory, enterprises will give priority to the best channel, namely, internal financing. However, according to the results of the special research on the living status of small, medium and micro enterprises (2020), about 50% of the enterprises are difficult to run their existing cash flow for more than three months. Nearly 14% of the enterprises are even difficult to spend one month. 23.11% of large and medium-sized enterprises said that their cash flow would dry up within three months, making many enterprises face negative income growth and rising expenses, which directly leads to the shortage of internal cash flow. Enterprises are in the quagmire of the epidemic and it is difficult to maintain the existing business scale, especially for the investment conducive to the development of enterprises. Therefore, it is difficult for most enterprises to complete it alone without relying on external funds. Therefore, almost all enterprises need to rely on external financing to raise funds. However, the impact of the epidemic has made it more difficult for enterprises to

obtain the "trust" of bank credit and commercial credit financing. On the one hand, the dynamic outbreak of COVID-19 has led to a decline in operating income and a rise in operating costs of enterprises. And their stability and ability to continue operations have been seriously questioned. It is difficult for banks to form considerable expectations for enterprises' future operating performance. Therefore, banks' willingness to credit weakens in the process of credit evaluation. At the same time, the epidemic has intensified the degree of information asymmetry between banks and enterprises. As a result, the potential and valuable projects of enterprises cannot get financial support. So the financing constraints are more serious than before the epidemic, which hinders the development and progress of enterprises and the improvement of total factor productivity. On the other hand, the dynamic outbreak of COVID-19 has also reduced or even interrupted the exchange of technical cooperation, resource exchange and information sharing between enterprises. So it is more difficult to know the true and reliable business information and future development status of each other than before. In addition, investors' negative attitude and panic about future expectations make it more difficult for enterprises to obtain commercial credit financing (Yang et al., 2020). As a result, corporate investment deviates from the optimal level, reduces corporate investment efficiency and further inhibits corporate total factor productivity. At the same time, in the market environment where enterprises are generally faced with "difficult and expensive financing," the scale of enterprises further aggravates the differences in corporate financing constraints. Compared with large enterprises, small and medium-sized enterprises often face higher conditions in financing so they face more serious external financing constraints. This improper allocation of resources not only directly increases the financing cost of enterprises' R&D activities, but also inhibits the improvement of enterprises' total factor productivity. Therefore, this paper proposes the following hypothesis:

Hypothesis H2: The impact of the COVID-19 epidemic inhibits the improvement of the total factor productivity of enterprises by intensifying financing constraints.

4. Research Design

4.1. Sample selection and data sources

This paper selects the data of Chinese A-share listed companies from 2014 to 2021 as the research object. At the same time, according to the usual practises, the observation values of financial and insurance enterprises, ST, PT and other abnormal states. Missing main data are excluded and 21,152 samples are finally obtained. The data in this paper come from CSMAR and STATA.17 is used for data processing and analysis. In order to weaken the influence of outliers, this paper further carries out the tailing process of 1%.

4.2. Variable definition

The variables in this paper mainly include total factor productivity of enterprises, COVID-19, financing constraints. The specific definitions and calculation methods of each variable are as follows:

First of all, common methods for estimating TFP include OLS method, FE method, OP method, LP method and GMM method, which have their own shortcomings. In order to better avoid the sample selection bias, referring to the research of Levinsohn and Petrin (2003), we use the LP method to estimate the total factor productivity of enterprises. The formula is as follows:

$$LnY_{i,t} = \partial_0 + \partial_L LnL_{i,t} + \partial_K LnK_{i,t} + \partial_M LnM_{i,t} + \varepsilon_{i,t} \tag{1}$$

Among them, Y indicates the main business income; L indicates labour investment, which is measured by the number of employees of the enterprise; K indicates capital investment, which is measured by the net value of fixed

assets; M indicates intermediate investment, which is measured by "cash for purchasing goods and receiving labour payment". The residuals obtained after the return of the model are the total factor productivity of the enterprise. At the same time, in order to make the results more robust, this article adopts the OLS method and the GMM method to test the robustness.

COVID-19 is represented by zero and one, that is, one for 2020 and beyond, and zero otherwise.

Intervening variable is financing constraint. Since the SA index can eliminate the endogenous impact of internal financial elements, this measurement method is selected in this article. We use cost to represent financial constraints. The formula is as follows. Because the SA index is negative, in order to facilitate understanding, it is absolutely worth taking the SA index to cost to measure the financing constraint.

$$SA = -0.737 * Size + 0.043 * Size^2 - 0.04 * Age \tag{2}$$

The control variables mainly include enterprise characteristic variable. In order to avoid the omitted variable problem caused by the omitted enterprise characteristic variables, this paper adds indicators such as profitability (roa), financial leverage (lev), operating capacity (TAT), shareholding ratio of the top ten shareholders (top10), growth rate (growth), fixed asset ratio (fix), enterprise size (size), cash flow (cf) and property rights (soe). Among them, profitability is expressed by the rate of return on total assets. Financial leverage is equal to liabilities divided by assets. Operating capacity is expressed by the turnover rate of total assets. Growth rate is expressed by the growth rate of operating income. Fixed asset ratio is equal to fixed assets divided by assets. Enterprise size comes from the logarithm of assets. Cash flow is equal to the net cash flow generated by operating activities divided by total assets. Property rights are dummy variables that take the value of one for state-owned enterprises and zero otherwise.

4.3. Model Setting

In order to verify the impact of COVID-19 on total factor productivity of enterprises, the following model is constructed:

$$TFP\_LP_{it} = \beta_0 + \beta_1 COVID-19_t + \lambda Control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \tag{3}$$

Among them, TFP_LP_{it} represents the total factor productivity of enterprises in city i in t year; COVID-19 is a virtual variable, with 2020 as the outbreak node, taking 1 in 2020 and beyond, otherwise 0; λ is a series of control variables, γ is the time fixed effect, μ is the regional fixed effect and the use of clustering.

5. Empirical Research

5.1. Descriptive Statistics

Table 1 shows the descriptive statistical results of the main variables. The results show that the average value of TFP_LP is 10.657, which is significantly lower than the existing literature data (Liu et al.,2023). Moreover, the maximum value gap is large, indicating that there is a large difference in total factor productivity within the sample firms. The mean value of COVID-19 is 0.3373, indicating that 33.73% of the enterprises in the samples are affected by the epidemic, that is, the number of samples in 2020-2021 accounts for 33.73% of the total samples. At the same time, other control variables also fluctuate in a large range, which is worth further exploration, leaving research materials for this paper to explore the impact of COVID-19 on total factor productivity.

Table 1. Descriptive Statistical Results of Main Variables.

Variables	N	Mean	SD	Min	Median	Max
TFP_LP	20915	10.6570	0.9918	7.0694	10.9745	11.7624
COVID-19	20915	0.3373	0.4728	0	0	1
soe	20915	0.3120	0.4633	0	0	1
roa	20915	0.0407	0.0642	-0.2678	0.0410	0.2054
lev	20915	0.4033	0.1935	0.0610	0.3929	0.8670
TAT	20915	0.6128	0.3751	0.1083	0.5330	2.3356
top10	20915	0.5936	0.1500	0.2459	0.6031	0.9066
growth	20915	0.3114	0.6670	-0.6226	0.1401	4.1906
fix	20915	0.2036	0.1441	0.0038	0.1756	0.6493
size	20915	9.4497	1.0251	5.6095	9.7589	10.5028
cf	20915	0.0522	0.0643	-0.1255	0.0500	0.2411

5.2. Baseline Regression

Table 2 reports the results of the impact of COVID-19 on the total factor productivity of enterprises. Among them, Column (1) only tests the impact of independent variables and controls the time and region fixed effects, while Column (2) is the result of adding control variables. The results show that the regression coefficients of COVID-19 are all significantly negative at the level of 1%, indicating that the impact of COVID-19 does reduce the total factor productivity of enterprises, which confirms Hypothesis 1. In Column (2), the regression coefficient of COVID-19 is -0.0924, indicating that the impact of COVID-19 has caused the total factor productivity of enterprises to decline by 9%.

Table 2. Baseline Regression Results.

	(1) TFP_LP	(2) TFP_LP
COVID-19	-0.1054***	-0.0924***
	(-3.6250)	(-3.1556)
soe		-0.0307
		(-1.0814)
roa		-0.0083
		(-0.0610)
lev		-0.3226***
		(-5.0409)
TAT		-0.1793***
		(-4.5516)
top10		0.0461
		(0.5968)
growth		0.0028
		(0.2321)
fix		0.1835**
		(2.1444)
size		0.0181*
		(1.6577)
cf		-0.3356***
		(-2.6373)
Cons	10.7771***	10.7556***
	(575.6359)	(105.8577)
Year	Yes	Yes
Region	Yes	Yes
N	20915	20915
Within R2	0.0021	0.0053

*Notes: *** indicates significance at the 1% level, ** indicates significance at the 5% level, and * indicates significance at the 10% level. The values in brackets are the clustering robust standard errors of firm.*

The above results show that the impact of COVID-19 significantly reduces the total factor productivity of enterprises. On the one hand, the negative impact of the dynamic outbreak of the epidemic and the subsequent mutation of the virus strain on most enterprises is continuous and incalculable, which weakens the liquidity of various factor resources in the market, making financing more difficult. The cost of enterprises using various factors and their transaction costs rise, the rupture of the capital chain, resource mismatch. As a result, the enterprise is passively or actively unable to carry out normal production and operation activities in the quagmire of the epidemic. On the other hand, the external environment on which the enterprise depends is seriously damaged, which challenges the enterprise's scientific business decision-making and has a fatal impact on the enterprise's total factor productivity.

5.3. Threshold Effect Test

Change dependent variable measurement indicators. In order to avoid different measurement methods affecting the conclusion, as mentioned above, we adopts the OLS method and GMM method to recalculate the total factor productivity of the enterprise and then carries out regression analysis. The results are shown in Table 3. Columns (1) and (2) are the regression results of the OLS method, and columns (3) and (4) are the regression results of the GMM. The results show that whether the control variable is added or not, the regression coefficient of COVID-19 is negative, which is consistent with the previous conclusion.

Table 3. Change dependent variable measurement indicators.

	(1) TFP_OLS	(2) TFP_OLS	(3) TFP_GMM	(4) TFP_GMM
COVID-19	-0.1138***	-0.1073***	-0.1086***	-0.0980***
	(-3.9114)	(-3.6598)	(-3.7331)	(-3.3468)
soe		-0.0443		-0.0358
		(-1.5581)		(-1.2601)
roa		-0.0427		-0.0212
		(-0.3135)		(-0.1559)
lev		-0.3560***		-0.3349***
		(-5.5590)		(-5.2323)
TAT		-0.1657***		-0.1740***
		(-4.1940)		(-4.4144)
top10		0.0436		0.0452
		(0.5632)		(0.5853)
growth		0.0045		0.0034
		(0.3770)		(0.2863)
fix		0.0069		0.1165
		(0.0804)		(1.3614)
size		0.0187*		0.0184*
		(1.7130)		(1.6785)
cf		-0.3368***		-0.3358***
		(-2.6461)		(-2.6392)
Cons	10.2790***	10.3068***	10.5892***	10.5862***
	(548.7994)	(101.3785)	(565.5588)	(104.1726)
Year	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes
N	20915	20915	20915	20915
Within R2	0.0025	0.0052	0.0022	0.0052

Replace fixed effects and cluster analysis. First, considering that the total factor productivity of the enterprise may be affected by the characteristic factors of the industry in which the enterprise is located, we further introduces the fixed effect of the industry for robustness test. Secondly, in order to make the estimator of the variance of the estimation coefficient closer to the real value, the robust standard error of industry level clustering and the robust standard error of province level clustering are introduced successively. The results are shown in Table 4. Column (1) is the result of fixed year, region and industry effects, and column (2) is the result of robust standard error

clustering at the industry level. Column (3) shows the results of robust standard error clustering at the provincial level, and the regression results are basically consistent with the above.

Table 4. Replace fixed effects and cluster analysis.

	(1) TFP_LP	(2) TFP_LP	(3) TFP_LP
COVID-19	-0.0916***	-0.0916***	-0.0916***
	(-3.1141)	(-3.1511)	(-3.2149)
soe	-0.0186	-0.0186	-0.0186
	(-0.6442)	(-0.6841)	(-0.5714)
roa	-0.0340	-0.0340	-0.0340
	(-0.2490)	(-0.3363)	(-0.2699)
lev	-0.3338***	-0.3338***	-0.3338***
	(-5.0553)	(-6.0954)	(-4.2040)
TAT	-0.1769***	-0.1769***	-0.1769***
	(-4.3461)	(-4.9435)	(-4.0820)
top10	0.0519	0.0519	0.0519
	(0.6700)	(0.8564)	(0.6005)
growth	0.0037	0.0037	0.0037
	(0.3038)	(0.2377)	(0.2384)
fix	0.1809**	0.1809**	0.1809***
	(2.0689)	(2.3644)	(2.8212)
size	0.0175	0.0175	0.0175
	(1.6019)	(1.0315)	(1.5119)
cf	-0.3146**	-0.3146***	-0.3146**
	(-2.4621)	(-5.2540)	(-2.5693)
Cons	10.5932***	10.5932***	10.5932***
	(72.7918)	(69.3135)	(67.8715)
Year	Yes	Yes	Yes
Region	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	20915	20915	20915
Within R2	0.0052	0.0052	0.0052

Table 5. Propensity score matching analysis.

|	TFP_LP
COVID-19	-0.0952***
	(-2.9589)
soe	-0.0247
	(-0.8419)
roa	-0.0653
	(-0.4500)
lev	-0.3372***
	(-5.1556)
TAT	-0.1804***
	(-4.4868)
top10	0.0047
	(0.0603)
growth	-0.0055
	(-0.4171)
fix	0.2269**
	(2.5486)
size	0.0159
	(1.4144)
cf	-0.4017***
	(-2.8719)
Cons	10.8384***
	(104.6027)
Year	Yes
Region	Yes
N	17049
Within R2	0.0060

Propensity score matching analysis. In order to better reveal the causal relationship between COVID-19 and enterprise TFP, this paper uses the propensity score matching method to eliminate the sample selection problem caused by individual heterogeneity. Firstly, the multi-dimensional covariates are transformed into one-dimensional propensity scores through functional relations, and the 1:3 nearest neighbor matching is used to match the obtained propensity scores, so as to find the enterprises with the most similar characteristics to the affected enterprises, and then separate the net effect of the COVID-19 impact on the total factor productivity of enterprises. The standardized deviation rates are all less than 5% and the t values after matching are not significant, indicating that there is basically no significant difference between the matching variables of the treatment group and the control group, which conforms to the hypothesis of balance. The PSM method is used to estimate the average treatment effect of the impact of COVID-19 on the total factor productivity of enterprises. Propensity score matching method. In order to better reveal the causal relationship between COVID-19 and enterprise TFP, this paper uses the propensity score matching method to eliminate the sample selection problem caused by individual heterogeneity. Firstly, the multi-dimensional covariates are transformed into one-dimensional propensity scores through functional relations, and the 1:3 nearest neighbor matching is used to match the obtained propensity scores, so as to find the enterprises with the most similar characteristics to the affected enterprises, and then separate the net effect of the COVID-19 impact on the total factor productivity of enterprises. The standardized deviation rates are all less than 5% and the t values after matching are not significant, indicating that there is basically no significant difference between the matching variables of the treatment group and the control group, which conforms to the hypothesis of balance. The PSM method is used to estimate the average treatment effect of the impact of COVID-19 on the total factor productivity of enterprises.

Propensity score matching analysis. To better reveal the causal relationship between the new crown epidemic and the total factor productivity of enterprises, this paper adopts the propensity score matching method to eliminate the sample selection problem caused by individual heterogeneity. First, the multi-dimensional covariates are transformed into one-dimensional propensity scores through functional relationships, and the propensity scores are matched using 1:3 nearest neighbor matching, so that the firms with the most similar characteristics to those affected by the epidemic can be found, and the net effect of the COVID-19 shock on the total factor productivity of firms can be separated. The results are shown in Table 6. The standardized deviation rates are all less than 5% and none of the t-values are significant after matching, indicating that there is basically no significant difference between the matching variables of the treatment and control groups, which is consistent with the equilibrium hypothesis. The PSM method was used to estimate the average treatment effect of the impact of the COVID-19 on the total factor productivity of enterprises, and the results showed no fundamental change in the sign and significance level of the estimated coefficients, which further verified the reliability of the conclusions of this paper.

Placebo test. In order to test to what extent the above benchmark regression results are affected by random factors and other unobserved variables, this paper constructs a virtual processing group, selects samples before 2020, and randomly generates new virtual independent variables with the independent variables in the original data, and proceeds according to the T value of the regression coefficient obtained by the virtual experiment. In order to enhance the persuasiveness of the placebo test, 1,000 repeated simulations are carried out. As shown in Figure 1, the X-axis represents the T value corresponding to the effect estimation coefficient from 1000 random allocation processing groups. The curve is the estimated nuclear density distribution, and the vertical line is the real estimated T value without placebo testing. From the model results, it can be seen that the corresponding t-values of most random sampling coefficients are averaged at zero and are normally distributed, indicating that there is no serious missing variables in this model, and the core conclusion is robust.

Table 6. Mechanism test.

	(1) TFP_LP	(2) cost	(3) TFP_LP
COVID-19	-0.0924***	30.8116***	-0.0726**
	(-3.1556)	(193.0180)	(-2.5050)
cost			-0.0012***
			(-2.7057)
soe	-0.0307	38.5266***	0.0051
	(-1.0814)	(27.5879)	(0.1676)
roa	-0.0083	-0.3074	-0.0124
	(-0.0610)	(-0.5211)	(-0.0913)
lev	-0.3226***	3.0256***	-0.2885***
	(-5.0409)	(6.5667)	(-4.4141)
TAT	-0.1793***	0.2187	-0.1756***
	(-4.5516)	(1.0059)	(-4.4543)
top10	0.0461	-8.7177***	-0.0355
	(0.5968)	(-12.0108)	(-0.4070)
growth	0.0028	0.1355**	0.0022
	(0.2321)	(2.2592)	(0.1849)
fix	0.1835**	1.2172*	0.1910**
	(2.1444)	(1.7706)	(2.2361)
size	0.0181*	8.3132***	0.0271**
	(1.6577)	(56.0611)	(2.3699)
cf	-0.3356***	-0.9519	-0.3239**
	(-2.6373)	(-1.4065)	(-2.5504)
Cons	10.7556***	-33.8323***	10.7494***
	(105.8577)	(-27.7371)	(106.0328)
Year	Yes	Yes	Yes
Region	Yes	Yes	Yes
N	20915	20915	20915
Within R2	0.0053	0.9169	0.0053
Sobel test		Z= -4.54	
Goodman test 1		Z= -4.517	
Goodman test 2		Z= -4.564	
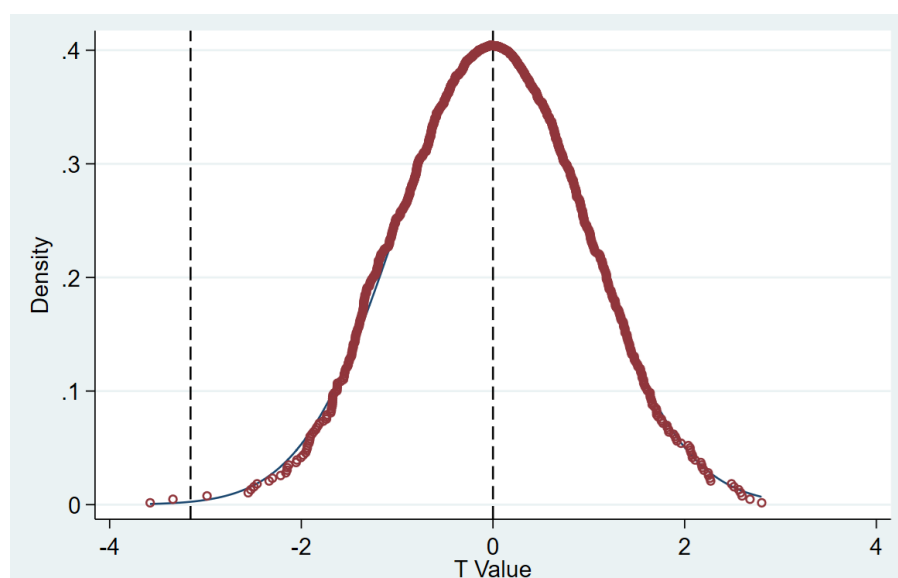
Figure 1. Placebo test.

6. Mechanism Test

The above results show that the impact of COVID-19 has an inhibitory effect on the total factor productivity of enterprises. Then, through what channel does COVID-19 affect the total factor productivity of enterprises? Considering that the outbreak of COVID-19 has greatly changed the internal and external environment that enterprises rely on for survival, this paper explores the impact of the epidemic on enterprises' financial constraints from the perspective of financial constraints, so as to clarify the mechanism of the impact of COVID-19 on enterprises' total factor productivity.

With the accelerated spread of the epidemic, the usual money market environment and capital market environment have been damaged. The financing environment of enterprises has intensified and deteriorated, making the external financing cost of enterprises higher than the internal financing cost and it is even difficult to enter the capital market to raise funds. However, it is difficult for smart women to cook without rice, and the total factor productivity of Influence. Based on this, referring to the research of Baron and Kenny (1986), the three-step method is used for testing. The model is set as follows:

$$cost_i = \delta_0 + \delta_1 COVID-19_t + \lambda Control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \qquad (4)$$

$$TFP_{LP_{it}} = \eta_0 + \eta_1 COVID-19_t + \eta_2 cost_{it} + \gamma_t + \mu_i + \varepsilon_{it} \qquad (5)$$

Among them, cost reflects financial constraints. The greater the cost is, the more serious the financial constraints are. The model (3) represents the total effect of the impact of the COVID-19 epidemic on the total factor productivity of the enterprise. Model (4) represents the impact of COVID-19 on the financial constraints of enterprises. In Model (5), η_1 represents the direct effect of the COVID-19 impact on corporate TFP, the product of η_2 and δ_1 represents the mediating effect of financial constraints. According to the regression results in Table 6, the absolute value of η_1 is less than that of β_1. Therefore, financial constraints play a partial mediating role in the impact of COVID-19 on the total factor productivity of enterprises.

In Table 6, column (1) shows that at the significance level of 1%, the occurrence of COVID-19 significantly reduces the total factor productivity of enterprises. Column (2) shows that the coefficient of COVID-19 is significantly positive, indicating that the occurrence of COVID-19 has significantly intensified the financial constraints of enterprises. Column (3) shows that the coefficient of cost is significantly negative, indicating that financial constraints do restrict the improvement of corporate TFP and the coefficient changes from -0.0924 to -0.0726. The mediating effect is -0.036974 (-0.0012×30.8116), indicating that the occurrence of COVID-19 has intensified the financing constraints of enterprises, thus significantly reducing the total factor productivity of enterprises. In this paper, three significance tests are provided in the sgmediation order test process, and all of them are significant. The conclusion supports Hypothesis 2, that is, the impact of the COVID-19 epidemic exacerbates the financing constraint of the enterprise, thus it makes the total factor productivity of the enterprise reduce.

7. Heterogeneity Test

7.1. Heterogeneity of enterprise scale

By combing the existing literature, it is found that compared with large enterprises, the impact on small and medium-sized enterprises is more serious. On the one hand, large enterprises have richer and deeper elements and resources, with relatively large scale effects, strong market competitiveness and relatively strong economic strength. In response to the sudden outbreak of the epidemic, they have more capital and ability to deal with it. On the other hand, even if the enterprise does not have rich capital accumulation, it will be more likely and have the opportunity to apply for credit support, so the decision to give up favourable projects due to the limitations of the actual situation will be reduced, and to a certain extent, the impact on the total factor productivity of the enterprise will be alleviated. In order to describe the heterogeneous impact of the impact of the COVID-19 epidemic on the total factor

productivity of the enterprise from the perspective of enterprise scale, this article divides the sample into two sub-samples of large enterprises and small and medium-sized enterprises according to the median asset size of the sample enterprise. It can be seen from Table 6 columns (1) and (2) that the COVID-19 coefficient is not statistically significant, while the COVID-19 coefficient of small and medium-sized enterprises is -0.1779. Through a significant level of 1%, it shows that the impact of the epidemic on the total factor productivity of small and medium-sized enterprises is greater and in line with expectations.

7.2. Heterogeneity of the main business of the enterprise

According to the theoretical analysis of this paper, epidemic prevention measures such as home isolation and online office have hindered the flow of labor and personnel exchanges in enterprises, which has brought great challenges to the improvement of total factor productivity of labor-intensive enterprises. Therefore, taking this opportunity, can the digitisation and intelligence of office and production of enterprises alleviate their operating difficulties and improve their total factor productivity? Therefore, this paper classifies enterprises as intelligent enterprises according to the fields of "robot," "software development" and "software service" in their main business, while other enterprises are classified as non-intelligent enterprises. It can be seen from columns (3) and (4) of Table 7 that the COVID-19 coefficient of intelligent enterprises is 0.0022, but it is not statistically significant, indicating that the epidemic has not caused a significant impact on the total factor productivity of such enterprises. However, the COVID-19 coefficient of non-intelligent enterprises is -0.0975, which is statistically significant at the level of 1%, indicating that the epidemic has a great suppression and impact on the total factor productivity of non-intelligent enterprises. It also indicates that enterprises should pay attention to intelligent and digital development, and bring economic dividends to enterprise development.

Table 7. Heterogeneity test.

	TFP			
	Grouped by enterprise scale		Grouped by whether it is an intelligent enterprise	
	large enterprises	Small and medium-sized companies	intelligent enterprises	non-intelligent enterprises
	(1)	(2)	(3)	(4)
COVID-19	0.0115	-0.1779***	0.0022	-0.0975***
	(0.3357)	(-4.0778)	(0.0187)	(-3.2139)
soe	-0.0288	-0.0737*	-0.0490	-0.0274
	(-0.8810)	(-1.7350)	(-0.5726)	(-0.9267)
roa	0.7684***	-0.7557***	0.0983	-0.0065
	(4.5839)	(-3.7366)	(0.2638)	(-0.0452)
lev	0.1183	-0.7626***	-0.0470	-0.3388***
	(1.5426)	(-8.2810)	(-0.2418)	(-5.0870)
TAT	0.0560	-0.4239***	-0.1494	-0.1819***
	(0.8011)	(-8.0107)	(-0.9719)	(-4.4724)
top10	0.1464	0.0237	0.3085	0.0393
	(1.6176)	(0.2136)	(1.2686)	(0.4804)
growth	-0.0226	0.0458***	0.0054	0.0031
	(-1.4136)	(2.6800)	(0.1914)	(0.2395)
fix	0.4033***	0.0796	0.9362**	0.1698*
	(3.8911)	(0.6600)	(2.1052)	(1.9281)
size	0.8657***	-0.1363***	-0.0855***	0.0247**
	(15.2909)	(-7.5295)	(-2.8000)	(2.1550)
cf	0.1504	-0.9390***	-0.2191	-0.3457***
	(0.9963)	(-4.8530)	(-0.4308)	(-2.6300)
Cons	1.0775*	12.4386***	11.1553***	10.7259***
	(1.8030)	(92.3979)	(28.5512)	(100.6856)
Year	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes
N	10461	10454	1188	19727
Within R2	0.0472	0.0354	0.0212	0.0057

8. Research Conclusion and Policy Recommendations

Standing at a new historical starting point, we should not only pay attention to the speed of development but also the quality of development. We should not only improve macroeconomic efficiency, but also promote the in-depth development of micro-subjects. However, the "pandemic" of the epidemic has destroyed the normal production, operation, financing and financing environment. For this reason, how to improve the Productivity and solving development problems are particularly important. Based on the research object of Chinese A-share listed companies in 2014-2021, this article empirically examines the relationship between the COVID-19 epidemic, financing constraints and the total factor productivity of enterprises. The research results show that: (1) the impact of the COVID-19 epidemic has a significant negative impact on the total factor productivity of enterprises; (2) The impact of the COVID-19 epidemic inhibits the improvement of the total factor productivity of enterprises by increasing the financing constraints; (3) According to the heterogeneity test results of the enterprise scale and the main business type, it is found that the COVID-19 epidemic The negative impact of total factor productivity of small enterprises and non-intelligent enterprises is more obvious. Based on the research conclusions, this article puts forward three suggestions:

First, the government has adopted different assistance policies according to different stages of the COVID-19. According to theoretical economics, policy support can effectively help enterprises tide over difficulties in the face of exogenous shocks. First of all, in the outbreak and control stage of the COVID-19, the central government should lighten the burden of enterprises and empower them, such as implementing proactive fiscal policy and loose monetary policy, tax reduction and subsidy, so as to reduce the financial pressure of enterprises and alleviate the problem of tight cash flow of enterprises. Local governments at all levels should fully cooperate, give full play to the advantages of local tax departments and financial departments, and take targeted measures to help enterprises raise funds according to the situation of the COVID-19, provide low-interest loans, postpone repayment, and reduce interest, so as to ease the financing problems of enterprises and support their resumption of production and operation. Secondly, in the stage of normal COVID-19 prevention and control, the government should introduce some policies to "cure the root cause". According to the conclusions of this paper, we mainly start from two aspects. On the one hand, the government actively guides enterprises to alleviate the problem of information asymmetry, such as requiring enterprises to publicly provide business operations and risk factors and standardizing information disclosure and trading. At the same time, the government actively guides enterprises to alleviate financing constraints, such as expanding diversified financing channels and establishing cooperative activities with enterprises.On the other hand, the government should increase support for intelligent and digital enterprises, guide their transformation and upgrading, and improve their resilience to the crisis.

Second, enterprises should attach importance to the digitalization and intelligent development, and transform into technology-intensive enterprises. As mentioned in the conclusion of this article, the impact of the COVID-19 epidemic has little negative impact on the total factor productivity of intelligent enterprises. Therefore, enterprises should also seize the opportunity of the epidemic, accelerate the pace of intelligence and digitalisation, reduce the demand for cheap labour, develop "unmanned" and "intelligent" production and office, and promote artificial intelligence and 5G technology Internet technologies such as technology carry out all-round transformation of enterprises and improve the stabilising, strengthening and improving the role of science and technology in total factor productivity.

Third, enterprises should strengthen the awareness of enterprise anxiety, "more grain" to prepare for the winter. By the end of 2022, the impact of the epidemic is still continuing, and there are many examples of employees gathering to recuperate at home. It is impossible to predict when the dark cloud of the epidemic will no longer cover, and when the "black swan" event will appear in the market again. Therefore, in order to ensure the normal operation of enterprises, managers should strengthen the sense of danger, do not rush forward, do not leap forward, maintain

the normal cash flow of enterprises, and treat the surplus funds of enterprises rationally and prudently to ensure their maximum use.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

Conceptualization: Yuxi Sun; Investigation: Ling Ye; Methodology: Ling Ye; Formal analysis: Yuxi Sun; Writing – original draft: Ling Ye; Writing – review & editing: Yuxi Sun.

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