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HOW DOES FINTECH ENABLE ENTERPRISE TOTAL FACTOR PRODUCTIVITY? EVIDENCE FROM LISTED COMPANIES IN CHINA'S STRATEGIC EMERGING INDUSTRIES

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ABSTRACT. *The new round of scientific and technological revolution and industrial transformation has led to new opportunities and challenges for various economic entities. Determining whether the development of financial technology can activate the innovation vitality of strategic emerging industries and improve the total factor productivity of enterprises is a completely new research topic. To explore the pathways available for improving the total factor productivity of enterprises, based on the neo-classical economic growth theory, micro-banking theory, and spillover effect theory, the development level of financial technology (fintech) in China's prefecture-level cities was measured using the method of determining the annual cumulative number of key word frequencies in the Baidu News. The impact mechanism of fintech on the total factor productivity of these enterprises was examined using data from listed companies in China's A-share strategic emerging industries from 2010 to 2022. Results show that fintech can significantly promote the improvement of the total factor productivity*

of listed companies in strategic emerging industries in three ways: easing the financing constraints of enterprises, reducing the agency cost of enterprises, and improving the innovation strategy of enterprises. Fintech has a more obvious effect on the total factor productivity of private enterprises than it does on that of state-owned enterprises. Fintech also plays a stronger role in promoting the total factor productivity of enterprises in coastal areas than in inland areas. The conclusions obtained from this study have important practical guiding significance for ensuring the continuous promotion of fintech innovation and consolidating the long-term mechanism through which fintech serves the real economy.

KEYWORDS: financial technology, strategic emerging industries, total factor productivity, innovation.

JEL classification: C22, D21, E51.

Introduction

For strategic emerging industries, improving total factor productivity is not only the crux to the sustainable and sound development of industrial entities but also serves as a strong agent in helping the China's economy complete the transformation of old and new growth drivers and high-quality development. Since the country's reform and opening up, its inherent path of relying on traditional factors such as labor, land, and capital to drive rapid economic development has become a thing of the past, and the elevation of total factor productivity has become the key to maintaining sustained economic growth in China (Tang *et al.*, 2019). In particular, in the current international situation where uncertainties continue to intertwine and rise, determining how to maintain the steady and healthy development of China's economy has become the focus of widespread attention from both the public and the academic community, and it also highlights the urgency of promoting high-quality economic development through the elevation of total factor productivity. Therefore, it is of vital theoretical and practical importance to further identify the key factors for improving total factor productivity and to explore the ways and strategies used to activate the endogenous power of technological innovation.

An increasing number of studies have claimed that the elevation in the total factor productivity of enterprises is closely related to the level of innovative research and development (R&D) of those enterprises (Cohen *et al.*, 1990; Wu *et al.*, 2022; Luo, Hu, 2021). The characteristics of innovative R&D activities, such as large capital investment, high-risk uncertainty, and long return cycles, cause enterprises to choose the former when faced with the two topics of "preserving strength" and "advanced development," (Iandolo, Ferragina, 2019). Among factors, blocked capital source channels, inefficient capital allocation methods and short-sighted innovation strategies can become roadblocks for enterprise innovation research and development activities, and they can ultimately hinder the improvement of total factor productivity. Fortunately, rapid developments of cloud computing, big data and artificial intelligence, the emergence of financial technology has broken through the inherent boundaries of financial services, provided transparency in regard to the informational black boxes of both investment and financing, provided strong help for enterprises in the areas of capital sources and allocation, and alleviated the pressure on enterprise R&D funds. In addition, while promoting enterprises to develop innovative projects aligned with their development vision, fintech also provides investment subjects with the convenience of monitoring the flow of corporate funds in real-time (Li *et al.*, 2020; Zhu, 2019). The efficient financial support

provided by fintech is more conducive to the formulation of substantive and high-quality innovation decisions. The implementation of innovation projects and technological innovations inevitably has a beneficial impact on the total factor productivity of enterprises. Therefore, examining the impact of fintech development on the total factor productivity of enterprises and clarifying the path and mechanism of its effect on the total factor productivity of enterprises helps us expand and develop the research content related to the improvement of the total factor productivity of enterprises. At the current critical stage of China's economic transformation, this study can also provide useful inspiration for promoting the empowerment of the real economy and optimizing its high-quality development path through the use of financial technology.

There are many investigations on the influencing factors on total factor productivity in the literature. Among them, macro-level studies have focused primarily on the technology spillovers brought about by trade openness (Gan *et al.*, 2022; Miller *et al.*, 2000; Cao *et al.*, 2021), the allocation efficiency of factor resources (Hsieh and Klenow, 2009; Khan *et al.*, 2023), and the impact of industrial agglomerations (Sun *et al.*, 2022; Hu, Wu, 2022) on total factor productivity. Investigations on the influencing factors of total factor productivity at the micro-level have focused mainly on corporate governance (Yu, Qi, 2021; Ferraris *et al.*, 2019), R&D investment and capability (Lu *et al.*, 2023), and financing constraints (Xiao, Xue, 2019; Santos, Cincera, 2022). Total factor productivity has a crucial role to play in promoting the high-quality development of the real economy, and it is also a topic of continuing study of the contributing factors that affect total factor productivity in academic circles. Several researchers have developed an indicator framework for the level of development of the digital economy (Wan, Luo, 2022) and studied the impact of the development of intelligence (Li *et al.*, 2020) and financial technology (Tang *et al.*, 2019) on the total factor productivity of the manufacturing industry. However, from the micro-perspective of enterprises, there is still a theoretical gap in the existing studies regarding the explanation of the impact of fintech on the total factor productivity of enterprises. Some fintech development studies conducted on the micro-level of enterprises have placed a greater focus on technology transformation, investment and financing, and risk control, and the discussion on enterprise factor productivity has been fragmented thus far. In the context of the digital economy, can the rapid development of fintech promote the elevation of total factor productivity in strategic emerging industries? If so, what is the transmission mechanism by which this effect occurs? Furthermore, what beneficial implications does this transmission mechanism provide for the high-quality development of corporate governance and the real economy? The answers to the above questions are important to the examination and evaluation of the total factor productivity of firms in strategic emerging industries as enabled by fintech.

With an increasingly complex international environment and new scientific and technological developments, the China's government has continuously adjusted its financial and fiscal policies during the decade ranging from 2010 to 2020, focusing on cultivating strategic emerging industries with high scientific and technological content, environmental friendliness and high growth potential and fully leveraging the role of innovation as an engine for the promotion of economic growth (Lu *et al.*, 2014). The China's government has applied these strategies in leading the China's economy toward high-quality development. According to the classical micro-banking theory, the asymmetry of information between banks and enterprises leads to moral hazard and adverse selection, lead to relatively simple financing channels and tools for enterprises. China's enterprises in general face financing constraint problems, which have been alleviated by the development of financial technology. Neoclassical economic growth theory also regards total factor productivity as a significant influencing factor

in the promotion of sustained economic growth. Fintech innovation can realize spatial knowledge and technology spillover through network communication and personnel flow, and its further integration into the science and technology industry can upgrade the resource factor endowment structure, which not only improves financial services but also improves the efficient operation of the real economy. Therefore, exploring the connection between fintech and total factor productivity in strategic emerging industries is of considerable theoretical and practical importance for the goal of promoting high-quality economic development. Based on the three perspectives of financing constraints, agency costs and innovation strategy, listed companies in strategic emerging industries were chosen as the research object to investigate the impact mechanism of fintech on the total factor productivity of enterprises.

Some novel contributions in this study include the following: First, taking the total factor productivity of enterprises as the starting point, the connection between the development of fintech and the total factor productivity of enterprises in strategic emerging industries was investigated, and whether the elevation of fintech can contribute to the improvement of the total factor productivity of enterprises in strategic emerging industries was discussed, which is helpful for further enriching the studies on the micro- and medium-level economic impact and system of fintech. Second, from the three perspectives of reducing enterprise agency costs, easing enterprise financing constraints, and improving enterprise innovation strategies, the internal path mechanism through which fintech development affects enterprise total factor productivity was systematically and comprehensively examined, which reveals the logical relationship between the “new hot spots” of fintech development and the “old topics” of enterprise total factor productivity. Third, using the interdisciplinary python language, quantitative indicators of fintech were constructed in this study through text mining and the identification of word frequency, and the possible structural characteristics of ownership and the regional characteristics were identified in the process of assessing the effect of fintech development on enterprise total factor productivity. This study is a contribution to the empirical research on the impact of fintech on the total factor productivity of enterprises in strategic emerging industries and further improves the theoretical research on the interaction mechanism between fintech and the total factor productivity of enterprises.

The rest of the structure of this study is organized in the following way: In Section 1, the relationship between fintech and total factor productivity in strategic emerging industries was analyzed theoretically and the research hypothesis was developed. Section 2 presents the models, data, and variables. Section 3 is the analysis of the results. Section 4 is a discussion of the results of this study. Section 5 presents the conclusion, which summarizes the conclusions and limitations of this study.

1. Theoretical Analysis and Hypothesis Development

1.1 Impact of Fintech Development on the Total Factor Productivity of Strategic Emerging Enterprises

According to the neoclassical economic growth theory, total factor productivity is an essential factor in the promotion of sustained economic growth. Improving the overall economic benefits of strategic emerging industries is an essential step for China in its aim to accelerate the establishment of a modern industrial system and promote high-quality economic elevation. The establishment of fintech is also one of the key goals for enabling the development of the real economy (Huang *et al.*, 2018; Li, Cheng, 2018). Productivity, as an important measure of economic benefit, can be used to effectively describe the degree of progress achieved in

developing the economic benefits of industries and enterprises (Chen *et al.*, 2020). Based on the Financial Stability Board (2016) and the *Report on the Panoramic Description and Analysis Framework of Financial Technology*, financial technology refers to big data, blockchains, cloud computing, artificial intelligence and other emerging cutting-edge technologies, and has significant implications for financial markets and services, such as emerging business models, applications and services. The coupling of finance and emerging cutting-edge technologies improves the efficiency of financial service enterprises. Based on the perspectives of financial institutions and investors, the application of artificial intelligence and big data can promote the scientific accuracy of decision-making by optimizing the estimation model used by investors. In addition, with the help of machine algorithms used to evaluate credit qualifications and returns on investment and the use of intelligent information check technology, traditional financial businesses can obtain some relief, as it can easily overcome the disadvantages of light asset enterprises. Moreover, it is difficult to obtain financial support through the traditional financial service path to broaden financing channels (Huang *et al.*, 2020). From an enterprises perspective, existing research has shown that financing constraints have become an Achilles' heel and hinder the improvement of total factor productivity. Smoothing the entry and exit of enterprises in relevant industries is not conducive to the effective allocation of resources and can subsequently lead to a decrease in enterprise productivity (Jiang, Jiang, 2021). , compared with traditional industries, the more frequent strategic emergence of enterprises can stimulate the more accurate development of science and technology to help enterprises free their innovation activities from financing difficulties and alleviate the need for the enterprise to engage in long cyclical innovation projects to obtain more stable and sustained funding. In addition, smooth innovation activities are conducive to the elevation of enterprise total factor productivity. From the reverse moral hazard prevention function, financial technology combines intelligence and intelligent technology. In the collection of enterprise data elements and the provision of coverage far beyond traditional finance, from the enterprise capital flow monitoring and enterprise credit and management status perspective, good supervision occurs simultaneously. Additionally, for enterprise managers, opportunistic behavior has constraints and exerts normative effects.

Therefore, fintech strengthens the scientific and efficient nature of financial institutions' investment in enterprises, solves the financing difficulties of enterprises, involves reverse constraints and normative effects on enterprise behavior, increases the information transparency between financial institutions and enterprises, and provides high-quality conditions for enterprises to improve their total factor productivity. Accordingly, the following hypothesis is proposed:

H1: The development of fintech contributes positively to the total factor productivity of enterprises in strategic emerging industries.

1.2 The Effect Mechanism of Fintech Development on the Total Factor Productivity of Enterprises

1.2.1 The Enterprise Agency Cost

According to the theory of information asymmetry, information asymmetry between banks and enterprises leads to moral hazard and adverse selection problems. Under the modern enterprise system, the corporate governance structure of separate enterprise ownership and management rights easily produces more serious agency problems. The resulting high agency cost is also one of the major drivers hindering the management efficiency of enterprises. The

generation of agency costs indirectly affects the efficiency of resource allocation, technological research and development, and labor productivity in enterprises and subsequently exerts a negative impact on the total factor productivity of enterprises (Kornai *et al.*, 2003; Chen *et al.*, 2020). Due to the leading characteristics of strategic emerging industries, they are more vulnerable to the industrial planning of local governments than most traditional industries, and the political correlation factors of corporate executives are relatively stronger. The right to appoint and remove agents from some state-owned strategic emerging enterprises is directly controlled by local governments. In addition, with the GDP performance appraisal system of China's local governments, private enterprises in strategic emerging industries are more likely to attract the attention of local governments than private enterprises in traditional industries. Under the influence of such external forces, enterprise agents are more likely to cater to the "intervening hand" of the government (Yuan *et al.*, 2015; Xing *et al.*, 2019). The above situation may lead to the problem of "insider control" in enterprises. However, while financial development in science and technology can help to improve the enterprise supervision and supervision efficiency of financial and auditing institutions, big data and artificial intelligence technology can increase the transparency of capital flow and deter the noncompliant behavior of enterprise agents. It can also facilitate the development of more accurate scientific performance systems for the enterprise, provide the reference basis for reducing the enterprise agent cost and optimizing the enterprise resources allocation, and have a positive impact on the total factor productivity of the enterprise. Accordingly, the following hypothesis is proposed:

H2: The fintech development can promote the improvement of total factor productivity by reducing the agency costs of enterprises.

1.2.2 Easing Financing Constraints

Based on the classical micro-banking theory, information asymmetry between banks and enterprises easily leads to the availability of relatively simple financing channels and tools for enterprises. Adequate financial support is the basis of the sustainable and healthy development of enterprises. The improvement in the total factor productivity of enterprises is closely related to stable capital flow and effective capital allocation. However, in the actual operation process, owing to the information asymmetry between credit parties and the predilection of financial institutions for "preferring the rich to the poor," enterprises often face financing difficulties of different degrees (Jiang, Jiang, 2021). In particular, traditional financial institutions are more inclined to consider the tangible assets of enterprises and, in turn, to adopt corresponding lending policies; however, some strategic emerging industries are inclined to adopt these policies in the early stage of establishment, and more intangible assets are represented by technology and innovation in the form of enterprise capital. In the case of a lack of tangible collateral, it is difficult to obtain effective financing. Fortunately, fintech development can alleviate financing constraints for enterprises by opening financing channels, expanding total financing, and reducing financing costs (Huang *et al.*, 2020; Lee, Shin, 2018). In terms of financing channels, fintech makes it possible for financial institutions to collect and analyze users' soft information. By means of big data processing, user profiles, loan automation, etc., fintech greatly reduces the barriers to entry for borrowers and plays a positive role in dredging corporate financing channels (Pitianlei *et al.*, 2018).

Furthermore, fintech integrates technologies such as mobile devices, social media, and distributed ledger systems into the field of financial services, providing a useful reference for investors lacking financial investment knowledge. Moreover, machine learning, artificial intelligence, and other technologies can be used to more accurately predict market trends. This

helps financial institutions launch financial products that are more in line with the needs of financial investors and helps them penetrate financial services for financial investment, thus increasing the total amount of financing in the capital market.

Finally, in terms of reducing the cost of financing, reverse moral hazard due to information asymmetry can be reduced by increasing transparency for both lenders and borrowers through the use of technologies such as big data and blockchain. In addition, an effective portrayal of corporate credit compensates financial institutions for the risks faced and reduces corporate financing costs. According to the findings of Heiskanen (2017), an effective reduction in the channels and costs of financing has a positive impact on the expansion of business investment, thereby easing the financing constraints faced by firms. When enterprises are no longer faced with the dilemma of financing constraints, they are better able to formulate business strategies based on the long-term interests of enterprises, increase their technological innovation efforts, abandon their short-sighted innovation strategies that are solely focused on short-term earnings and are not conducive to the long-term operation and development of enterprises, and optimize the allocation of existing resources. This will eventually have a positive impact on the enhancement of enterprises' total factor productivity. As a result, the following hypothesis is proposed in the present study.

H3: The fintech development can improve the total factor productivity of enterprises by easing their financing constraints.

1.2.3 Improving Enterprise Innovation Strategy

Spillover theory states that when an organisation undertakes an activity, it not only produces its desired impact, but also has an impact on people or society outside of it. Fintech innovation has knowledge and technology spillover effects. Fintech innovation can realize spatial knowledge and technology spillover through network communication and personnel flow. Previous studies have shown that innovation projects corresponding to enterprise innovation strategies can be divided into two categories: exploratory innovation with a high technical level, high level of innovation difficulty and high risk, which can have a significant or subversive impact on the industry and market; and conventional innovation, which tends to improve technology, is strongly robust, carries less risk, and can play a positive role in the local productivity or marketization of enterprises (Kamien, Schwartz, 1978; Li *et al.*, 2016). In line with the characteristics of the two types of R&D activities, exploratory innovation can be more effective in improving the total factor productivity of enterprises and is more consistent with the definition of high-quality technological innovation. In addition, as conventional innovation R&D costs are lower and results are easier to achieve in a short period, this not only brings immediate benefits to the enterprise but also helps management display a positive image of the enterprise innovation project. Therefore, in the process of formulating innovation strategies, enterprises prefer to rationally choose conventional innovation strategies. In particular, strategic emerging industries rely more on government subsidies at the capital level in the early stage of development. To achieve innovation results more quickly, the choice of conventional innovation strategies with low technology-added value is easier for catering to government subsidies. However, in the long run, leading strategic emerging enterprises in the industry find it easier to meet government subsidies. A large number of conventional innovation projects are not conducive to furthering the high-quality development of the industry. Therefore, due to the characteristics of high risk, high innovation difficulty, and a long R&D cycle, exploratory innovation is more dependent on the internal resources of enterprises and more sensitive to the external financial environment and financing status (Sun, Zhang, 2019). Therefore, enterprises

are more sensitive to the influence of the external financial environment when making exploratory innovation decisions.

It is hypothesized that the financial evolution of science and technology can alleviate financing constraints for enterprises and establish a relatively slack financing environment; at the same time, big data and the use of artificial intelligence technology also influence the financial external governance effect of science and technology, effectively alleviating the information asymmetry between financial institutions and enterprises while simultaneously helping financial institutions to more accurately identify enterprise capital flow, thus enhancing the supervision of enterprise managers and research and development activities, and, to some extent, releasing the enterprise from the black box of research and development. Improving the enterprise financing environment through fintech development helps enterprise managers make exploratory and innovative decisions that are better aligned with the long-term development vision of enterprises. An increase in the smooth progress of exploratory innovation projects is conducive to the technological transformation and upgrading of enterprises, and the market-oriented application of subsequent innovation projects is also conducive to product value-added and results in great benefits for enterprises. In this virtuous cycle, the total factor productivity of enterprises is bound to significantly improve. Accordingly, the following hypothesis is proposed:

H4: The fintech development can boost the improvement of enterprise total factor productivity by improving enterprise innovation strategies and increasing enterprise exploratory innovation decisions.

2. Methodology

2.1 Modeling

Referring to the research of Wu *et al.* (2022), the following regression model is constructed to investigate the impact of fintech on enterprise total factor productivity:

$$TFP_{i,t} = \beta_0 + \beta_1 LNINDEX_{i,t} + \sum \lambda_1 CONTROLS + \sum Year + \sum City + \varepsilon_{i,t} \quad (1)$$

Where the subscript i represents the listed company of a strategic emerging industry, t represents the year, $CONTROLS$ represents the other control variables in the model, $\sum Year$ and $\sum City$ represent the fixed effects of year and region, respectively, and $\varepsilon^{i,t}$ represents the random error term. The core focus of Model (1) is the estimated coefficient β_1 of fintech ($INDEX$), which, based on the previous assumptions, is significantly greater than 0.

2.2 Variables

2.2.1 The Change Rate of Enterprise Total Factor Productivity (TFP)

In this study, the total factor productivity is measured using the Malmquist nonparametric form in DEA (data envelopment analysis). The main reasons for using this method are as follows: First, the nonparametric form enables the method to effectively avoid the characteristics of the strategic emerging industry production function before construction, prevents unreasonable measurement errors in the production function design, and contributes to scientific and objective research. Second, the DEA-Malmquist method does not require the uniform scaling of the input-output data, so there is no large limit on the unit of the input-

output factor index, which is convenient for future research. Furthermore, the use of the DEA-Malmquist method can meet the purpose of detailed decomposition of the total factor productivity results and help to determine the underlying mechanism and underlying productivity in the process of research and analysis. Finally, thorough an analysis of the total factor productivity of enterprises in strategic emerging industries, this study is aimed at exploring the dynamic trend of productivity in strategic emerging industries. The DEA-Malmquist method can be applied to long time series and the analysis of samples across regions. In conclusion, Caves *et al.* (1982) adopted the theoretical calculation method of Free *et al.* (1994). The specific expressions are as follows:

$$TFP = M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)} \right]^{1/2} \quad (2)$$

Where $x_{t+1}, y_{t+1}, x_t, y_t$ represent the input and output of the decision unit in t and $t+1$, respectively; d_0^t and d_0^{t+1} represent the distance functions under the technology frontier in the adjacent period, and this expression can reflect the change direction of total factor productivity in t and $t+1$. If the calculated $TFP > 1$, a downward trend is indicated. Furthermore, TFP can be decomposed into the technical progress rate (*TECHCH*) and the technical efficiency (*EFFCH*) under the condition of a constant return on scale (*CRS*).

In terms of index selection, the total factor productivity measurements required for the input and output variables have not been unified across selection criteria; rather, they are determined through the use of existing research and appropriate extensions based on the comprehensive consideration of strategic emerging industry development characteristics, the availability of data, and the input indices of capital elements (Ren, Wang, 2014), labor elements (Yuan, 2009) and research and development elements (Ju *et al.*, 2013). In terms of output indicators, this study draws on the method of Liu and Wang (2008) and selects the main business income and net profit as the output indicators of enterprises. The main business income and net profit can comprehensively reflect the operation and profit of the enterprise in financial statistics and are high-quality output measurement indicators at the enterprise level. See *Table 1*.

In the following empirical analysis, the change rate of total factor productivity and its decomposition indicators for strategic emerging industries as calculated by the above methods are the change rate of total factor productivity (*tfpch*), the technological progress rate (*techch*) and technical efficiency (*effch*).

Table 1. Input-output variables for the DEA-Malmquist productivity index

Input Variable		Output Variable	
Variable Name	Specific Indicators	Variable Name	Specific Indicators
<i>capital</i>	Annual average net fixed assets	<i>output-input ratio</i>	Main business income and net profit
<i>work</i>	Annual average number of employees		
<i>R&D</i>	Net intangible assets at year-end		

Source: authors' own results.

2.2.2 The Fintech Development Index (InIndex)

As with internet finance, financial technology also has a wide range, strong penetration, and rapid development. Further, the scientific quantitative fitting of the financial technology development index is the main priority in the empirical research conducted in this study. In

addition to the characteristics of financial technology and operational feasibility, the construction of a financial technology development index uses Shen and Guo (2015) as a reference in developing the Internet financial index and uses Python to capture the frequency with which financial technology keywords and city names appear in Baidu news as a measure of the regional level of financial technology development. Key words are chosen mainly according to the fintech-related entries that appear in *The China Fintech Operation Report (2020)*, *The White Paper on The Development of China's Digital Economy and the Fintech Development Plan (2019-2021)* issued by the People's Bank of China and matched to the fintech fields of listed companies. This study selected 30 keywords, such as cloud computing, blockchain, intelligent investment banking, open banking, and quantitative finance. As the development of fintech is increasing annually, to avoid interference from the right side of the data, the word frequency is then logarithmically used as a measure of the development degree of fintech.

2.2.3 Control Variables

Considering that multiple factors influence the total factor productivity of enterprises, the indicators used in this study are selected from the dimensions of enterprise characteristics, corporate governance, capital and asset structure, financial and operating status, management structure, regional economic development degree, and so on.

(1) Company scale (*scale*). The enterprise scale intuitively reflects enterprise size and is also an important factor affecting enterprise innovation. The larger the size of an enterprise is, the greater its capacity for the innovation and R&D of new products. Additionally, enterprise goals are long-term goals that are more apt to improve enterprise total factor productivity through technological innovation. Therefore, following Li *et al.* (2020) and Cai *et al.* (2019), company size was included among the control variables as measured by the logarithm of total assets at the end of the year.

(2) Enterprise age (*Age*). The age of the enterprise reflects the period of establishment of the enterprise. Many studies show that the age of an enterprise affects its innovation capacity and productivity in different situations (Zhou *et al.*, 2017; Coad *et al.*, 2016). Thus, the sample observation value is used to indicate the age of the enterprise.

(3) Asset-liability ratio (*Loar*). The asset-liability ratio reflects the capital structure and solvency of enterprises to some extent. A moderate leverage ratio contributes to improving enterprise innovation capacity and sustainable development (Jensen, Meckling, 1976; Ferraris *et al.*, 2019). Therefore, the asset-liability ratio is taken as the control variable and total debt at the end of the year is measured rather than total assets at the end of the year.

(4) Profitability (*Able*). The profitability of an enterprise is an important standard for judging its growth. In general, the profitability of an enterprise is closely related to its market competitiveness, business performance, research and development decisions, etc. (Cainelli *et al.*, 2015); thus, it affects the total factor productivity of an enterprise to some extent. In this study, profitability is measured using the ratio of net profit to total assets.

(5) Independent directors' ratio (*Indep*). Since independent directors, aside from the director, do not hold any position in the company, they are more objective in making strategic decisions, such as that involving enterprise innovation. Several studies have shown that independent directors have an impact on the R&D investment and innovation efficiency of enterprises (Li *et al.*, 2020; Jiao, Sun, 2021). Therefore, the proportion of independent directors is taken as the control variable and the proportion of the number of independent directors to the total number of directors is also adopted.

(6) Fixed assets ratio (*PPE*). The amount of fixed assets reflects the mortgage repayment ability of enterprises to a certain extent, which is closely related to the financing ability of enterprises and thus affects their innovation input and total factor productivity (Ren and Wang, 2014). Thus, the ratio of net fixed assets to total assets at year-end is used.

Furthermore, the increase in the total factor productivity of listed companies and the region of economic development are inseparable, economically developed areas have more diverse factor endowments, and the possibility of total factor productivity increase is greatly enhanced. Thus, this study also combines the control variables at both the regional level and the regional economic development level using the logarithm of urban GDP (one hundred million CNY). Year-fixed effects were also controlled for in the regression.

2.4 Descriptive Statistics of the Variables

Table 2 shows the data characteristics of the main variables, and the average annual TFP growth rate among the measured strategic emerging industry enterprises was 4.6% during the 10 year sample period. After dividing the TFP change rate (*tfpch*) into the technological progress rate (*techch*) and technological efficiency (*effch*), it can be seen that the annual average technological efficiency (*effch*) is less than 1, indicating that the technological efficiency of strategic emerging enterprises underwent negative growth during the period of 2010 to 2019 and that the average annual growth in the technological progress rate (*tech*) was 9.1%. This shows that the growth in the total factor productivity of strategic emerging industries during the sample period is mainly derived from the improvement in the technological progress rate rather than from the improvement in technical efficiency. The existing studies claim that a decline in technical efficiency is often caused by improper resource allocation efficiency. In addition, the low-end development mode of “neglecting technological innovation and focusing on scale expansion” is also the main factor driving the deterioration of technical efficiency.

Table 2. Descriptive statistics of the variables

Variables	Mean	Median	Standard Deviation	Least Value	Maximum Value	Number of Observations
<i>Tfpch</i>	1.046	1.024	0.319	0.503	1.824	6870
<i>Effch</i>	0.958	0.999	0.561	0.164	2.373	6870
<i>Techch</i>	1.091	1.030	1.401	0.543	6.437	6870
<i>Lnindex</i>	15.97	17.65	4.576	0	20.18	6870
<i>Scale</i>	21.95	21.84	1.162	19.56	25.70	6870
<i>Age</i>	21.52	21	5.178	11	64.00	6870
<i>Loar</i>	0.383	0.375	0.199	0.008	2.024	6870
<i>Able</i>	0.0400	0.0400	0.0740	-1.067	1.126	6870
<i>Indep</i>	0.371	0.333	0.0540	0	0.670	6870
<i>PPE</i>	0.190	0.167	0.125	0.00100	0.800	6870
<i>lnGDP</i>	8.844	8.953	1.040	5.187	10.55	6870

Source: authors' own results.

2.5 Data Sources

The financial data of listed companies in strategic emerging industries used in this study are all taken from annual reports from the Juchao website (<http://www.cninfo.com.cn>) and the Wind database. Regional data come from the China Stock Market & Accounting Research Database (CSMAR). The data used to measure the regional fintech level are expressed by the frequency of words used by Baidu news fintech keywords and prefecture-level city names. Strategic emerging industry screening results in a list of company standards on the basis of *The State Intellectual Property Office of China issued by the Strategic Emerging Industries*

Classification and International Patent Classification Reference Table (2021) (trial) and *The China Securities Regulatory Commission issued City Company Industry Classification Guidance* (2012 revision). The primary business class is linked to strategic emerging industries and accounts for more than or equal to 20% of the listed companies in the category of strategic emerging industries. In addition, the data have been properly processed by excluding listed companies with stock codes of * ST, ST, PT and any delisted companies; excluding enterprises with major changes in their main business structure over three consecutive years; excluding the negative book value of owner equity and the related listed companies; and excluding 1% of the continuous variables to avoid the interference of outliers on the empirical results. After the above treatment, 687 listed companies in strategic emerging industries were ultimately retained, covering the sample period of 2010 to 2022.

3. Results Analysis

3.1 Benchmark Regression Results

Table 3 reports the regression results of Model (1). In Columns (2), (4) and (6) in Table 3, control variables are added at the enterprise and region levels, and the fixed effects of year and region are controlled by the city. As seen from the results displayed in Table 3, Column (1) shows the estimated coefficient of fintech is significantly positive at the 1% level without the addition of any control variables, indicating that the development of regional fintech contributes to the improvement in the change rate of the *TFP* of enterprises. In addition, after controlling for the multiple factors that may affect the total factor productivity of enterprises, the development of fintech still shows a significant positive impact on the total factor productivity of enterprises; that is, fintech significantly improves the total factor productivity of enterprises. The better the development of fintech is the greater the total factor productivity of enterprises.

Table 3. Benchmark regression results

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	<i>tfpch</i>	<i>tfpch</i>	<i>effch</i>	<i>effch</i>	<i>techch</i>	<i>techch</i>
<i>lnindex</i>	0.0128*** (10.18)	0.00731*** (3.70)	0.0116*** (6.21)	0.0123*** (4.30)	0.0708*** (27.46)	0.0676*** (11.97)
<i>scale</i>		-0.0179 (-1.10)		-0.115*** (-5.82)		0.223*** (4.47)
<i>age</i>		0.0167 (0.56)		0.0037 (0.79)		0.282 * (1.92)
<i>loar</i>		0.326*** (7.83)		0.404*** (6.38)		-0.146 (-1.01)
<i>able</i>		1.228*** (7.41)		1.523*** (11.79)		0.0174 (0.08)
<i>indep</i>		0.0125 (0.11)		-0.0171 (-0.08)		0.174 (0.44)
<i>ppe</i>		-0.129 (-1.27)		-0.318*** (-2.88)		0.513** (2.54)
<i>lnGDP</i>		0.185*** (6.06)		0.265*** (7.24)		-0.259** (-2.36)
<i>_cons</i>	0.841*** (41.03)	-0.463* (-1.90)	1.227*** (41.10)	1.269*** (3.36)	0.360*** (8.74)	-2.294** (-2.30)
<i>Year</i>	Not	Yes	Not	Yes	Not	Yes
<i>City/City</i>	Not	Yes	Not	Yes	Not	Yes
<i>N</i>	6870	6870	6870	6870	6870	6870
<i>r2 w</i>	0.0165	0.0603	0.00420	0.0319	0.0245	0.0250

Note: Robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

Furthermore, in *Table 3*, columns (4) and (6) show that the financial estimated coefficient of technology is still significantly greater than zero, and that financial technology exerts a positive influence on the efficiency of enterprise technology and the technology progress rate. A comparison of columns (4) and (6) reveal the estimated coefficient of absolute value. Relative to the influence of technical efficiency, the financial development of science and technology exerts a more positive impact on the progress of enterprise technology.

3.2 Robustness Test

Considering the data characteristics of the change rate of the explained variable, namely, *TFP*, the panel Tobit model is used in this study to further test the impact of fintech on the total factor productivity of enterprises, following the research of Faleye *et al.* (2014). The regression results are shown in *Table 4*. As shown in *Table 4*, the regression coefficient symbols for fintech are consistent with those of the benchmark regression, and both are significant at the 1% level, indicating that the development of fintech still significantly promotes the improvement of the total factor productivity of enterprises after different regression methods are adopted, which confirms the robustness of the benchmark regression.

Table 4. Robustness test based on the Tobit model

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	<i>tfpch</i>	<i>tfpch</i>	<i>effch</i>	<i>effch</i>	<i>techch</i>	<i>techch</i>
<i>lnindex</i>	0.0411*** (4.33)	0.0103*** (6.81)	0.00667*** (6.08)	0.00778*** (3.87)	0.0294*** (10.08)	0.0605*** (15.13)
<i>scale</i>		0.00804** (-2.27)		-0.0317*** (-7.22)		0.0338*** (3.55)
<i>age</i>		-0.000314 (-0.37)		0.000237 (0.24)		0.00111 (0.88)
<i>loar</i>		0.201*** (8.06)		0.300*** (9.24)		0.238*** (3.90)
<i>able</i>		0.794*** (8.24)		1.040*** (12.72)		-0.606*** (-3.30)
<i>indep</i>		0.00986 (0.15)		0.104 (1.10)		-0.0270 (-0.15)
<i>ppe</i>		0.0129 (0.43)		0.0384 (0.80)		0.235*** (2.62)
<i>lnGDP</i>		0.0255*** (3.66)		0.0246*** (3.17)		-0.180*** (-9.43)
<i>_cons</i>	0.981*** (6.30)	1.175*** (13.46)	1.148*** (6.12)	1.434*** (12.54)	1.021*** (33.12)	1.256*** (4.75)
<i>N</i>	6870	6870	6870	6870	6870	6870
<i>rho</i>	0.318	0.102	0.313	0.139	0.247	0.151

Note: z values in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

3.3 Mechanism Analysis

The above research results show that the development of regional fintech can effectively promote the improvement of the total factor productivity of enterprises, particularly in promoting the role of the technological progress rate. To further explore the mechanism through which fintech development affects the total factor productivity of enterprises, this topic is analyzed from three perspectives in this study, namely, enterprise agency costs, financing constraints and innovation strategy.

(1) Based on the enterprise agency cost perspective

Following the logic of the aforementioned mechanism analysis and existing studies, fintech can effectively facilitate the utilization of emerging technologies such as big data and cloud computing to help regulators gain insight into the capital flow of enterprises, and it can play an effective role in supervising corporate managers engaged in long-term projects, such as the promotion of the technological progress and innovation ability of enterprises, to avoid the dominance of funds being applied based on personal interests, such as performance. Enterprise agency costs need to be reduced (Sun and Zhang, 2019). Therefore, we further investigate whether fintech can improve the total factor productivity of enterprises by reducing agency costs, enabling funds to be applied more accurately for research and development or technological innovation. Specifically, to empirically demonstrate the hypothesis that fintech can promote the improvement of total factor productivity by alleviating corporate financing constraints, the following intermediary effect regression model is constructed:

$$AGENCY_{i,t} = \alpha_0 + \alpha_1 LNINDEX_{i,t} + CONTROLS + \sum YEAR + \sum CITY + \varepsilon \quad (2)$$

$$TFPCH_{i,t}(EFFCH_{i,t}, TECHCH_{i,t}) = \beta_0 + \beta_1 LNINDEX_{i,t} + \beta_2 AGENCY_{i,t} + CONTROL_s + \sum YEAR + \sum CITY + \varepsilon_{i,t} \quad (3)$$

Where *AGENCY* represents the annual agency cost of the enterprise, and the meanings of the other symbols are the same as those given above. In Model (2), the regression coefficient of the fintech index is the focus. A significantly negative regression coefficient indicates that the development of fintech inhibits the agency cost of the enterprise. In addition, Model (3) focuses on the absolute value of the coefficient β_1 . If the absolute value β_1 is less than the absolute value of the coefficient *LNINDEX* in the benchmark regression, then reducing the agency cost of enterprises is indicated to have played an intermediary role in promoting the improvement of enterprise total factor productivity in the development of fintech. The enterprise agency cost (*AGENCY*) is calculated following the method of Luo *et al.* (2017), who measured the operating expense ratio of listed companies. The operating expense ratio is calculated as the sum of the management expenses and sales expenses of the enterprise in reference to the operating income. The agency cost reflects the costs of business consumption to some extent.

The regression results are shown in *Table 5*. Column (1) of the results shows that the financial development of science and technology has a significant inhibitory effect on enterprise agency cost. The results confirm the mechanism analysis. Financial technology development can strengthen the enterprise capital flow supervision function shown in *Table 5* after the analysis of the three columns. The absolute value of the financial technology regression coefficient is less than the absolute value of the benchmark regression. This finding shows that financial technology can reduce enterprise agency costs and exert a positive impact on total factor productivity. Further, it verifies the mechanism analysis presented in *H2*.

Table 5. Mechanism analysis based on the enterprise agency cost perspective

Variables	(1)	(2)	(3)	(4)
	<i>AGENCY</i>	<i>TFPCH</i>	<i>EFFCH</i>	<i>TECHCH</i>
<i>lnindex</i>	-0.00177*** (-4.69)	0.00717*** (4.83)	0.0114*** (3.85)	0.0655*** (8.63)
<i>agency</i>		-0.266*** (-4.83)	-0.617*** (-6.09)	1.448*** (5.58)
<i>scale</i>	-0.0198*** (-7.86)	-0.0240** (-2.23)	-0.127*** (-6.37)	0.252*** (4.95)

Table 5 (continuation). Mechanism analysis based on the enterprise agency cost perspective

<i>age</i>	0.00612 (0.57)	0.00384 (1.01)	0.00256 (0.91)	0.0101 (0.79)
<i>loar</i>	-0.0521*** (-5.57)	0.314*** (7.87)	0.368*** (5.02)	-0.0734 (-0.39)
<i>able</i>	-0.280*** (-18.63)	1.155*** (17.56)	1.354*** (11.19)	0.427 (1.38)
<i>indep</i>	-0.00440 (-0.16)	0.00985 (0.09)	-0.0492 (-0.23)	0.213 (0.40)
<i>ppe</i>	0.0428*** (2.79)	0.119* (-1.82)	-0.310*** (-2.58)	0.465 (1.51)
<i>lnGDP</i>	0.00334 (0.61)	0.189*** (8.07)	0.272*** (6.32)	-0.267** (-2.42)
<i>_cons</i>	0.603*** (13.58)	-0.312 (-1.63)	1.596*** (4.53)	-3.155*** (-3.49)
<i>N</i>	6870	6870	6870	6870
<i>Year</i>	Yes	Yes	Yes	Yes
<i>City</i>	Yes	Yes	Yes	Yes
<i>r2 within</i>	0.0740	0.0885	0.0443	0.0346

Note: Robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

(2) From the perspective of enterprise financing constraints

For many enterprises in strategic emerging industries, due to their industry-leading characteristics, large investments in research and development and innovation activities serve as the basis for enterprises to establish a foothold and pursue development, and such development is difficult to maintain through sole reliance on very limited internal resources, such as capital (Liu, Hua, 2020). Therefore, regardless of whether the enterprise external financing path is smooth, the degree of diversification of the channel, and the level of cost are related to the long-term survival and development of the enterprise. Financial technology, through emerging digital technology, accurate enterprise profiles, technology "soft power" in the place of tangible assets, and abundant enterprise objective descriptions involving the investment and financing of information blind areas, attracts high-quality investment to the enterprise. Additionally, the financing path of enterprises simultaneously broadens their financing channels (Li, Cheng, 2018). Solutions to financing constraint problems are bound to stimulate the investment of enterprises in technological innovation activities such as research and development and provide support for improving the total factor productivity of enterprises. Specifically, to test whether the development of fintech can alleviate the inhibitory effect of enterprise financing constraints on the total factor productivity of enterprises, the following intermediary effect measurement model is constructed.

$$FC_{i,t} = \alpha_0 + \alpha_1 LNINDEX_{i,t} + CONTROLS + \sum YEAR + \sum CITY + \varepsilon_{i,t} \quad (4)$$

$$TFPCH_{i,t}(EFFCH_{i,t}, TECHCH_{i,t}) = \beta_0 + \beta_1 LNINDEX_{i,t} + \beta_2 FC_{i,t} + CONTROL_s + \sum YEAR + \sum CITY + \varepsilon_{i,t} \quad (5)$$

Where FC represents the enterprise financing constraint, and the other variables take the same definitions as previously provided. In Models (4) and (5), the focus is on the regression coefficient of the fintech index. Based on the aforementioned mechanism analysis, it is expected that $\alpha_1 > 0$ in Model (4), and the value of β_1 in Model (5) is less than the value of the fintech regression coefficient in the benchmark regression Chinese style (1). With reference to the findings of Wang *et al.* (2015), the comprehensive index scoring method is used to measure the

financing constraints faced by enterprises by selecting six dimensions that are closely and positively correlated with the financing ability of enterprises: enterprise age, enterprise size, enterprise fixed assets ratio, cash ratio, liquidity ratio, profitability, and the value obtained after fitting. These six indicators are used to construct a quantitative description of enterprise financing ability. Then, the enterprise financing ability is assigned a reverse score according to the descending order of financing ability; the higher the enterprise score is, the weaker the financing ability.

The regression results are shown in *Table 6*. As seen from the regression results displayed in Column (1), the regression coefficient of the fintech index is significantly negative at the 10% level, indicating that the development of fintech can effectively alleviate the financing constraints of enterprises. The regression results displayed in columns (2), (3) and (4) show that the regression coefficient of fintech here is significantly smaller than that in the benchmark regression, indicating that the development of fintech significantly suppresses the negative effect of financing constraints on the total factor productivity of enterprises and subsequently improves total factor productivity. Thus, *H3* is verified.

Table 6. Mechanism analysis based on the perspective of enterprise financing constraints

<i>Variables</i>	(1)	(2)	(3)	(4)
	<i>FC</i>	<i>TFPCH</i>	<i>EFFCH</i>	<i>TECHCH</i>
<i>lnindex</i>	-0.00178** (-2.08)	0.00666*** (5.63)	0.0097*** (3.92)	0.0252*** (4.41)
<i>fc</i>		0.0930*** (-3.91)	-0.135*** (-3.06)	-0.0302* (-1.77)
<i>scale</i>	-0.397*** (-32.36)	-0.0536*** (-4.69)	-0.130*** (-6.16)	0.196*** (3.63)
<i>age</i>	0.442 (1.40)	0.648 (0.49)	0.104 (0.09)	0.0260 (0.12)
<i>loar</i>	0.221*** (8.10)	0.523*** (11.25)	0.488*** (5.67)	0.00250 (0.01)
<i>able</i>	-1.722*** (-23.06)	1.076*** (16.13)	1.484*** (12.02)	-0.124 (-0.39)
<i>independent</i>	-0.0648 (-0.49)	0.00695 (0.06)	-0.00952 (-0.05)	0.160 (0.30)
<i>ppe</i>	-0.509*** (-6.70)	-0.173*** (-2.66)	-0.327*** (-2.71)	0.469 (1.52)
<i>lnGDP</i>	0.121*** (4.15)	0.192*** (8.27)	0.272*** (6.30)	-0.256** (-2.33)
<i>_cons</i>	0.972*** (4.15)	0.443** (1.98)	1.887*** (4.56)	-1.856* (1.76)
<i>N</i>	6870	6870	6870	6870
<i>Year</i>	Yes	Yes	Yes	Yes
<i>City</i>	Yes	Yes	Yes	Yes
<i>r2 within</i>	0.0414	0.0937	0.0396	0.0300

Note: Robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

(3) The perspective of enterprise innovation strategy.

Due to the high risk and uncertainty of innovation activities combined with the selective support of fiscal and tax policies, listed companies in strategic emerging industries are strongly willing to develop non-substantive innovation strategies that involve seeking of support (Li, Zheng, 2016). These non-substantive innovation strategies can quickly aid enterprises in engaging in optimal innovation in quantity and further help enterprises obtain fiscal and taxation policy dividends; however, these enterprises cannot meet the high-quality survival development requirements for technical innovation and industrial upgrading, and they also cause little

improve to the total factor productivity of enterprises. Previous studies have shown that a high-quality external financial environment is an important factor in motivating enterprise willingness to make exploratory innovation decisions (Sun, Zhang, 2019). According to the above analysis, the development of fintech can optimize the financial environment at multiple levels and help promote the willingness of enterprises to explore and innovate. Therefore, the research hypothesis that fintech can increase the positive effect of exploratory innovation projects on enterprise total factor productivity by improving enterprise innovation strategy is presented in this study. To test this hypothesis, the following mediation effect test model is used:

$$LNINNO_{i,t} = \alpha_0 + \alpha_1 LNINDEX_{i,t} + CONTROL_s + \sum YEAR + \sum CITY + \varepsilon_{i,t} \quad (6)$$

$$TFPCH_{i,t}(EFFCH_{i,t}, TECHCH_{i,t}) = \beta_0 + \beta_1 LNINDEX_{i,t} + \beta_2 LNINNO_{i,t} + CONTROL_s + \sum YEAR + \sum CITY + \varepsilon_{i,t} \quad (7)$$

Where *LNINNO* represents the enterprise exploratory innovation strategy, and the definitions of the other variables are the same as those previously provided. According to the Accounting Standards for Business Enterprises—Intangible Assets issued by the Ministry of Finance of China and with reference to the research of Bi *et al.* (2017), R&D expenditure is used to reflect the exploratory innovation strategy of enterprises. From the perspective of the classification of accounting standards, R&D spending is divided into R&D capitalization spending and R&D spending, which are applied to basic and transformative R&D, while capitalization spending is applied to relatively mature improved innovation projects. Therefore, the logarithm of R&D expenditure from the R&D expenditure category in enterprise financial statements is taken as a proxy variable of the enterprise's exploratory innovation strategy.

Table 7. The Mechanism Underlying the Improvement in Corporate Financing Strategies

Variables	(1)	(2)	(3)	(4)
	<i>LNINNO</i>	<i>TFPCH</i>	<i>EFFCH</i>	<i>TECHCH</i>
<i>lnindex</i>	0.0348*** (9.86)	0.00707*** (4.26)	0.0114*** (3.71)	0.0599*** (7.63)
<i>lninno</i>		0.0161*** (2.63)	0.0304*** (2.69)	0.0300*** (10.37)
<i>scale</i>	0.795*** (33.56)	0.0337*** (-2.78)	-0.0910*** (-4.07)	-0.0198 (-0.35)
<i>age</i>	0.327 (1.07)	0.223 (0.82)	0.336 (1.27)	0.406 (1.03)
<i>loar</i>	-0.355*** (-4.07)	0.341*** (8.34)	0.399*** (5.29)	0.0465 (-0.24)
<i>able</i>	0.411*** (2.97)	1.233*** (19.06)	1.550*** (12.98)	-0.112 (-0.37)
<i>independent</i>	-0.525** (-2.11)	0.0154 (0.13)	-0.0139 (-0.06)	0.295 (0.54)
<i>ppe</i>	1.000*** (7.02)	-0.161** (2.41)	-0.323*** (-2.62)	0.304 (0.96)
<i>lnGDP</i>	1.167*** (22.68)	0.182*** (7.25)	0.324*** (6.99)	-0.646*** (-5.46)
<i>_cons</i>	-10.81*** (-25.96)	0.375* (-1.82)	0.728* (1.92)	1.334 (1.37)
<i>N</i>	6870	6870	6870	6870
<i>Year</i>	Yes	Yes	Yes	Yes
<i>City</i>	Yes	Yes	Yes	Yes
<i>r2 within</i>	0.583	0.0892	0.0397	0.0458

Note: Robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

Table 7 displays the regression results. Column (1) of the table shows that fintech can effectively promote the willingness of enterprises to make exploratory innovation decisions, indicating that the development of fintech improves the external financial environment, strengthens the trial-and-error capability of enterprises in exploratory R&D, and consolidates the backing of enterprise R&D funds to a certain extent. This approach provides a guarantee for enterprises enabling them to conduct risky but exploratory innovation projects sufficient for the promotion of technological change and industrial advancement. The regression results displayed in Columns (2), (3) and (4) show that the coefficient of fintech is still significantly positive, but the absolute value is smaller than that of the coefficient of fintech regression in the benchmark regression, which indicates that an increase in exploratory innovation strategy plays an intermediary role in the process of fintech development promoting the improvement of enterprise total factor productivity, thus verifying *Hypothesis 4*.

3.4 Heterogeneity Analysis

(1) Subsample study on the nature of company ownership.

Under the action of multiple factors, the financing environment faced by private enterprises is more disruptive than that faced by state-owned enterprises, and private enterprises are more sensitive to favorable external financial environments. Therefore, to further investigate the different impacts of fintech on enterprises with different ownership structures, the sample enterprises are divided into two subsamples, namely, state-owned enterprises and private enterprises.

The regression results are reported in columns (1) and (2) of *Table 8*. The research shows that the estimated coefficient of fintech is significantly positive for both state-owned enterprises and private enterprises; however, the absolute value of the regression coefficient of fintech is much greater for the sample of private enterprises than for the sample of state-owned enterprises. Fintech has a greater role in promoting the total factor productivity of private enterprises than it does in promoting the TFP of state-owned enterprises.

(2) Regional-based sample study

China has a vast territory that spans five time zones; thus, there are major differences in factor endowment and economic development among regions. Thus, to further investigate the regional heterogeneity of the impact of fintech on enterprise total factor productivity, according to the National Bureau of Statistics of Coastal and Inland Areas and announced by the Division Notice, the listed companies located in Liaoning, Hebei, Beijing, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, and Hainan are used as the coastal area enterprise sample. The listed companies located in Anhui, Guizhou, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi, Shanxi, Sichuan, the Xinjiang Uygur Autonomous Region and Yunnan are classified as the inland area enterprise sample. The difference in the degree of total factor productivity as affected by fintech between coastal and inland areas was studied.

The final two columns in *Table 8* display the regression results. The results show that fintech development has a significant positive impact on the total factor productivity of enterprises in coastal and inland areas, but the absolute value of the fintech regression coefficient in coastal areas is greater than that in inland areas, and it is also more significant in coastal areas. This shows that the development of fintech in coastal areas has a stronger penetrating effect on enterprises and that the all-factor power effect of fintech development on enterprises is affected by the regional economy, system, talent and related supporting measures.

Table 8. Heterogeneity Analysis

Variables	Ownership Heterogeneity		Regional Heterogeneity	
	(1) state-owned TFPCH	(2) privately operated TFPCH	(3) coastal TFPCH	(4) inland TFPCH
<i>lnindex</i>	0.0070*** (2.80)	0.0133*** (8.19)	0.0143*** (8.68)	0.0107* (1.81)
<i>Control variable</i>	Yes	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes	Yes
<i>City</i>	Yes	Yes	Yes	Yes
<i>N</i>	2390	4480	4840	2030
<i>r² within</i>	0.0170	0.0164	0.0170	0.0163

Note: Robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: authors' own results.

4. Discussion

In this study, the impact and the mechanism of fintech on the total factor productivity of the enterprises has been discussed.

First, in strategic emerging industries, fintech is a major driver of total factor productivity. The empirical evidence presented in *Table 3* and *Table 4* confirms this conclusion. *H1* is supported, which is in line with the findings of the Chen *et al.* (2020) and Iandolo and Ferragina (2019). Moreover, these findings also confirm the neoclassical economic growth theory. On the one hand, fintech improves the efficiency of capital allocation and optimizes the structure of capital allocation (Frost *et al.*, 2018), providing a solid foundation for industrial upgrading and the enhancement of total factor productivity. The evolution and adoption of financial technologies (including big data and cloud computing) is reducing the need for search, transmission and financing costs of financial resources for strategic emerging enterprises and alleviate the problem of information asymmetry (Lu, Liu, 2018). The application of artificial intelligence and other technologies improves the production automation of enterprises and improves the level of production efficiency (Guo, 2019). On the other side, compared with traditional industries, the development of fintech can more accurately help strategic emerging enterprises alleviate the financing difficulties that constrain their innovation activities and provide more stable and sustained financial support for enterprise long-term cyclical innovation projects. Fintech enables stronger collection and coverage of enterprise data elements and realizes the perspective and monitoring of enterprise capital flow, credit status and business status, which results in a good external regulatory effect.

Second, fintech reduces agency costs and improves total factor productivity. The regression results displayed in *Table 5* confirm this conclusion, and *H2* is supported. This conclusion is aligned with those of Yuan *et al.* (2015) and Xing *et al.* (2019). The evolution of financial technology is reducing the information asymmetry between banks and enterprises, and greater information transparency also enhances the external supervision of enterprises by banks (Song *et al.*, 2019). Moreover, compared with most traditional industries, strategic emerging industries are more likely to attract the attention of local governments, their corporate executives have stronger political connections, and their positive government-enterprise relations are more likely to be affected by government industrial planning. In addition, the appointment and removal of the heads of some state-owned strategic emerging industries are controlled by local governments, so corporate agents are more likely to cater to the government under government intervention. However, big data and the financial introduction of artificial intelligence can increase the transparency of capital flows, increase the financial development

of science and technology to improve the efficiency of financial institutions and auditing departments, deter enterprise agents from engaging in compliance behavior, reduce the cost of enterprise agents, optimize the allocation of resources, and improve enterprise total factor productivity.

Third, the results displayed in *Table 6* show that fintech alleviates financing constraints and improves the total factor productivity of enterprises, and thus *H3* is supported. This conclusion is in accordance with the findings of Lee, Shin (2018), Chiu, Koepl (2019), and Huang *et al.* (2020). According to the micro-banking theory, a positive relationship between banks and enterprises is conducive to easing the financing constraints on enterprises. Fintech has eased the financing constraints on strategic emerging enterprises by dredging financing channels to increase the total amount of financing and reduce financing costs. In an environment where the government focuses on strategic emerging industries, fintech entails the use of digital technology to collect and analyze user information to obtain loan customer profiles, which improves the lack of enterprise information and credit risk identification. Loan automation greatly reduces the entry barriers of borrowers and assists in dredging the financing channels of enterprises. Financial technology for mobile devices, social media and distributed accounting system technology are applied in financial services, accurate market predictions, and the intelligent identification of financial consumer demand to help financial institutions align themselves with actual financial products, increase the likelihood of the long-tail group penetration of financial services, and increase the level of total financing. Fintech can leverage big data, blockchain, artificial intelligence and other technologies to improve infrastructure construction, rules and system construction across all links of the capital market, increase the transparency of borrowers and borrowers, reduce the reverse moral risk caused by information asymmetry, and reduce the financing costs of enterprises.

Fourth, the empirical evidence displayed in *Table 7* shows that fintech improves enterprise innovation strategies and improves enterprise total factor productivity; thus, *H4* is supported, which represents an innovative finding of this study. Strategic emerging enterprises, especially in their early stages of development, prefer to pursue conventional innovation with strong robustness, low risk and low technology-added value, while the development of financial technology improves the sensitivity of strategic emerging enterprises to exploratory innovation. Furthermore, the spillover effect of knowledge and technology is more conducive to improving the total factor production efficiency of enterprises (Li *et al.*, 2016; Braunerhjelm *et al.*, 2018). As previously mentioned, the development of fintech, through the dredging of financing channels, increases the total amount of financing and reduces financing cost, thus providing a relatively loose financing environment for strategic emerging enterprises. The application of technologies such as big data, blockchain and artificial intelligence, and the external governance effect of fintech are being leveraged. Additionally, alleviating the information asymmetry between lenders and borrowers and improving regulatory efficiency clarifies, to some extent, the informational black box of enterprise research and development helps the managers of strategic emerging enterprises make exploratory innovation decisions that are better aligned with the long-term development of enterprises and promotes the technological transformation and upgrading of enterprises to further improve their total factor productivity (Sun and Zhang, 2019).

Fifth, the development of fintech can significantly improve the total factor productivity of private enterprises and enterprises in coastal areas compared with state-owned enterprises and inland areas, which is also a novel finding of this study, and the empirical evidence displayed in *Table 8* confirms this conclusion. Private companies face a more restrictive financing environment than state-owned enterprises, which makes them more responsive to

favorable external financial environments than private enterprises (Lee *et al.*, 2019). The development of financial technology has increased the transparency of information between lenders and borrowers, reduced the cost of information processing by financial institutions, and increased the cost of corporate default through efficient supervision, which provides a relaxed and efficient market environment that is suitable for research and development for private enterprises, which exhibit greater sensitivity. In addition, the economy, system, talent and related supporting measures in China's coastal areas are relatively complete, the level of science and technology is more developed, and the development of financial technology has a stronger penetration effect on enterprises (Basdekis *et al.*, 2022), all of which can help strategic emerging companies improve their total factor productivity.

Conclusions and Managerial Implications

Main Findings

In this study, using the data of companies listed in China's strategic emerging industries from 2010 to 2022, the level of fintech development was determined by mining the annual cumulative frequency of keywords in Baidu news, and the effect and mechanism of fintech on firms' total factor productivity was examined. The following conclusions can be drawn from this: (1) the development of fintech exerts a significant positive effect on the promotion of the total factor productivity of enterprises. (2) The development of fintech can alleviate the inhibitory effect of enterprise financing constraints and agency costs on total factor productivity, increase the exploratory innovation decision-making of enterprises by improving enterprise innovation strategy, and ultimately promote the improvement of enterprise total factor productivity. (3) Compared with state-owned enterprises, fintech better promotes the total factor productivity of private enterprises; compared with inland enterprises, fintech better promotes total factor productivity in coastal areas.

Managerial Implications

The implications of this study for promoting the development of regional fintech and improving the total factor productivity of strategic emerging industries are as follows:

(1) Focusing on the needs of cloud computing, big data and other basic major sciences and technologies in the financial and real industries, carrying out industry-university-research innovation, promoting and developing key technologies in the field of fintech, promoting the marketization of technological innovation achievements, and increasing the dimension of application scenarios are all important actions for enterprises. In addition, the construction of the internet and other infrastructure in coastal and inland areas should be further accelerated to provide the necessary underlying infrastructure support for the development of regional fintech and to help further develop a smart, convenient and accessible fintech-enabled service system.

(2) The goal of this study is the promotion of industrial optimization and upgrade to help fintech empower the real economy. In the context of unprecedented changes occurring over the last century, the enhancement of the resilience of the real economy and the improvement in total factor productivity are inseparable from the empowerment achieved through the adoption of fintech. Therefore, the government should simultaneously prioritize the power of financial innovation in science and technology, further guide financial technology in improving the service entity economy, and give full play to the financial technology innovation of science and technology to further broaden the existing financing channels. In addition, while lowering the financial threshold to break the black box, information can stimulate the optimal flow of innovation funds. More suitable financial services can be provided for the leading technological

innovation enterprises that can drive their industrial upgrading and enhance their innovation determination.

(3) The construction of laws and regulations regarding the application of fintech should be further improved, financial risk awareness should be strengthened, and the macro supervision capacity of enterprises should be enhanced. While using fintech to help facilitate the real economy, we should also guard against the financial risks that can arise from fintech innovation. Specifically, financial technology within the scope of responsible services and the real economy should be used to strengthen banks and other financial institutions and enhance their capability to shoulder national major scientific and technological innovation mission enterprise service capacity, improve the function of multidimensional capital market convenient financing, facilitate institutional guarantees, and strengthen the financial power of the real economy to support science and technology.

Limitations and Future Directions

The research is limited in several ways. (1) The selection of control variables is based on the endogenous variables of enterprises, and there is a lack of exogenous variables that affect the development of fintech, such as policy support and technological infrastructure. In further studies, the influence mechanism of important exogenous variables can be further analyzed and explored. (2) The selected sample comprises strategic emerging industries, including various industry types, but there is no clear definition of this concept in the current research. The selected sample includes only listed companies in common strategic emerging industries; it is still worthwhile to provide guidance on how to improve the total factor productivity and practices of other enterprises. Subsequent research should focus on ways to elaborate on the concepts presented in this study. (3) To measure the enterprise total factor productivity change rate (TFP), the DEA-Malmquist method is adopted; however, this method only takes into account changes in the number of inputs and outputs and does not take into account possible changes in quality. In some cases, changes may be more of a reflection of improvements in quality than of changes in productivity. Other methods, such as stochastic frontier analysis (randomized front analysis) or the total factor productivity index, can be combined to further consider the impact of quality changes on productivity.

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KAIP FINTECH ĮGALINA BENDRĄ ĮMONĖS GAMYBOS VEIKSNIŲ NAŠUMĄ? KINIJS STRATEGINIŲ BESIFORMUOJANČIŲ PRAMONĖS ŠAKŲ BIRŽINIŲ BENDROVIŲ DUOMENYS**Mingfei Liu, Ye Wang, Zongyi Yin****SANTRAUKA**

Naujas mokslo ir technologijų revoliucijos ir pramonės pertvarkos etapas atvėrė naujų galimybių ir iššūkių įvairiems ūkio subjektams. Visiškai nauja mokslinių tyrimų tema – nustatyti, ar finansinių technologijų plėtra gali suaktyvinti strateginių besiformuojančių pramonės šakų naujovių gyvybingumą ir pagerinti bendrą įmonių gamybos veiksmų produktyvumą. Siekta iširti galimus būdus, kaip pagerinti bendrą įmonių gamybos veiksmų produktyvumą remiantis neoklasikine ekonomikos augimo teorija, mikrobankininkystės teorija ir šalutinio poveikio teorija. Finansinių technologijų (FinTech) plėtros lygis Kinijos prefektūros lygio miestuose buvo matuojamas pasitelkus metinio kaupiamojo reikšminių žodžių dažnių skaičiaus nustatymo metodą Baidu News. FinTech poveikio šių įmonių bendram gamybos veiksmų produktyvumui mechanizmas buvo išnagrinėtas naudojant 2010–2022 m. Kinijos A akcijų strateginių besiformuojančių pramonės šakų biržinių bendrovių duomenis. Rezultatai rodo, kad FinTech gali reikšmingai paskatinti biržinių bendrovių bendro gamybos veiksmų našumo didinimą strateginėse besiformuojančiose pramonės šakose trimis būdais: mažinant įmonių finansavimo suvaržymus, mažinant įmonių agentavimo išlaidas ir tobulinant įmonių inovacijų strategiją. FinTech turi akivaizdesnį poveikį bendram privačių įmonių gamybos veiksmų produktyvumui nei valstybės valdomų įmonių produktyvumui. FinTech taip pat atlieka svarbesnį vaidmenį skatinant bendrą gamybos veiksmų našumą pakrančių zonose nei vidaus teritorijose. Šio tyrimo išvados turi svarbią praktinę orientacinę reikšmę užtikrinant nuolatinį FinTech inovacijų skatinimą ir konsoliduojant ilgalaikį mechanizmą, kuriuo FinTech tarnauja realiajai ekonomikai.

REIKŠMINIAI ŽODŽIAI: finansinės technologijos; strateginės besiformuojančios pramonės šakos; bendras veiksmų našumas; inovacijos.