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Research on the measurement and influencing factors of sci-tech finance efficiency based on the DEA-Tobit model

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Abstract. The development of sci-tech finance is conducive to promoting technological innovation and providing important technical support for comprehensively deepening reforms. Using the DEA-Malmquist model, a mainstream method for efficiency evaluation, this paper collects panel data on sci-tech finance of various provinces nationwide from 2008 to 2019, selects six input-output factors to measure the dynamic and static efficiency of sci-tech finance, and analyzes the results. It is concluded that the efficiency of China's sci-tech finance is mainly affected by pure technical factors; the eastern region performs better than the central and western regions; the total factor productivity of China's sci-tech finance has declined, while the central and western regions are developing well, along with other conclusions. Based on the empirical results, seven theoretical and practical factors are selected, and the Tobit model is used for empirical analysis. It is found that the level of internet development is significantly positively correlated with the efficiency of China's sci-tech finance and has a relatively large impact, while R&D expenditure investment is negatively correlated, and other factors are positively correlated. On this basis, suggestions for improving efficiency are put forward from three dimensions: strengthening innovation capabilities and technological progress, improving the management level of sci-tech and financial enterprises, and promoting the coordinated development of the eastern, central, and western regions.

Keywords: sci-tech finance, sci-tech finance efficiency, BCC model, Malmquist model, Tobit model

1. Introduction

The coordinated development of science and technology, financial capital, and industrial systems is an important foundation for the market-oriented allocation of factors such as data, technology, and management in the modern economy. With the continuous growth of R&D investment in China's high-tech industries, technological innovation has become increasingly prominent in promoting industrial upgrading and economic restructuring. However, technological innovation activities are characterized by high risk, high uncertainty, and long return cycles, and their smooth progress is inseparable from the effective support of the financial system in terms of resource allocation, risk sharing, and capital supply. As an important institutional arrangement connecting technological innovation and financial capital, sci-tech finance has become a key component of the coordinated operation of the national technological innovation system and the financial system. As part of industrial finance, sci-tech finance refers to a series of financial intermediaries serving technological progress, the development of sci-tech industries, the transformation of sci-tech achievements, and the upgrading of sci-tech tools, including the integration of various resources by the government and third parties.

Against the backdrop of the innovation-driven development strategy and the "14th Five-Year Plan", China has continuously strengthened the in-depth integration of science and technology with finance to support the tackling of key core technologies and the development of emerging industries. Despite the continuous expansion of investment in sci-tech finance, there are significant differences among different regions in terms of economic foundation, financial development level, and technological innovation capabilities. It is still necessary to systematically evaluate whether the allocation of sci-tech financial resources has achieved effective utilization from the perspective of efficiency. It is difficult to fully reflect the real supporting effect of sci-tech finance on technological innovation and industrial development only from the perspective of investment scale or policy intensity.

Based on this, measuring the efficiency of sci-tech finance can not only reveal the allocation results of financial resources in supporting technological innovation but also help identify the key factors restricting the improvement of sci-tech finance efficiency, providing empirical basis for optimizing sci-tech financial policies and enhancing implementation effects.

2. Literature review

Sci-tech finance refers to financial activities carried out by multiple subjects (such as the government, social organizations and individuals, markets, and intermediary institutions) in the process of technological innovation financing to promote the improvement of the sci-tech system. Its behavioral activities mainly include a series of arrangements such as creating financial tools, improving financial systems, and improving financial policies, aiming to provide funds and services for scientific and technological innovation activities. Sci-tech finance is regarded as an important part of the national technological innovation system and the financial system [1, 2]. The concept of technical efficiency was first proposed by Koopmans, who believed that technical efficiency means that no additional output can be increased technically under the condition of unchanged input and output. In 1961, it was expanded by Leibenstein: technical efficiency means that the actual output is the maximum when the input quantity, proportion, and market price are equal [3]. Jiao Yingjun defined technical efficiency as the deviation degree of actual output from the production possibility frontier in the production process of producers [4]. To sum up, efficiency refers to an evaluation method of using resources most effectively to meet needs under given conditions such as input and technology, that is, an input-output evaluation system under specific conditions. Based on the definitions of sci-tech finance and sci-tech finance efficiency by various scholars, sci-tech finance efficiency can be defined as the achievements of relevant sci-tech outputs obtained from the input of various financial resources under specific technical conditions and environments.

In the literature on the measurement of sci-tech finance efficiency, Atanassov analyzed the data of listed companies in the United States from 1974 to 2000 through policy analysis and concluded that technological innovation enterprises with more capital and greater dependence on the capital market develop better [5]; Zhang et al. believed that the state and government should diversify investment by establishing systems and setting up special funds, and empirical analysis showed that the improvement of the financial system is conducive to promoting technological progress [6]; while Verdu et al.'s research pointed out that the relationship between the government, financial markets, and enterprises is inseparable, and the development of sci-tech finance to a large extent requires the government's policy and financial support to make up for the defects of spontaneous market regulation [7]. Lin Qizhu summarized relevant works of scholars, measured sci-tech finance output data using the entropy weight method, and constructed a Bayesian stochastic frontier model to calculate and analyze the development efficiency of sci-tech finance in various provinces [8]. Zhang Qianxia used the DEA-Tobit model to measure and analyze the development efficiency of sci-tech finance in typical regions of the central, eastern, and western regions, concluded that the development efficiency of sci-tech finance in the eastern region is the highest, and put forward suggestions according to the actual situation of some regions [9].

In the research on the influencing factors of sci-tech finance efficiency, Li Kai, Deng Xiangrong, and Chen Rui constructed a DEA-Tobit model using data from 2013 to 2016 for the national sci-tech finance situation, analyzed the factors affecting pure technical efficiency and scale efficiency, and put forward relevant suggestions for government policies and local scientific research institutions based on the empirical results [10]. Yang Xu analyzed the input and output of sci-tech finance, evaluated the dynamic and static efficiency of sci-tech finance using the BCC and Malmquist models, and selected five indicators as influencing factors: government support intensity, financial scale, R&D investment intensity, human capital, and loan support degree [11]. In the same year, Xu Shiqin et al. used the BCC and panel models to measure the efficiency of sci-tech finance in various provinces and concluded that there are significant inter-provincial differences in China's sci-tech finance, and the development efficiency in the eastern region is significantly higher than that in the western region. They selected six indicators to conduct spatial econometric analysis on relevant influencing factors [12].

To sum up, current foreign scholars focus more on policy formulation and industry orientation for the development of sci-tech finance, while domestic scholars pay more attention to the development status of sci-tech finance. Most of the models used conduct one-sided static or dynamic analysis without combining the two; when selecting influencing factors, scholars mostly focus on the impact of theoretical significance and industry factors on sci-tech finance efficiency, lacking the measurement and analysis of environmental factors. In this paper, the DEA-Malmquist model is selected to analyze the dynamic and static efficiency of China's sci-tech finance, and seven indicators are selected to analyze the influencing factors of China's sci-tech finance in terms of theoretical and practical factors.

3. Measurement of sci-tech finance efficiency based on the DEA-Malmquist model

3.1. Indicator selection

When determining the input and output indicators of sci-tech finance, this paper first follows the four principles for establishing the evaluation index system, namely the objectivity principle, comparability principle, systematic principle, and dynamic principle. Referring to the selection of evaluation indicators in existing relevant research on sci-tech finance, an evaluation index system for sci-tech finance input and output is established, as shown in Table 1:

Table 1. Evaluation index system of sci-tech finance input and output

Dimension	Items
Input Indicators (TR)	R&D Personnel
	Internal R&D Expenditure
	Local Fiscal Expenditure on Science and Technology
Output Indicators (CC)	Number of Patent Authorizations
	Turnover of Technology Market
	Sales Revenue of New Products

3.1.1. Sci-tech finance input indicators

(1) R&D Personnel: Measured by the total number of R&D personnel in scientific and technological research in each region, it reflects the local human capital investment level and R&D investment level. Generally speaking, the higher the number of R&D personnel, the higher the local sci-tech finance efficiency. Unit: Personnel.

(2) Internal R&D Expenditure: Measured by the total R&D expenditure invested in each region, including not only pure research expenditure but also the wages and welfare guarantee of R&D personnel. R&D investment provides important financial support for regional technological innovation activities. Unit: 100 million yuan.

(3) Local Fiscal Expenditure on Science and Technology: As the main subject of public sci-tech finance investment, fiscal sci-tech expenditure is the direct financial support given by the government to scientific and technological development in accordance with national goals, and is an important source of China's scientific and technological funds. Unit: 100 million yuan.

3.1.2. Sci-tech finance output indicators

Sci-tech finance output is mainly reflected in two aspects: output in the R&D stage and output indicators in the achievement transformation stage. This paper selects evaluation indicators for these two aspects of output.

(1) Output in the R&D Stage

The output in the R&D stage is mainly reflected in patent authorization and protection. Therefore, this paper uses the number of patent authorizations in each region to represent the output in the R&D stage. The number of patent authorizations refers to the number of patents granted by patent administrative departments during the reporting period. Unit: Items.

(2) Output in the Achievement Transformation Stage

a) Turnover of Technology Market: Science and technology also have its own market, and the technology market is a place for the circulation and transaction of sci-tech achievements. The turnover of the technology market can reflect the transformation efficiency of technological innovation achievements. Unit: 100 million yuan.

b) Sales Revenue of New Products: This indicator refers to the total sales volume of new products developed by enterprises. New products are mainly products developed by high-tech industries and are a form of innovative output. Unit: 100 million yuan.

The input and output data used to calculate sci-tech finance efficiency in this paper are obtained from the China Statistical Yearbook on Science and Technology, statistical bulletins of various provinces, statistical yearbooks of various provinces, the WIND database, and the China Statistical Yearbook. Data from 2008 to 2019 are selected, with 2008 as the base period. The GDP deflator is used to deflate R&D expenditure, local fiscal expenditure on science and technology, turnover of the technology market, and sales revenue of new products.

3.2. Static efficiency measurement and analysis based on the BCC model

The premise of using the DEA-BCC method to calculate sci-tech finance efficiency is that input and output are positively correlated. Therefore, this paper uses SPSS to conduct correlation analysis on each input and output, and the results are shown in Table 2.

Table 2. Correlation coefficients of input and output variables

Variables	R&D Personnel	R&D Expenditure	Fiscal Sci-tech Expenditure	Number of Patent Authorizations	Turnover of Technology Market	Sales Revenue of New Products
R&D Personnel	1	-	-	-	-	-
R&D Expenditure	0.966**	1	-	-	-	-
Fiscal Sci-tech Expenditure	0.896**	0.920**	1	-	-	-
Number of Patent Authorizations	0.907**	0.850**	0.863**	1	-	-
Turnover of Technology Market	0.542**	0.632**	0.667**	0.289	1	-
Sales Revenue of New Products	0.911**	0.907**	0.878**	0.954**	0.340	1

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

It can be seen from Table 2 that all variables are positively correlated, meeting the requirements of the DEA model. Therefore, the above variables can be used as input and output indicators to calculate the sci-tech finance efficiency of each province.

3.2.1. Comprehensive technical efficiency analysis

The DEAP 2.1 software is used to calculate the efficiency of the BCC model. The comprehensive technical efficiency (TE) of sci-tech finance in each region calculated by CRSTE in the results is selected. Among them, comprehensive technical efficiency is the product of pure technical efficiency and scale efficiency, referring to technical efficiency without considering economies of scale. The results of comprehensive technical efficiency are shown in Table 3:

Table 3. Comprehensive technical efficiency of sci-tech finance

Regions	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Beijing	1	1	1	1	1	1	1	1	1	1	1	1	1
Tianjin	1	0.614	0.675	0.837	1	1	0.963	0.94	0.906	0.957	1	1	0.908
Hebei	0.536	0.37	0.401	0.492	0.638	0.615	0.659	0.765	0.578	0.824	1	1	0.657
Shanxi	0.401	0.298	0.342	0.341	0.461	0.47	0.385	0.431	0.481	0.59	0.818	0.71	0.477
Inner Mongolia	0.4	0.287	0.356	0.314	0.676	0.396	0.258	0.278	0.303	0.539	0.774	0.799	0.448
Liaoning	0.609	0.539	0.582	0.674	0.805	0.796	0.732	0.827	0.839	1	1	0.899	0.775
Jilin	0.82	0.433	0.613	1	1	0.41	0.702	0.707	1	1	1	1	0.807

Heilongjiang	0.523	0.498	0.415	0.608	0.745	0.65	0.614	0.656	0.69	0.803	0.847	0.913	0.664
Shanghai	1	0.999	1	0.998	1	0.983	0.979	0.877	0.864	0.947	0.946	0.934	0.961
Jiangsu	0.922	0.983	1	1	1	0.914	0.845	0.796	0.801	0.886	0.975	0.912	0.920
Zhejiang	1	1	1	1	1	1	1	1	1	1	1	1	1
Anhui	0.47	0.449	0.599	0.855	0.866	0.789	0.778	0.804	0.879	0.975	1	0.911	0.781
Fujian	0.709	0.577	0.667	0.736	0.812	0.697	0.651	0.876	0.993	0.978	1	1	0.808
Jiangxi	0.52	0.335	0.363	0.482	0.735	0.763	0.697	0.851	1	0.989	0.995	1	0.728
Shandong	1	0.779	0.745	0.851	1	0.965	0.964	0.919	0.946	1	0.977	0.905	0.921
Henan	0.567	0.46	0.437	0.459	0.504	0.751	0.718	0.724	0.694	0.739	0.875	0.75	0.640
Hubei	0.864	0.798	0.781	0.722	0.868	0.886	0.864	1	1	1	1	0.896	0.890
Hunan	0.652	1	1	0.741	1	1	1	1	1	1	0.988	0.818	0.933
Guangdong	0.913	0.737	0.76	0.769	0.821	0.785	0.847	0.791	0.828	1	1	1	0.854
Guangxi	0.701	0.355	0.373	0.598	0.683	0.809	0.664	0.828	0.89	0.967	0.848	0.792	0.709
Hainan	1	0.565	0.663	0.582	0.549	0.659	0.482	0.526	0.466	0.546	0.646	0.845	0.627
Chongqing	1	0.851	1	1	1	1	1	1	1	1	0.941	0.848	0.970

Table 3. (continued)

Sichuan	0.955	1	1	0.718	0.733	0.737	0.787	0.956	0.818	0.911	0.964	0.811	0.866
Guizhou	0.596	0.41	0.562	0.655	0.644	0.797	0.967	1	0.764	0.878	0.933	1	0.767
Yunnan	0.479	0.505	0.47	0.435	0.607	0.501	0.577	0.519	0.528	0.599	0.649	0.675	0.545
Shaanxi	0.607	0.615	0.715	0.935	0.937	1	1	1	1	1	1	1	0.901
Gansu	0.6	0.607	0.667	0.808	0.915	1	0.902	0.807	0.72	0.942	1	0.997	0.830
Qinghai	1	0.746	0.608	0.704	0.643	0.812	0.822	1	1	1	1	0.862	0.850
Ningxia	0.532	0.462	0.454	0.406	0.552	0.735	0.443	0.604	0.497	0.744	0.825	0.704	0.580
Xinjiang	0.724	0.423	0.461	0.436	0.446	0.49	0.611	0.802	0.701	0.938	1	0.953	0.665
Average	0.737	0.623	0.657	0.705	0.788	0.78	0.764	0.81	0.806	0.892	0.933	0.898	0.783

According to Table 3, only when the sci-tech finance efficiency reaches 1 can all resource allocation be optimal. It can be seen from Table 3-4 that the average value of China's sci-tech finance efficiency has increased from 0.737 to 0.898 over the past 12 years, with a peak of 0.939. Only in 2018 was it 0.933, which is in a relatively effective state. The average efficiency in other years is lower than 0.9, that is, it is in an ineffective state and needs a long time of adjustment to reach an effective level. This indicates that China's sci-tech finance efficiency is increasing year by year, and most provinces and cities are in a state of increasing scale efficiency, with improved development.

According to the division of China's eastern, central, and western regions, there are obvious regional differences in the development of China's sci-tech finance. There are 16 provinces and cities above the average level, most of which are located in the eastern region. The eastern region has maintained a good growth trend over the past 12 years. Beijing and Zhejiang have reached the production efficiency frontier; Tianjin, Shandong, and other regions have generally maintained a stable trend of relatively effective sci-tech finance efficiency; Jiangsu, Shanghai, and other regions have an average sci-tech finance efficiency of more than 0.9, which is related to their advanced science and technology and sound relevant financial support. However, the development momentum of sci-tech finance has slowed down in recent years, which may be due to the saturation of relevant resources and development opportunities. Since 2014, the western region has shown a good development momentum, which is related to the national financial policy support, the increase in sci-tech innovation resources, and the implementation of national major scientific and technological projects. The central region has the least prominent advantage in sci-tech finance efficiency among the three regions. Taking Shanxi, Heilongjiang, and Henan as examples, they are still in the stage of needing long-term adjustment for sci-tech finance efficiency.

The average value of the 12-year data of each province is 0.783. Divided into four echelons according to 0.9 and above, average to 0.9, 0.6 to average, and below 0.6, the following Table 4 on the distribution of the average sci-tech finance efficiency of each province is obtained:

Table 4. Distribution of average sci-tech finance efficiency of each province

Distribution Range	Distributing Provinces	Number	Proportion
First Echelon ($0.9 \leq \theta$)	Shaanxi, Tianjin, Jiangsu, Shandong, Hunan, Shanghai, Chongqing, Beijing, Zhejiang	9	30%
Second Echelon ($0.783 \leq \theta < 0.9$)	Jilin, Fujian, Gansu, Qinghai, Guangdong, Sichuan, Hubei	7	23.3%

Third Echelon (0.6 ≤ θ < 0.783)	Hainan, Henan, Hebei, Heilongjiang, Xinjiang, Guangxi, Jiangxi, Guizhou, Liaoning, Anhui	10	33.4%
Fourth Echelon (θ < 0.6)	Inner Mongolia, Shanxi, Yunnan, Ningxia	4	13.3%

It can be seen from Table 4 that among the 30 provinces and cities surveyed, there are more provinces and cities in the second and third echelons, accounting for about 56.7%. Beijing and Zhejiang in the first echelon have maintained the optimal and effective state of sci-tech finance efficiency with a value of 1 and constant returns to scale, indicating that the overall utilization rate of sci-tech financial resources is good, and the sci-tech finance efficiency is in a fully effective state. This is related to the large number of technological innovation parks in these regions, the agglomeration of sci-tech enterprises to form industrial parks, as well as the developed local economy, frequent domestic and foreign trade, fast capital circulation, and advanced financial services. Chongqing, Shanghai, Hunan, Shandong, Jiangsu, Tianjin, and Shaanxi have relatively prominent sci-tech finance efficiency. Although they have not reached the fully effective level, they can reasonably use resources under the relatively effective level. In contrast, several provinces such as Inner Mongolia, Yunnan, Ningxia, and Shanxi have been in a state of low input-output efficiency of sci-tech finance for a long time. Most of the data in the statistical years are below the average, in a state of ineffective sci-tech finance. This is mainly due to factors such as poor local endogenous resources and insignificant advantages in the sci-tech and financial industries.

3.2.2. Pure technical efficiency analysis

Table 5. TE, PTE, and SE values of sci-tech finance in various provinces and cities in China (2008-2019)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Comprehensive Technical Efficiency (TE)	0.737	0.623	0.657	0.705	0.788	0.780	0.764	0.810	0.806	0.892	0.933	0.898
Pure Technical Efficiency (PTE)	0.797	0.737	0.740	0.789	0.863	0.845	0.855	0.879	0.866	0.933	0.958	0.937
Scale Efficiency (SE)	0.921	0.839	0.885	0.896	0.914	0.923	0.892	0.918	0.923	0.955	0.974	0.958

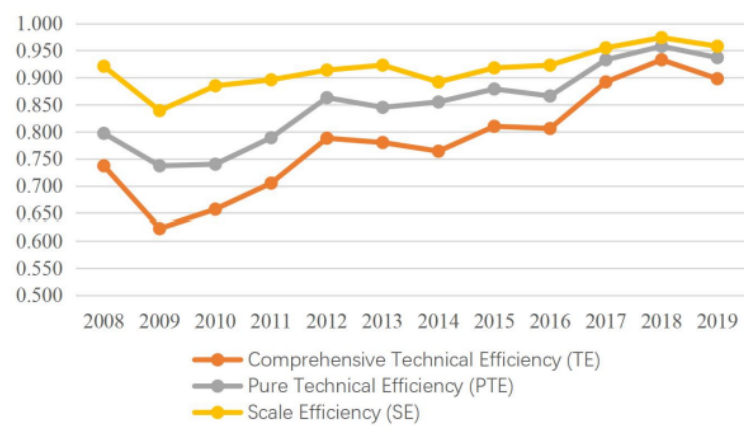

Figure 1. TE, PTE, and SE values of sci-tech finance in various provinces and cities in China (2008-2019)

It can be seen from Table 5 and Figure 1 that the pure technical efficiency (PTE) values of China's sci-tech finance are mainly distributed in the range of 0.7-0.95, while the scale efficiency (SE) values are mainly distributed in the range of 0.8-0.95. In 2009, the overall efficiency of China's sci-tech finance decreased compared with the previous year, mainly due to the combined effect of decreasing scale efficiency and low pure technical efficiency. However, in recent years, China's sci-tech finance efficiency has been continuously improving, reaching a peak in 2018 with a scale efficiency of 0.974. This indicates that China's technical and management levels have been improved to a certain extent with the implementation and improvement of innovation incentive policies and the reform of the scientific and technological management system.

3.2.3. Scale efficiency analysis

The product of pure technical efficiency and scale efficiency is comprehensive technical efficiency. When the values of pure technical efficiency and comprehensive technical efficiency are infinitely close, the scale efficiency value tends to 1. As shown in Figure 2, China's returns to scale generally show a trend of first decreasing and then increasing, which is relatively flat. Among the 12 years of selected data, 27 provinces and cities have a scale efficiency above the average of 0.917, indicating that China's scale efficiency is relatively high, and the decision-making units are close to the optimal production state. Before 2015, more than 55% of the 30 provinces and cities in China had increasing returns to scale, and less than 30% had decreasing scale efficiency. Each additional unit of sci-tech finance input could bring more than one unit of sci-tech finance output, indicating that the investment in sci-tech financial resources was insufficient at that time. Since 2016, the proportion of provinces and cities with decreasing sci-tech finance scale efficiency in China has increased, indicating that the percentage increase in sci-tech finance output is less than the percentage increase in input. More than one-third of China's regions have redundant investment in sci-tech financial resources. Simply increasing the scale of sci-tech finance investment cannot effectively improve sci-tech finance efficiency. In the future, the focus should be on technological innovation.

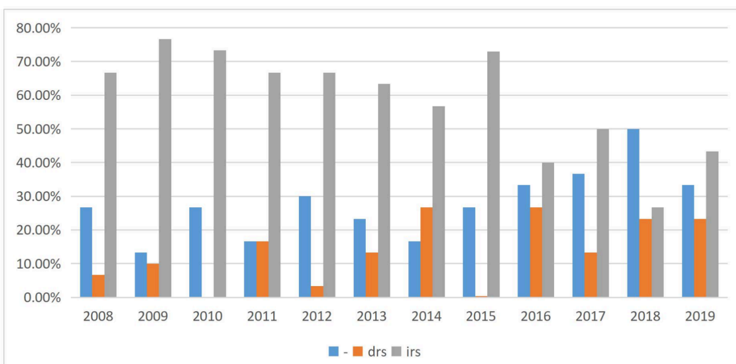

Figure 2. Proportion of increasing (irs), decreasing (drs), and constant (-) sci-tech finance scale efficiency in various provinces and cities in China (2008-2019)

Note: -, drs, and irs respectively represent constant, decreasing, and increasing returns to scale.

3.3. Dynamic index efficiency measurement and analysis based on the Malmquist model

Using the Malmquist index to dynamically measure China's sci-tech finance efficiency from 2008 to 2019, the total factor productivity and its index decomposition values by province and time series can be obtained, as shown in Table 6 and Table 7:

Table 6. Total factor productivity and decomposition of China's sci-tech finance (2008-2019)

Time Interval	Technical Efficiency Change Index (EFFCH)	Technological Progress Index (TECHCH)	Pure Technical Efficiency Change Index (PECH)	Scale Efficiency Change Index (SECH)	Total Factor Productivity Index (TFPCH)
2008-2009	0.802	0.717	0.91	0.882	0.576
2009-2010	1.024	1.445	0.957	1.07	1.479
2010-2011	1.263	0.925	1.176	1.074	1.168
2011-2012	0.985	0.834	1.004	0.981	0.822
2012-2013	0.99	0.955	1.008	0.983	0.946
2013-2014	0.923	1.166	0.961	0.961	1.076
2014-2015	1.108	0.829	1.006	1.102	0.918
2015-2016	0.859	1.21	0.897	0.958	1.04
2016-2017	1.077	0.733	1.049	1.026	0.789
2017-2018	0.973	1.146	1.017	0.957	1.115
2018-2019	0.997	0.874	0.978	1.019	0.871
Average	0.993	0.962	0.994	0.999	0.956

Table 7. Malmquist dynamic efficiency results of various provinces and cities in China

Provinces	Technical Efficiency Change Index (EFFCH)	Technological Progress Index (TECHCH)	Pure Technical Efficiency Change Index (PECH)	Scale Efficiency Change Index (SECH)	Total Factor Productivity Index (TFPCH)
Beijing	0.944	0.904	1.003	0.941	0.853
Tianjin	1.007	0.918	1.018	0.99	0.925
Hebei	1.011	0.887	1.02	0.991	0.896
Shanxi	1.008	0.892	1.012	0.996	0.899
Inner Mongolia	1.007	0.931	1.007	1	0.938

Liaoning	1.007	0.9	1.007	1	0.906
Jilin	0.989	0.928	1.005	0.984	0.918

Table 7. (continued)

Heilongjiang	1.005	0.899	1.005	1	0.903
Shanghai	1	0.902	1	1	0.902
Jiangsu	0.97	0.925	0.985	0.985	0.897
Zhejiang	0.977	0.935	0.984	0.993	0.914
Anhui	1	0.937	1	1	0.937
Fujian	0.972	0.942	0.974	0.998	0.917
Jiangxi	0.996	0.901	0.992	1.003	0.897
Shandong	0.975	0.919	0.977	0.999	0.897
Henan	1.004	0.947	1.002	1.002	0.951
Hubei	1.015	0.952	1.008	1.007	0.966
Hunan	1	0.956	1	1	0.955
Guangdong	0.997	0.961	0.991	1.007	0.959
Guangxi	0.955	0.995	0.96	0.995	0.95
Hainan	0.972	0.992	0.969	1.002	0.964
Chongqing	0.982	0.969	0.981	1.001	0.951
Sichuan	0.964	1.011	0.965	0.999	0.975
Guizhou	0.975	0.961	0.976	0.999	0.938
Yunnan	1.023	1.036	0.993	1.031	1.061
Shaanxi	1.034	1.047	1.004	1.03	1.083
Gansu	0.997	1.071	0.984	1.014	1.068
Qinghai	1	1.077	0.992	1.009	1.078
Ningxia	1.011	1.12	1.008	1.003	1.132
Xinjiang	1.005	1.122	1.005	1	1.128
Average	0.993	0.962	0.994	0.999	0.956

The data results in Table 6 show that during the period 2008-2019, Ningxia had the highest average growth rate of total factor productivity among the 30 provinces and cities in China, with an increase of 13.2%; Beijing had the lowest, with an average decrease of 14.7%. Among the surveyed provinces and cities, only 6 provinces and cities had an increase in total factor productivity, namely Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang, indicating that their sci-tech finance development is good. The Malmquist values of the other 24 provinces and cities are less than 1, and the sci-tech finance efficiency of these provinces and cities has decreased to varying degrees. The decline in total factor productivity in the eastern region is generally higher than that in the western and central regions. The decline in total factor productivity in the central region is about 10%, and only Inner Mongolia, Jiangxi, Guangxi, Chongqing, Sichuan, and Guizhou in the western region have a slight decline, while the rest are on the rise. Overall, the total factor productivity of sci-tech finance exceeding the national average of 0.956 is mainly concentrated in the central and western regions, and the growth of sci-tech finance efficiency in the western region is significantly better than that in the central and eastern regions. This indicates that the support and guidance of China's current series of sci-tech finance policies are very significant. Especially with the support of the Western Development Strategy, the government's sci-tech policies and financial tool support have effectively promoted the development of local sci-tech industries, and the endogenous motivation for science and technology in various provinces and cities in the western region has been significantly enhanced.

It can be seen from Table 7 that the average total factor productivity index over the 12 years from 2008 to 2019 is close to 1, indicating that the total factor productivity of sci-tech finance has slightly decreased but with little fluctuation. Analyzing the changes in total factor productivity alone, the total factor productivity was the lowest in 2008-2009, at 0.576, a decrease of 42.4% compared with the previous year; the total factor productivity index reached its peak in 2009-2010, at 1.479, an increase of about 47.9% compared with the previous year. Over the 12 years, the change trend of China's sci-tech finance total factor efficiency is significant, showing a volatile trend. It first rose and then fell between 2008 and 2010, with obvious fluctuations, with an amplitude of about 50%; it gradually stabilized in the later 10 years, with a fluctuation amplitude of 20%. As can be seen from Table 3-10, the technological change curve (TECHCH) has a similar trend and good fit with the total factor production curve (TFPCH), indicating that the main factor affecting the fluctuation of China's sci-tech finance total factor production efficiency is technological change, which is consistent with the previous analysis, that is, the decline in the total factor productivity index is mainly due to the decline in the technological progress index.

According to the index decomposition in the table, the main reason for the large differences in the total factor efficiency of sci-tech finance among different provinces and cities in China is the technological progress index. The change of the technological progress index will be affected by policy orientation and the progress of scientific and technological level. The average value has decreased by about 3.8%, indicating that the production technology and market environment regulation are still insufficient. The comprehensive technical efficiency of various provinces and cities has not changed much over the 12 years, only decreasing by 0.7%. The technical efficiency index can be further decomposed into the pure technical efficiency index and the scale efficiency index, with a decrease of 0.6% and 0.1% respectively. This indicates that the total factor productivity of sci-tech finance is less affected by technical efficiency, and attention should be paid to the catalytic and promoting effect of technological progress on sci-tech finance.

4. Empirical analysis of influencing factors of sci-tech finance efficiency based on the Tobit model

4.1. Variable selection and data sources

4.1.1. Variable selection and processing

This paper mainly studies the influencing factors of sci-tech finance efficiency, so the BCC sci-tech finance efficiency calculated in Chapter 3 is taken as the explained variable. Combined with existing literature and relevant data collation results, the indicators selected by the model are as follows:

(1) Legal Environment (flhj): Sci-tech finance needs to use a series of financial tools and systems as intermediaries to promote the development of the sci-tech industry. The legal environment such as the relevant financial supervision system plays an important regulatory role in China's sci-tech finance system. Therefore, the legal index in the Fan Gang Index is selected as the legal environment indicator [13].

(2) Factor Market Indicator (yssc): As a sub-market in the factor market, the financial market plays a key role in promoting sci-tech finance. The development level of the factor market in the Fan Gang Index is selected as the factor indicator.

(3) R&D Investment Intensity (rdqd): R&D investment intensity, that is, the ratio of total social R&D expenditure to GDP, can represent the investment level of each province in scientific and technological R&D

and the attention and support degree of each region to scientific research in terms of economy.

(4) Funding Situation of High-tech Industries (gjszj): The output and transformation of sci-tech achievements mainly come from high-tech industries. Their funding revenue and expenditure situation can reflect the output of financial capital in scientific and technological R&D.

(5) Financial Interrelation Ratio (jrxgbl): Indirect financing is still an important way for sci-tech enterprises to raise funds, which can effectively alleviate the financing difficulties of sci-tech enterprises. Timely access to the required funds for scientific and technological investment has a great impact on sci-tech finance efficiency. Therefore, the ratio of financial loans to GDP in each province and city is selected as the financial interrelation ratio.

(6) Human Capital (zxdxs): Both technological innovation and financial activities are inseparable from the support of knowledge factors. Sci-tech and financial talents are of great significance to the development of sci-tech finance. Therefore, the number of college students and graduates per 100,000 people is selected as the human capital indicator.

(7) Internet Development Level (hlw): The government and financial institutions realize regional resource allocation through the Internet, forming an efficient innovation chain and production chain. The ratio of Internet users to the year-end population is selected as the indicator to measure the level of Internet development [14].

4.1.2. Descriptive analysis

The descriptive analysis results of the explained variable y and the explanatory variables flhj, yssc, rdqd, gjszj, jrxgbl, zxdxs, and hlw are shown in Table 8.

Table 8. Descriptive analysis results of each variable

Variables	Sample Size	Mean	Standard Deviation	Minimum	Maximum
y	330	0.787	0.208	0.258	1.000
flhj	330	6.258	4.548	-0.410	24.330
yssc	330	5.842	2.722	0.370	15.870
rdqd	330	1.594	1.098	0.339	6.310
gjszj	330	11.136	11.065	0.008	48.055
jrxgbl	330	1.324	0.439	0.655	2.585
zxdxs	330	2,543.294	855.450	1,043.000	6,410.000
hlw	330	0.175	0.091	0.032	0.475

It can be seen from Table 8 that the model includes 330 samples. The maximum value of the explained variable sci-tech finance efficiency is 1, the minimum value is 0.258, and the standard deviation is 0.208, indicating that there is still a certain gap in sci-tech finance efficiency among various provinces and cities in China. Among the selected explanatory variables, the human capital (zxdxs) has the largest difference with a standard deviation of 855.45, and the maximum and minimum values are 6,410 and 1,043 respectively, indicating that the educational resources among various provinces and cities in China are unbalanced and there is a large regional difference in talents. The internet development level (hlw) has the smallest difference, only 0.091, with the maximum and minimum values of 0.475 and 0.032 respectively, indicating that the difference in internet development level among various provinces and cities is small and the internet penetration rate is relatively high.

4.2. Construction of the Tobit model

Based on the research on the influencing factors of sci-tech finance efficiency in this paper, the explained variable is sci-tech finance efficiency, and the core explanatory variable is human capital.

The model form is as follows:

$$y^* = \beta' x_i + u_i \tag{1}$$

$$y_i^* = y_i(y_i^* > 0); y_i^* = 0(y_i^* < 0) \tag{2}$$

y_i^* is a latent dependent variable. When the latent variable is greater than 0, it is observed, and the value is y_i . x_i is the explanatory variable, β is the coefficient vector, u_i $N(0,\sigma)^2$.

In this paper, the explained variable is sci-tech finance efficiency. Due to the particularity of the efficiency value, its value is limited between 0 and 1. Although the variable is continuous in [0,1], it is restricted, which meets the basic conditions for the construction of the Tobit model. Therefore, the Tobit model constructed in this paper is as follows:

$$\varepsilon_{i,t} \ N(0,\sigma^2), i = 1, 2, \ldots \tag{3}$$

where represents the sci-tech finance efficiency of the i-th province at time t, $\varepsilon_{i,t}$ represents the regression error term, and represents the explanatory variable [15].

4.3. Analysis of empirical results

This paper constructs a panel Tobit model, with sci-tech finance efficiency as the explained variable and government support intensity, economic development level, human capital, and internet development level as explanatory variables. Stata 16 is used for Tobit regression, and the results are shown in Table 9.

Table 9. Tobit regression results

Variables	Coefficient	Z-value	P-value
flhj	0.0066	1.45	0.147
yssc	0.0127	2.33	0.020
rdqd	-0.075	-2.75	0.006
gjszj	0.0043	3.98	0.000
jrxgbl	0.1578	4.34	0.000
zxdxs	0.0001	3.26	0.001
hlw	0.3870	2.62	0.009
LR Test	-	158.59	0.0000
Wald chi2	-	236.59	0.0000

According to Table 9, different factors have obvious differences in their impact on China's sci-tech finance efficiency. The legal environment (flhj) has no significant impact on sci-tech finance efficiency (p-value = 0.147), indicating that under the background of the rapid development of sci-tech finance, the current legal system is still lagging behind in adapting to new financial formats, and its regulatory role has not been effectively transformed into efficiency improvement. The development level of the factor market (yssc) has a significant positive impact on sci-tech finance efficiency (correlation coefficient is 0.0127, significant at the 5% level), indicating that a sound financial market and technology market help guide the rational flow of capital and promote the transformation of sci-tech achievements. R&D investment intensity (rdqd) is significantly negatively correlated with sci-tech finance efficiency (correlation coefficient is -0.0746, p-value = 1%), reflecting that the utilization efficiency of scientific research funds in some regions is low, and there are problems of unreasonable allocation or occupation of funds by inefficient entities. The funding situation of high-tech industries (gjszj) has a significant positive effect on sci-tech finance efficiency, but the impact is limited. For every 1% increase in the funding of high-tech industries, the sci-tech finance efficiency increases by about 0.43%. The financial interrelation ratio (jrxgbl) has a significant promoting effect on sci-tech finance efficiency (correlation coefficient is 0.1578), indicating that indirect financing is still an important channel for sci-tech enterprises to obtain innovation funds. The level of human capital (zxdxs) is positive at the 1% significance level, but the coefficient is small, indicating that the role of talent accumulation in efficiency improvement has not been fully released. The level of internet development (hlw) has the most significant impact on sci-tech finance efficiency (correlation coefficient is 0.387, significant at the 1% level), showing that internet technology plays a key supporting role in the development of sci-tech finance by improving the efficiency of information transmission and financial services.

5. Conclusion

5.1. Research conclusion

Taking China's provinces (excluding Tibet) as the research objects, this paper selects R&D personnel, internal R&D expenditure, and local fiscal expenditure on science and technology as input indicators, and the number of patent authorizations, turnover of the technology market, and sales revenue of new products as output indicators to measure the sci-tech finance efficiency of 30 provinces and analyze the influencing factors of sci-tech finance efficiency. The DEA-BCC model and the Malmquist index model are used to measure the static and dynamic efficiency of sci-tech finance respectively; in the analysis of the influencing factors of China's sci-tech finance efficiency, data from 2008 to 2019 are selected, and the Tobit model is used to analyze seven indicators: legal environment, development level of the factor market, R&D investment intensity, funding situation of high-tech industries, financial interrelation ratio, human capital, and internet development level, and relevant conclusions are drawn.

In terms of sci-tech finance efficiency, since China introduced relevant support policies for sci-tech finance, the sci-tech finance efficiency of 30 provinces, autonomous regions, and municipalities directly under the Central Government in China has basically been increasing year by year. However, from the perspective of the total technical efficiency values of sci-tech finance in various provinces, there are significant regional differences in sci-tech finance efficiency, which are mainly affected by pure technical efficiency and less by scale efficiency. The eastern region is ahead of the central and western regions in development, but the gap in sci-tech finance efficiency between the central region and others tends to narrow. From the perspective of the total factor productivity index, the total factor productivity in China's western region is significantly higher than that in the eastern and central regions, greater than 1, indicating that the development of sci-tech finance is on an upward trend. Through index decomposition, the total factor productivity of China's sci-tech finance is mainly affected by the technological progress index, and China's scientific and technological level should be improved.

In terms of the influencing factors of sci-tech finance efficiency, the level of internet development and the financial interrelation ratio have a significant impact on China's sci-tech finance efficiency. The development of internet finance and internet technology has also provided a new ecological chain for sci-tech finance, and at the same time improved the speed of information transmission and the possibility of technological value-added. The continuous improvement of financial services can also bring capital support to science and technology, and the development level of the factor market also has an important impact on the transformation of sci-tech achievements. At the same time, the richer the human capital, the profounder the R&D foundation of technological innovation activities, and the ability to carry out technological innovation activities with high talent input. In the R&D process, the absorption and utilization of invested sci-tech financial resources and the transformation and utilization of R&D achievements will be more sufficient, promoting the improvement of regional sci-tech finance efficiency. In addition, China still needs to strengthen the construction of laws and regulations, pay attention to the targeted investment and effective utilization of funds, and focus on the impact of technological progress on sci-tech finance, which is consistent with the efficiency analysis results. It is suggested to use blockchain and internet finance technologies to strengthen innovation activities and technical support, improve the efficiency of technological progress; strengthen the "enclave model", break the administrative divisions between the eastern and western regions, balance the allocation of sci-tech financial resources, and promote coordinated regional development.

5.2. Prospects

The measurement and analysis of the influencing factors of sci-tech finance efficiency mainly involve the inter-provincial level in China. Due to the limitations of relevant data acquisition and the author's research capabilities, the research content of this paper is not comprehensive and in-depth enough. Future research can be further carried out from the following aspects:

(1) The evaluation index system of sci-tech finance needs to be improved and refined. China's sci-tech finance has just started in recent years and is in a growth stage that still needs attention. The structural system of sci-tech finance development is incomplete, and the relevant policies and enterprise management systems are not standardized. Some data are facing serious missing problems, resulting in the incomplete evaluation index of the development level of sci-tech finance, which has a certain deviation from the actual situation. To improve the scientificity and reliability of the research, it is still necessary to collect relevant data in subsequent research, continuously improve the index system, and ensure the rigor of the research.

(2) The research perspective of this paper is 30 provinces and cities nationwide. Although the research scope is comprehensive, the sample is still small. In addition, affected by the lack of relevant data, the latest research period of this paper is 2008-2019, which fails to fully reflect the development status of China's sci-tech finance efficiency in recent years. Therefore, the research objects and research regions can be further refined, taking prefecture-level cities in some regions as the research objects, and expanding the research period for a more comprehensive analysis.

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