Research on the Coupling between the Efficiency of Technological Innovation and the Development of Technological Finance in the Yangtze River Delta Region

Huang Kun[1], Li Zhenyi[1], Zhang Jian[2]

[1]School of Economics and Management, Shanghai Maritime University, Shanghai, 200120, China

[2]School of Business, East China University of Science and Technology, Shanghai, 200237, China

Keywords: Technological innovation, Technological finance, Network DEA, Entropy weight topsis method, Coupling

Abstract: Development is the first essence, technological innovation is the driving force for development and progress, and the technological finance is an important support. The degree of those has greatly influenced the development power level of cities and regions. Taking the four regions in the Yangtze River Delta from 2011 to 2020 as an research object, this paper constructs an indicator system for the efficiency of technological innovation and the development of technological finance, calculates the efficiency of technological innovation in the four cities in the Yangtze River Delta by using the two-stage network DEA model, judges the expand degree of technological finance of the four cities by using the entropy weight TOPSIS method, and finally uses the coupling coordination degree model to couple the efficiency of technological innovation and the development level of technological finance in the cities in the Yangtze River Delta. According to the coupling results, it analyzes the degree of coupling and coordination of technology finance and technical innovation in four cities, discusses the main factors which affect the level of coupling and coordination, and puts forward different suggestions according to the characteristics of each city, such as its geographical location and resource endowment, in order to provide ideas for the mutual promotion and coordinated development of technology finance with technical innovation in the Yangtze River Delta.

1. Introduction

In 2018, the three provinces and one city in the Yangtze River Delta jointly issued the Three-Year Action Plan for the Integrated Development of the Yangtze River Delta Region (2018-2020), which clearly pointed out that it is necessary to promote the coordinated development of regional science and technology and finance, and build a national-level regional collaborative innovation network for science and technology. This action plan is important in promoting the high-quality unifies arise of the region. In 2019, the State Council issued the Outline of the Yangtze River Delta Regional Integration Development Programme, which further specified the Yangtze River Delta from 2025 to 2035 years of development direction. The “Outline” pointed out the necessity of giving full play to Shanghai's leading action, Jiangsu, Zhejiang and Anhui have their respective strengths, give play to their comparative advantages, jointly build a scientific and technological innovation community in the Yangtze River Delta. It also calls for strengthening the support of collaborative innovation policies. Since then, the Yangtze River Delta Regional Cooperation Office has issued the Three-Year Action Plan for the Integrated Development of the Yangtze River Delta Region (2021-2023). The “Plan” proposes to deepen the joint construction, promoting the coordinated development of finance, actively promote the integrated development of science and technology and finance in the Yangtze River Delta, improve the development level of the real economy of financial services, and promote cross-regional financial information sharing and work coordination.

The concept of innovation was first proposed by the Austrian economist Schumpeter in his book Economic Development Theory in 1912, which he defined as “the introduction into the production

system of a new combination of factors and conditions of production that did not exist, thereby establishing a new production function". With the rise of internal research and development after the 20th century, the results of innovation as successful inventions and the creation of value in practice gave new meaning to Schumpeter's concept of innovation. The fifth edition of the Heritage Dictionary of the English Language defines technology as "scientific methods and things used to achieve business and industrial goals" or "the volume of knowledge that society possesses to manipulate, practice, and obtain materials."

The improvement of the comprehensive competitiveness of the Yangtze River Delta region needs to rely on the support of the regional technology innovation chain and the technology finance advancement chain. The advancement of science and finance has injected innovative capital into all kinds of high-tech enterprises, providing strong power support for scientific and technological innovation, and the improvement of scientific and technological innovation level has also driven the overall strength of high-tech enterprises, and there is a relatively obvious coupling relationship between scientific and technological innovation and scientific and technological finance. Therefore, continuously improving the coupling degree of regional technology innovation and technology finance, improving the coupling efficiency of regional scientific and technological innovation and financial ecosystem are the internal mechanisms for promoting the overall coordinated development of the Yangtze River Delta region.

2. Literature Review

In 2020, China's R&D investment exceeded 2.4 trillion yuan, injecting strong momentum into scientific and technological innovation. However, judging the level of scientific and technological innovation should not only focus on input costs, but also look at the utilization and allocation efficiency of resources.

Stephen P. Robbins defined efficiency as obtaining the maximum output with the least input, so efficiency is used to express the relationship between input and output under certain assumptions. The input and cost here include, under certain conditions, material and human resources, that is, all the resources required to produce quantitative products[1].

The focus of efficiency is to reduce the redundancy of various inputs in the production activities of the enterprise or increase the inadequacy of various inputs, narrow the proportional gap between the resource input and the optimal output, and maximize the benefits of the production activities of the enterprise[2].

Different scholars have chosen different efficiency measurement methods, including comprehensive evaluation method [3], index method [4], production function method [5] and data envelopment analysis method [6] et al. Liu Xinpeng combined the global comparison model, the super-efficiency model and the MinDS model to construct a super-efficient MinDS measure model for global comparison [7]. Among them, the data envelopment analysis method has obvious advantages in general, and is widely used in the efficiency research. Jiang Lanling applied the DEA's BCC model and Malmqist index method [8], and Xu Jiahui used a two-stage tandem network DEA model [9], some scholars divided the scientific and technological innovation process into three stages, applying the three-stage network DEA method, Wang Haihua divided the three stages into technology research and development, technology transformation and value creation [10], Li Peizhe divided it into knowledge production, technology research and development, and achievement transformation stages[11].

Scholars have also adopted different methods to determine the progress of technological banking. Wei Xushi used the entropy value method to determine the index weight, and measured the high-quality growth of technical finance[12]; Lin Yaopeng chose the entropy value method to evaluate the development level of regional science and technology finance, divided technical finance into several subsystems, and analyzed the coupling and coordination relationship between several subsystems[13]; Wang Wanqiu et al. used the fixed-effect spatial lag model to analyze the factors affecting the level of financial development[14]; Zhang Xilin used the index method to measure the development level of science and technology finance in Shanxi Province[15], and Liu

Zebin et al. used factor analysis model and cluster analysis model to measure the progress of technological banking in Anhui Province[16].

Efficiency measurement and then efficiency coupling is also the research idea of some scholars. Based on the DEA cross-efficiency model, Li Yong separately measured the intersection efficiency of transportation and regional economy, and constructed the coupling model about the intersection efficiency to evaluate the coupling and coordination level of different regions in China[17]. Yang Hongwei et al. first used the DEA model to calculate the regional efficiency of innovation and the level of high-quality economic development, and then calculated the coupling degree between them, and analyzed it from multiple angles[18].

In general, there have been a large number of research on technology innovation and technology finance, which has laid a solid theoretical foundation for the research of this paper, but the coupling and coordination relationship between the two is still relatively rare.

Therefore, this paper takes four cities in the Yangtze River Delta as the research object, the time span is 2011-2020, the two-stage chain network DEA model is used to measure the efficiency of technology innovation, and the entropy weight TOPSIS method is used to measure the progress of technology finance. After that, Coupling Coordination model is used to analyze the coupling and coordination relationship between the efficiency of technological innovation and the development of technology finance, then four types of zones are divided, and different suggestions are given according to the different coupling types of the different cities and their changing trends over time, in order to break the development obstacles and inefficient operation modes between cities, improve the coupling quality of scientific and technological innovation and technology finance, and provide ideas for the overall coordinated development of the Delta.

3. Model Construction and Sample Selection

3.1 Model Building

The first step is to build a DEA model to measure the efficiency of scientific and technological innovation.

The achievements of scientific and technological innovation are not directly related to the economy[19], and under the impetus of certain deliberate investment and R&D activities, the knowledge contained in the achievements of scientific and technological innovation is constantly updated and accumulated. This knowledge needs to be transformed into economic knowledge through potential profitable opportunities, that is, the evaluation and development of the market and the identification of products by enterprises, so that scientific and technological innovation achievements can bring visible economic benefits to enterprises[20]. Therefore, scientific and technological innovation has obvious chain process characteristics. Think of it as two phases.

The first stage is the technology research and development stage, in which the input of various personnel, funds, etc. is transformed into intermediate output of papers, patents, etc.; The second stage is the transformation stage, in which the output of the first stage, such as papers and patents, is used as new inputs, and the final output of output value and transaction amount is obtained. Therefore, this paper refers to the ideas of Xu Jiahui and other scholars, introduces virtual processes, and decomposes the efficiency of network systems into two-stage tandem forms[9].

Suppose there are n production decision units (DMUs), each decision unit has m inputs, k intermediate outputs, and s final outputs.

X_i input for the i th decision-making unit in the first phase, $X_i = (x_{i1}, x_{i2}, \cdots, x_{im})^T$; Z_i is the intermediate output of the i th decision module in the first phase, $Z_i = (z_{i1}, z_{i2}, \cdots, z_{ik})^T$; Y_i is the final output. $Y_i = (y_{i1}, y_{i2}, \cdots, y_{is})^T$. V, W, and U represent the weights of input variables, intermediate outputs, and output variables, respectively, $U = (u_1, u_2, \cdots, u_s), V = (v_1, v_2, \cdots, v_m), W = (w_1, w_2, \cdots, w_k)$, then a two-stage chain network The DEA model can be represented as follows:

$$E_0 - \max U^T Y_0$$

$$\begin{cases} V^T X_0 = 1 \\ U^T Y_i - V^T X_i \le 0 \\ s.t. W^T Z_i - V^T X_i \le 0 \\ U^T Y_i - W^T Z_i \le 0 \\ U \ge \varepsilon e_s, V \ge \varepsilon e_m, W \ge \varepsilon e_k \end{cases}$$

where ε is Archimedes infinitesimal, e= $(1,1,\cdots,1)^T$.

If U^*, V^*, W^* are the pbest , the overall efficiency and the efficiency of the first and second stages are respectively $E_0 = \frac{U^{*T} Y_0}{V^{*T} X_0}, E_1 = \frac{U^{*T} Z_0}{V^{*T} X_0}, E_2 = \frac{U^{*T} Y_0}{V^{*T} Z_0}$ E_0 is the overall efficiency of scientific and technological innovation, E_1 is the efficiency of the first stage of technology research and development, E_2 is the efficiency of the transformation of the second stage of achievements, and $E_0 = E_1 \times E_2$. When the overall efficiency value is equal to 1, it is defined as the decision-making unit is valid.

In the second step, referring to the practice of Zhou Xiaoyang and other scholars, the entropy weight TOPSIS method was used to measure the progress of science and technology finance in four cities in the Yangtze River Delta [21].

After standardizing the original data, we use the entropy weight method to calculate the weight value of each index, and then calculate the score of science and technology finance development according to the TOPSIS method, and sort according to the score.

First, We calculate the contribution of the index, $p_{ij} = X_{ij} \Big/ \sum_{i=1}^{m} X_{ij}$, Wherein, X_{ij} is the standardized indicator data of the original value of the j th $j = (1, 2, \cdots, n)$ index in the i th $i = (1, 2, \cdots, m)$ province. Then we calculate the entropy value corresponding to each index, $e_j = \frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij}$, Thereafter, We calculate the weight of each index, $w_j = (1 - e_j) \Big/ \sum_{j=1}^{n} (1 - e_j)$, and construct a weighted matrix,

$$M = (m_{ij})_{m \times n} \begin{pmatrix} w_1 X_{11} & \cdots & w_n X_{1n} \\ \vdots & \ddots & \vdots \\ w_1 X_{m1} & \cdots & w_n X_{mn} \end{pmatrix}$$

To obtain the positive and negative ideal solutions, $M^+ = (\max m_{i1}, \max m_{i2}, \cdots, \max m_{in})$, $M^- = (\min m_{i1}, \min m_{i2}, \cdots, \min m_{in})$, We calculate the Euclidean distance between the evaluation object and the positive and negative ideal solutions, $d_i^+ = \sqrt{\sum_{j=1}^{n} (M^+ - m_{ij})^2}$, $d_i^- = \sqrt{\sum_{j=1}^{n} (M^- - m_{ij})^2}$, and find the relative proximity of the evaluation object to the ideal solution, $C_i = \frac{d_i^-}{d_i^+ + d_i^-}$. By comparing the distance from each evaluation object to the positive ideal solution and the negative ideal solution, the degree of superiority and disadvantage was judged.

In the third step, in order to distinguish between high and low levels of coupling, this paper construct a coupling coordination model on the basis of the coupling degree model, so as to judge whether the system achieves a virtuous circle of mutual promotion. Specific models are as follows:

$$C = \frac{2\sqrt{u_1 \times u_2}}{u_1 + u_2}, T = \alpha_1 u_1 + \alpha_2 u_2, D = C \times T$$

Among them, C is the coupling degree , $C \in [0,1]$, T is the comprehensive coordination index, D is the degree of coupling coordination. u_1 is the efficiency of technology innovation, u_2 is the growth of technological finance, α_1, α_2 is the coefficient to be determined, and $\alpha_1 + \alpha_2 = 1$, This paper believes that the efficiency of technological innovation and the development of technological finance are equally important, so $\alpha_1 = \alpha_2 = 0.5$ is set.

Figure 1 is the Overall Model Skeleton.

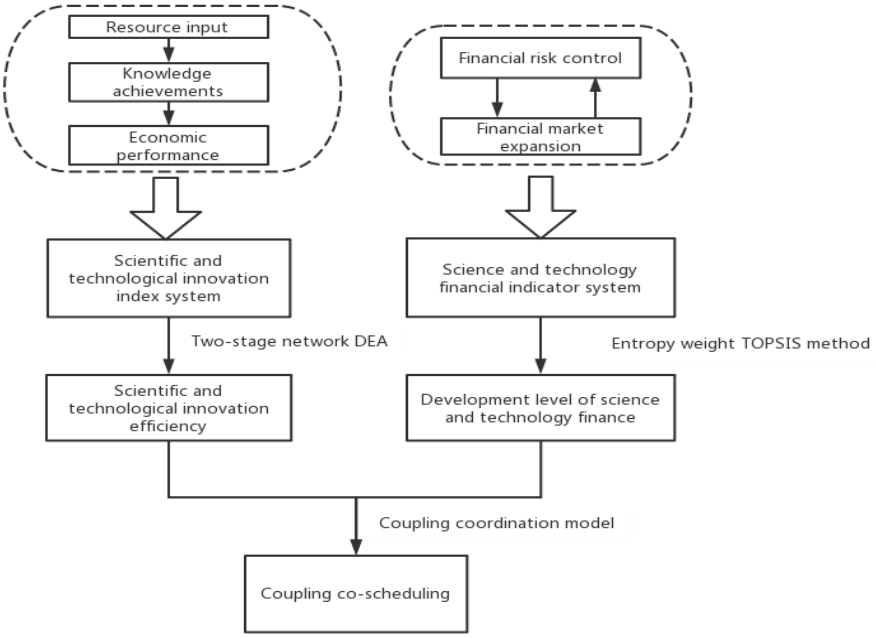


Figure 1 Coupling and Coordination Mechanism between the Efficiency of Technology Innovation and the Development of Technology Finance

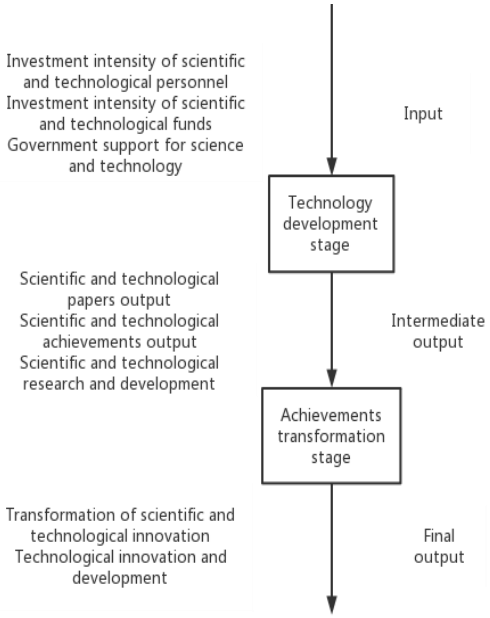


Figure 2 Two-Stage Network Dea Technology Innovation Process

3.2 Index System

Selecting the appropriate input-output index is the premise of using the DEA model for efficiency measurement. Based on the current situation in the Delta, it fully draws on the existing research, takes into account the rationality of index selection, the availability of data and the operability of empirical evidence, etc., and selects the specific index as Figure 2.

Then evaluate of the progress of technology finance. In terms of technology financial risk management and control, the amount of bank technology credit, venture risk management capital and insurance market depth are selected to measure, and in terms of the expansion of the technology financial market, the total amount of funds raised by ChiNext, the number of enterprises listed on ChiNext and the number of listed companies are selected to measure.Detailed indicators for each stage and corresponding specific explanations are shown in Table 1.

Table 1 Evaluation Indicators of Technology Innovation Efficiency and Progress of Technology Finance

	Index		Specific explanation
Efficiency of technological innovation	Input indicators	Intensity of technological personnel	R&D full-time personnel equivalent (person-years).
		Intensity of investment in technology	R&D internal expenditure (million yuan).
		The government supports in technology	Science and Technology Expenditure (100 million yuan)
	Intermediate indicators	The output of technological paper	Number of scientific papers published (articles)
		The output of technological patent	Number of patent applications granted (pieces)
		Technological research and development	Number of enterprises with R&D institutions in high-tech industrial enterprises
	Output indicators	Scientific and technological innovation transformation	Technical contract transaction amount (100 million yuan)
		Technological innovation and development	High-tech output value (100 million yuan)
The progress of technology finance	Financial risk control		Bank Technology Credit Amount (100 million yuan)
			Venture Risk Management Capital (100 million yuan)
			Insurance Market Depth (Insurance Revenue/GDP) (%).
	Financial market expansion		Total fundraising on GEM as of the year (RMB100 million)
			Number of GEM listed companies as of the current year (pcs)
			Number of listed companies (units)

3.3 Sample Selection and Data Sources

This paper takes three provinces and one city in the Delta region (Shanghai, Jiangsu, Zhejiang and Anhui) as the research object, covering the period from 2011 to 2020, a total of 10 years of data, mainly from CSMAR database and flush iFind Database, Wind database, statistical yearbooks of provinces and cities, statistical bulletins of national economic and social development, etc.

Some missing values are handled by the prediction function Trend; Unified data of different units of the same indicator; In order to avoid the influence of dimensionality, the method of Li Xingqi and Gao Xiaohong (2021) was used for meanification dimensionless treatment.

$$y_{ij} = \frac{x_{ij}}{\bar{x}_j}, i = 1,...,m,\ j = 1,...,n$$

There into x_{ij} is the original data, y_{ij} is dimensionless processed data, $\bar{x}_j$ is the mean of the indicator j, $\bar{x}_j = \frac{1}{m}\sum_{j=1}^{m} x_{ij}$ .Mean-based dimensionless processing does not change the distribution and variation characteristics of the data, and is highly efficient.

4. Empirical Analysis

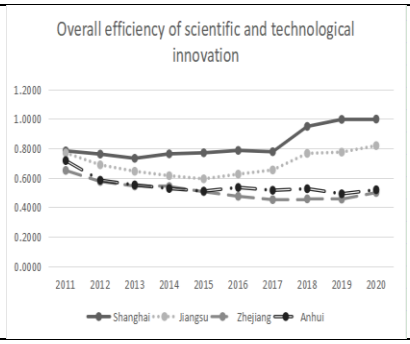
4.1 Efficiency of Technological Innovation

From the city's perspective, Shanghai has been leading the way in overall efficiency, and efficiency has improved significantly since 2017. This is because Shanghai has always had a relatively complete industry-university-research system and excellent higher education resources, and has a rich innovation culture, which provides a foundation for the gathering of high-tech talents and the stationing and development of high-tech enterprises, thus providing a steady stream of power for scientific and technological innovation.

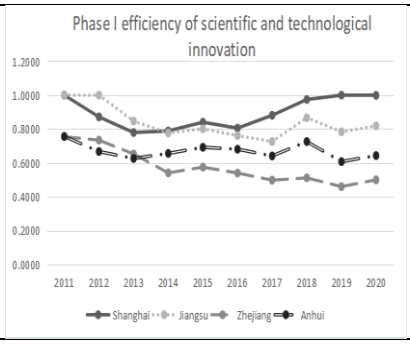
Jiangsu's overall innovation efficiency is second only to Shanghai, maintaining a fluctuating upward trend, and the overall efficiency has also been greatly improved in the long run. Jiangsu Province itself has a relatively complete education system and a relatively developed digital economy and private economy, and because it is adjacent to Shanghai and has a superior geographical location, it is affected by the radiation driving effect and the spillover effect of Shanghai's technological innovation, and has better development space overall. Jiangsu Province has invested the most in scientific and technological innovation, much higher than Zhejiang and Anhui, and more than Shanghai, but the improvement of innovation output has not reached the same level, that is, there is a certain degree of redundancy in technological innovation, so the final efficiency of technological innovation is lower than that of Shanghai.

Zhejiang and Anhui in 2011 to 2020 The efficiency of technological innovation in the past decade is comparable, and it is at a low level in the Delta. Although the total investment in scientific and technological innovation in Zhejiang and Anhui is large, the overall innovation efficiency is low considering factors such as the large population base of the province. In the long run, the efficiency of technological innovation in these two provinces has shown a slight downward trend, which may be because Shanghai and Jiangsu have concentrated more high-quality resources and have a relatively fast development speed of technological innovation, and the siphon influence on Anhui Province and Zhejiang Province has made it difficult to improve their technological innovation efficiency.

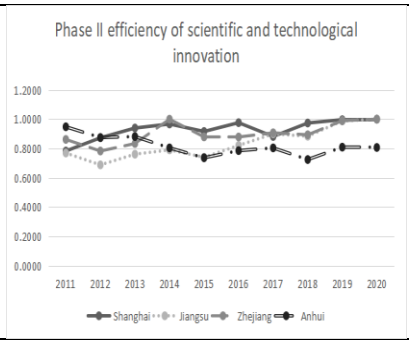
Comparing the efficiency time series trend of technological innovation in the two sub-stages (Figure 3-b and Figure 3-c), it can be seen that in the first stage, that is, the technology research and development stage, the efficiency value gap between the three provinces and one city is large, and in recent years, the efficiency gap between several provinces and cities has continued to widen. This shows that the output transformation level of human resources and capital input to scientific and technological papers and patents shows a gradient distribution of Shanghai-Jiangsu-Anhui-Zhejiang. Shanghai reached an efficiency value of 1 in 2019 and 2020, indicating that Shanghai's technology R&D transformation efficiency reached DEA Effective. In the second stage, the efficiency fluctuated greatly in ten years, but the gap between the provinces and cities was relatively small. It can be seen that the gap in the overall efficiency of technological innovation between the those cities in the Delta in the past ten years is mainly attributed to the gap in the efficiency of the first stage.



(3-a)



(3-b)



(3-c)

Figure 3 Timeline Diagram of Technological Innovation Efficiency in Four Cities in the Yangtze River Delta

From 2011 to 2020, the average efficiency of technology innovation in the Yangtze River Delta region fluctuated from 0.730 in 2011 to 0.709 in 2020. The overall efficiency level is declining.

Overall, the efficiency of technological innovation in the Delta has basically remained between 0.6 and 0.8 in various years, which indicates that the region has actively implemented the innovation-driven development strategy and achieved good results, but the overall efficiency still has some room for improvement. It can be seen from Figure 4 that most of the efficiency values of the first stage of the Yangtze River Delta in the past ten years have been between 0.6 and 0.8, and the efficiency value of the second stage has basically remained above 0.8, so it is necessary to focus on enhancing the efficiency of the research and progress stage of technological innovation.

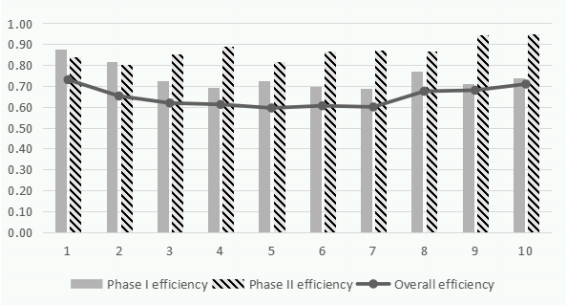


Figure 4 Timing Diagram of Overall Scientific and Technological Innovation Efficiency in the Yangtze River Delta

4.2 The Level of Development of Science and Technology Finance

Based on the index system constructed above, the entropy weight TOPSIS method was used to measure the comprehensive development level of technology finance in the decade from 2011 to 2020 in the four cities in the Delta, and the results are shown in Figure 5.

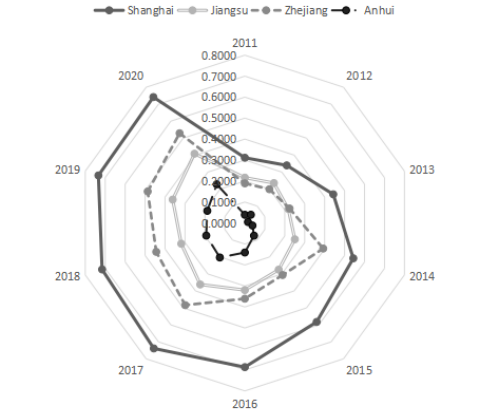


Figure 5 Radar Map of the Development Level of Technology Finance in Four Cities in the Yangtze River Delta

From the perspective of the entire sample interval, the radar chart showed a relatively obvious conch type, indicating that the development level of technology finance in the cities has increased to varying degrees in the past ten years. This shows that the state's policy has played a certain role, and various supporting mechanisms and innovative measures have achieved considerable results. However, except for Shanghai, the development level in other provinces is still at a low value, showing that there is still large development potential and development space overall.

From a geographical point of view, the problem of uneven development of technology finance in the Yangtze River Delta region is still prominent. Shanghai's development comprehensive index is relatively the highest, indicating that its power of technology finance is far ahead in the Delta region. As one of the top international financial centers, Shanghai is a national high-tech industry cluster with a strong foundation and strength for financial development. In recent years, Shanghai has still vigorously promoted the development of technology finance, attracted more dependent talents with superior policies, and strived to form a virtuous circle of resource introduction and financial development.

Zhejiang and Jiangsu are the next in terms of development level. As the vanguard of China's science and technology finance innovation and development, these two provinces have experienced a long stage of development, have rich experience, make full use of the government's guidance funds and further attract social capital, vigorously introduce financial talents, and show a complete development mechanism as a whole.

In comparison, the level in Anhui Province is not high. The basic environment for the development of science and technology finance in Anhui Province is relatively backward, coupled with insufficient policy support, it is so hard to introduce high-tech enterprises to take root and develop. Therefore, Anhui Province needs to enhance the competitiveness of technology finance in all aspects, increase policy support, attract relevant enterprises and talents to settle down, and actively absorb the spillover effect of Jiangsu and Zhejiang cities by leveraging the surrounding Jiangsu and Zhejiang cities to accelerate the improvement of its comprehensive strength.

4.3 The Coupling of the Efficiency of Technological Innovation with the Development Level of Technological Finance

Using the coupling coordination model, this paper measures the coupling coordination degree between urban technology innovation efficiency and technology finance development in those four cities from 2011 to 2020, and draws a heat map accordingly, as shown in Figure 6.

Referring to the criteria for dividing the coupling coordination level, this paper divides the coupling coordination degree of the four cities in the Delta into low-level coupling (0.200-0.399), medium-low level coupling (0.400-0.599), and medium-high level coupling (0.600-0.799), high-level coupling (0.800-1.000) four categories.

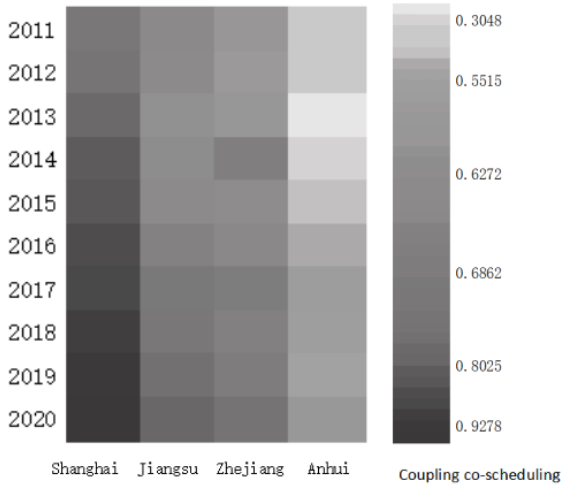


Fig. 6 Heat Map of Coupling Coordination Degree of Three Provinces and One City in the Yangtze River Delta

On the whole, the coupling and coordination degree shows a fluctuating upward trend, which indicates that in each cities, it have achieved initial benign coordinated development, but there is still a lot of room for progress to reach a high level of coordination.

It can be seen from the heat map that although the coupling coordination degree of those cities shows an upward trend, the gap between the coupling coordination levels between cities has not narrowed, and it has always remained at different gradient levels.

Shanghai's scientific and technological innovation and technology finance started earlier, Shanghai, as the national economic and trade center, the level of financial development is very high, and at the same time attracts a large number of technology and talents, and the scientific and technological innovation ability is also at the top level in the country. Technology finance and innovation complement each other, promote each other, and form a good coordination. The integration of the two has played a certain demonstration and leading role in the Yangtze River Delta region, and has played a good driving role in the surrounding areas.

Both Zhejiang and Jiangsu provinces have gradually developed from low-level coupling in 2011 to 2020 The medium and high level of coupling in the year mainly benefited from the positive effect of Shanghai's innovation spillover. In addition, Nanjing, Suzhou, Hangzhou, Ningbo and other cities in Jiangsu, Zhejiang, the overall economy is relatively developed, gathering a large number of high-quality resources, high-tech industry is more developed, the location of many universities makes these cities have good higher education resources, the government's introduction policy for high-tech enterprises and talents has also promoted the dual progress of technological innovation and technology finance. The development of such cities has well promoted the overall development level of their respective provinces.

The coupling and coordination degree of Anhui Province has increased year by year, but compared with other provinces and cities, the lag is more obvious. Anhui is a vast region, and about half of the cities are not included in the Yangtze River Delta region, so it is rarely affected by the innovation policies of the region. Compared with Jiangsu and Zhejiang, Anhui does not border Shanghai, and it is difficult to directly receive the positive spillover effect of Shanghai's scientific and technological innovation and technology finance. On the contrary, affected by the “siphon effect” of surrounding big cities, Anhui is also facing the dilemma of resource factors flowing to surrounding cities. To improve the current predicament, Anhui needs to actively adjust its industrial structure, cultivate innovative leading enterprises, and improve the level of higher education development, starting from improving the city's own soft and hard power. At present, most Anhui cities still have the problem of a large loss of technical talents and labor, so it is necessary to invest a lot of money on the basis of improving the city's strength, and cooperate with the talent introduction policy to attract the inflow of high-tech talents and capital. In addition, Anhui Province also needs to establish a cooperation and exchange mechanism with other provinces and cities, learn advanced technology and introduce related industries. At the same time, cities with high coupling levels also need to play a leading role in radiation, diffuse mature management experience and technology to other regions, drive neighboring cities, and achieve regional integration development as soon as possible.

5. Research Conclusions and Countermeasures

5.1 Conclusion of the Study

Based on reviewing relevant literature, this paper selects the data of four cities in the Yangtze River Delta from 2011 to 2020, establishes a spatial panel data model, and analyzes the efficiency of scientific and technological innovation, the development level of science and technology finance, and the coupling and coordination level of the four cities in the Delta.

From 2011 to 2020, the coupling and coordination level between the efficiency of technological innovation and the development of technology finance in the four cities in the Yangtze River Delta region has been improved to varying degrees, showing a continuous upward trend. Nevertheless, whether it is the efficiency of technological innovation, the development level of technology

finance, or the level of coupling and coordination between the two, there is still much room for improvement.

There is a large gap in the development level between cities in the Yangtze River Delta region, Shanghai's technological innovation efficiency and the progress of technology finance are far ahead, and its coupling degree and coordination degree of them are also at the top of the pyramid in the Yangtze River Delta city cluster. Jiangsu Province and Zhejiang Province have a relatively high level of development, but there is still a wide range of further possibilities. Anhui Province has the lowest level of development, and it is necessary to explore development ideas as soon as possible and keep up with the pace of regional integration and development in the Yangtze River Delta.

5.2 Countermeasure Recommendations

5.2.1 Differentiated Development Strategies

Shanghai, which has a high level of coordination, should strive to maintain its own vitality of scientific and technological innovation and its strength in science and technology finance, and continue to achieve a healthy virtuous circle by relying on its location advantages and resource endowments; Jiangsu and Zhejiang regions, which have a comparatively low level of coordination, should improve the structure of high-tech industries, actively absorb Shanghai's positive spillover, and enhance the transformation of high-tech enterprises; Anhui Province, which has a low level of coordination, should enhance the construction of basic high-tech industrial structure, increase capital investment and policy support, introduce high-tech enterprises, and actively cooperate with cities with a high level of coordination to ensure sufficient resource investment in scientific and technological innovation and scientific and technological finance.

5.2.2 Synergistic Development Strategy

Although the Yangtze River Delta region has put forward an integrated development strategy, at present, there is still a phenomenon of inconsistent resource input and unbalanced development among the three provinces and one city in the Yangtze River Delta, and there is much room for improvement in the quality of cooperation between provinces and cities. Therefore, the Delta needs to play a government-oriented role, strengthen exchanges and cooperation between regions, break the restrictions and constraints of administrative divisions, encourage the exchange of talents and technology between provinces and cities, and learn from each other advanced management models, so as to promote the resource integration of high-tech industries in the region, and continue to improve the platform for the integrated development in the Yangtze River Delta, so as to promote the coordinated development of the entire region.

5.2.3 Precise Development Strategy

In addition to financial enterprises at the national level, small and medium-sized financial services should also optimize the allocation of resources and promote their own expansion and strength by supporting the innovation of technology enterprises. Financial institutions enrich the types of financial products through precise financial innovation, so as to improve the level of financial services, reduce the risk of financial transactions, and ultimately improve financial returns. Financial enterprises should pursue stable development in the process of financial innovation and avoid the situation of turning from real to virtual. The financial industry should provide capital support and optimal allocation of resources for technological innovation, so that its innovation can develop stably rather than rootless.

Acknowledgment

Fund project: General project of National Social Science Foundation (19BGL269), special project of Shanghai Philosophy Society (2019CSJ003).

References

[1] Lin Rong, Ge Siyou. Analysis and Reflection on Efficiency, Benefit and Their Relationship[J]. Journal of Zhejiang University,1998(3),1(12):20-26.

[2] Ren Zexuan. Research on R&D Efficiency of Listed Construction Enterprises Based on DEA Malmquist[D]. Yangzhou University, 2022.

[3] LIBERATORE M. An extension of the analytic hierarchy process for industrial R&D project selection and resource allocation[J]. IEEE Translation on Engineering Management, 1987, 00(1):12-18.

[4] Wang Weiguang. Empirical Study on Technological Innovation in China's Industrial Industry[M]. Beijing: China Social Sciences Press, 2003.

[5] Hu Enhua, Liu Hong, Zhang Long. An Empirical Study on the Economic Effect of Science and Technology Investment in China[J]. Research Management, 2006,00(4): 71-75, 60.

[6] Yin Ziyi. Research on the Impact of the Scale of Science and Technology Innovation Investment and Technology Absorption Capacity on the Efficiency of Science and Technology Innovation in Nanjing City[J]. 2022, 39(22): 4-8.

[7] Liu Xinpeng, Xinhai Lu. Spatial synergy and trend prediction of technological innovation efficiency among the seven major urban agglomerations in the Yellow River Basin[J]. Urban Issues, 2022,00(07): 54-65.

[8] Jiang Lanling. Research on the Efficiency of Technological Innovation in Local Higher Education Institutions Based on DEA[J]. Science and Technology Wind, 2022,00(22): 1-5.

[9] Xu Jiahui, Erlin Fu. Research on the Efficiency of Science and Technology Innovation in China Based on the Network DEA Model[J]. Science and Technology and Economy, 2022, 35(03):101-105.

[10] Wang Haihua, Wang Ying, Li Yajie. Research on the Efficiency Evaluation of Technological Innovation in High tech Industries in the Yangtze River Delta Region: A Three Stage Network DEA Model Based on Shared Investment[J]. East China Economic Management, 2022, 36(08):26-33.

[11] Lee Pei-chut. Research on the Efficiency of Regional High tech Industry Innovation Process[J]. Studies in Science of Science, 2022,40(04):713-722.

[12] Wei Xushi . Research on Measuring the High Quality Development Level of Regional Science and Technology Finance[D]. Liaocheng University, 2020.

[13] Lin Yaopeng, Lin Liulin, Qi Gao. Research on the Evaluation of the Development Level of Regional Science and Technology Finance[J]. Journal of Technical Economics and Management, 2022,00(06): 70-75.

[14] Wang Wanqiu, Zeng Ying. An empirical study on the influencing factors of interprovincial financial development level[J]. Journal of Hubei University of Technology,2022,37(04):115-120.

[15] Zhang Xilin. Measurement of the Development Level of Science and Technology Finance in Shaanxi Province[J]. Modern Business, 2021,00(20): 83-85.

[16] Liu Zebin, L ü Hui, Yong jun. Research on Measuring the Development Level of Science and Technology Finance in Anhui Province[J]. Journal of Anhui University of Science and Technology (Social Science Edition),2022,24(02):33-40.

[17] Li Yong, Luo Lin, Li Yufeng. Analysis of the Coupling Coordination Degree between Transportation and Regional Economic Development Based on DEA Cross Efficiency[J]. Statistics and Decision, 2021, 37(22): 107-110.

[18] Arrow K J. The Economic Implications of Learning by Doing[J]. Review of Economic Studies, 1962, 29(3) : 63 -78.

[19] Acs Z, Plummer L A, Sutter R. Penetrating the knowledge filter in “rust belt” economies[J]. The Annals of Regional Science, 2009, 43: 989-1012.

[20] Zhou Xiaoyang, Zuo Guocun, Jincheng Zhou. Evaluation of High Quality Economic Development Level and Research on Obstacle Factors in the Yangtze River Economic Belt[J]. Journal of Hunan Institute of Technology (Natural Science Edition), 2022, 35(04): 61-66+80.

[21] Li Xingqi, Gao Xiaohong. Evaluation of the effectiveness of dimensionless methods[J]. Statistics and Decision,2021,37(15):24-28.