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Research article

Analysis on Efficiency and Influencing Factors of Guangxi technology and finance Based on DEA Model

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Statement:

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ABSTRACT

With the global economy increasingly relying on scientific and technological innovation, technology and finance's efficiency has become a key factor to enhance regional competitiveness.As an important province in western China, Guangxi faces both opportunities and challenges in its technology and finance development.Based on the data envelopment analysis (DEA) model, this paper makes an empirical measurement and evaluation on the efficiency of technology and finance, Guangxi, and deeply explores its influencing factors. In the specific research, this paper first constructs an efficiency evaluation system of technology and finance, which includes input and output indicators, and makes an empirical analysis of technology and

finance's efficiency by using CCR and BCC DEA models.Through data collection and arrangement, we have made a comprehensive description of the input-output status of technology and finance, Guangxi, and made a scientific evaluation of the efficiency by using an empirical model.It is found that the efficiency of technology and finance shows a certain trend of improvement, but there are still obvious regional differences and deficiencies.Specifically, the efficiency of technology and finance in some areas or fields is high, while that in others is low.In addition, this paper also reveals the key factors affecting the efficiency of technology and finance, which provides a theoretical basis for improving the efficiency. Based on the empirical results, this paper puts forward some countermeasures and suggestions to improve the efficiency of technology and finance.Including strengthening the construction of scientific and technological innovation system, establishing the core position of scientific and technological enterprises and optimizing the business environment in Guangxi.These suggestions are aimed at providing practical guidance for policy makers to promote the healthy development of technology and finance.Generally speaking, through the empirical analysis based on DEA model, this paper makes a comprehensive evaluation of the efficiency of technology and finance, Guangxi, and puts forward some targeted countermeasures and suggestions.

Keywords: Technology and finance; Financial efficiency; DEA model

Introduction

In the 21st century with the rapid development of science and technology, scientific and technological innovation has become the core driving force to promote the national economic growth and social progress. General Secretary Xi Jinping has emphasized the importance of scientific and technological innovation in many speeches, and the Opinions on Accelerating the Implementation of the Innovation-driven Development Strategy clearly stated that we should adhere to scientific and technological innovation as the center and take it as the core position of national development, thus further providing the direction for China's scientific and technological innovation. At present, under the wave of global economic integration and scientific and technological revolution, science and technology finance, as an important bridge for the combination of scientific and technological innovation and financial capital, has had a profound impact on the optimization of China's industrial structure, the transformation of economic growth mode and the coordinated development of regional economy.

Guangxi is a big province in southwest China, with unique resource endowment and location conditions. However, its development in science and technology finance is relatively backward, mainly manifested in the lack of capital and the lack of technological innovation ability. During his inspection visit to Guangxi, General Secretary Xi Jinping pointed out that we should accelerate the high-quality development of Guangxi and strive to write a new chapter of the beautiful Guangxi socialism with Chinese characteristics, which is of basic guiding significance to the development of Guangxi. Therefore, it is of great significance to improve the efficiency of Guangxi's science and technology finance, promote the deep integration of science and technology and finance, and promote the comprehensive development of Guangxi's economy and society.

This project aims to quantify the efficiency of science and technology finance in Guangxi based on the data envelope analysis (hereinafter referred to as DEA) model, and deeply analyze the influencing factors. Through systematic data analysis and

empirical research, it provides scientific theoretical basis and practical guidance for the healthy development of scientific and technological finance in Guangxi, in order to promote the deep integration of scientific and technological innovation and financial services in Guangxi, and inject new vitality into the economic and social development of Guangxi. This research can not only help to enrich and improve the theoretical system of science and technology finance, but also provide useful reference for the practice of science and technology finance in Guangxi and even the whole country.

Study content and methods

The core goal of this paper is to deeply explore the efficiency level of science and technology finance in Guangxi Zhuang Autonomous Region and the influencing factors behind it, and to put forward a series of policy suggestions accordingly. First, in the opening part, the background and importance of the research will be comprehensively expounded, and the core content and methods used of the research will be clarified. At the same time, the basic concepts and measurement methods of the efficiency of science and technology finance are systematically combed and discussed. Then, from the two dimensions of input and output of technology and finance, the current development situation of technology and finance is analyzed in detail. Through data collection and analysis, we strive to comprehensively and accurately grasp the status quo and characteristics of science and technology finance in this region. In order to more accurately evaluate the efficiency level of science and technology finance in Guangxi Province, the data envelope analysis (DEA) model is used to reveal the actual efficiency of the combination of science and technology and finance in this region through scientific data processing and model analysis. Finally, according to the previous analysis results, a series of specific policy suggestions will be put forward from the three levels of the government, enterprises and the financial market. These suggestions aim to promote the healthy development of science and technology finance in Guangxi Zhuang Autonomous Region, improve the efficiency

level of science and technology finance, and then promote the sustainable development of regional economy.

Specifically, the research in this paper will focus on the following main parts:

(1) It summarizes the research background, significance, research content, research methods, and the basic concepts related to the efficiency of technology and finance, and summarizes its measurement methods.

(2) The development status of science and technology finance in Guangxi Zhuang Autonomous Region is comprehensively studied from the two aspects of input and output.

(3) The DEA model was applied to quantitatively evaluate the efficiency of technology and finance in Guangxi Zhuang Autonomous Region.

(4) Using the DEA analysis method, the main influencing factors of the efficiency of science and technology finance in Guangxi are deeply analyzed.

(5) Combined with empirical analysis, to provide targeted policy suggestions for improving the efficiency of science and technology finance in Guangxi and promoting the sustainable development of regional economy.

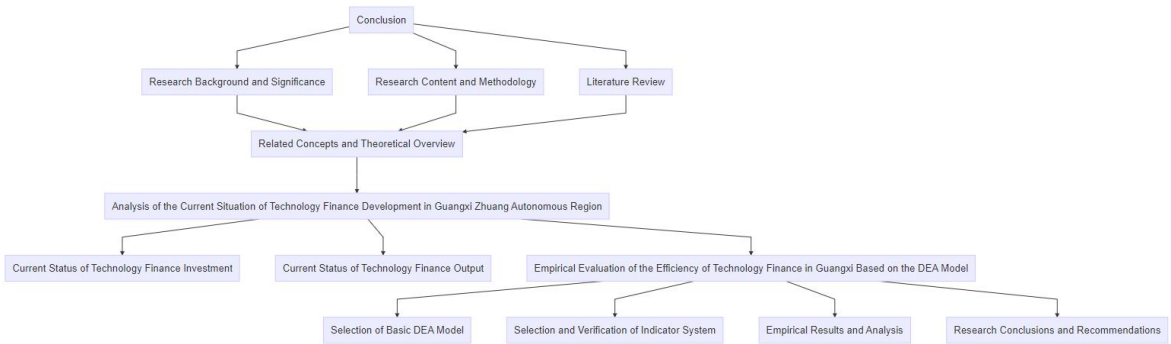


Figure 1-1 Technical Roadmap

2. Research methods

(1) Literature research

After extensive and in-depth literature sorting and integration in the field of science and technology finance at home and abroad, this paper constructs three core parts: literature review, core concept interpretation and theoretical framework of science and technology finance. First, in the literature review section, the research trends and main achievements in the field of science, technology and finance at home and abroad are systematically reviewed, providing readers with a comprehensive research background and reference. Then, in the core concept interpretation section, the key concepts involved in this paper are accurately defined, which lays a foundation for the subsequent in-depth analysis. Finally, in the theoretical framework part of science and technology finance, the theoretical support system of this research is constructed, which provides a solid theoretical basis and logical support for the whole research.

(2) Statistical analysis method

Based on the analysis of the efficiency of science and technology finance in Guangxi, by collecting and sorting out the input and output index data of science and technology finance in Anhui Province, the development status of science and technology finance in Guangxi is statistically analyzed and formed a clear display, so as to provide the data basis for the subsequent calculation and analysis of the efficiency of science and technology finance in this paper.

(3) Data analysis method

This paper through the Guangxi zhuang autonomous region in 2015-2023 technology financial input and output index data, and using the DEA analysis of Guangxi zhuang autonomous science and technology financial input and output index data system measurement analysis, to explore the effectiveness of the Guangxi zhuang autonomous region, science and technology financial, and evaluate the financial efficiency of Guangxi science and technology, and analyze the existing factors.

Literature review

Research on the efficiency of technology and finance

In 1957, Farrell first adopted the non-parametric method to measure the evaluation efficiency, and systematically measured it through econometric analysis[1]. As soon as this systematic model was introduced, there were many professional efficiency assessment methods, including the SFA method, mainly through the use of econometrics to further evaluate the production or cost frontier, plus the DEA method. With the passage of time, the DEA method will be widely used in various efficiency assessment categories. For example, Filipa Da Silva Fernandes (2018) evaluated the efficiency of European domestic banks using a two-stage DEA-truncated regression model and measured the impact of bank risk determinants on their 2007-2014 performance. Using data calculation analysis on the malquist productivity index of bank efficiency scores, and examine the efficiency level of bank with different changes in changing financial conditions, empirical results show that liquidity and credit risk negative effect, capital and profit risk has a positive effect, and when the financial development level is low, the bank risk variables become hidden dangers on the road of economic development[2]. Julian Atanassov (2021) explores the efficiency of science and technology finance from 2009 to 2020, and analyzed the influencing factors such as the proportion of total output value of high-tech industry in GDP, the number of venture capital enterprises in various regions and the attraction of investment funds by venture capital enterprises, and finally concluded that these factors promote the efficiency of science and technology finance[3].

Jiang Chong and Yan Xiaoxu (2019) selected 2005-2019 technology and financial input and output data as the index value, for China's 30 provinces (autonomous regions and municipalities directly under the central government) (except Tibet) using the data envelope analysis for efficiency evaluation, obtain the financial efficiency of each province, and the country is divided into eastern, central, western, through quantitative research for financial efficiency in each parts of the region of the mean,

the results of science and technology in the financial development imbalance, etc[4]. Zhang Weiqiang et al. (2023) used DEA method to consider the integration efficiency of science and technology finance in Henan Province, and used time series data to calculate. The results show that the efficiency of science and technology finance in Henan province is not good[5].

Research on the influencing factors of fintech

Jeong (2019) revealed the impact of financial deepening on the total factor growth rate of Thailand through the establishment of the transition growth model of micro data. Benfratello (2019) Using the data of a large number of Italian companies, it examined the impact of bank development on corporate performance and innovation behavior, and revealed the impact of banks on high-tech companies and companies dependent on external financing[7]. Martinsson (2021) Taking British and European high-tech enterprises as samples, using dynamic R & D regression model research, found that the internal and external ownership structure of enterprises have an obvious impact on research and development activities, and the effect of the market financial system is better than that of the banking financial system[8].

In the aspect of government behavior, Wuyiquan (2022) collected the cross-section data of the five provinces of the Yangtze River Economic Belt, measured and analyzed the DEA-Tobit two-step analysis method to analyze the efficiency of science and technology and finance in China, and concluded that the government increased financial investment will lead to the decline of the efficiency of science and technology and finance[9]. In the financial market, Zeng Shuai (2022) collected the cross-section data of 30 provinces and cities, measured them by using DEA method, and analyzed the various influencing factors by using Tobit regression. The results show that the proportion of the annual loan balance of local financial institutions in the local GDP has an obvious positive relationship with the efficiency of technology and finance[10]..For human capital, Wang Heng (2019) used the three-stage DEA model to conduct empirical analysis of the cross-sectional data of various provinces and autonomous regions in Hubei, and concluded that the quality of labor force represented by the number of students is the key factor to improve the efficiency of technology and finance in China[11].

To sum up, foreign literature focuses on the efficiency problem under the

background of financial system, while domestic research focuses more on the empirical analysis of the operation efficiency of financial system. Despite the improvement of the efficiency of technology and finance, the widely recognized measures and evidence are still insufficient. In particular, the efficiency of science and technology finance in the autonomous region such as Guangxi lacks specific quantitative evaluation and in-depth actual state analysis. Therefore, this study aims to build a reasonable efficiency evaluation system of technology and finance, and empirically evaluate the efficiency level of Guangxi region, so as to establish its role in promoting the sustainable development of regional economy. In terms of research methods, this paper adopts the DEA model to overcome the limitations of the traditional efficiency evaluation method and provide an accurate measure for the efficiency of science and technology finance in Guangxi.

The innovation point of this paper is mainly reflected in the following two aspects.

One is the innovation of the research perspective. From the novel perspective of establishing the core position of science and technology enterprises, this paper deeply analyzes the countermeasures to improve the efficiency of science and technology finance in Guangxi. Previous studies have mostly focused on the macro level of science and technology finance policy and capital investment, while this paper focuses on the micro subject of science and technology enterprises. By discussing the core role of science and technology enterprises in the science and technology finance system, it provides new ideas and methods for improving the efficiency of science and technology finance.

Second, the innovation of research methods. This paper uses data envelope analysis (DEA) model to evaluate the efficiency of technology and finance in Guangxi. This method can not only comprehensively consider multiple input-output indicators, but also can effectively deal with the multi-objective decision-making problem, making the evaluation results more objective and scientific. In addition, this paper also combines CCR, model and BCC model to conduct a multi-angle and multi-level in-depth analysis of the efficiency of Guangxi science and technology finance, which further enhances the depth and breadth of research.

Analysis of the development status of science and technology finance in Guangxi Zhuang Autonomous Region

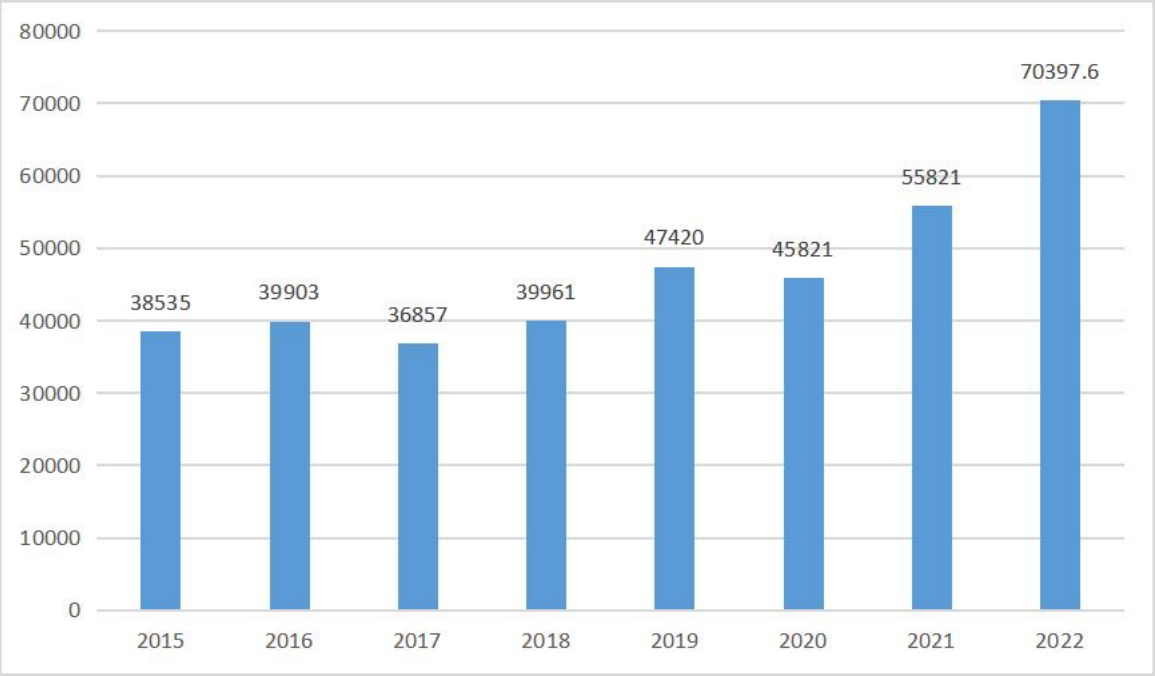
In recent years, thanks to the effective implementation and promotion of a series of policies at the national and autonomous region levels, Guangxi has made

significant progress in the field of science, technology and finance. Given that the specific data for 2023 have not been published, this paper chooses to review and analyze the development of technology and finance in Guangxi Zhuang Autonomous Region between 2015 and 2022. By selecting three key input indicators and three corresponding output indicators, a preliminary cognition of the current situation of the development of science, technology and finance in Guangxi can be constructed. This analysis not only helps to have a more comprehensive understanding of the current situation of the science and technology finance in Guangxi, but also lays a solid foundation for the subsequent in-depth discussion of its efficiency measure and influencing factors analysis.

Current situation of science and technology and finance investment

Research and Experimental Development (R & D) personnel equivalent time

The data collected in this study were obtained from Guangxi Statistical Yearbook 2015-2023, reflecting the details of the full-time equivalent of R & D personnel. The specific equivalent data on research and trial development (R & D) personnel are shown in Figure 3-1 below.



[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-1 Research and Experimental Development of Personnel (R & D) in Guangxi Zhuang

Autonomous Region (unit: person)

From the general trend, from 2015 to 2022, the number of R & D personnel in Guangxi Zhuang Autonomous Region has shown a distinct growth trajectory, rising from 38,535 in 2015 to 70,397.6 in 2022, with an annual growth rate of nearly 83%. This remarkable increase not only reflects Guangxi's increasing attention to scientific and technological research and development, but also highlights the continuous investment in scientific and technological innovation in human resources.

However, a thorough analysis of the data found that between 2015 and 2017, R & D personnel declined briefly, from 38,535 to 36,857 person-years. This change is not accidental, but is closely linked with the macroeconomic strategy of promoting the transformation and upgrading of traditional industries in Guangxi at that time. At this stage, Guangxi focused on the optimization and upgrading of traditional industries, so the demand for research and innovation was reduced to a large extent, leading to the adjustment of the investment of R & D personnel. However, this adjustment is temporary and also reflects the flexible adjustment of resource allocation in the process of economic development in Guangxi.

Since 2017, with the gradual emergence of the transformation and upgrading of traditional industries, the growth trend of R & D personnel in Guangxi has recovered in full-time equivalent, and the growth rate has gradually accelerated. In particular, from 2020 to 2022, the growth rate is significant, which fully shows that Guangxi has deeply realized the key role of scientific and technological innovation in promoting regional economic development, and therefore increased the investment in R & D.

Compared with other regions in the same period, R & D human resource investment in Guangxi increased relatively fast, which to some extent shows Guangxi's aggressive attitude in the field of scientific and technological innovation and its unremitting efforts in building a scientific and technological innovation system. This growth trend will not only help Guangxi to accumulate advantages in scientific and

technological talents, but also lay a solid foundation for its breakthroughs in the field of scientific and technological innovation in the future.

In general, the R & D personnel investment in Guangxi Zhuang Autonomous Region showed a steady and positive growth trend, especially in recent years, the growth momentum has been stronger. This not only provides a strong human resource guarantee for Guangxi's scientific and technological innovation, but also provides a solid data support for the subsequent formulation of relevant policies. In the future, Guangxi should continue to increase its investment in R & D and constantly optimize the environment for scientific and technological innovation, so as to promote scientific and technological innovation to become the core driving force leading regional economic development.

Internal expenditure of research and trial development (R & D) funds

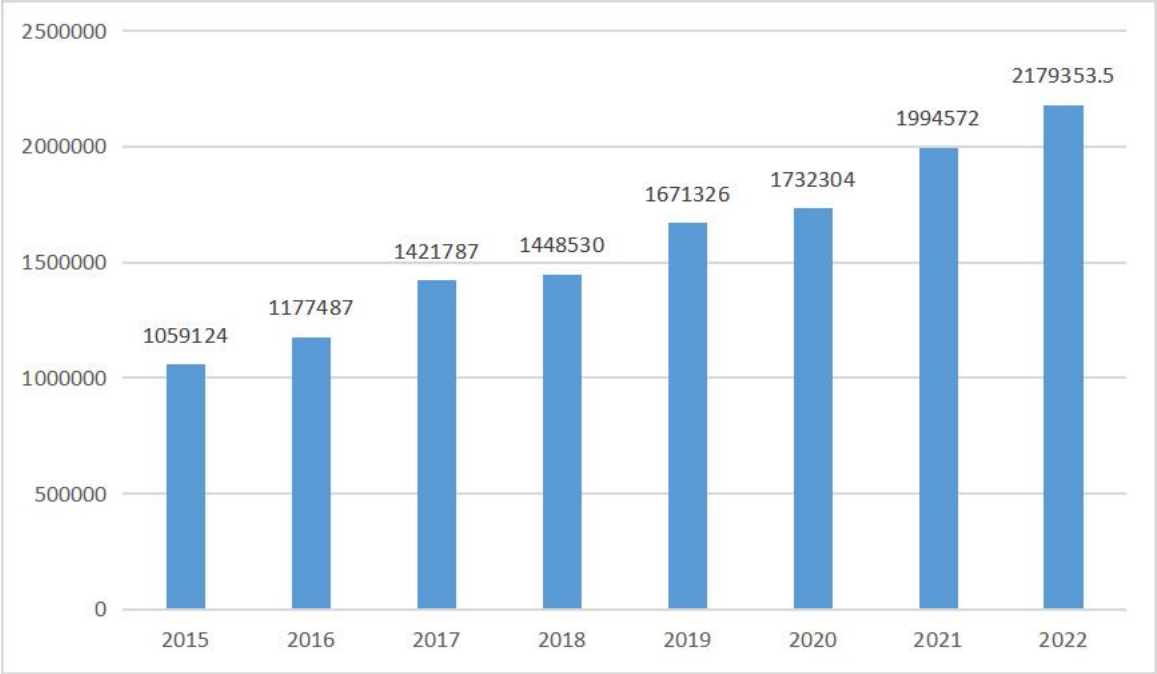
Due to the inherent high risk and high investment characteristics, the high-tech industry is particularly sensitive to the investment demand of science and technology funds, which is directly related to the healthy development and continuous innovation of the industry. As an important indicator to measure the intensity of research and experimental development (R & D) in science and technology investment, the internal expenditure of Guangxi has shown a remarkable growth trend in recent years.

From the overall trend, the internal expenditure of R & D funds in Guangxi shows a strong momentum of increasing year by year, with the average annual growth rate basically maintained at more than 10%. The continuation of this growth trend fully demonstrates the long-term commitment and firm support of the Guangxi government to R & D, and reflects its strategic vision and determination in promoting scientific and technological innovation and the development of high-tech industries.

However, in 2018, the growth rate of R & D funds in Guangxi slowed down. To a large extent, this is closely related to the special economic policy adjustment, the fluctuation of macroeconomic environment and the change of domestic and foreign trade situation. Nevertheless, Guangxi's investment in the R & D field did not show

negative growth, but still maintained a positive growth trend, showing its stability and resilience in the investment in scientific and technological innovation.

According to the comprehensive data, Guangxi's investment in research and experimental development (R & D) continues to increase. Although the growth rate has slowed down under the influence of specific factors in some years, the overall trend is still stable.



[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-2 Internal expenditure of Research and Experimental Development (R & D) in Guangxi Zhuang Autonomous Region (Unit: ten thousand yuan)

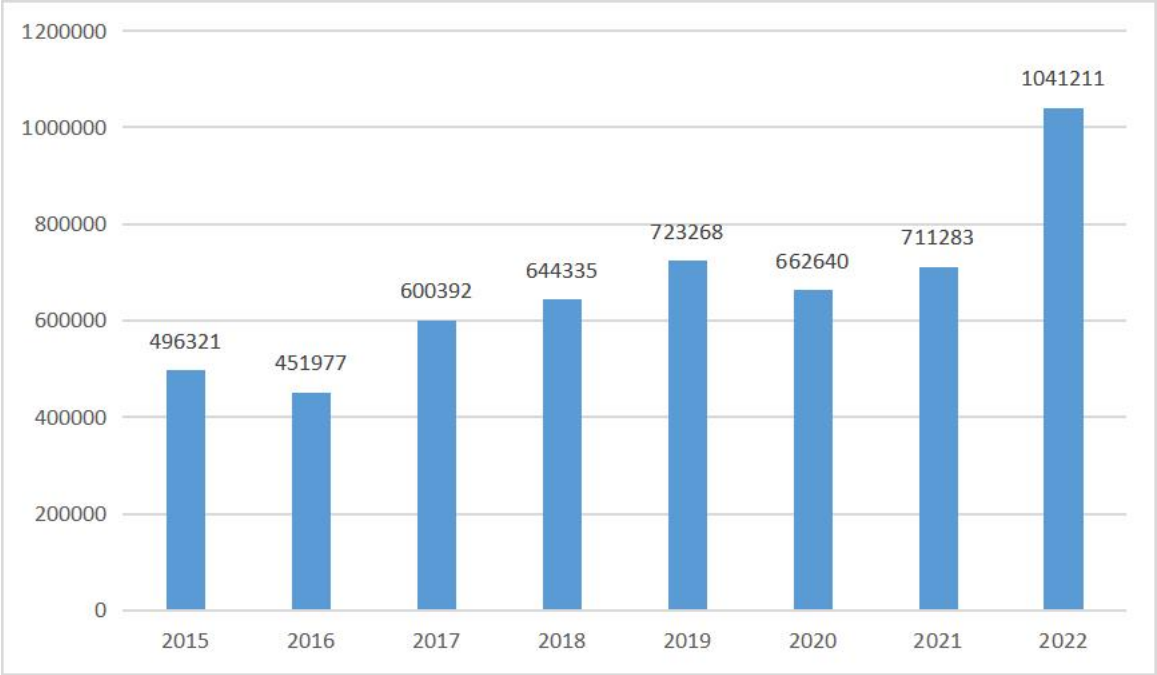
Fiscal expenditure on science and technology

In view of the characteristics of long research and development cycle, high technology threshold and high market uncertainty, it is often difficult to meet their capital needs by relying solely on market forces and the self-development of enterprises. Therefore, the government's financial support plays a key role in the development of high-tech industry. Guangxi's attitude towards financial science and

technology expenditure in recent years fully reflects its strategic vision and determination in promoting the development of high-tech industry.

From 2015 to 2022, Guangxi's fiscal expenditure on science and technology showed an overall upward trend. Specifically, the amount of expenditure steadily increased from 4,96,3.21 million yuan in 2015 to 10,0412.11 million yuan in 2022, which more than doubled. This change clearly shows that Guangxi attaches great importance to and firmly invests in the development of science and technology.

In terms of annual change, some change trends were also observed from the data in the figure below. In 2016, there was a slight decline in fiscal expenditure on science and technology, which may be due to the economic adjustment policy of the year, which led the government adjusting the allocation of fiscal expenditure in the short term. Since 2017, with the implementation of Guangxi's greater scientific and technological innovation strategy, the fiscal expenditure on science and technology has risen rapidly again, which reflects the government's firm support for scientific and technological innovation. In particular, from 2017 to 2018 and from 2019 to 2022, fiscal spending on science and technology increased particularly significantly, highlighting Guangxi's determination to promote scientific and technological innovation and development. Although there was a certain degree of decline in 2020 compared with 2019, the growth momentum then resumed in 2021 and 2022, and the growth rate in 2022 was particularly prominent, which may be related to Guangxi's continuous investment and policy guidance in the field of scientific and technological innovation. This continuous trend of financial investment not only confirms the long-term commitment of the Guangxi government to the field of science and technology, but also lays a solid foundation for the future scientific and technological innovation and industrial upgrading.



[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-3 Financial science and technology expenditure of Guangxi Zhuang Autonomous Region (Unit: ten thousand Yuan)

The status quo of technology and financial output

Number of invention patent application granted

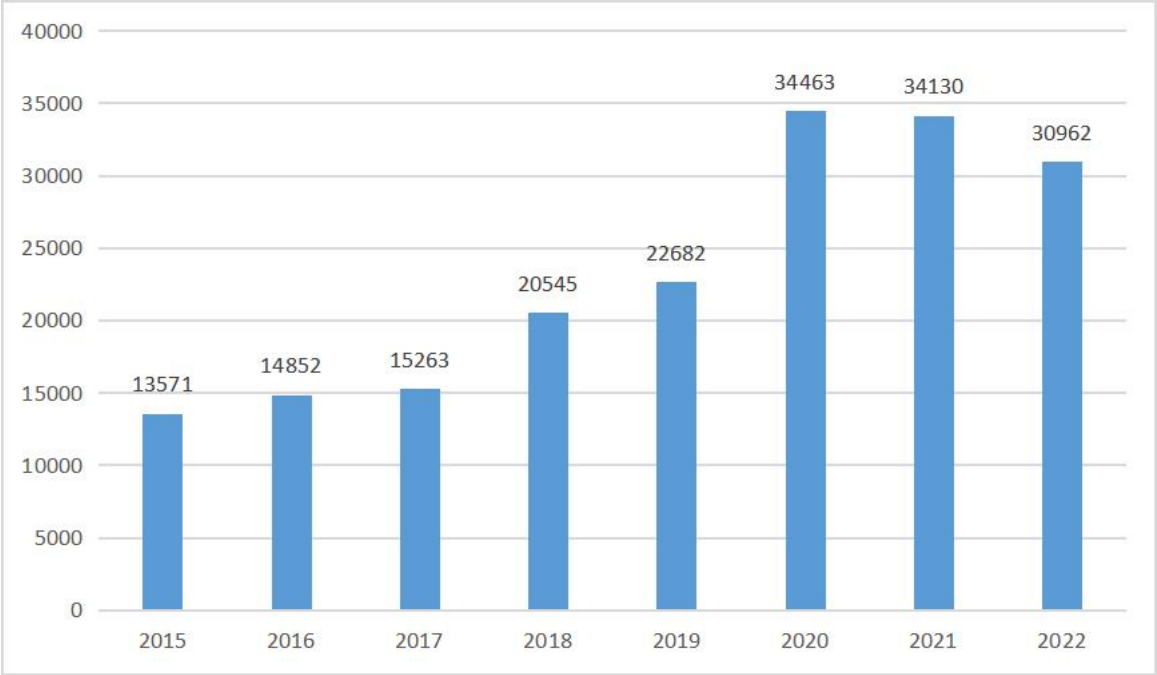
Compared with other patent types, invention patent, as an important indicator to measure independent innovation ability and technology accumulation, plays a core role in the evaluation of regional technology and financial output. This paper selects the authorization data of invention patent as the analysis object, aiming to reflect the performance of Guangxi Zhuang Autonomous Region in the output of technology and finance.

According to the data shown in Figure 3-4, the number of invention patent applications granted in Guangxi Zhuang Autonomous Region has shown a rapid growth trend in the past eight years. In particular, the number increased from 13,517 in 2015 to 30,962 in 2022, accounting for about 129%. This significant increase is

mainly due to Guangxi's strong encouragement of scientific and technological innovation and the increasing strengthening of intellectual property rights protection. Among the participants in the economic society, enterprises, as the main force of innovation, have greatly enhanced their importance to the patent invention. Especially in the high-tech industry, such as electronic information, biomedicine and other fields, it has become the main driving force of the growth of invention patents.

However, despite the overall trend, the number of invention patents granted in Guangxi showed a decline in 2021 and 2022. Further investigation has also revealed that the specific reasons for this situation include the changes in the domestic and foreign economic environment, the fluctuations of market demand, and the cyclical adjustments encountered by enterprises in the process of research and development. In addition, the policy adjustment may also have a certain impact on the application and authorization of invention patents.

Through the data analysis results, it not only confirms the policy effect of Guangxi in strengthening scientific and technological innovation and intellectual property protection, but also reveals the multi-dimensional factors to be considered to further enhance Guangxi's scientific and technological innovation ability and stimulate the innovation vitality of enterprise subjects. Future research can further explore how to optimize science and technology financial services and promote the construction of regional innovation ecosystem, so as to promote the more comprehensive and sustainable development in the field of science and technology finance in Guangxi.



[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-4 Number of invention patent applications granted in Guangxi Zhuang Autonomous Region (unit: piece)

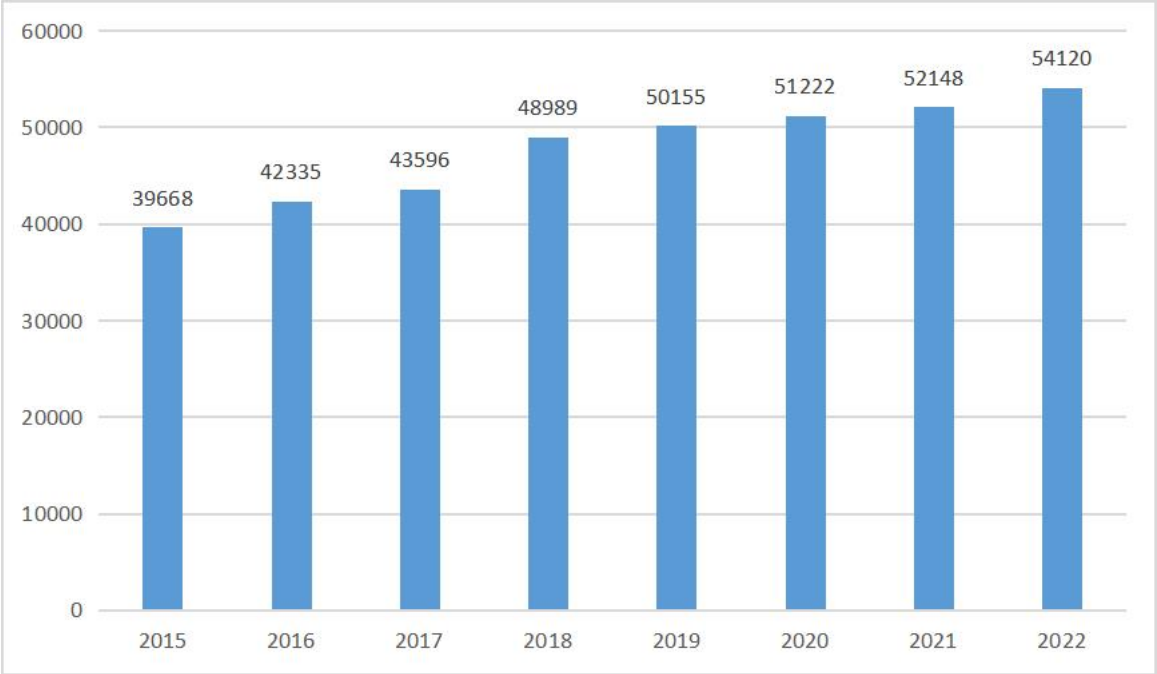
Number of published scientific papers published

Scientific and technological papers not only show the research ability and scientific achievements of the region, but also reflect the support degree and maturity of the regional scientific and technological financial environment, and are an important indicator to evaluate their scientific and technological financial output and the ecological quality of scientific research.

Combined with the data statistics in Figure 3-5 below, the publication trend of scientific and technological papers in Guangxi shows a steady growth year by year. From 39,668 in 2015 to 54,120 in 2022, an increase of 36.43%, with an average annual growth rate of about 8%.

Through the growth trend of the number of scientific and technological papers published in Guangxi, we can see the positive trend of Guangxi Zhuang Autonomous

Region in the output of science and technology finance and scientific research activities. This remarkable growth not only highlights the efforts and strength of the Guangxi's research team, but also highlights the region's continued investment and deep development in the research field.



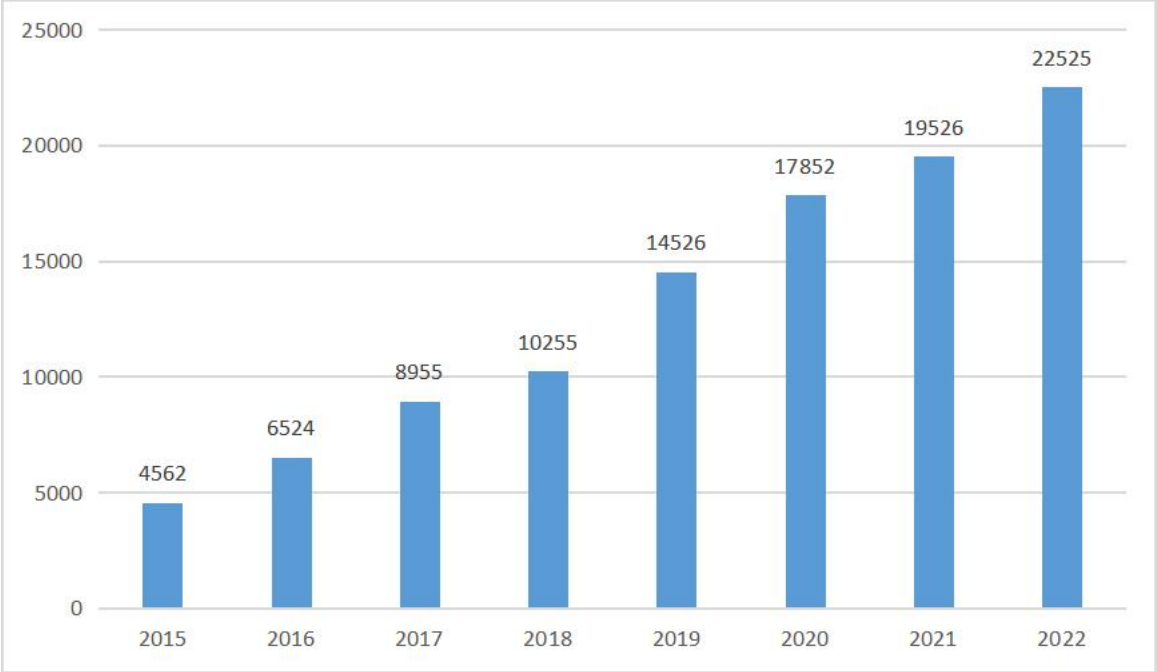
[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-5 Number of scientific and technological papers published in Guangxi Zhuang Autonomous Region (unit: part)

Total output value of high-tech industries above designated size

Science and technology finance refers to the financial activities led by science and technology, aiming to promote the development of high-tech industries through financial support and innovation. By providing necessary financial support for high-tech enterprises, it accelerates technological innovation and product research and development, and is the key driving force to promote the development of high-tech industry.

Combined with Figure 3-6, the overall output value of high-tech industries above the scale in Guangxi Zhuang Autonomous Region shows a trend of rapid increase year by year. From 456.2 billion yuan in 2015 to 2252.5 billion yuan in 2022, this significant growth not only reflects the strong development momentum of the high-tech industry itself, but also the direct result of the Guangxi government's continuous increase in science and technology financial policies and optimize the innovation ecological environment. During this period, the increased policy support, the continuous growth of market demand and the continuous improvement of scientific and technological innovation ability have jointly promoted the rapid development of high-tech industry.



[Data source] According to the relevant data of Guangxi Statistical Yearbook in 2015-2023.

Figure 3-6 Total Output value of high-tech industries above designated size in Guangxi Zhuang Autonomous Region (unit: 100 million Yuan)

At the same time, the growth rate of the output value of high-tech industry exceeds the GDP growth rate of Guangxi in the same period, which not only shows that the proportion of high-tech industry in the overall economic structure of Guangxi is increasing year by year, but also marks that the industry is becoming a new engine

driving the regional economic growth. High-tech industry, with its high added value, high technology content and strong driving characteristics, is of great significance to promoting the regional economic transformation and upgrading, and injects new impetus into the sustainable development of Guangxi.

Combined with the research, the rapid development of high-tech industry in Guangxi highlights the key role of science and technology finance in promoting industrial upgrading and innovative development. In order to further promote the sustainable and healthy development of high-tech industries, it is suggested that policy makers should continue to increase their support for science and technology finance, optimize the investment and financing environment, and reduce the financing threshold and cost of enterprises. At the same time, we will encourage new and high-tech enterprises to increase investment in research and development, foster more achievements in scientific and technological innovation, and promote the development of new and high-tech industries to a higher level and in a wider range of areas.

Empirical calculation and evaluation of Guangxi efficiency of technology and finance based on DEA model

DEA, basic model selection

Basic principle of the DEA model

DEA model (Data Envelopment Analysis, data envelope analysis) is a non-parametric efficiency evaluation method. It is based on linear planning theory, and evaluates the relative efficiency of comparable similar units by constructing multi-input and multi-output evaluation models.

(1) Basic principles

DEA is a boundary assessment method designed to measure the relative efficiency of decision units (DMUs) in multi-input and multi-output contexts. Since the first introduction of Charnes, Cooper and Rhodes in 1978, DEA has been widely used in

efficiency evaluation research in many fields, including finance, healthcare, education and manufacturing. DEA provides a scientific and effective framework for evaluating and comparing the relative efficiency of decision units under multi-input and multi-output conditions. This not only helps to identify and quantify the lack of efficiency, but also provides a powerful analytical tool and decision support to improve the overall operational efficiency[19].

One of the key features of the DEA model is its ability to handle multiple inputs and outputs. In the real production and service process, enterprises or organizations often need to invest a variety of resources (such as capital, manpower, materials, etc.) to produce a variety of products or services. DEA provides a comprehensive reflection of production efficiency by incorporating multiple input and output data.

The core of the DEA approach is to assess the relative efficiency of the DMUs. This is done by comparing the actual input and output of each DMU with the built production possibility boundary (i. e., the efficiency front). DMU at the efficiency front are considered the efficiency optimal with an efficiency value of 1 or 100%, while those DMU inside the efficiency front have the potential to improve efficiency[20].

DEA belongs to the category of non-parametric methods, whose advantage is that it does not need to preset the specific functional relationship between input and output. This feature gives DEA great flexibility and wide applicability, allowing it to be applied in different economic activities and organizational structures.

(2) Formula

Taking the BCC model as an example, the basic formula is as follows

Assuming that there are n decision units, combined with the data indicators selected in this paper, each decision unit uses 3 inputs to produce 3 outputs. For the j-th decision unit (DMU j), the input and output vectors are expressed as: DMU_j

$$x_j = (x_{1j},\ x_{2j},\ x_{3j})^T \quad (4\text{-}1)$$

$$y_j = (y_{1j},\ y_{2j},\ y_{3j})^t \quad (4\text{-}2)$$

x_{1j} Among them, the input vector represents the equivalent of the research and experimental development (R & D) personnel in the j-th decision unit, represents the research and experimental development (R & D) funds, and represents the financial expenditure of science and technology. $x_{2j}x_{3j}$

y_{1j} The output vector represents the number of invention patent applications granted in the j th decision unit, the number of published scientific and technological papers is represented, and the total output value of high-tech industries above the designated scale. $y_{2j}y_{3j}$

DMU_j For each, an efficiency assessment index was defined as

$$\theta_B = max\left\{\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum^{m} u_i x_{ij}}\right\} \quad (4\text{-}3)$$

The optimal solution of the C model can be obtained by solving the following linear programming problem

$$max\theta_B \quad (4\text{-}4)$$

$$s.t.\sum_{j=1}^{n}\lambda_j x_{ij} \le \theta_B x_{ij}, i = 1, ..., m \quad (4\text{-}5)$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} \ge \theta_B y_{rj}, r = 1, ..., s \quad (4\text{-}6)$$

$$\sum_{j=1}^{n}\lambda_j = 1 \quad (4\text{-}7)$$

$$\lambda_j \ge 0, j = 1, ..., n$$

λ_j Where it is the weighted coefficient of the decision unit j.

BCC The model introduces relaxation variables (slack variables) to consider the redundancy of input and outputs to distinguish between effective DMU and weak effective DMU. If a DMU is 1 under the BCC model, the DMU is considered technically effective; if the efficiency value is less than 1, there is room for improvement.

Take the CCR model as an example: its basic formula is similar to BCC, whose core difference lies in the different assumptions of scale remuneration. The specific formula is as follows:

Assuming that there are n decision units, combined with the data indicators selected in this paper, each decision unit uses 3 inputs to produce 3 outputs. For the j-th decision unit (DMU j), the input and output vectors are expressed as:

$$x_j = (x_{1j},\ x_{2j},\ x_{3j})^T \quad (4\text{-}8)$$

$$y_j = (y_{1j},\ y_{2j},\ y_{3j})^T \quad (4\text{-}9)$$

x_{1j} Among them, the input vector represents the equivalent of the research and experimental development (R & D) personnel in the j-th decision unit, represents the research and experimental development (R & D) funds, and represents the financial expenditure of science and technology. $x_{2j}x_{3j}$

y_{1j} The output vector represents the number of invention patent applications granted in the j th decision unit, the number of published scientific and technological papers is represented, and the total output value of high-tech industries above the designated scale. $y_{2j}y_{3j}$

The optimal solution of the CCR model can be obtained by solving the following linear programming problem

$$max\theta_C \quad (4\text{-}10)$$

$$s.t.\sum_{j=1}^{n}\lambda_j x_{ij} \leq \theta_C x_{ij}, i = 1, ..., m \quad (4\text{-}11)$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} \geq \theta_C y_{rj}, r = 1, ..., s \quad (4\text{-}12)$$

$$\sum_{j=1}^{n}\lambda_j = 1 \quad (4\text{-}13)$$

$$\lambda_j \geq 0, j = 1, ..., n$$

λ_jWhere it is the weighted coefficient of the decision unit j.

The CCR model assumes that all DMUs operate at the optimal scale, where the return of scale is constant. This means that the CCR model cannot distinguish between technical efficiency and scale efficiency. Therefore, if a DMU has an efficiency evaluation value of 1 under the CCR model, the DMU is considered overall effective, i. e. both technically effective and scale effective; if the efficiency evaluation value is less than 1, the DMU is not efficient in technology or scale[21].

CCR model

The CCR model, also known as the Charnes-Cooper-Rhodes model, is A cornerstone model in the field of data envelope analysis (DEA), by A.Charnes、W.W. Cooper and E. R hodes Raised jointly in 1978. This model is mainly used to measure and compare the relative performance between similar departments or units, especially in the evaluation of technical efficiency.

The core of CCR model is to find the best weight configuration for each decision unit (Decision Making Unit, DMU). The underlying assumption is that all DMUs can theoretically achieve the highest efficiency, that is, an ideal state with an efficiency

value of 1. In addition, the CCR model also assumes that there is invariance of remuneration of scale, which means that all production combinations can keep their efficiency proportional to scale up or out.

In model applications, input and output indicators are combined into different linear relationships through linear programming techniques, and the efficiency of DMU is assessed by the ratio between these combinations. Since the CCR model is based on the assumption of invariant value of scale remuneration, its evaluation results not only reflect pure technical efficiency, but also include the effect of scale efficiency, which is often referred to as integrated technical efficiency.

The efficiency values calculated by the CCR model range from 0 to 1, where "1" indicates that the DMU reaches the optimal state of technical efficiency, while "non-1" indicates that the technical efficiency is not yet optimal. The closer the efficiency value is to 1, the higher the technical efficiency of the DMU is[22].

BCC model

BCC Model, also known as Banker-Charnes-Cooper model, is an important model in the field of data envelope analysis (DEA), composed by A.Charnes、 W.W. Cooper and R.D. Banker Co-proposed in 1984. Unlike the previous CCR models, the BCC model introduces a key assumption in assessing the efficiency of the decision unit (DMU) that the DMUs may be in a variable reward of scale (VRS) state, which means that not all DMUs can operate at their optimal scale.

In the efficiency evaluation framework of the BCC model, it is not only limited to the consideration of pure technical efficiency, but also covers the important dimension of scale efficiency. Pure technical efficiency is focused on the ability of DMU to achieve maximum output with a given input, while scale efficiency focuses on assessing whether DMU reaches the optimal scale in the production process. Through the BCC model, the comprehensive technical efficiency can be further subdivided into the product of pure technical efficiency and scale efficiency. This decomposition provides

a more detailed and in-depth efficiency analysis perspective, enabling a more comprehensive understanding of the efficiency performance of DMU.

Selection and inspection of the index system

Test of index correlation

This paper uses SPSS26.0 software to do the correlation analysis of each index. For convenience, index correlation selection for Y1 invention patent application authorization, Y2 published papers, Y3 for high-tech industry output, X1 for research and experimental development (R & D) personnel into full equivalent, X2 for research and experimental development (R & D) funds internal spending, X3 for fiscal spending on science and technology[23].

Table 4-1 Correlation analysis of each indicator

	average value	standard deviation	Y1	Y2	Y3	X1	X2	X3
Y1	23308.500	8776.548	1					
Y2	47779.125	5226.076	0.897**	1				
Y3	13090.625	6504.445	0.935**	0.952**	1			
X1	46839.450	11345.670	0.724*	0.783*	0.877**	1		
X2	1585560.438	385084.109	0.880**	0.942**	0.986**	0.894**	1	
X3	666428.375	179480.950	0.866**	0.836**	0.867**	0.911**	0.901**	1

[Note] * p <0.05 * *, p <0.01.

From the above tabular data, a correlation analysis was used to explore the association between Y1, Y2 and Y3 and X1, X2 and X3. To quantify the strength of this correlation, the Pearson correlation coefficient was chosen as a measure. After detailed analysis, significant associations were observed, with specific correlation coefficients of 0.897,0.935,0.724,0.880 and 0.866, all values greater than 0, indicating a positive correlation between X and Y. This finding not only verifies the effectiveness of the technology and finance efficiency evaluation indicators selected

in this paper, but also further confirms the applicability of these indicators in the DEA model.

In terms of the coefficient, all the Pearson correlation coefficient are non-zero, and the significance test (* p <0.05, * * p <0.01) indicates that these correlations are statistically significant, which also indicates that there is a positive correlation between the selected technology and financial efficiency evaluation indicators. Specifically, when one indicator (e. g. X1) increases, the other indicator (e. g. Y1) also tends to increase. The value of the correlation coefficient is close to 1 (e. g. 0.897,0.935, etc.) indicates a strong correlation between these variables, while a value close to 0 indicates a weak correlation. In the analysis presented here, the correlation coefficients all reached moderate to high intensity, supporting the hypothesis of a significant relationship between these variables.

Selection of indicators

To fully reflect the Guangxi zhuang autonomous region financial input and the actual situation of science and technology output, and effectively play the important role of financial technology in economic development, according to the principle of index system, combined with the characteristics of DEA evaluation method, chose three input index, three output index to build effective evaluation index system, specific indicators are as follows:

Table 4-2 Selection of input and output indicators of technology and finance

Target layer	metric
Investment in technology and finance	Fiscal expenditure on science and technology
	Funding for Research and Trial Development (R & D)
	Research and Trial Development (R & D) equivalent
Technology financial output	The total output value of high-tech industries above designated size
	The number of published scientific papers published
	Number of invention patent application granted

Table 4-2 Selection of input and output indicators of technology and finance

Target layer	metric

Data sources

The data of this paper are mainly derived from the statistical data of Guangxi Statistical Yearbook (2015-2023), and the specific data are shown in Table 4-3 below.

Table 4-3 Specific data of each indicator

a particular year	Number of authorization for invention patent applications (pieces)	The number of published scientific papers published	The total output value of high-tech industries above designated size	Research and Trial Development (R & D) equivalent (person year)	Research and Experimental Development (R & D) Fund (ten thousand yuan)	Financial expenditure on science and technology (RMB ten thousand yuan)
2015	13571	39668	4562	38535	1059124	496321
2016	14852	42335	6524	39903	1177487	451977
2017	15263	43596	8955	36857	1421787	600392
2018	20545	48989	10255	39961	1448530	644335
2019	22682	50155	14526	47420	1671326	723268
2020	34463	51222	17852	45821	1732304	662640
2021	34130	52148	19526	55821	1994572	711283
2022	30962	54120	22525	70397.6	2179353.5	1041211

Empirical results and analysis

Results of the CCR model analysis

Based on the established DEA model, DEAPVERSION (3.0) software. The results of the specific analysis are shown in Table Table 4-4 below.

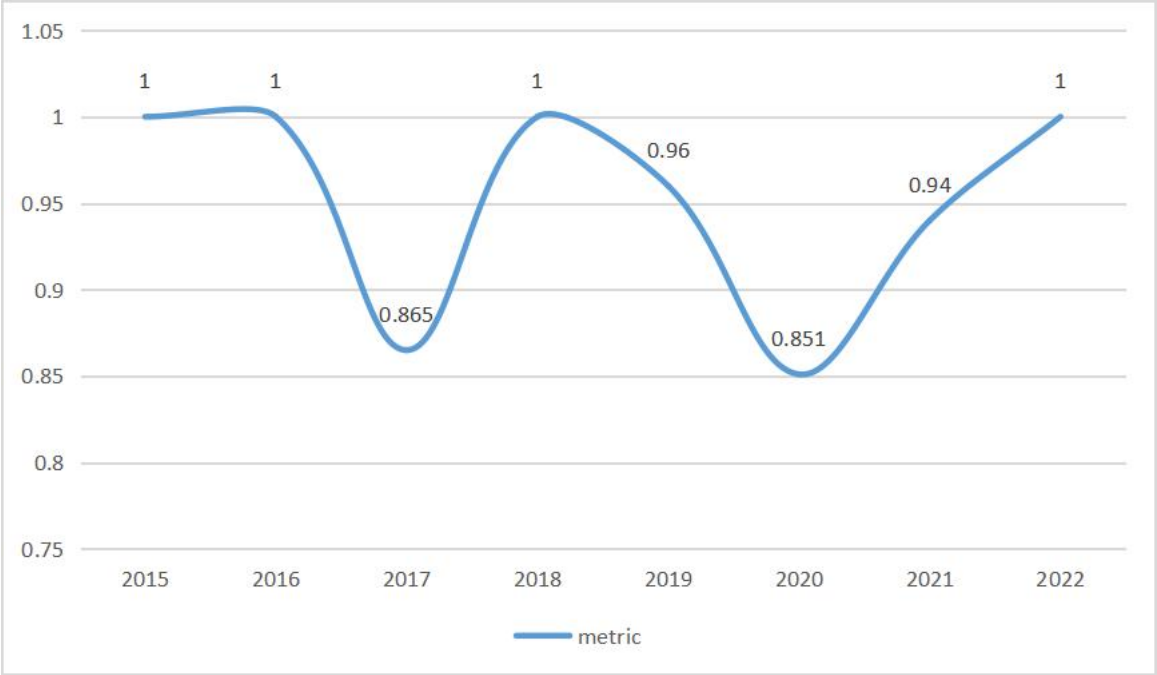


Figure 4-4 Results of the CCR model analysis

The results show that the efficiency of technology finance in Guangxi Zhuang Autonomous Region was fully effective in 2015,2016,2018 and 2022; the efficiency of technology finance in 2019 and 2021 was relatively ineffective in 2017 and 2020. From 2019 to 2022, the efficiency of science and technology finance has been effective year by year, which indicates that the development of science and technology finance in Guangxi Zhuang Autonomous Region is in a good trend during this period, and there is still a lot of room for improvement in the future.

Results of the BCC model analysis

Based on the DEA model, DEAPVERSION (3.0) software. The detailed results of the analysis are shown in Figure Figure 4-5 below.

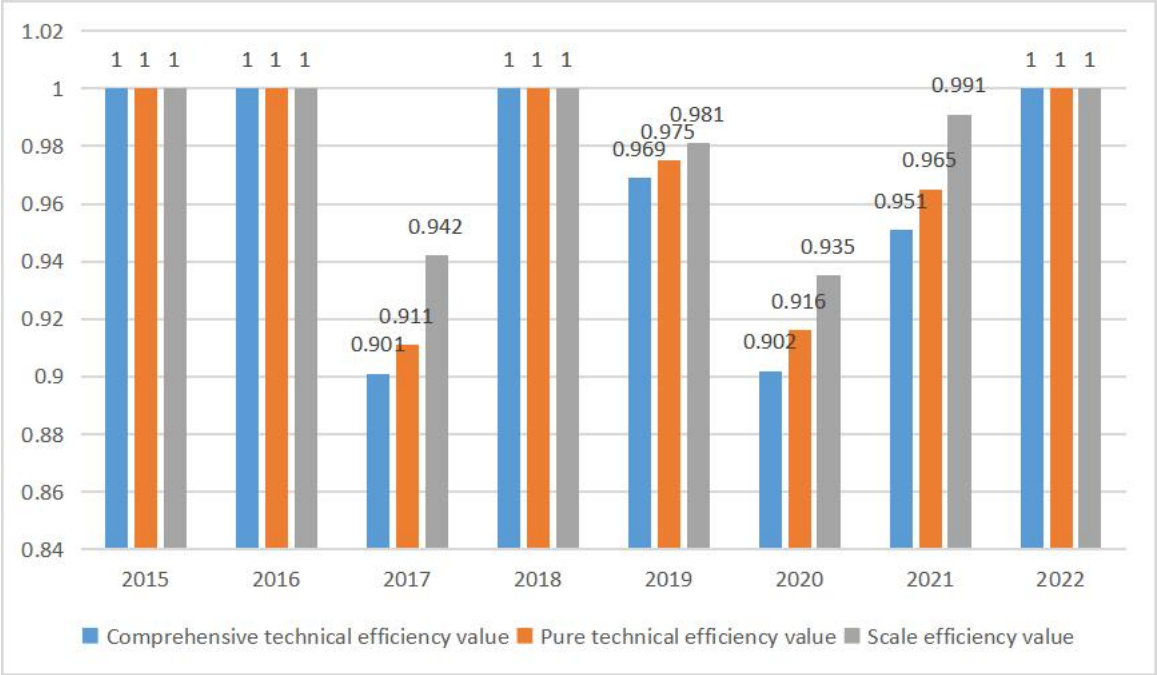


Figure 4-5 Results of the BBC model analysis

(1) Comprehensive efficiency analysis

As shown in Figure 4-5, the comprehensive technical efficiency values in 2015,2016,2018 and 2022 are all 1, which means that in these specific years, the input and output of technology and finance in Guangxi has reached the maximum resource utilization and achieved a fully effective state. In these years, the input and output of technology and finance have reached the optimal balance, with no waste of resources.

But not all years have reached that ideal state. The comprehensive technical efficiency values in 2017,2019,2020 and 2021 were all below 1, indicating that non-DEA was effective in the input and output of technology finance in these years. Specifically, the efficiency values of these non-fully valid years all fell within the range of 0.90 to 0.97. Among them, the efficiency value in 2020 is only 0.902, which is the lowest efficient year in this period, which clearly points to the loopholes and deficiencies in the allocation of technology and financial resources in that year.

Further analysis of the reasons for these non-DEA effective years found that multiple factors may have contributed to the low efficiency values. For example, the imbalance

in resource allocation in 2020 may be due to the untimely timing of scientific and technological innovation policies, or the mismatch of global macroeconomic fluctuations with regional markets. In addition, external factors such as the lack of input factors, the loss of output opportunities, and changes in the market environment may also have a negative impact on efficiency.

In response to these problems, the investment structure of research and development should be optimized to ensure the sufficient support of the investment in key areas; at the same time, further enhance the ability of technological transformation and accelerate the commercialization of scientific and technological achievements; and strengthen the coordination between policy and market environment to ensure that the technology and financial policies fit with the needs of regional economic development.

(2) Pure technical efficiency analysis

Throughout the input-output efficiency of the science and technology finance in Guangxi, it is found that there are obvious loss of technical efficiency and scale efficiency loss between 2017 and 2021. As shown in Figure 4-5, the pure technical efficiency and scale efficiency in 2017 were significantly lower than 1 (0.911 and 0.942, respectively), indicating a large lack of efficiency compared to other years. This lack of efficiency is largely due to the omission of management architecture, the lag of technology update or the expansion of business and market demand.

In view of the above problems, Guangxi should consider strengthening the fine management in the science and technology finance business, such as the introduction of optimized resource allocation model and efficiency monitoring mechanism, and learn from the successful case model, and implement mature project management methods. In addition, the introduction of advanced fintech through innovative research and technology investment is expected to significantly improve the technology efficiency and scale efficiency in the medium and long term.

To sum up, although Guangxi has achieved high technical efficiency in some years, there is still a lot of room for comprehensively improving the efficiency of technology and finance. To this end, Guangxi needs to deeply analyze the current problems, and adopt targeted strategies to realize the balance between resource input and output, so as to enhance the competitiveness of the overall financial ecosystem.

Conclusions

Through the in-depth DEA evaluation of the efficiency of technology and finance in Guangxi Zhuang Autonomous Region, the following conclusions are drawn. Under the CCR model, the efficiency of technology and finance in 2015,2016,2018 and 2022 is 1.0, that is, the fully effective state, showing that the ratio of resource input and output in these years reaches the best state, which is the model development stage of science and technology finance in Guangxi. Under the same model, the efficiency values in 2019 and 2021 were 0.96 and 0.94, respectively, indicating that Performance in these years is only slightly worse than fully effective, highlighting the potential to achieve higher efficiency through fine adjustment. In contrast, the efficiency values for 2017 and 2020 were 0.865 and 051, respectively, indicating the significant deficiencies in resource use and output effects in these two years.

BCC The inclusion of the BCC model provides a multi-angle perspective to analyze the efficiency of technology and finance, especially in terms of pure technical efficiency and scale efficiency. The analysis shows that the output has not been fully maximized in some years, revealing the existing difficulties in technology application, management restrictions, or improper allocation of funds and resources. In particular, the analysis of scale efficiency reveals the improper scale decision-making of enterprises, and the existing problems of too large or too small need to be adjusted through fine strategic planning.

Combined with the analysis results of CCR and BCC model, it is suggested that Guangxi should continue to strengthen technological innovation and optimize the resource allocation mechanism in the development of science, technology and finance, so as to improve the overall efficiency. In response to the inefficiency seen in 2017

and 2020, special attention is needed to the risks caused by market turbulence or policy changes, and flexible adjustments to strategies to cope with possible sudden changes.

In short, although the overall efficiency development trend of science and technology finance in Guangxi is good, the non-effective years clearly indicate the existing risks and instability. In order to achieve sustainable and long-term efficiency growth, it is necessary to implement more detailed and targeted improvement measures, and fundamentally improve the comprehensive efficiency and stability of technology finance.

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