

Research on the Coupled and Coordinated Development of Science and Technology Innovation and Science and Technology Finance in Chengdu

Jun Zhang, Jian Wang and Qianyu Fu*

School of Economics and Management, Southwest Petroleum University, Chengdu, 610500, China

Abstract

The coupling and coordination between science and technology innovation and science and technology finance is an important manifestation to promote economic transformation. Based on the data of evaluation indexes related to science and technology innovation and science and technology finance in Chengdu from 2011 to 2020, a coupling and coordination degree model was constructed to measure the coupling and coordination development level of science and technology innovation and science and technology finance. The results show that: (i) the overall evaluation index of science and technology innovation and science and technology finance in Chengdu has been increasing and rising, but the development level of science and technology finance has been lagging behind science and technology innovation; (ii) the level of coupling coordination between science and technology innovation and science and technology finance has been increasing and has realized the leap from disorder to coordination, but the level of coupling coordination is still low and is at the stage of barely coordination.

Keywords

Science and Technology Innovation; Science and Technology Finance; Entropy Method; Coupled Coordination Degree Model.

1. Introduction

"Science and technology" and "innovation" have always been the indispensable theme words in the economic development strategies of countries all over the world. In the 14th Five-Year Plan and the 2035 Vision, innovation has been elevated to an unprecedented strategic level, insisting on the central position of innovation in the overall situation of China's modernization, and making science and technology self-reliance and self-improvement as the strategic support for national development [1]. And finance as the core of modern economy, with the continuous development of science and technology innovation, the role of finance is becoming more and more prominent, and science and technology finance has become a new paradigm of economic growth. As the two engines of economic development science and technology innovation and financial innovation, the overall economy will show rapid growth when the value of both financial innovation and science and technology innovation are fully reflected. However, for the western region of China, which is relatively backward in terms of comprehensive level of science and technology development, it is currently in an important period of leapfrog economic development, coupled with the gradual implementation of the Western Development Strategy, science and technology finance has become an inevitable choice for Chengdu to adjust its economic structure and develop towards a frugal economy. How about the coordination degree of science and technology innovation and science and technology finance coupling in Chengdu? How to realize the coupled and coordinated development of science and technology innovation and science and technology finance? Therefore, it is of great significance to study

the coupled and coordinated development of science and technology innovation and science and technology finance in Chengdu city to promote the economic transformation of Chengdu city.

Relevant researches have been conducted at home and abroad for science and technology innovation and science and technology finance from different perspectives. Schumpeter [2], Wellalage [3], Fan Rui [4] and so on analyzed the development of financial expenditure on science and technology innovation from the perspectives of enterprises, banks and venture capital respectively; Abubakar [5], Faria [6], Rudra [7] and so on analyzed the development of science and technology innovation from the perspectives of science and technology innovation and financial market and other perspectives analyzed the financial development supported by science and technology innovation; Yulian Xu [8], Jiangpeng Zhang [9] and others studied the coupling relationship between science and technology innovation and science and technology finance at the national level and regional level. At this stage, in empirical studies, generally only national or eastern economically developed provinces and cities have been studied, and few studies on science and technology finance in western regions have been conducted. Under the new situation of national in-depth implementation of innovation-driven development strategy, how can we effectively integrate and activate the resources of science and technology and financial system to truly form a regional investment and financing environment for science and technology innovation with obvious competitive advantages? Based on this, a coupling coordination degree model is constructed to measure the level of coupled and coordinated development of science and technology innovation and science and technology finance in Chengdu, with a view to objectively reflecting the coordinated development trend of science and technology innovation and science and technology finance in Chengdu, and suggesting suggestions to further accelerate the combination of science and technology and finance in Chengdu and improve the level of synergy between science and technology innovation and science and technology finance.

2. Mechanisms of Impact of Science and Technology Innovation and Science and Technology Finance

Science and technology innovation and science and technology finance are an organic whole that promotes each other and is mutually linked, and their development cannot be separated from the support of economic construction and resource endowment [10]. Science and technology innovation has the characteristics of high investment, high risk and high return, and according to its chronological order, science and technology innovation activities can be divided into three stages: knowledge innovation, technological innovation and industrialization. Knowledge innovation is the starting point of technological innovation and industrialization, while technological innovation and industrialization are the core of realizing the ultimate value of science and technology innovation. Science and technology finance, on the other hand, includes public science and technology finance and market science and technology finance. Specifically, science and technology finance is the material basis of science and technology innovation, which cannot be separated from the support of science and technology finance, and every stage of science and technology innovation activities needs financial support from the government as well as the financial market. At the same time, the development of science and technology innovation will also accelerate the development of science and technology finance. On the one hand, with the development of science and technology innovation activities, it will put forward higher requirements for the financial industry and promote the transformation and upgrading of the financial industry, thus making science and technology finance develop in the direction of high quality, on the other hand, with the improvement of the level of science and technology, the level of intelligence and digitalization of the financial industry is also

increasing, improving the efficiency of resource allocation in the financial industry and promoting the science and technology. On the other hand, as the level of technology improves, the level of intelligence and digitalization of the financial industry is also increasing, improving the efficiency of resource allocation in the financial industry and promoting the continuous improvement of the financial service system.

Based on this theme of "coordination and development", we will seek a positive interaction between science and technology innovation and science and technology finance, so as to realize the harmonious co-existence of science and technology innovation and science and technology finance.

3. Construction of Index System and Research Method

3.1. Construction of Evaluation Index System

Table 1. Evaluation index system of science and technology innovation and science and technology finance

System layer	Level 1 Indicators	Secondary indicators	Weights	
Technology Innovation	Knowledge Innovation	Number of Research Institutions	0.0498	
		Number of Research Staff	0.0385	
		Number of scientific papers published	0.0452	
		Number of Scientific Publications	0.0578	
	Technology Innovation	Technology Innovation	Turnover of Technology Contracts	0.0910
			Number of Invention Patent Applications	0.0349
			Patents granted	0.0488
			R&D expenditure	0.0450
			R&D expenditure as a proportion of GDP	0.0372
	Industrialization level	Industrialization level	High-tech industry output value	0.0483
			High-tech industry high-tech product income	0.0515
			High-tech industry product sales revenue accounted for the proportion of the main business income	0.0546
			Export value of new products in high-tech industry	0.0354
Technology Finance	Public Technology Finance	Financial investment in science and technology	0.0641	
		Financial investment in science and technology as a proportion of fiscal expenditure	0.0585	
		Local financial allocations for science and technology	0.0498	
		The proportion of local financial allocations for science and technology to financial expenditures	0.0375	
	Market Technology Finance	Market Technology Finance	Amount of loans from financial institutions	0.0511
			Amount of financing in science and technology capital market	0.0580
			Government funds in R&D funding of research and development institutions	0.0431

Combining the actual situation of science and technology innovation and science and technology finance in Chengdu and referring to the existing research results [10], the evaluation index system of science and technology innovation and science and technology finance is constructed, as shown in Table 1. The science and technology innovation subsystem is reflected by three dimensions of knowledge innovation, technological innovation and industrialization level, and the science and technology finance subsystem is reflected by two dimensions of public science and technology finance and market science and technology finance.

3.2. Research Methods

3.2.1. Entropy Method

Step1, Standardization of the original data values X_{ij} using the polarization method.

$$\text{Positive indicators: } Y_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \times 0.9 + 0.1$$

$$\text{Negative indicators: } Y_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \times 0.9 + 0.1$$

Step2, Calculate the characteristic weight P_{ij} of the j th indicator in the i th year based on the results of the standardization of the raw data of each indicator, $P_{ij} = \frac{X_{ij}}{\sum_{i=1}^n X_{ij}}$.

Step3, Calculate the entropy value of the j th index e_j , $e_j = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} (\ln P_{ij})$.

Step4, Calculate the coefficient of variation g_j , then $g_j = 1 - e_j$.

Step5, Calculate the weight W_j of the j th indicator, then $W_j = \frac{g_j}{\sum_{i=1}^n g_j}$.

Step6, Calculate the integrated evaluation value of the binary system of science and technology innovation and science and technology finance, then $s_j = \sum_{j=1}^n W_j \times Y_{ij}$.

3.2.2. Coupling Coordination Degree Model

In analyzing the coordination of science and technology innovation and science and technology finance in Chengdu, a binary system coupling model was established based on the coupling model modified by Wang Shujia et al [11] and based on the actual situation in Chengdu, with the following expressions.

When $n=2$, it is assumed that $\max U_i$ is U_2 .

$$C = \sqrt{\left[1 - \sqrt{(U_2 - U_1)^2}\right] \times \left(\frac{U_1}{U_2}\right)} = \sqrt{[1 - (U_2 - U_1)] \times \left(\frac{U_1}{U_2}\right)} \tag{1}$$

Where U_1 denotes the evaluation index of science and technology innovation subsystem, U_2 denotes the evaluation index of science and technology finance subsystem, C denotes the coupling degree, $C \in [0, 1]$, and the larger the value of C , the higher the level of coupling degree of each subsystem; conversely, the lower it is. In order to better distinguish the type of coupling degree, the coupling degree of the energy economy and environment system is classified into levels by drawing on the research results [12], and the results are as follows: when the coupling degree C is between 0 and 0.3, the coupling degree type is low level coupling; when the coupling degree C is between 0.3 and 0.5, the coupling degree type is antagonistic stage; when the coupling degree C is between 0.5 and 0.8, the coupling degree type is medium level coupling; when the coupling degree C is between 0.8 and 1, the coupling degree type is high level coupling.

Although the coupling degree can reflect the interconnection between the two subsystems of science and technology innovation and science and technology finance, it is still lacking in studying the coordination between the two subsystems of science and technology innovation and science and technology finance. In order to better analyze the coordination between the

systems, a coupling coordination degree model was established based on the coupling degree model as follows.

$$D = \sqrt{C \times T}, T = a_1U_1 + a_2U_2, a_1 + a_2 = 1 \tag{2}$$

Where D denotes the coupling coordination degree, $D \in [0, 1]$, the larger the value of D, the higher the coordination level, and T denotes the comprehensive evaluation index of the binary system of science and technology innovation and science and technology finance. a_1 and a_2 denote the weights of each subsystem, and here both are taken as 0.5, considering that science and technology innovation and science and technology finance are equally important. In order to better evaluate and compare the coordination level, the coupling coordination degree of science and technology innovation and science and technology finance is classified into levels by drawing on the existing research results [12], and the classification results are shown in Table 2.

Table 2. Classification of coupling coordination level and evaluation level

Coherence D	Coordination level	Coherence D	Coordination level
[0.000-0.099)	Extremely dysfunctional	[0.499-0.599)	Barely Coordinated
[0.099-0.199)	Severe Dissonance	[0.599-0.699)	Primary coordination
[0.199-0.299)	Moderate Dissonance	[0.699-0.799)	Intermediate coordination
[0.299-0.399)	Mild disorder	[0.799-0.899)	Good Coordination
[0.399-0.499)	Near Dissonance	[0.899-1.000]	Quality Coordination

3.2.3. Data Sources

Taking Chengdu as the research object, in order to ensure the credibility of the research results, the data of science and technology innovation and science and technology finance evaluation indexes from 2011-2020 are selected from the Statistical Yearbook of Chengdu and the Statistical Yearbook of Sichuan Province.

4. Empirical Analysis

4.1. Analysis of the Comprehensive Development Level of Science and Technology Innovation and Science and Technology Financial System

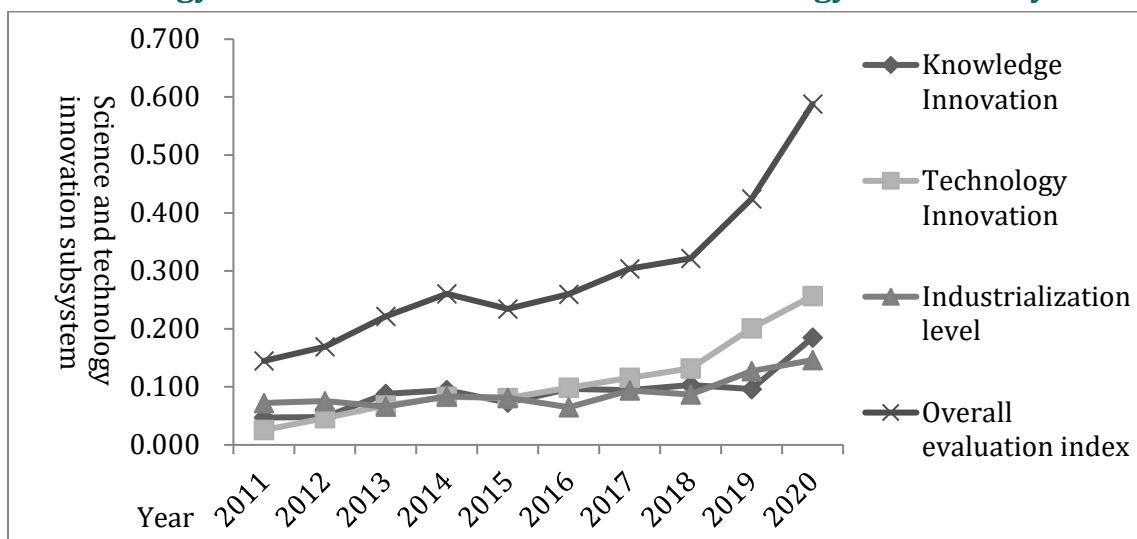


Figure 1. Trend of comprehensive evaluation index of science and technology innovation subsystem

Using the entropy value method and the index data of two subsystems of science and technology innovation and science and technology finance in Chengdu, the comprehensive evaluation index of science and technology innovation and science and technology finance system in Chengdu from 2011 to 2020 can be obtained. The change trend of the science and technology innovation subsystem is shown in Figure 1.

As can be seen from Figure 1, from 2011 to 2020, the overall comprehensive evaluation index of science and technology innovation subsystem of Chengdu city shows an upward trend, rising from 0.1449 in 2011 to 0.5881 in 2020, with an increase of 305.87%, which is mainly due to the substantial increase in the evaluation index of technological innovation, which gradually develops from the lowest to the highest. As the most economically developed city in the western region, Chengdu City experienced a decline in the evaluation indexes of knowledge innovation, technological innovation, and industrialization level in 2015 with the macro backgrounds of industrial restructuring and economic growth slowdown, which eventually made the comprehensive evaluation index of science and technology innovation subsystem also slightly lower compared with 2014. The change trend of the evaluation index of technological innovation is similar to the overall comprehensive evaluation index of the science and technology innovation subsystem, with the evaluation value rising from 0.0403 in 2011 to 0.4026 in 2019, an astonishing increase of 899.61%, indicating that the technological innovation in Chengdu has developed faster in the past 10 years, thanks to the policy support, and the large investment in scientific research activities. In contrast, the evaluation index of knowledge innovation and the evaluation index of industrialization level are relatively stable on the whole, and both rise less than the comprehensive evaluation index of science and technology innovation subsystem, indicating that the degree of influence of knowledge innovation and industrialization level on science and technology innovation subsystem is slightly lower compared with that of technology innovation.

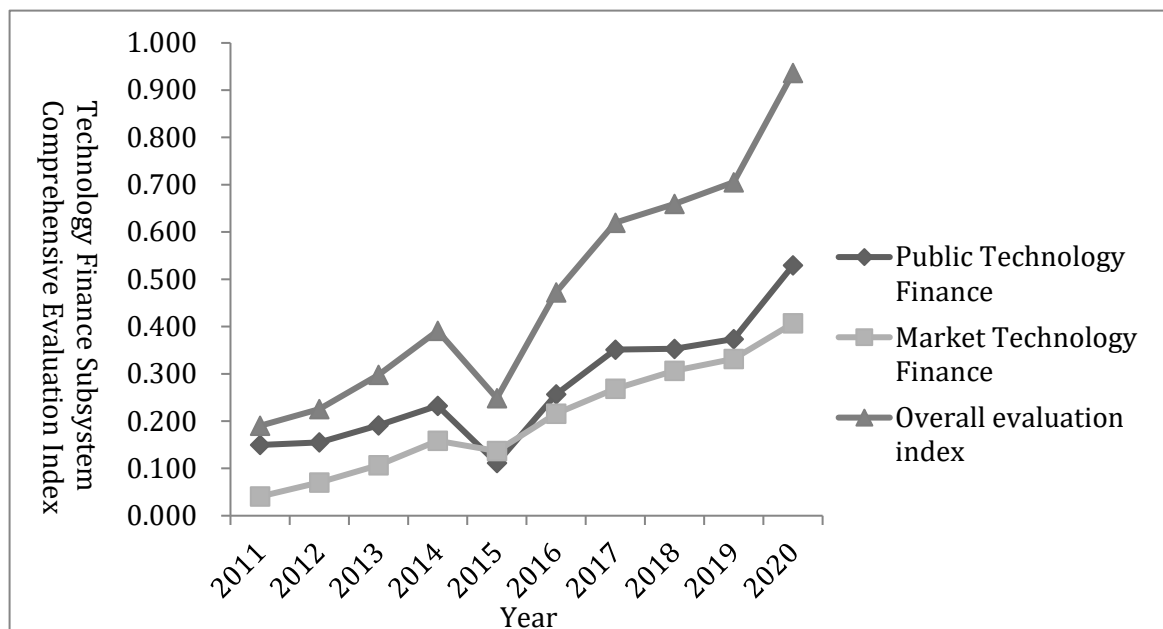


Figure 2. Trend of comprehensive evaluation index of science and technology finance subsystem

Through Figure 2, it can be concluded that from 2011-2020, the comprehensive evaluation index of Chengdu science and technology financial subsystem shows an upward trend, rising from 0.0700 in 2011 to 0.3381 in 2020, with a rise of 383.00%, and the change trend is divided into three stages: the first stage is the rising stage from 2011-2014, the second stage is the rising

stage from 2014 to 2015 declining stage, and the third stage is the rising stage from 2015-2020. The change trends of the public science and technology finance evaluation index and the comprehensive evaluation index of science and technology finance subsystem are roughly the same, both of them have a sharp decline in 2015, and then begin to rise year by year. The reason is that due to the downward pressure of the economy in 2015, local financial allocations for science and technology experienced a serious decline in 2015 making the evaluation index of public science and technology finance in 2015 lower than that of 2014, while the government funding in R&D funding for research and development institutions in market science and technology finance also experienced a serious decline in 2015, also making the evaluation index of market science and technology finance in 2015 slightly lower compared with 2014, which is influenced by both public science and technology finance and market science and technology finance subsystems, ultimately making the comprehensive evaluation index of the science and technology innovation subsystem show a serious decline in 2015.

Overall, the evaluation index of the science and technology innovation subsystem in Chengdu is higher than that of the science and technology finance subsystem from 2011 to 2020, which is closely related to the economic development status, science and technology finance resources, and the high or low role of government guidance on science and technology finance industrial policies.

4.2. Analysis of the Coupling and Coordination Degree between Science and Technology Innovation and Science and Technology Finance

4.2.1. Coupling Degree Analysis

The coupling degree between science and technology innovation and science and technology finance in Chengdu from 2011 to 2020 is calculated according to the coupling degree model, and the calculation results are shown in Table 3.

Table 3. Analysis of the coupling degree between science and technology innovation and science and technology finance in Chengdu, 2011-2019

Year	Coupling degree C	Type of coupling
2011	0.6683	Break-in phase
2012	0.6691	Grinding stage
2013	0.6581	Grinding stage
2014	0.6876	Break-in phase
2015	0.6232	Break-in phase
2016	0.7722	Break-in phase
2017	0.8181	High level coupling
2018	0.8196	High level coupling
2019	0.7066	Break-in phase
2020	0.6567	Grinding stage

It can be concluded from Table 3 that the coupling level of science and technology innovation and science and technology finance in Chengdu from 2011 to 2020 is generally high, indicating that science and technology innovation and science and technology finance delivery are closely coupled, with strong interaction and a large degree of mutual influence among the subsystems. Among them, 2017 and 2018 are higher than 0.8, with a high level of coupling, while the coupling degree of the remaining years is between 0.6 and 0.8, in the grinding stage. The reason why the coupling level of science and technology innovation and science and technology finance in Chengdu turned around in 2015 is that the comprehensive evaluation indexes of both the science and technology innovation subsystem and the science and technology finance

subsystem declined in 2015, and the decline of the science and technology finance subsystem was much larger than that of the science and technology innovation subsystem, as well as the fact that science and technology finance was still in its initial stage, which made the interaction effect between the two decline. 2019 and The reason for the decrease in coupling level in 2019 and 2020 is that the comprehensive evaluation value of the science and technology innovation subsystem has increased significantly due to the strong policy support and investment in scientific research activities, while the comprehensive evaluation value of the science and technology finance subsystem has increased, but the magnitude of the increase is much smaller than that of science and technology innovation, which finally leads to the decrease in coupling level in these two years.

4.2.2. Analysis of Coupling Coordination Degree

The coupling coordination degree of science and technology innovation and science and technology finance in Chengdu from 2011 to 2020 is calculated according to the coupling coordination degree model, and the calculation results are shown in Table 4.

Table 4. Analysis of the coupling coordination between science and technology innovation and science and technology finance in Chengdu, 2011-2020

Year	Coupling coordination	Type of Coordination
2011	0.2680	Moderate disorder
2012	0.2903	Moderate disorder
2013	0.3294	Mild disorder
2014	0.3712	Mild disorder
2015	0.3251	Mild disorder
2016	0.4075	Near disorder
2017	0.4635	Near disorder
2018	0.4781	Near disorder
2019	0.4899	Near dissonance
2020	0.5515	Barely coordinated

It can be concluded from Table 4 that the overall trend of the coupled and coordinated development level of science and technology innovation and science and technology finance in Chengdu from 2011 to 2020 is on the rise, from 0.2680 to 0.5515, with an increase of 105.78%, and the overall change to a good direction, achieving a leap in the coordination level, experiencing the process of dysfunction to coordination, with the inflection point being 2015, and the type of coordination from moderate disorder in 2011 gradually developed to barely coordinated in 2020, indicating that the coupled coordination mechanism of science and technology innovation and science and technology finance in Chengdu has been improving during these 10 years. Specifically.

(1) The coordination degree type from 2011 to 2012 is moderate dissonance stage, and the coupling coordination degree is relatively low at this stage, and the fluctuation range is not large, and it does not realize the leap from dissonance to coordination. The reason is that the development level of both science and technology innovation and science and technology finance in Chengdu is relatively low at this stage, and science and technology finance is in its initial stage, which makes the coupling coordination degree of both low.

(2) From 2013 to 2015, the coordination degree is mildly dysfunctional. Although the coupling coordination degree is improved at this stage, it is still relatively low and has not yet completed the transformation from dysfunctional to coordinated. The reason is that the development level of science and technology innovation and science and technology finance in this stage has been

greatly improved compared with 2011 and 2012, and with the strengthening of economic development and the guiding role of government policies on science and technology finance industry, the development level of science and technology finance has also been qualitatively improved compared with 2011 and 2012, which finally makes the coupling coordination degree of the two rise, but because this stage is still in the initial stage of science and technology The development level of science and technology finance is much lower than that of science and technology innovation, and the level of coupling and coordination between the two has not yet reached the coordination stage, due to the initial stage of science and technology finance, insufficient resources for science and technology finance, and strong support from government departments, but subject to their own factors. Especially in 2015, Chengdu was affected by industrial restructuring and economic downward pressure, which made the industrialization level of science and technology innovation in Chengdu suffer a drastic impact, as well as the government's role in guiding the industrial policy of science and technology finance was reduced, which finally made the coupling and coordination degree of science and technology innovation and science and technology finance in Chengdu in 2015 drop significantly compared with that in 2014.

(3) The coordination degree type of 2016-2019 is the stage of near disorder, and the coupling coordination degree of this stage keeps improving and is slightly higher compared with the previous years. The reason is that the good economic development of Chengdu city in this stage and the strengthening of government policy support, such as the release of the Proposal on Strengthening the Synergistic Development of Science and Technology Innovation and Science and Technology Finance in Chengdu city, which provides policy guarantee for the synergistic development of science and technology innovation and science and technology finance, make the coupling coordination degree of science and technology innovation and science and technology finance in Chengdu city increase.

(4) The coordination degree type in 2020 is barely coordinated stage, and the coupling coordination degree in this stage finally reaches above 0.5, which realizes the transformation from disorder to coordination. The reason is that after years of development, the development level of science and technology innovation and science and technology finance has gradually improved, and the government's support for science and technology innovation and science and technology finance has been further strengthened at this stage, and a large amount of science and technology financial resources have been invested as well as the guarantee of government macro policies, which makes the coupling coordination degree of the two gradually improve and a benign coupling emerges, and reaches the barely coordinated stage in 2020.

Overall, the coupling and coordination degree of science and technology innovation and science and technology finance in Chengdu from 2011 to 2020 shows frequent fluctuations, reflecting that the coupling and coordination relationship between the two in the development process is still not stable enough.

5. Conclusion and Recommendations

5.1. Conclusion

(1) In terms of development level, the overall development level of both science and technology innovation and science and technology finance in Chengdu has been improving, with a large rise. Although the development level of science and technology finance has been lagging behind that of science and technology innovation, the gap between the two is gradually narrowing.

(2) In terms of coupling and coordination, although the level of coupling and coordination between science and technology innovation and science and technology finance in Chengdu has gradually improved and risen significantly, and the interaction between science and technology innovation and science and technology finance has become more and more obvious, the

synergy between the two still needs to be further strengthened and has not yet crossed the primary coordination stage.

5.2. Suggestions

(1) Adhere to the concept of coordinated development of science and technology innovation and science and technology finance, and promote the virtuous mutual promotion of science and technology innovation and science and technology finance. Fully understand the law of coupling and coordination between science and technology innovation and science and technology finance in Chengdu, scientifically formulate the development plan of science and technology innovation and science and technology finance in Chengdu, strengthen the policy coordination and mechanism connection between science and technology innovation and science and technology finance, optimize the coordinated development strategy, and further improve the level of coordinated development between them.

(2) Strengthen the construction of science and technology finance and enhance the support capacity of science and technology finance for science and technology innovation. Integrate science and technology finance into the overall economic and social development of Chengdu, increase investment in science and technology finance, improve the institutional mechanism of science and technology finance, integrate science and technology, finance and other related resources, improve the level of development of science and technology finance, change the development trend that science and technology finance has been lagging behind science and technology innovation, and further reduce the scissors difference between the two.

(3) Promote the transfer and transformation of science and technology innovation results to further drive the development level of science and technology finance. The research results show that there is a high coupling relationship between science and technology innovation and science and technology finance in Chengdu, but the coupling coordination level is low due to the limitation of its own development level. Therefore, it is necessary to continuously implement special projects on science and technology innovation, promote the transformation of science and technology achievements into real productivity, and drive the development of science and technology finance, so as to consolidate and improve the level of coordinated development of the two.

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