Research on the synergetic effect of financial development, scientific and technological innovation and industrial economy

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Keywords: Financial development, Technological innovation, Industrial economy, Synergistic effect

Abstract. Based on the perspective of system view, this paper explores the relationship between financial development, scientific and technological innovation and industrial economy. Then constructs the relevant evaluation index system from the perspective of high-quality economic development requirements and connotation，and uses coupled coordinated development model to examine the coordinated development of the three systems in China's developed areas (Guangdong Province) after the financial crisis. The research shows that the harmonious development trend of the three systems is gradually formed, but the synergy effect needs to be further promoted. At the stage of high-quality economic development, it is necessary to further strengthen the coordinated development of finance, science and technology and industrial economy from the aspects of financial development serving the real economy, efficient transformation and industrialization of scientific and technological achievements.

1. Introduction

In recent years, with the implementation of the innovation-driven development strategy, scientific and technological innovation and financial innovation have become an important way for China's local governments to promote economic transformation and development through "two-wheel drive", and also one of the important experiences of China's economic construction over the past four decades of reform and opening up. At present, China's economy has shifted from a stage of rapid growth to a stage of high-quality development. We should focus on supply-side structural reform and promote quality, efficiency and driving force reform as the core of economic development. Based on the background of the new era and the new development concept, it is of great practical significance and policy value to grasp the synergetic effect and coordinated development degree of finance, science and technology and industrial economy in the context of high-quality economic development from the macro level, so as to further deepen the institutional reform in related fields and promote the construction of a modernized economic system.

2. Literature review and questions raised

As the foundation of regional economic operation, finance has a close interaction with industrial economic development. Just as the results of many scholars' researches, financial development plays an important role in promoting economic development, and economic development also feeds back financial development. But, this kind of action mechanism and path is a kind of extremely complex relation however. Patrick (1966) holds that financial development and economic growth are "demand-following" (demand-pulling) and "supply-leading" (supply-pushing) [1]. Later, Gold Smith (1969) formally put forward the concept of "financial development", pointed out that financial development was the change of financial structure, and established the basic index system to measure the financial structure and financial development level of a country. The research results showed that there was a roughly parallel relationship between economic development and financial development in most countries, but the research did not clearly point out the dominant relationship between finance and economy [2].

King and Levine (1993,1997) further studied the role of financial development in innovation and economic development in endogenous financial economic growth model from the perspective of financial market structure such as back and risk investment institutions. At the same time, they also pointed out that only innovation activities can improve productivity, and the development of the financial system can well provide impetus for innovation activities [3-4]. On this basis, some scholars further expand the structure of financial market research, includes:banking, venture capital and capital market [5-6]. In general, the development and competition of the financial system led by the banking industry can help promote the development of enterprise innovation activities or ease the financing constraints of enterprises [7-9].

On the basis of the research on financial market structure and economic development, some scholars conducted further research from the perspective of financial deepening, and generally affirmed the role of financial development in technological innovation, economic growth or industrial structure optimization [10-11]. A few scholars have also reflected on the relationship between financial development and the real economy in the context of the financial crisis, such as the performance difference of financial crisis spreading in different industries in the real economy [12], and the adverse impact of financial integration of capital market and credit market [13]. Recent further studies by relevant scholars provided reference for the current reflection on the financial crisis and further rationalizing the relationship between financial development and real economy. Dimitrios and Konstantinos (2019) showed that financial development promoted economic growth before the crisis, while hindered economic activities after the crisis [14]. Ali and Robert (2019) found that large-scale financial development supported by financial quality can relatively mitigate the adverse impact of financial crisis on the real economy [15].

In view of the complexity of the interaction between finance, science and technology and economy in the above literatures, this paper will further examine the interaction between financial development, technological innovation and industrial economy from the perspective of system theory and from the perspective of coordinated development. At the same time, China has made great achievements in science, technology and economy in the past four decades of reform and opening up. After the financial crisis, China maintained a relatively stable and rapid growth momentum and became the second largest economy in the world in terms of economic aggregate. However, according to the data released by the international monetary fund (IMF), China's per capita GDP ranked 67th among 192 countries and regions in the world in 2018, which was lower than the global per capita GDP level. As China's rapid economic growth turns to high-quality development, it is of great practical significance to implement the new development concept and better promote the coordinated development of finance, science and technology, economy and other fields. Therefore, taking Guangdong Province as an example, which is a typical representative of China's economically developed regions but also a region with unbalanced and uncoordinated development, this paper further carries out empirical analysis on the coordinated development of finance, science and technology and economy, trying to provide reference for the policy design and practice exploration of local government in the current stage of high-quality economic development.

3. Model building

3.1 Coupling coordination model

According to the aforementioned literature analysis, financial development, scientific and technological innovation and economic growth have close interaction, but at the same time, compared with the large socio-economic system, the three fields are relatively independent operating systems. Therefore, the coupling coordination degree model in physics is used to measure the comprehensive development level of the three systems and the coordination development degree among them [16].

$$C = \left[\frac{U_1 \times U_2 \times U_3}{\left(\frac{U_1 + U_2 + U_3}{3} \right)} \right]^{\frac{1}{3}} \quad (1)$$

In the above formula, C represents three system coupling, Ui (I = 1, 2, 3) represent the comprehensive development level index of each system. On this basis, the subsystem's contribution to the total system can be determined by the following linear weighting method formula:

$$U_i = \sum_{j=1}^{n} w_{ij} u_{ij} \quad \text{, where: } \sum_{j=1}^{n} w_{ij} = 1 \quad (2)$$

Coupling C∈[0,1]. When C=1, the coupling degree of the system is maximized, indicating that benign resonance coupling is achieved between subsystems. When C=0, the coupling degree of the four systems is minimal, indicating that the subsystems are in an independent state. Based on the previous studies, the coupling degree is divided into five levels: low coupling (0≤C<0.2); relatively low coupling (0.2≤C<0.4); moderate coupling (0.4≤C<0.6); relatively moderate coupled (0.6≤C<0.8); highly coupled (0.8≤C<1).

In view of the different indicator standards contained in each subsystem and the interaction effect of the three subsystems, the pure reference coupling cannot reflect the overall efficacy and collaboration level. To this end, the system coupling coordination degree model (D) is further introduced:

$$D = \sqrt{C \times T} \quad \text{, where: } T = \alpha U_1 + \beta U_2 + \chi U_3 \quad (3)$$

Where, T is the comprehensive coordination coefficient of the system, and α、β、χ are the contribution coefficients of the subsystem. In view of the fact that the financial development, scientific and technological innovation and industrial economy are equally important in the process of the operation and development of the large social and economic system, but the financial development and scientific and technological innovation ultimately serve the comprehensive development of industrial economy and society, it is assumed that the contribution proportion of the three systems is (3:3:4).

Under the coupling coordination degree model, the coupling coordination degree is divided into four levels: (1) Low coordination degree (0≤D<0.4), indicating that the coordinated development effect of the three systems is relatively low, and there are problems such as incoordination between financial development and real economy, incoordination between financial development and scientific and technological innovation, and incoordination between scientific and technological innovation and industrialization of scientific and technological achievements. (2) Antagonistic running-in (0.4≤D<0.6), indicating that the coordinated development effect of the three systems is not high, and the degree of the above uncoordinated phenomenon is relatively reduced. (3) Moderate coordination (0.6≤D<0.8), indicating that the coordinated development effect of the three systems is relatively good, and certain interaction mechanism and benign circulation mechanism have been formed among the systems. (4) High coordination (0.8≤D<1) indicates that the coordinated development effect of the three systems is relatively high, and a good interaction mechanism and a benign circulation mechanism are formed among the systems.

3.2 Establishment of indicator system

On the basis of learning from the previous achievements of relevant scholars, based on the systematic view of coordinated development effect measurement, following the principles of system, science and data availability, in view of the requirements and implications of China's current high-quality economic development, and taking into account the structure, quality, efficiency and benefits of the development of subsystems, the following evaluation index system is constructed (see table 1 for details). In terms of the specific indicators of a few dimensions, considering the subsequent standardized treatment, negative indicators have been converted into positive indicators according to their economic meanings. Therefore, all indicators in table 1 are positive indicators.

Table 1 Evaluation index system and weight of coupling coordination between financial development, scientific and technological innovation and industrial economic system

Criterion layer	Element layer	Index	Weight
U1	Financial industry	Loan balance of financial institution	0.0857
		Total assets of financial institutions /GDP	0.0568
		Per capita added value in financial industry	0.0731
	Insurance industry	Insurance density	0.0996
		Insurance penestration	0.0184
	Capital market	Market value of listed companies	0.1362
		Fund-raising amount by venture capital market	0.3717
		Financed amount by listed companies	0.1585
U2	Science and technology input	Number of scientific and technological personnel per 10,000	0.0751
		Internal expenditure of R&D fund	0.2040
		proportion of R&D fund in GDP	0.0284
	Science and technology output	sales revenue of new products	0.1770
		Number of patents authorized per 10,000 people	0.1930
		Output value of high and new technology industry	0.0890
		Technical contract turnover	0.2335
U3	Soci-economic performance	Per capita GDP	0.1770
		Comparison of income level of urban and rural residents（urban=1）	0.0284
		Comparison of consumption level of urban and rural residents（urban=1）	0.2448
	Quality of industrial structure	Added value of the tertiary industry/the secondary industry	0.1003
		Contribution of the tertiary industry to GDP growth	0.1355
		share of value-added of high-tech manufacturing above scale in GDP	0.0204
	Industrial economic efficiency	Assets contribution rate of above scale industry	0.0262
		Cost of profit margins of above-scale industry	0.0386
		GDP/ total energy consumed	0.2289

Note: U1 represents financial development system; U2 represents scientific and technological innovation system; U3 represents industrial economic system.

3.3 Data source and processing

According to the evaluation model and index system, combined with the purpose of the study, data in the financial, scientific and technological, economic and social development fields of Guangdong province from 2007 to 2018 were selected for empirical analysis. The data are from the Guangdong statistical yearbook, Guangdong science and technology yearbook, China science and technology statistical yearbook and the official websites of relevant government departments. Due to the differences in the units, properties and orders of magnitude of each indicator, it is necessary to standardize the original data in order to eliminate the effects of different dimensions. During the construction of the above index system, a few negative indicators have been converted into positive indicators, so the following formula is adopted for standardization.

$$X_{ij}^{*} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}} \tag{4}$$

Where, Xij is the actual value of the J index in the i system; i = 1,2,3; j = 1,2,3...n.

3.4 Determination of index weight

Referring to the ideas of relevant scholars, the index weight is determined by the entropy method in the objective weighting method [16]. The calculation steps are as follows:

(1) Calculate the proportion of the system corresponding to the standardized indicators, and m is the number of years:

$$S_{ij} = \frac{X'_{ij}}{\sqrt{\sum_{j=1}^{m} x'_{ij}}} \tag{5}$$

(2) Evaluate the entropy of indicator j:

$$h_j = -\frac{1}{lnm}\sum_{j=1}^{m} s_{ij} lns_{ij} \tag{6}$$

(3) Calculate the information utility value of the evaluation index:

$$a_j = 1 - h_j \tag{7}$$

(4) Establish the entropy weight of the evaluation index:

$$w_j = \frac{a_j}{\sum_{j=1}^{n} a_j} \tag{8}$$

According to the above calculation steps and relevant data, the weights of the four-system synergistic effect evaluation index system for high-quality economic development in Guangdong province were calculated (see table 1).

4. Empirical result analysis

4.1 Analysis of coupling degree of the three systems

According to the above model and calculation steps, the comprehensive development level index and coupling coordination degree of the three systems in Guangdong province from 2007 to 2018 were obtained (as shown in table 2). In general, the coupling degree of the three systems of financial development (U1), scientific and technological innovation (U2) and industrial economy (U3) in Guangdong is very high, with the average value of the 12 years from 2007 to 2018 reaching 0.9723. In the previous stage (2007-2013), due to the impact of the financial and economic crisis, there were relatively small fluctuations and shocks.

Table 2 financial development, technological innovation and industrial economic system development index and coupling coordination degree (2007-2018)

Year	U1	U2	U3	T	C	D	Coordination degree
2007	0.0987	0.0696	0.2235	0.1399	0.8832	0.3515	Low coordination
2008	0.0805	0.0882	0.2343	0.1443	0.8821	0.3568	Low coordination
2009	0.1121	0.1251	0.2446	0.1690	0.9391	0.3984	Low coordination
2010	0.1614	0.1518	0.2305	0.1862	0.9826	0.4277	Antagonistic running-in
2011	0.1787	0.1818	0.2533	0.2095	0.9867	0.4546	Antagonistic running-in
2012	0.1289	0.2131	0.2697	0.2105	0.9561	0.4486	Antagonistic running-in
2013	0.1552	0.2535	0.2824	0.2356	0.9686	0.4777	Antagonistic running-in
2014	0.2406	0.2714	0.3050	0.2756	0.9953	0.5238	Antagonistic running-in
2015	0.3341	0.3155	0.3189	0.3224	0.9997	0.5677	Antagonistic running-in
2016	0.4457	0.3624	0.3385	0.3778	0.9930	0.6125	Moderate coordination
2017	0.4771	0.4354	0.3502	0.4138	0.9918	0.6406	Moderate coordination
2018	0.5080	0.5458	0.3556	0.4584	0.9834	0.6714	Moderate coordination
Average value	0.2643	0.2735	0.2910	0.2778	0.9723	0.5122	--

4.2 Analysis of the comprehensive development level index

4.2.1 Analysis of the financial development subsystem

The comprehensive development level index of the financial development subsystem shows a stage fluctuation state, and the fluctuation range is the largest among the three systems. Before 2013, due to the impact of the financial crisis and the downturn in the venture capital market, the development was slow and showed a downward trend. After 2013, the impact of the financial crisis was weakened, but with the rise of Internet finance, the real estate market, capital market and other aspects, it gradually

became less authentic. This trend was restrained to a certain extent in 2016 by policy measures such as supply-side reform in the financial sector, systemic risk prevention and control, and financial disorder management. On the whole, the financial development system is more consistent with the development level index trend of the scientific and technological innovation system than the industrial economic system. It shows that the direct effect of financial development on scientific and technological innovation is greater than that of industrial economic system. The above empirical analysis results also indicate that the current financial supply-side reform and deepening development need to further optimize the financial market structure so as to further improve the ability to serve the real economy.

4.2.2 Analysis of scientific and technological innovation subsystem

The index of the comprehensive development level of the scientific and technological innovation subsystem changes in stages to some extent. Before 2015, it lagged behind the industrial economic development system, and after 2015, it was ahead of the industrial economic system. It indicates that the innovation-driven development of Guangdong province has made significant achievements in the implementation of a series of policies and measures at the end of the 12th five-year plan period to promote innovation-driven development (from 2017 to 2019, the regional innovation capacity of Guangdong province ranked no.1 in China for three consecutive years). It also indirectly reflects the development trend of Guangdong province's economy from innovation-driven to innovation-led. At the same time, the gap in the index of comprehensive development level between the subsystem of scientific and technological innovation and the subsystem of industrial economy increases, which indirectly indicates that the transformation efficiency and industrialization degree of scientific and technological innovation in the stage of high-quality development need to be further improved.

4.2.3 Analysis of industrial economy subsystem

The index of the comprehensive development level of the industrial economic subsystem is characterized by distinct stages. From 2007 to 2015, it was ahead of the two subsystems of finance and science and technology, because it was driven by factors in the early stage, driven by investment and influenced by a series of stimulus policies issued by local governments to deal with the financial crisis. From 2015-2018, it lagged behind those two subsystems, mainly because of the influence of the new normal of the economy in the post-financial crisis era of "three-phase superposition" (shifting period of growth rate, painful period of structural adjustment and digestion period of earlier stimulus policies). In addition, since the financial crisis, the comprehensive development level index of the industrial economic system has been slowly improved, which indicates that although Guangdong province currently leads the country in regional innovation capacity and economic aggregate, from the perspective of high-quality economic development, there is still a gap, which indirectly illustrates the reality of unbalanced and uncoordinated development in Guangdong province for a long time.

4.3 Analysis of the coupling coordination of the three subsystems

4.3.1 Overall analysis of system coupling coordination

In general, from 2007 to 2018, the coupling and coordination degree of the three subsystems maintained a stable growth trend, indicating that since the 12th Five-year Plan period, the three subsystems of financial development, scientific and technological innovation and industrial economy in Guangdong province have significantly interacted and promoted each other's development. From the perspective of the specific value level of the overall coupling coordination degree of the system, the overall coordination level is not high enough despite the steady improvement, with the mean value of 0.5122 in 12 years and the moderate coordination state in only 3 years. This shows that the synergistic effect of mutual promotion and coordinated development of financial development, scientific and technological innovation and industrial economy has not been given full play, and is still incompatible with the requirements of high-quality economic development.

4.3.2 Staged analysis of system coupling coordination degree

The first stage is the low-degree coordination and antagonistic running-in stage (2007-2015), which reflects the lack of interaction, coordination and coupling of the three systems during the structural adjustment and transformation in Guangdong province. The main reasons are as follows. First, due to

the impact of the international financial and economic crisis, most financial institutions like banks were reluctant to lend loads, and the financing function of the capital market failed. Second, although the double-transfer policy of Guangdong province has achieved good results, a large number of traditional manufacturing industries with high energy consumption and high pollution have been transferred to the north and west of Guangdong. Therefore, the quality of industrial restructuring, transformation and upgrading needs to be further improved at the provincial level. Third, the long-term element-driven and investment-driven model and the economic stimulus policies formulated by the state in response to the financial crisis at this stage have played a positive role in maintaining growth and stability, but have not played an obvious role in promoting high-quality economic development. The second stage is the medium coordination stage (2016-2018), during which the interaction of the three systems and the synergistic effect of coordinated development are enhanced. This is mainly because of the innovation-driven development strategy at the national level, the implementation of comprehensively deepening reform, and the deepening of the comprehensive reform of local governments in the financial, scientific, technological and economic fields, which has produced a series of results. However, at this stage, the degree of system coupling and coordination is still not highly coordinated.

5. Conclusion

The overall results of empirical analysis show that the effects of Guangdong 's financial development, technological innovation, and coordinated development of industrial economy, as a representative of China's developed regions, have been continuously highlighted. Howerver, there are still problems in the coordination of the three systems, such as the supporting role of finance in scientific and technological innovation and industrial economic development, transformation of scientific and technological achievements and industrialization efficiency. Therefore, the supporting effect of financial development and scientific and technological innovation on the industrial economic system based on high-quality economic development and the synergetic development effect need to be further strengthened. The main measures are as follows. First, optimize the structure of the financial market, strengthen the development of the capital market (including venture capital investment), deepen the supply-side reform in the financial sector and enhance the ability to serve the real economy and innovation-driven development. Second, improve the market for the transformation of scientific and technological achievements and improve the efficiency of the transformation and industrialization of scientific and technological achievements. Third, accelerate the development of an industrial system that promotes the coordinated development of the real economy, scientific and technological innovation, modern finance and human resources. Fourth, focus on supply-side structural reform, adhere to the principle of quality first and efficiency first, give consideration to coordinated and sustainable development, and improve the overall quality of industrial and economic development.

Acknowledgements

This paper is one of the results of key platform and major scientific research projects of Education Department of Guangdong Province(2017WTSCX118).

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