Calculation and Empirical Analysis of Synergistic Degree of Composite System Based on Technological Innovation, Financial Deepening and High-quality Development Subsystem

Yan Song[1, 2], Xinyun Li[1], and Yumei Jiang[1]

[1]Shandong University of Finance and Economics, Jinan, Shandong, 250014, China

[2]Qilu Normal University, Zhangqiu, Jinan, Shandong, 250200, China

Keywords: High quality development, Composite system, Synergism

Abstract: Cooperative development among technological innovation, financial deepening and high quality is of great significance for enhancing our overall economic strength and competitiveness. On the basis of deeply analyzing the development connotation, it builds concept model among education development, natural resources, social needs, scientific and technological innovation, financial deepening and high quality development. 2008-2016 time series data is used to compound system model and analyze the factors that affect the synergy degree of the composite system. The results show that the synergistic degree of the system of scientific and technological innovation and financial deepening has a steady rising trend; the scientific and technological innovation and the high-quality development system, the financial deepening and the high-quality development system and the three composite systems tend to be consistent; the total amount of risk investment management has biggest effect on the synergistic degree of the composite system, and the next factor is the incremental capital output rate and the amount of patent application authorization.

1. Introduction

At present, China's economy has changed from the stage of high-speed growth to the stage of high-quality development. Promoting high-quality development is an inevitable requirement to maintain the sustained and healthy development of China's economy. High-quality development requires that the whole supply system, including investment, finance, factor input, institutional innovation and scientific and technological progress Interaction, mutual promotion, vitality, effectiveness and quality. Technological innovation and financial deepening are two important and key driving factors for achieving high quality development. The development of scientific and technological innovation is inseparable from the strong support of finance. Financial deepening, as an important influencing factor of scientific and technological innovation, is the blood of modern economy. Docking with science and technology can promote scientific and technological innovation and accelerate the development of scientific and technological enterprises. ROMAIN et.al [1] have shown that the intensity of venture capital activities and the increase in the amount of investment in financial deepening will promote the increase of R&D application rate. GORODNICHENKO et.al[2]point out that risk investments are easy to gather in developed areas, and financial restraint will hinder innovation and development. From 2012 to 2016, the average growth rate of R&D expenditure in China has reached 11%, and the growth rate of financial venture capital is 4.5%. This shows that China has been creating a good environment for scientific and technological innovation, but whether the amount of financial investment and the output of scientific and technological innovation can develop in harmony, and whether financial investment and scientific and technological innovation can advance to China. Can high quality development play the greatest extent? Whether high-quality development can further promote the further optimization of scientific and technological innovation achievements, whether high-quality development can further guide the further rationalization of the financial deepening system structure, and whether the three can coordinate development to promote the promotion of China's economic level are worthy of our study.

  DOI: 10.25236/iccse.18.051

2. Conceptual model and index system establishment

2.1 Conceptual model of collaborative development system.

China pursues a new stage of high-quality development. While maintaining a certain rate of development of advanced productive forces, it pays more attention to the quality of development and the development of "innovation, coordination, green, opening and sharing". To realize the strategic objectives of the modern economic system and to construct an industrial system with coordinated development, it is necessary to speed up the coordinated development of the real economy, scientific and technological innovation and modern finance, focusing on the improvement of quality, people's livelihood, social progress and ecological environment protection.

Scientific and technological innovation provides new products, new technologies and new processes for high-quality development, and high-quality development provides the correct guidance for scientific and technological innovation to create industrial demand, thus promoting the continuous improvement of scientific and technological innovation level. Financial deepening is mainly reflected in the amount of government investment, the amount of venture capital, the total amount of bank loans, the number of equity funds, the amount of debt funds. Financial deepening can provide R&D funds for scientific and technological innovation. Zhang Minglong [3] pointed out that the effective integration of science and technology and finance will help scientific and technological enterprises to win greater opportunities for development, and is conductive to the structural transformation and rapid development of the modern economy. The ability of introducing new products has prominent effect, and venture capital can become the core factor to promote the transformation of high-tech clusters under certain conditions. Alessandra & Stoneman [4] found that technology credit support from banks and other financial institutions can greatly stimulate the R&D enthusiasm of high-tech enterprises. At the same time, the financial deepening of industrialization funds can provide financial power for the upgrading of industrial structure, thereby promoting the continuous optimization and upgrading of industrial structure, and ultimately achieve high-quality economic development.

The interaction among scientific and technological innovation, financial deepening and high-quality development is also influenced by relevant environmental variables. Educational development is one of the preconditions of scientific and technological innovation, which can provide important support for R&D talents. At the same time, education can improve the overall quality of the labor force, thereby promoting the high-quality development of the economy. Implementing high-quality development can meet the higher demand of the society for products and services, and increasing social demand can stimulate and lead consumption demand, thus promoting high-quality development. Conservation of natural resources, reducing the discharge of waste and pollutants in the ecological environment, and strengthening environmental management can achieve ecological green development. The conceptual model of the composite system thus provides the basis for the selection of the index system.

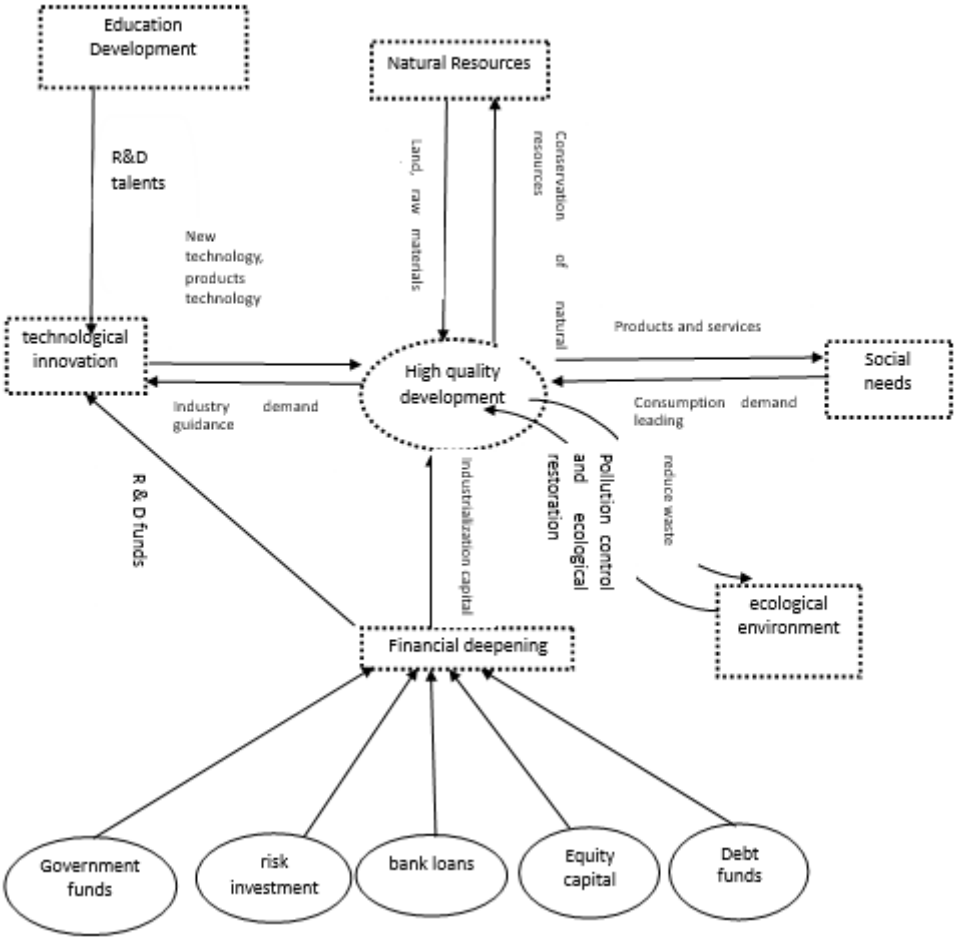

Fig. 1 Conceptual model

2.2 Collaborative development subsystem index system.

Based on the conceptual model constructed above, and referring to relevant research literature and government reports, the index system of this paper is constructed. Scientific and technological innovation mainly includes three aspects: manpower, financial input and R&D output. The financial deepening system selects venture capital and bank loans to measure its investment intensity. As an innovative financial tool, venture capital has become an important driving force to promote industrial development, promote economic restructuring and transformation, and maintain stable economic growth. In terms of high quality development, it mainly includes three dimensions: quality, efficiency and motivation. High and new technology industry is the main demand body of science and technology innovation and financial support system. The proportion of added value of high and new technology industry represents the structure of economic growth. The proportion of added value of new service industry also reflects the structure of economic growth in recent years in China. It can be seen that the proportion of added value of service industry is one of the most important indicators in economic development; the assessment of environmental quality and energy utilization is more comprehensive and stricter for high-quality development; this paper selects the output value of unit energy consumption and the pollutant emission amount per unit GDP as the measurement indicators; the 13th Five-Year Plan indicators are compared with the 12th Five-Year Plan indicators. The planning index increases the total labor productivity, which reflects the main trend of high-quality development in China during the 13th Five-Year Plan period. Guo Chunli and Yi Xin [5] also pointed out that the total labor productivity is an important index to measure the efficiency of economic activities in a country and a region, and it is also an important indicator of production technology level, management and management. The comprehensive performance of management level, technical proficiency and labor enthusiasm; the proportion of new product sales revenue represents the degree of innovation. To sum up, the index system is built in Table 1.

Table 1 Index system

Subsystem		order parameter	Nature
technological innovation	Investment	R&DFunds input	positive
		R&DFull time equivalent of personnel	positive
	output	Authorized amount of patent application	positive
		Quantity of scientific papers	positive
Financial deepening		bank loans	positive
		Total capital of venture capital management	positive
High quality development	quality	Proportion of added value of high and new technology industry	positive
		Proportion of added value in new service industry	positive
		Unit GDP pollutant emissions	negative
	efficiency	Total labour productivity	positive
		Incremental capital output ratio	negative
		Unit energy consumption output value	positive
	power	Proportion of new product sales revenue	positive
		High and new technology industry pulling	positive
		New service industry pulling	positive

3. Collaboration degree measurement

3.1 Index standardization.

Each index in the index system has different dimensions, which is especially common in the high quality development subsystem. For example, the proportion of added value of high-tech industry is a percentage, and the unit of labor productivity is yuan / person, which brings difficulties for subsequent calculation. Therefore, the range transformation method is used for dimensionless processing in advance. Through the range transformation, the negative and positive indicators in the index system are unified into positive indicators。Positive indicatorsf_j

make $x_j^* = maxx_{ij}$ where $1 \le i \le m$

$x_j^0 = minx_{ij}$ where $1 \le j \le m$

$$y_{ij} = \frac{x_{ij} - x_j^0}{x_j^* - x_j^0} \tag{1}$$

Reverse index f_i make $x_j^* = minx_{ij}$ where $1 \le i \le m, x_j^0 = maxx_{ij}$ and $1 \le j \le n$

$$y_{ij} = \frac{x_{j-x_{ij}}^0}{x_j^0 - x_j^*} \tag{2}$$

3.2 Index reliability test.

In this paper, Cronbach's alpha coefficient is used to measure the reliability of the indicators. Generally, Cronbach's alpha coefficient is greater than 0.5, indicating that the indicators have certain reliability and stability, greater than 0.7 indicates that reliability and stability is better. Cronbach's alpha reliability test is carried out on the indicators in SPSS, and the test results are shown in Table 2.

Table 2 Index reliability

Latent variable	Number of observed variables	Cronbach's α coefficient
technological innovation	4	0.99
Financial deepening	2	0.989
High quality development	9	0.823

3.3 The improved CRITIC method determines the weights of ordinal variables in each subsystem.

The CRITIC method is an objective weight weighting method proposed by Diakoulaki. Its basic train of thought is to determine the objective weights of indicators based on two basic concepts. The first is the contrast intensity, which indicates the difference of the value of each evaluation scheme in the same index, in the form of standard deviation, that is, the size of standardized deviation indicates the difference of the value of each scheme in the same index, the greater the standard deviation, the greater the difference of the value of each scheme. The second is the conflict between the evaluation indicators, the conflict between the indicators is based on the correlation between the indicators, such as the two indicators have a strong positive correlation, indicating that the conflict between the two indicators is low. The specific implementation process of the improved CRITIC method is:

(a) Degree of deviation :

$$d_j = \frac{\sigma_j}{\overline{x}_j} \tag{3}$$

Where σ_j isstandard deviation.

(b) Irrelevance

$$C_j = \sum_{k=1}^{n}(1-|r_{jk}|) \quad \text{or} \quad C_j = 1 - R_j \tag{4}$$

Where r_{jk} is correlation coefficient. R_j is Multiple correlation coefficient，regression model $x_{ij} = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_{j-1} x_{i,j-1} + \beta_{j+1} x_{i,j+1} + ... + \beta_{m1} x_{im} + u_i$ is Square root.

(c) Information content

$$I_j = d_j * C_j \tag{5}$$

(d) Objective weight

$$w_j = \frac{I_j}{\sum_{k=1}^{n} I_k} \tag{6}$$

3.4 Subsystem order degree.

Suppose $S = f(S1, S2, S3 \ldots\ldots Sj)$, where Sj representing the subsystem. In this paper, ST stands for science and technology innovation subsystem, SM stands for financial deepening subsystem, and SQ stands for high quality development subsystem. Suppose subsystem Sj,j∈[1,3],order parameter

$$e_j = (e_{j1}, e_{j2}, \ldots . e_{jn}), \text{where} n \geq 1,\ \beta_{ji} \leq e_{ji} \leq \alpha_{ji}, i = 1,2,\ldots n, \alpha_{ji}, \beta_{ji}$$

The upper and lower limits of order parameter components at the critical point of system stability are respectively represented. The larger the value of the positive index is, the higher the order degree of the system is, the larger the value of the negative index is, but the lower the order degree of the system is. The order parameter calculation formula of subsystem order parameter

$$\mu_j(e_{ji}) = \begin{cases} \dfrac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}} & \text{（positive index）} \\ \dfrac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}} & \text{（negative index）} \end{cases} \tag{7}$$

In this paper, the order degree of subsystems is obtained by integrating the order parameter order degree of subsystems with the linear weighting method.

$$\mu_j(e_j) = \sum_{i=1}^{n} \omega_i \mu_j(e_{ji}), \omega_i \geq 0 \text{ 且 } \sum_{i=1}^{n} w_i = 1 \tag{8}$$

3.5 Coordination degree calculation of composite system.

Haken H [6]from the point of view of natural science, synergy is defined as the interaction of subsystems in a complex system through synergistic behavior, resulting in the joint effect of the whole system beyond the individual rental of the elements. Ansov[7] believed that synergy was the process of sharing resources and coordinating operations by separate systems to achieve the overall goal. Synergetics is a cross-cutting discipline proposed by German physicist Hacken in 1969 and now widely used to study the interaction of a large number of subsystems in a complex manner. How does a composite system produce the effect of 1+1>2 through the synergy between subsystems? This paper focuses on the factors affecting the development of Industrial Enterprises above the scale, and studies the degree of consistency of these factors in the process of system evolution. At present, the composite system synergy model has been used in the direction of technology innovation and synergy development, and can be used for empirical analysis based on the synergy model. Based on the theoretical knowledge and principles of synergetics, and on the basis of scholar's research, this paper refers to Meng Qingsong and Han Wenxiu's research on the compound system model and Jia Jun and Zhang Zhuo's research methods on the coordinated development of high-tech industry innovation and energy efficiency, and combines the investment in scientific and technological innovation, the transformation of scientific and technological innovation, and the creation of scientific and technological innovation in China over the New output and financial industry support to high-tech industry, this paper constructs a synergy model with three subsystems of science and technology innovation, financial deepening and high-quality development as the composite system and carries out empirical research.

Set at the initial time t_0, The order of each subsystem is expressed as $\mu_j^0(e_j)$, When the whole composite system evolves to the moment t_1, The order degree of each subsystem is represented as $\mu_j^1(e_j)$. The coordination degree of the whole system is as follows

$$Y = \theta . \sqrt[n]{\prod_{j=1}^{n} [\mu_j^1(c_j) - \mu_j^0(c_j)]} \tag{9}$$

where: $\theta = \dfrac{\min[u_j^1(c_j) - u_j^0(c_j)]}{|\min[u_j^1(c_j) - u_j^0(c_j)]|}, j = 1,2,3.$

Table 3 Synergetic standard of composite system

Synergism	[-1,0]	(0,0.3)	(0.3,0.7]	(0.7,1)	1
status	No	Low	Common	High	Synergetic agreement

3.6 Grey correlation analysis of synergy degree.

Relevance analysis is to measure the degree of correlation between factors according to the similarity or dissimilarity of development situation between factors, and reveal the characteristics and degree of dynamic correlation of things. The results of synergy measure are influenced by the selected index system, i. e. order parameter. Each evaluation index plays a different role in each subsystem. In this paper, the grey correlation method is used to analyze the influence degree of each index on the synergy development of composite system.

Step 1: Deterministic analysis sequence: $X_0(t)=\{x_0(1),x_0(2),x_0(3).....x_0(n)\}$

Reference sequence $X_i(t)=\{x_i(1),x_i(2),.....x_i(n)\}$

$x_0(t)$Represents the coordination degree of composite system, $x_i(t)$representing the value of each year.

$$\xi_i(k)=\frac{\min\min\left|x_0(k)-x_i(k)\right|+\rho\max\max\left|x_0(k)-x_i(k)\right|}{\left|x_0(k)-x_i(k)\right|+\rho\max\max\left|x_0(k)-x_i(k)\right|} \tag{10}$$

is called Correlation coefficient.

Correlation degree

$$r_i=\frac{1}{N}\sum_{k=1}^{N}\xi_i(k) \tag{11}$$

4. Empirical analysis

4.1 Data sources.

According to the availability, reliability and authoritativeness of the sample data, this paper chooses nine years'data from 2008 to 2016 to measure the degree of synergy. The statistical data come from the "China Statistical Yearbook" and "China Statistical Yearbook of Science and Technology", some of which are indicators, such as the proportion of added value of high-tech industries, high-tech production. Industry pulling is derived from the 2016 data. The three order parameters in the subsystem of scientific and technological innovation are represented by Y1, Y2, Y3 and Y4, respectively. The two order parameters in the subsystem of financial deepening are represented by X1 and X2, and the nine indexes in the high-quality development are represented by Z1, Z2... .Z8 says. High-tech industries include information transmission, software and information, finance, real estate, leasing and business services, scientific research and technology services. Emerging services include finance, real estate, leasing and business services. The amount of pollutants discharged is calculated from the three parts of sulfur dioxide, nitrogen oxides and soot contained in the exhaust gas.

Table 4 Weight of each order parameter of the system

index	Y1	Y2	Y3	Y4	X1	X2	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
weight	0.248	0.258	0.209	0.284	0.442	0.558	0.099	0.075	0.055	0.077	0.076	0.064	0.061	0.14	0.354

4.2 Order degree of each subsystem.

The upper limit of the order parameter component is 1.05 times of the maximum value of the current sample data, and the lower limit of the order parameter component is 0.95 times of the minimum value of the current sample data. As shown in Table 5, the results are described in Excel.

Table 5 Order degree of each subsystem

S	2008	2009	2010	2011	2012	2013	2014	2015	2016
ST	0.0458	0.2114	0.3313	0.4599	0.5886	0.6682	0.7287	0.8557	0.91
SM	0.1605	0.29	0.4277	0.5251	0.5697	0.6227	0.7479	0.8518	0.9423
SQ	0.2231	0.2421	0.3185	0.5957	0.3386	0.4364	0.3898	0.5696	0.5699

Fig. 2 Order degree of each subsystem

4.3 Subsystem collaboration degree and computation of coordination degree of composite system.

Taking 2008 as the base period, the synergy degree of S&T innovation and financial support subsystem, S&T innovation and high-quality development subsystem, financial support and high-quality development subsystem and the composite system composed of the three subsystems are obtained by using Eq.9 as shown in the following table. Excel is used to describe the collaboration degree of each subsystem and the coordination degree of the composite system as shown in Table 6.

Table 6 System synergy

Year	ST&SM	ST&SQ	SM&SQ	ST&SM&SQ
2009	0.1465	0.0561	0.0496	0.0742
2010	0.2762	0.165	0.1596	0.1938
2011	0.3885	0.3928	0.3686	0.3832
2012	0.4713	0.2504	0.2174	0.295
2013	0.5363	0.3644	0.314	0.3944
2014	0.6333	0.3374	0.313	0.4059
2015	0.7482	0.5297	0.4894	0.5789
2016	0.822	0.5475	0.5208	0.6165

Fig. 3 Variation trend of synergistic degree of composite system

According to the composite system synergy standard, the synergy development status of related composite systems during 2008-2016 is shown in Table 7.

Table 7 System cooperative state

Year	ST&SM	ST&SQ	SM&SQ	ST&SM&SQ
2009	Low	Low	Low	Low
2010	Low	Low	Low	Low
2011	Common	Common	Common	Common
2012	Common	Common	Low	Low
2013	Common	Common	Common	Common
2014	Common	Common	Common	Common
2015	High	Common	Common	Common
2016	High	Common	Common	Common

4.4 Grey relational grade analysis.

In order to further determine the degree of influence of the factors affecting the synergy of the three systems, the correlation degree is calculated according to Eq.10, Eq.11 as shown in table 8.

Table 8 Correlation analysis

SS	RD	SP	TP	MD	MM	HZ	NZ	GDPP	LR	ZR	DD	NS	GD	GN
0.642	0.622	0.592	0.573	0.611	0.676	0.618	0.58	0.55	0.589	0.673	0.585	0.585	0.568	0.569

(Note: SS represents patent application authorization, RD represents R&D expenditure, SP represents R&D personnel full-time equivalent, TP represents scientific papers, MD represents bank loans, MM represents total venture capital, HZ represents the proportion of added value of high-tech industries, NZ represents the proportion of added value of emerging services, and GDP P represents the unit GDP Pollutant emissions, LR represents total labor productivity, ZR represents incremental capital output, DD represents unit energy output, NS represents the proportion of new product sales, GD represents the percentage of high-tech industry pull, GN represents the percentage of emerging services pull.)

5. Conclusions and deficiencies

By measuring the synergy degree of the composite system composed of scientific and technological innovation, financial support and high-quality development from 2008 to 2016, it is found that the order degree of the subsystem of scientific and technological innovation and financial support presents an increasing trend, and the changing trend shows that the input of science and technology and the output of science and technology are in direct proportion during 2008-2016. For two consecutive years, China's R&D investment intensity exceeded 2%, and showed a continuous upward trend, China's R&D strength further strengthened, and the level of scientific and technological cooperation and technology transfer continued to improve. The orderliness of the high-quality development subsystem fluctuates greatly, reaching its peak in 2011 and declining in 2012, followed by an S-shaped growth trend. The orderliness of the financial deepening system as a whole is higher than that of the other two systems. The composite system composed of three subsystems of science and technology innovation, financial deepening and high-quality development and the synergy degree of the three subsystems have gone through a process from low degree of synergy to general synergy. The composite system composed of science and technology innovation and financial deepening system has reached a high degree of synergy, showing a stable growth. The trend is higher than that of other systems. This shows that scientific and technological innovation and financial deepening have achieved a good coordinated development. China's scientific research input and financial support have made an important contribution to scientific research output. Input and output are in direct proportion. In 2009-2011, the trend of synergy between scientific and technological innovation and high-quality development system, financial support and high-quality development system, and the three composite systems tended to be consistent, showing a linear upward trend. Beginning in 2011, in addition to the composite system

of scientific and technological innovation and financial deepening, the composite system composed of other subsystems showed a trend of alternating valleys and peaks, and the position of turning point was the same. This also shows that each composite system developed in coordination, but judging by the standard of coordinated development. The degree of synergy is not excellent. From the correlation analysis, the total amount of venture capital management has the greatest impact on the synergy degree of the composite system, followed by the incremental capital output rate and patent application authorization. The index selected by other subsystems is almost equal to the cooperative degree of composite system. There are some shortcomings in this paper: because of the inconsistent definition of high-tech industry and emerging service industry, the connotation of high-quality development is different. At the same time, considering the availability of indicators data, some indicators are not taken into account, and need to be further explored and improved.

Acknowledgements

This research has been supported by Shandong Natural Science Foundation Project(Grant No. 2016ZRB01A9L), Major projects of soft science in Shandong(Grant No.2016RZB01045),the State Key Program of National Natural Science of China (71671104)

References

[1] ROMAIN A, POTTELSBERGHE B V.The determinants of venture capital: a panel data analysis of 16 OECD countries [J]. Research Institute in Management Science Working Paper, 2004, 5.

[2] GORODNICHENKO Y, SCHNITZER M.Financial Constraints and Innovation: Why Poor Countries don’t Catch up [J].Journal of the European Economic Association, 2013, 11(5):1115-1152.

[3] Zhang Minglong. Efficiency Evaluation of Financial Support for Scientific and Technological Innovation in China-Based on Super-Efficiency DEA and Malmquist Index [J].Financial Development Research, 2015 (6): 18-25 (In Chinese)

[4] Alessandra C,Stoneman P. Financial Constraints to Innovation in the UK:Evidence from CIS2 and CIS3[J].Oxford Economic Papers,2008,60(1).

[5] Guo Chunli, Yi Xin. How to understand the transition of China's economy to high-quality development stage [M], China Economic Times, 2018.

[6] Haken H.Synergetics:An Introduction.3nd ed.Berlin:Spring-Verlag.1983.

[7] Ansoff H I..Corporate Strategy [M].New York: McGraw Hill,1965.227-236.