Research on the Coupling and Coordinated Evolution Trend of Science and Technology Resource Allocation in High-tech Industry in Hebei Province

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Abstract. The optimal allocation of scientific and technological resources in high-tech industries is of great significance to promoting the coordinated, sustainable and high-quality development of the economy. Based on the subsystem of scientific and technological resource allocation capacity and the subsystem of industrial development capacity of high-tech industry, the index system was constructed, and the coupling and coordinated development level of scientific and technological resource allocation system of high-tech industry in Hebei Province was measured with the help of the coupling coordination degree model, and the reasons for the low-level coordinated development were found. In view of the obstacles, a system dynamics simulation model was constructed, and four scenarios were set up: resource input, industrial upgrading, profit increase and natural development, and the evolution trend was studied, and the coupling coordination model was used to simulate the coupling coordination development trend in Hebei under different scenarios from 2021 to 2025. The results show that the allocation structure of scientific and technological resources is not coordinated with the development capacity of high-tech industries, and the agglomeration capacity of high-tech industries is not coordinated with the allocation capacity of scientific and technological resources. Under the four scenarios, the coupling coordination degree of the scientific and technological resource allocation system of Hebei high-tech industry showed an upward trend, among which the coupling coordination degree of profit increase type was the highest, followed by resource investment type and industrial upgrading type, and the natural development type was the lowest. This study can provide a reference for the coordinated, sustainable and high-quality development of Hebei region.

Keywords: high-tech industry science and technology resource allocation system; the ability to allocate scientific and technological resources; the ability to develop high-tech industries; coupling co-degree model; system dynamics;

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1 INTRODUCTION

With the continuous in-depth optimization of the high-quality development strategy, the efficient allocation of scientific and technological resources to develop high-tech industries has become an important development direction. In order to further promote the allocation and development of scientific and technological resources in high-tech industries, it is necessary to clarify the relationship between the allocation of scientific and technological resources and the development of high-tech industries. For the allocation of scientific and technological resources, the existing research mainly focuses on efficiency and its influencing factors. For example, scholars have studied the level of allocation of scientific and technological resources in Jiangsu Province[1] and the efficiency of scientific and technological resources allocation in Beijing-Tianjin-Hebei[2], respectively. For example, scholars have studied and measured the regional innovation efficiency[3] and the provincial high-tech industry innovation efficiency[4]. Some scholars believe that the allocation of scientific and technological resources plays an important role in improving the TFP[5] and industrial competitiveness of high-tech industries, and that high-tech industries play an important role in promoting the accumulation of scientific and technological resources and increasing investment[6]. At present, there is a lack of overall research on the two, so this paper divides the high-tech industry science and technology resource allocation system into the science and technology resource allocation capacity system and the high-tech industry development capacity system, so as to study their interaction mechanism, which has important theoretical and practical significance for promoting the high-quality and sustainable development of Hebei Province's economy.

2 RESEARCH METHODOLOGY

2.1 Evaluation Indicator System

Building upon existing literature, this study examines the complex system of technological resource allocation capability from four dimensions: intensity, structure, environment, and effectiveness of technological resource allocation. Similarly, the development capacity of high-tech industries is investigated from four dimensions: industrial innovation, driving force, aggregation, and expansion of high-tech industries. This is illustrated in Table 1and Table 2 .

Table 1. Evaluation System Table of Technological Resource Allocation Capacity Indicators

Primary indicators	Secondary indicators	Third level indicators
Ability to allocate technological resources	Configuration strength	Per capita research funding
		R&D funding intensity
		Density of technology personnel
	Configuration structure	The proportion of technology funding enterprises
		The proportion of technology personnel in enterprises

		The proportion of high-tech industries in enterprise technology funding
		The proportion of enterprise technology funding and new product research and development funding
	Configure Environment	The proportion of government technology support
		The proportion of enterprise technology support
		Enterprise Funding for University/Research Institution Science and Technology universities/research institutions
		Publication rate of scientific and technological papers
		Patent authorization rate
	Configuration effectiveness	The proportion of technology transaction volume
		New product output rate
		Social labor productivity
		Economic benefits per unit energy consumption

Table 2. Evaluation System Table of High-Tech Industry Development Capacity Indicators

Primary indicators	Secondary indicators	Third level indicators
Development capacity of high-tech industries	Industrial innovation	Total R&D expenditure
		Number of valid patents
		R&D personnel input
		New product sales revenue
	Industry driven	Technology intensity coefficient
		Employment absorption rate
		Market share
	Industrial agglomeration	location entropy
		Spatial gini coefficient
		The proportion of high-tech enterprises in the high-tech zone
	Industrial expansion	Income elasticity of demand
		Industrial profit
		Enterprise growth rate

2.2 Subsystem Evolution Direction Model

Referring to the existing literature[7], the evolution direction model between subsystems was introduced to determine the degree of coordination between the eight secondary indicators.According to the entropy weight method, the comprehensive score Zi(k) is calculated, which is denoted as the development index of subsystem i at k time.Let $Z_{(K)}$ be the development index value of the comprehensive development index of each subsystem in the k time period,$1 \le i \le m$.

$$Z_{(K)} = \sum_{i=1}^{m} \frac{a_i}{a_1 + \cdots a_i + \cdots a_m} Z_{i(k)} \tag{1}$$

According to the grey correlation analysis method, the excellent correlation coefficient and the grey correlation resolution coefficient were calculated. The gray correlation coefficient is distributed and mapped. P_i stands for the gray correlation coefficient distribution mapping, in which the gray comprehensive correlation entropy can be considered as the gray entropy.

$$P_i = \frac{\Delta\left(z_{O(k)}, z_{i(k)}\right)}{\sum_{i=1}^{m} \Delta\left(z_{O(k)}, z_{i(k)}\right)} \tag{2}$$

ΔS represents the entropy change of the system at time t, that is, by examining its positive or negative value, the trend of change between subsystems within the system is determined.

$$\Delta S = -\sum_{i=1}^{m} P_i \log P_i + \sum_{i=2}^{m-1} P_{i-1} \log P_{i-1} \tag{3}$$

2.3 The Coupling Coordination Model

Referring to other literatures, the coupling coordination degree D is introduced to solve the limitation problem of coupling degree C as a single indicator in evaluating coordination, that is, the low development level of the two systems may show a very high degree of coupling. The synergy level of the system can be evaluated by using the coupling coordination degree value, and the development level of coupling coordination is given with reference to the relevant literature: high coupling, general coupling, running-in stage, dysfunction stage and severe dysregulation.

2.4 System Dynamics Model

System dynamics was proposed by Jay W. Forrester [8] as a methodology for understanding, constructing, and solving complex problems. In this model, the geographical boundary of the system is Hebei Province, the practice range of operation is 2021-2025, the main historical data is 2010-2020, and the simulation step is 1 year. Using the data from the Hebei Statistical Yearbook and the China High-tech Statistical Yearbook, the problem of missing data is solved by interpolating the data of adjacent years to ensure the integrity and continuity of the data. There are many factors affecting the development of high-tech industry and the allocation of scientific and technological resources, and only the main factors are considered in the process of analysis, and it is necessary to make assumptions to avoid the impact: (1) The development of the scientific and technological resource allocation system of high-tech industries is a sustainable and dynamic process. (2) The change of the system is only caused by internal factors of the system and is not affected by force majeure. (3) Only the main factors affecting the development of high-tech industries and scientific and technological resource allocation systems are considered.

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Based on the analysis of 8 subsystems, the SD model is constructed by comprehensively considering the interaction between the system of scientific and technological resource allocation capacity and the system of high-tech industry development capacity, as shown in Figure 1, including a large number of system variables and auxiliary variables, 8 state variables and rate variables.

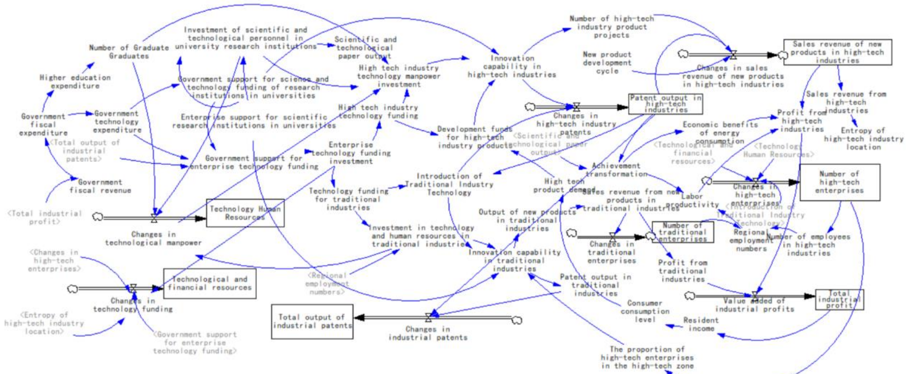

Fig. 1. Coupling Coordination System Flowchart

3 EMPIRICAL ANALYSIS

3.1 Analysis of Temporal Evolution Characteristics

3.1.1 Temporal Evolution Characteristics of Coupling Coordination Level between Technological Resource Allocation Capacity and High-Tech Industry Development Capacity

According to the coupling coordination degree model, the coupling degree and coupling coordination degree of the two first-level indicators of science and technology resource allocation ability and high-tech industry development ability with time are obtained. This is shown in Table 3.

Table 3. Time Series Graph of Coupling Coordination Development

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coupling degree	0.93	0.99	0.99	0.98	0.97	0.97	0.99	0.99	0.99	0.98
Coupled co scheduling	0.38	0.44	0.51	0.53	0.60	0.63	0.66	0.70	0.80	0.83

Since 2010, the coupling degree between technological resource allocation and high-tech industry development in Hebei Province has consistently remained above 0.9, indicating a strong correlation between the two. The coupling coordination degree has increased from 0.31 in 2010 to 0.82 in 2020, indicating a transition from mild disruption to good coordination.

3.1.2 Temporal Evolution Characteristics of Subsystem Coupling Coordination Level. The ability to allocate scientific and technological resources and the industrial development capacity of high-tech industries each contain four subsystems, and the second-level indicators are combined in pairs and pairs, with a total of 16 groups. The entropy change value of 16 groups of combinations is obtained, and the entropy change value can reflect the development trend of the system, so as to analyze the temporal evolution characteristics and entropy change of the combinations. An entropy value less than 0 indicates that the system is developing in a positive and orderly direction, and an entropy change value greater than 0 indicates that the system is developing in a disorderly manner. Figure 2 below shows the entropy change over time for the pairwise combination of 16 subsystems.

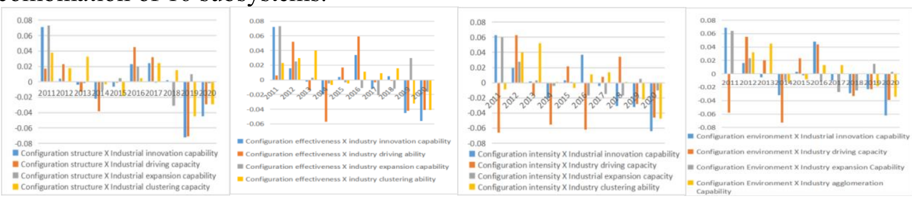

Fig. 2. Entropy Change Values of Sixteen Subsystem Combinations

Judging from the results of entropy change values: the structure of scientific and technological resource allocation and the development capacity of high-tech industries are not coordinated, and the agglomeration capacity of high-tech industries and the development capacity of scientific and technological resource allocation are also not coordinated.

3.2 SD model verification and simulation

3.2.1 SD model validity verification. In order to ensure that the operation of the established model is consistent with the actual situation, the validity of the SD model is tested. In order to ensure the scientificity of the model, the simulated values and actual values of important variables in terms of input and output are selected for comparison, and some of the comparison error results are shown in Figure 3. The error is basically maintained within the control range of 10%, the fitting degree is high, the model is effective, and the subsequent simulation prediction can be analyzed by the SD model.

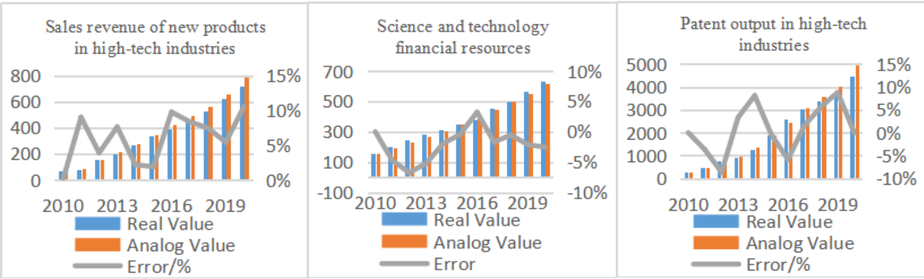

Fig. 3. Error Results

3.2.2 Scenario Setting. From the above analysis of entropy change, we can find the problems in the coupling and coordinated development of the scientific and technological resource allocation capacity and the high-tech industry development capacity: the scientific and technological resource allocation structure is not coordinated with the development of the high-tech industry development capacity, and the high-tech industry agglomeration capacity is not coordinated with the scientific and technological resource allocation capacity. The scientific and technological resource allocation structure affects the high-tech industry development capacity through scientific and technological financial resources and human resources, which is reflected in the system flow chart, that is, the enterprise science and technology funds affect the high-tech industry science and technology funds and traditional industry science and technology funds. The high-tech industry agglomeration capacity affects the scientific and technological resource allocation capacity through the high-tech industry agglomeration situation, that is, the high-tech industry profit.

Set up different scenarios for simulation. Scenario 1: Resource input. Set the annual growth rate of high-tech industry science and technology funds and human resources investment to 10% and 5% from 2021 to 2025. Scenario 2: Industry upgrading. Set the annual growth rate of traditional industry science and technology funds and technology introduction funds to 18% and 30% from 2021 to 2025. Scenario 3: Profit increase. Set the annual growth rate of high-tech industry sales revenue to 5% from 2021 to 2025. Scenario 4: Natural development. Do not adjust the model parameters and directly simulate its natural development trajectory.As shown in Figure 4.

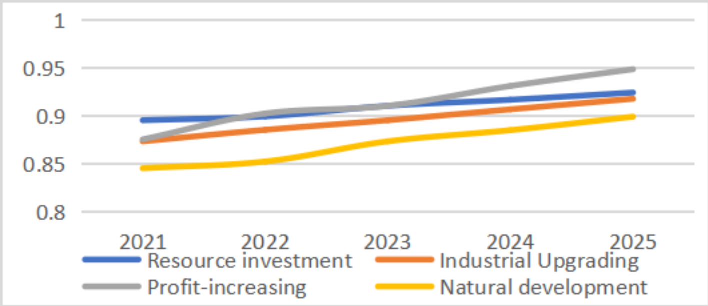

Fig. 4. Coupling coordination prediction

Figure 4 above reflects the development trend of the coupling coordination value of scientific and technological resource allocation capability and high-tech industry development capability under the four scenarios. It is generally on the rise, developing from general coupling to high coupling.

According to the simulation results of the SD model, the continuous increase in profits of high-tech industries will attract enterprises to gather, and the profit increase scenario will first reach the high coupling stage; with the continuous inclination of scientific and technological funds and scientific and technological human resources, the resource input scenario will also reach the high coupling stage; the industrial upgrading scenario is on the verge of breaking through the general coupling stage, and the coupling of the natural development scenario is slightly inferior to other scenarios.

4 CONCLUSIONS AND SHORTCOMINGS

There is uncertainty in any prediction, and the SD model deserves further optimization. First, there is an interpolation method in this study, and with the improvement of statistical data, the variable parameters can be continuously corrected, so that the key parameters and prediction results in the SD model are more accurate and realistic. Second, when making forecasts, the forecast data can only reflect the development goals formulated by the government, and policy adjustments will lead to the projection results not matching the reality.

However, in general, further improvement schemes can be given according to the coupling coordination prediction value: (1) Scenario 3 increases the profit of high-tech industry products, attracts other technology-based enterprises to enter high-tech industries, and high-tech enterprises form regional clusters. This scenario improves the disharmony between the agglomeration capacity of high-tech industries and the allocation capacity of scientific and technological resources. However, it should be noted that the agglomeration capacity of high-tech industries should be integrated with traditional industries in order to promote the upgrading of traditional industries. (2) Scenarios 2 and 3 can improve the mismatch between the allocation structure of scientific and technological resources and the development capacity of high-tech industries, and can also improve the support for high-tech industries and traditional industries by increasing enterprises' scientific and technological expenditures.

Research indicates that employing a method combining system dynamics and coordination coupling is an effective tool for studying local high-quality development, providing valuable insights into identifying obstacles in the development process. Simulating the characteristics of coordination coupling for high-quality development in Hebei Province suggests that the government can increase funding support to facilitate the transition of traditional industries to high-tech industries. Additionally, encouraging high-tech industries to increase product profits can promote healthy and sustainable high-quality economic development.

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