ISSN 2616-5902 Vol. 6, Issue 1: 192-200, DOI: 10.25236/AJBM.2024.060128

Research on evaluation of innovation ability of electronic information enterprises based on "two-chain fusion"

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Abstract: *The integration of industrial chain and innovation chain is an important way to improve the stability and creative development of industrial chain. As a representative enterprise of national scientific and technological innovation and economic development, it is very important to study the innovation ability of electronic information enterprises. The integration of the two chains is an important measure to solve the lack of original innovation power for the development of high-tech enterprises in China and achieve high-quality economic development. This paper systematically analyzes the integration of industrial chain and innovation chain of electronic information industry, constructs an evaluation index system of innovation ability of electronic information enterprises from the perspective of innovation knowledge input ability, innovation knowledge management ability, innovation knowledge guarantee ability and innovation knowledge output ability, and comprehensively uses entropy method and TOPSIS method to construct an evaluation model of enterprise knowledge innovation ability. Then select 5 enterprises in electronic information industry for empirical research, and put forward relevant countermeasures and suggestions according to the evaluation results.*

Keywords: *two-chain fusion, electronic information enterprise, innovation ability, TOPSIS*

1. Introduction

Under the interwoven wave of global scientific and technological revolution and industrial transformation, the development of science and technology is changing rapidly, and the speed of transforming technological achievements into real productive forces is accelerating. In the face of China's lack of original innovation, technology "jam neck" prominent, long-term mechanism needs to be improved and other practical problems, the 20 report pointed out that we should strengthen basic research, reasonable allocation of financial science and technology funds, strengthen the enterprise-led, deepen the integration of production, university and research, promote the conversion rate of scientific and technological achievements, strengthen the core subject position of enterprises, and promote the deep integration of industrial chain and innovation chain. Among them, to promote the integrated development of the industrial chain and the innovation chain is actually to create an innovation ecology in which the main body of the industrial chain and the main body of the innovation chain interact, such as core enterprises, collaborating manufacturers, governments, universities, and research institutes. Therefore, through the integration of the two chains, how to effectively and reasonably obtain knowledge resources with the help of enterprises and other integration subjects, improve the innovation ability and innovation level of specialized and special new enterprises, and then improve the core competitiveness of the whole industry in the world is an important issue facing the current national development, especially the development of high-tech enterprises represented by electronic information. Based on this, from the perspective of the integration of two chains, this paper studies the evaluation of the innovation ability of the knowledge dimension of electronic information enterprises, and provides an effective reference for promoting the innovation and development of China's electronic information enterprises.

2. Literature Review

2.1 Two-chain fusion

Domestic scholars have studied the fusion of two chains from many aspects. From the perspective of fusion path, Sun Qin took China's IC industry as the research object and analyzed the two-chain fusion

ISSN 2616-5902 Vol. 6, Issue 1: 192-200, DOI: 10.25236/AJBM.2024.060128

path of cluster circuit industry [1]. Liu Jingyue studied the development path of the integration of the two chains from the perspective of industrial policy, and proposed that the integration path includes the extension of the innovation chain to the end of the industrial chain, the extension of the industrial chain to the end of the innovation chain, and the construction of the "bridge" of the integration of the two chains [2]. In the exploration of audit coordination mechanism to promote the integration of industrial chain and innovation chain, Xie Liufang proposed that designing and implementing audit coordination mechanism from power operation and policy implementation is an effective practice path for audit to promote double-chain integration [3]. Han Jiangbo proposed two integration paths of promoting innovation chain by industrial chain and promoting innovation chain by industrial chain [4]. From the perspective of two-chain integration mechanism, Wu Zhongchao analyzed the operation mechanism of industry-university-research collaborative innovation implemented by application-oriented universities with two-chain integration [5]. Zhu Ruibo takes Shanghai's high-tech industry as his research object, and his research shows that the development of high-tech industry must focus on the organic integration of the two chains and build a double-chain integration mechanism [6]. After analyzing the actual progress of the two-chain integration, Gao Hongwei proposed the importance of building a mechanism for the transformation of scientific and technological achievements [7]. Some scholars have proposed three-chain fusion, four-chain fusion and so on under the premise of studying two-chain fusion. Based on the review and summary of relevant literature, this paper will further analyze and elaborate the connotation and composition of two-chain fusion from three dimensions: two-chain fusion node, two-chain fusion chain and two-chain fusion network.

2.2 Enterprise innovation ability

At present, because of the differences in research perspectives, subject areas and environment, different researchers have different definitions of enterprise innovation ability. Some scholars study innovation ability from the perspective of technology, which refers to the ability of enterprises to create new technologies. For example, Feng Yinhu constructed an evaluation index system from three dimensions of technological innovation input, output and environmental supporting ability to study the technological innovation ability of listed coal enterprises [8]. Li Yue studied the evaluation of technological innovation capability of enterprises from four aspects: innovation input, main body collaboration, innovation output and innovation environment [9]. Huang Chun elaborated on the connotation and definition of technological innovation capability of construction enterprises [10]. Some scholars study innovation ability from the perspective of management. Management innovation ability refers to the ability of enterprises to reorganize innovation resources and use them for innovation activities. For example, Ye Baosheng explored the process mechanism of whether management innovation can improve the competitive advantage of smes through resource patchwork ability [11]. Wang Qingjin discussed the influence mechanism of cognitive flexibility and management innovation ability from the perspective of cross-border search [12]. Some scholars study innovation ability from the perspective of knowledge. Knowledge innovation ability refers to the ability of enterprises to use knowledge to carry out innovation activities. This paper will sort out the innovation ability of electronic information enterprises from different research perspectives, and draw on the previous research results to further study the innovation ability of electronic information enterprises from the knowledge dimension.

3. Theoretical Analysis

3.1 Electronic information industry chain

The idea of industrial chain originated from Adam Smith's theory of division of production. Later, Hirschman first proposed the concept of industrial chain in the Economic Development Strategy. With the deepening of academic research, many scholars have expanded the connotation of the industrial chain from different angles. In essence, scholars generally believe that the industrial chain is a competitive enterprise and its related enterprises in the same industrial sector or in a certain industry in different industrial sectors within a certain geographical range Industry, based on products as a link, carries out division of labor and cooperation to achieve a chain set of industrial value appreciation [13]. Electronic information industry refers to the production, processing, processing, dissemination or receiving of information and other functions, the use of electronic technology and information technology engaged in electronic information products related to material manufacturing, system integration, software development, machine assembly and debugging and application services and other operational processes.

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The main body of the electronic information industry chain includes electronic information product material manufacturers, electronic information core enterprises, and electronic information product users. The formation of the electronic information industry chain is based on the specific logical relationship between the main bodies of the industry chain. The middle and downstream subjects in the electronic information industry chain form related organizations through the relationship between supply and demand, and carry out division of labor and cooperation on this basis to form a resource integration industry chain of knowledge sharing, technology joint research and product matching, so as to achieve value creation and value-added. Therefore, this paper holds that the electronic information industry chain is a chain with complete production process and close dynamic connection between upstream and downstream.

3.2 Electronic information innovation chain

The research of innovation chain originated from the scholars' thinking about the innovation process. The innovation chain is a chain from the generation of innovative ideas to the generation of scientific and technological achievements to the industrialization of knowledge. Its essence is a series of functional activity sequence set from new ideas to transforming products and acquiring value. With the continuous deepening of research by domestic and foreign scholars, the stage division of innovation chain based on the perspective of process shows diversity. The research integration of many scholars generally realizes the chain set of knowledge industrialization through six stages: innovative conception, basic research, applied research, technology development, productization and industrialization [14]. The electronic information innovation chain is an open complex chain that is influenced by the user's demand for terminal electronic products, and focuses on the innovation of precision electronic component design, innovation system research and development, software development and other technologies, and jointly carries out a series of innovative activities to achieve knowledge industrialization through the integration of innovation resources among innovation subjects. Therefore, this paper holds that electronic information innovation chain is a chain of collaborative innovation formed by electronic information enterprises around innovation points, through collaborative cooperation with other innovation subjects and integration of innovation resources.

3.3 Integration of two chains of electronic information

The integration of the two chains of electronic information is a multi-level integration, which generally includes the integration of the industry subject and the innovation subject, the integration of the industrial chain and the innovation chain, and the integration of the collaborative innovation network. The analysis of two-chain fusion of electronic information is carried out from the perspectives of two-chain fusion node, two-chain fusion chain and two-chain fusion network.

The two chain fusion nodes are mainly composed of industrial chain nodes and innovation chain nodes. The node of the industrial chain has core enterprises, cooperative manufacturers and users. The nodes of the innovation chain include universities, research institutes and core enterprises. In addition, the fusion nodes of the two chains also include financial institutions, intermediary service institutions and so on. With the two-chain fusion from the formation stage to the maturity stage, the division of tasks within the fusion has always been dynamically adjusted, and the relationship between the core enterprise and other fusion subjects is constantly changing. Relying on the strong connection and structural hole relationship between the fusion nodes of the two chains, the core enterprise will obtain various types of relevant knowledge resources. Promote enterprises to absorb the superior knowledge of various fusion subjects and internalize and apply it, providing knowledge sources and catalysts for technological innovation of enterprises.

The two-chain fusion chain refers to the industrial chain and the innovation chain. The deep docking of the two chains takes the innovation chain as the driving force to play the role of an engine, and the formation of an industrial structure in the industrial chain plays an optimization effect, so as to complete the transformation and docking of innovation achievements, complete the value creation of new products, and form an innovation-led modern industrial system and an innovation-driven development model. Specifically, the relationship between the two chains is shown as follows: the industrial chain and the innovation chain are like the DNA double helix chain structure, the two support each other, are interdependent, fuse with each other, and interact with each other, which is the organic unity of innovation subject and production subject, innovation process and industrial development, innovation achievement and product production. The innovation chain relies on the main body of the industry to drive innovation activities, integrate into and enhance the value of the industrial chain; The industrial chain relies on

ISSN 2616-5902 Vol. 6, Issue 1: 192-200, DOI: 10.25236/AJBM.2024.060128

resource concentration and driving advantages to support the orderly operation and optimization and upgrading of the innovation chain.

The two-chain fusion network refers to the network relationship structure composed of the main elements and the interaction chain between the main elements through the policy flow, capital flow, information flow, knowledge flow and talent flow. The fusion subjects involved include core enterprises, collaborating manufacturers, governments, universities and research institutes, financial institutions and intermediary service institutions, etc. Through knowledge sharing and technical cooperation, the fusion subjects obtain the optimal allocation of resources and form an interactive fusion mode with both competition and cooperation. It can be divided into: the integration relationship between government and enterprise. Fusion relationship between enterprises in a converged network. The integration of universities, research institutes and enterprises. The integration relationship between financial institutions and intermediary service agencies and enterprises. The integration of government with universities and research institutes. The integration of universities and research institutes with financial institutions and intermediary service institutions. Figure 1 Converged network shows a two-link converged network.

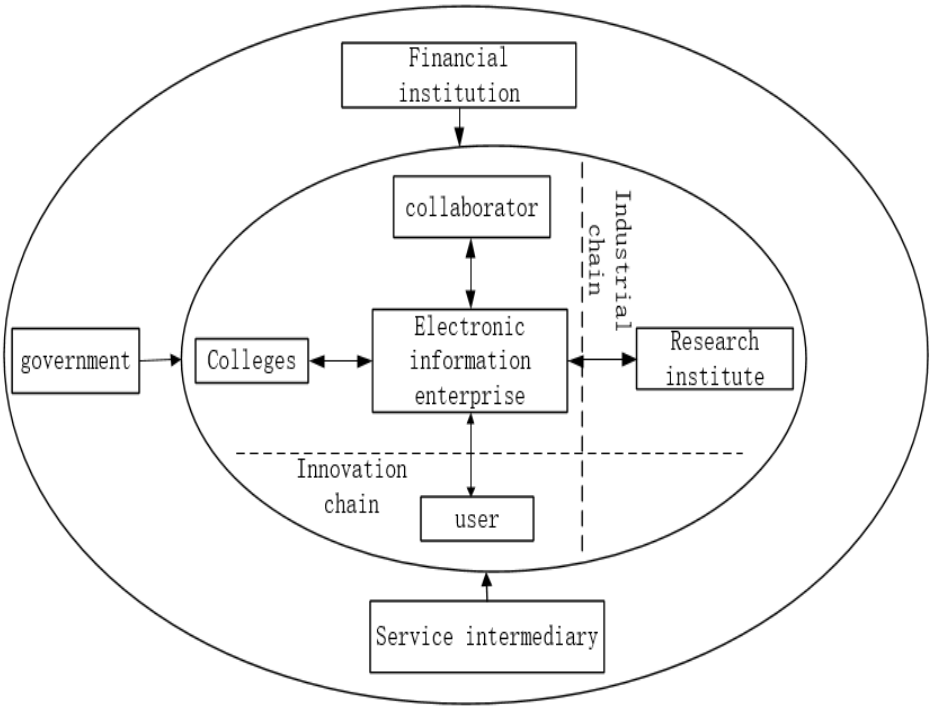

Figure 1: Converged network

4. Evaluation index system and model construction of innovation ability of electronic information enterprises

4.1 Evaluation index system of innovation ability of electronic information enterprises

By systematically sorting out and summarizing the factors that affect the innovation ability of electronic information enterprises, as well as literature reading and analysis of research data, combining the scientific and guiding nature of index screening, the unified purpose of qualitative and quantitative evaluation indicators, and fully considering the particularity of electronic information enterprises' acquisition, absorption, transformation and utilization of knowledge, the primary results of enterprise innovation ability evaluation indicators are obtained. Then the Delphi method is used to optimize the indicators, and the focus group interview method is applied to further modify the indicators, and the index system for evaluating the innovation ability of electronic information enterprises is obtained in the following table 1 evaluation index system of innovation ability of electronic information enterprises.

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Table 1: Evaluation index system of innovation ability of electronic information enterprises

Primary index	Secondary index	Three-level index
Electronic information enterprise innovation ability	Innovative knowledge input ability	R&d facilities and equipment investment
		R&d expenditure
		Input of researchers
	Innovative knowledge management ability	Comprehensive quality of management personnel
		Completeness of rules and regulations
		The rationality of organizational structure
	Innovative knowledge guarantee ability	Number of senior technical personnel
		Government support
		Number of universities and research institutes
	Innovative knowledge production ability	Number of valid invention patents
		Number of new product development projects
		Profit from sales of new products

4.2 Construction of evaluation index system model of innovation ability of electronic information enterprises

TOPSIS method is a multi-attribute decision making method proposed by C.L. Wang and K.Yun in 1981. It is a ranking method approximating the ideal solution and ranking the target to be evaluated according to its proximity to the idealized target.It has the characteristics of small computation and strong operability. The entropy method is an objective weighting method compared with the subjective weighting method. It determines the weights of indicators according to the information of the objective system, analyzes the amount of information of indicators and the degree of connection among indicators, and avoids the disadvantages of inaccurate results caused by subjective weighting. Therefore, this paper applies entropy method and TOPSIS method to evaluate the innovation capability of electronic information enterprises, so as to comprehensively evaluate and sort the innovation capability of electronic information enterprises more objectively and accurately. The specific steps are as follows:

(1)Standardization of raw data. The initial sample is $X=(x_{ij})_{m*n}(i=1,2,\cdots,m;j=1,2,\cdots,n;)$, The range normalization method is used to standardize the original index data, remove the dimension, and obtain the standardized matrix $Y=(y_{ij})_{m*n}$. Since all the evaluation indicators selected in this paper are positive indicators, the standardization process is shown in equation (1).

$$y_{ij}=C+\frac{x_{ij}-\min\{x_{ij}\}}{\max\{x_{ij}\}-\min\{x_{ij}\}}*D \tag{1}$$

(2) Calculate the entropy value of the first index, as shown in equation (2).

$$e_j=-k\sum_{i=1}^{m}P_{ij}\ln(P_{ij}) \tag{2}$$

Among them: $k=\frac{1}{\ln n},P_{ij}=\frac{y_{ij}}{\sum_{i=1}^{m}y_{ij}},0\le e_j\le 1.$

(3) Calculate the weight of the first indicator, as shown in equation (3).

$$w_j=\frac{g_j}{\sum_{j=1}^{m}g_j} \tag{3}$$

(4) Construct the weighted normalized matrix $V=(\mathrm{v}_{ij})_{m*n}$.

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$$V=\begin{bmatrix} w_1y_{11} & w_2y_{12} & \cdots & w_ny_{1n} \\ w_1y_{21} & w_2y_{22} & \cdots & w_ny_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1y_{m1} & w_2y_{m2} & \cdots & w_ny_{mn} \end{bmatrix}=\begin{bmatrix} \mathrm{v}_{11} & \mathrm{v}_{12} & \cdots & \mathrm{v}_{1n} \\ \mathrm{v}_{21} & \mathrm{v}_{21} & \cdots & \mathrm{v}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{v}_{m1} & \mathrm{v}_{m2} & \cdots & \mathrm{v}_{mn} \end{bmatrix} \tag{4}$$

(5) Determine positive ideal solutions V_j^+ and negative ideal solutions V_j^+, as shown in equations (5) and (6).

$$V_j^+=\max\left\{\mathrm{v}_{1j},\quad \mathrm{v}_{2j},\quad \cdots,\quad \mathrm{v}_{mj}\right\} \tag{5}$$

$$V_j^-=\min\left\{\mathrm{v}_{1j},\quad \mathrm{v}_{2j},\quad \cdots,\quad \mathrm{v}_{mj}\right\} \tag{6}$$

(6) Calculate the Euclidean distance between the evaluated object and the positive and negative ideal solution. The details are shown in formula (7) and formula (8).

$$d_i^+=\sqrt{\sum_{j=1}^{n}(\mathrm{v}_{ij}-\mathrm{v}_j^+)^2}(i=1,2,\cdots,\ \mathrm{m}) \tag{7}$$

$$d_i^-=\sqrt{\sum_{j=1}^{n}(\mathrm{v}_{ij}-\mathrm{v}_j^-)^2}(i=1,2,\cdots,\ \mathrm{m}) \tag{8}$$

(7) Calculate the relative closeness of the evaluated object c_i.

$$c_i=\frac{d_i^-}{d_i^++d_i^-}(i=1,2,\cdots,\ \mathrm{m}) \tag{9}$$

According to the relative proximity degree of each evaluation object, the strength of the technological innovation ability of the sample enterprises is ranked. The greater the relative proximity degree, the stronger the technological innovation ability of the evaluated object is. On the contrary, it is weaker.

5. Empirical analysis of innovation ability evaluation of electronic information enterprises

5.1 Data Sources

This paper selects 5 companies in the electronic information industry in Beijing area, namely ZGTX Microelectronics Co., LTD., XX Technology Co., LTD., LXZG Technology Co., LTD., SH Microelectronics Co., LTD., ZCDH Technology Co., LTD., to conduct empirical research on knowledge innovation ability evaluation. Among them, the quantitative indicator data are mainly taken from the statistical data of the company's 2022 annual report and the publicly released information on the official website of the company. Qualitative indicators are obtained through expert scoring method, telephone interview, E-mail and other ways, and can be divided into four grades of "excellent, good, average, poor, poor", namely, excellent (90-100), good (80-89), average (60-80), poor (40-59), poor (0-39). The authority in the field is hired to score the enterprise according to its actual technological innovation and development status and combined with its own practical experience, and the average score is finally taken as the original data of qualitative indicators.

5.2 Analysis of innovation capability evaluation results

The original data is standardized according to formula (1). Considering that the phenomenon of the index value being 0 after standardization should be avoided and the interval distance and difference degree of the index data after standardization should be ensured as far as possible, the values of C and D are set to 1 to obtain the standardized data of each evaluation index. The entropy, difference coefficient and weight of each evaluation index are calculated according to equation (2) and (3), as shown in Table 2 Entropy and weight of each evaluation index.

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Table 2: Entropy and weight of each evaluation index

Primary index	Secondary index	e_j	g_j	w_j
B_1	B_{11}	0.9672	0.0223	0.0762
	B_{12}	0.9725	0.0177	0.0659
	B_{13}	0.9856	0.0167	0.0745
B_2	B_{21}	0.9564	0.0172	0.0752
	B_{22}	0.9689	0.0156	0.0956
	B_{23}	0.9874	0.0289	0.0852
B_3	B_{31}	0.9856	0.0161	0.0766
	B_{32}	0.9891	0.0315	0.0852
	B_{33}	0.9745	0.0256	0.0682
B_4	B_{41}	0.9562	0.0184	0.0882
	B_{42}	0.9856	0.0196	0.0678
	B_{43}	0.9763	0.0177	0.0722

TOPSIS method was used to evaluate the samples comprehensively. Firstly, the weighted normalized matrix is constructed according to formula (4). Then, the values of positive ideal solution and negative ideal solution are determined according to equations (5) and (6). Then, according to equation (7) - (9), the Euclidean distance and relative proximity degree from each sample enterprise to the positive and negative ideal solution are calculated and sorted, as shown in Table 3 shows the positive and negative ideal solutions and relative closeness of innovation capability of sample enterprises.

Table 3: Shows the positive and negative ideal solutions and relative closeness of innovation capability of sample enterprises

	ZGTX	XX	LXZG	SH	ZCDH
d_i^+	0.1922	0.1235	0.2033	0.2896	0.1688
d_i^-	0.1225	0.2356	0.1256	0.0628	0.1678
c_i	0.4752	0.6725	0.3892	0.2567	0.5629
Sort	3	1	4	5	2

As can be seen from Table 5-2, the innovation ability of the five electronic information enterprises based on the perspective of two-chain integration is ranked as follows: XX company has the first evaluation score, and it has outstanding performance in innovative knowledge management ability and innovative knowledge output ability. The evaluation score of ZCDH company is the second, and its innovation knowledge investment is greater than that of other 4 sample enterprises. ZGTX Company and LXZG company ranked third and fourth respectively, and the overall innovation ability showed a growing trend; The evaluation score of SH company is fifth, and the overall innovation ability needs to be improved.

6. Research conclusions and suggestions

By combing relevant literature at home and abroad, This paper systematically analyzes the basic principle of two-chain integration of electronic information enterprises, and constructs four evaluation indexes of innovation capability including innovation knowledge input capability, innovation knowledge management capability, innovation environment guarantee capability and innovation knowledge output capability from the perspective of two-chain integration. In summary, the influence degree of the evaluation index of innovation ability of electronic information enterprises from strong to weak is: innovation knowledge input ability, innovation knowledge output ability, innovation knowledge management ability, innovation environment protection ability. Based on the comprehensive evaluation of the innovation ability of 5 sample electronic information enterprises, this paper puts forward

ISSN 2616-5902 Vol. 6, Issue 1: 192-200, DOI: 10.25236/AJBM.2024.060128

countermeasures and suggestions for improving the innovation ability of electronic information enterprises:

(1) Increase investment in enterprise innovation.

Increase the investment of funds, especially in the breakpoints and blocking points of the two chains such as basic research and core components, increase the proportion of innovation investment in the total investment, broaden the proportion of research funding, build a diversified investment system, and provide long-term and stable support for research in key areas related to the security and stability of the two chains. Fully implement the supporting role of funds in electronic information enterprises and advanced industrial clusters, and strengthen support for advanced key enterprises. Timely upgrading of facilities and equipment, especially for the sophisticated characteristics of electronic information enterprises, the application of more new facilities and equipment is more conducive to improving the innovation efficiency of enterprises. Increase investment in R&D personnel, strengthen the connection with universities, ensure a steady supply of talents or teams for the development of enterprise innovation activities, and promote the deep integration of talent chain and the two chains.

(2) Make full use of innovative service platforms.

Electronic information enterprises should attach importance to the innovation environment created by the government, pay close attention to the relevant innovation industrial policies continuously improved by the national and local governments, fully understand and rationally use policy tools such as science and technology finance and tax incentives, adapt to the allocation system of innovation resources such as capital and talent, reduce innovation costs and innovation risks, and improve innovation efficiency. Speed up the cultivation of electronic information enterprises independent innovation ability. At the same time, relying on the technology innovation technology platform and service platform, make full use of the innovation infrastructure of technology research and development, resource interaction, enterprise incubation and technology transfer and transformation, and obtain enterprise innovation resources and related services. Further strengthen the organic connection of innovation chain links such as basic research, applied research and industrialization, promote the optimal allocation and efficient use of innovation resources, better play the important role of innovation chain in the industrial chain consolidation, reinforcement and strong chain, promote the deep integration of industrial chain innovation chain, ensure the continuous development of knowledge innovation activities, and constantly improve the knowledge innovation ability of electronic information enterprises.

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