Analysis of Fusion Factors of The "Dual Chains" Based on The DEMATEL-ISM Model

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Abstract. The deep integration of the industry chain and innovation chain, known as the "dual chain," is an effective way to integrate the strengths of industry, academia, and research, enhance the research and development capabilities of key industrial technologies, and achieve high-quality industrial development. Therefore, this paper first analyzes the mechanism of the fusion of the "dual chains" and summarizes the main factors influencing this fusion, based on the systemic methodology, the DEMATEL-ISM method is used to construct a model of influencing factors for the fusion of the "dual chain," analyzing the interrelationships between various factors in the fusion system, and providing a reference for promoting the fusion of the "dual chain."

Keywords: Industrial Chain, Innovation Chain, Dual Chains Fusion, Influencing Factors, DEMATEL, ISM

1 Introduction

Since General Secretary Xi Jinping proposed to deploy the innovation chain around the industrial chain and layout the industrial chain around the innovation chain in the Academician Conference of the Chinese Academy of Sciences and Chinese Academy of Engineering in 2014, research and practice on the industry chain and innovation chain (referred to as the "dual chain") have gradually increased and deepened. However, most of the research has focused on the strategic research [1], theoretical connotations [2-4], mechanisms and paths [5-11], technology transfer [12-14], and other aspects of the fusion of the "dual chain," while research on the factors influencing the fusion of the "dual chain" is relatively lacking. Therefore, this paper identifies and summarizes the main factors influencing the fusion of the "dual chain." Additionally, by introducing the Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Interpretive Structural Modeling (ISM), an influencing factor model is constructed, analyzing the comprehensive relationships between various influencing factors and determining the key factors influencing the fusion of the "dual chain." This is aimed at providing a theoretical basis and practical reference for promoting the deep integration of the "dual chain" and facilitating high-quality industrial development.

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2 Fusion Mechanism of the "Dual Chains"

The industrial chain spans the entire process of a product, from research and development, design, production to sales and services. The key links in the chain involve the transmission and integration of various elements such as knowledge, information, talent, and funds, as well as organizational coordination among enterprises directly or indirectly involved in the production process. On the other hand, the innovation chain originates from knowledge innovation, linking various innovation stages from basic research to industrialization, requiring close cooperation among multiple stakeholders including government, industry, academia, research institutions, and funding bodies to enhance the value of products. The process of fusion between the two is characterized by the integration of knowledge and innovative resources such as technology into key links of the industrial chain by the innovation chain, resulting in their redesign and transformation. Simultaneously, the industrial chain, through the flow of funds and information, guides the innovation chain in carrying out innovative activities. The fusion of the two requires the establishment of effective communication, trust, and benefit-sharing mechanisms among participating entities, enabling interaction and interdependence between the "dual chains," ultimately promoting industrial transformation and upgrading, technological advancement, and industrialization. Additionally, the fusion of the "dual chains" necessitates positive policy guidance, a rich pool of human resources, and mature capital markets, among other external environmental factors, for encouragement and support. The specific fusion mechanism is illustrated in Figure 1:

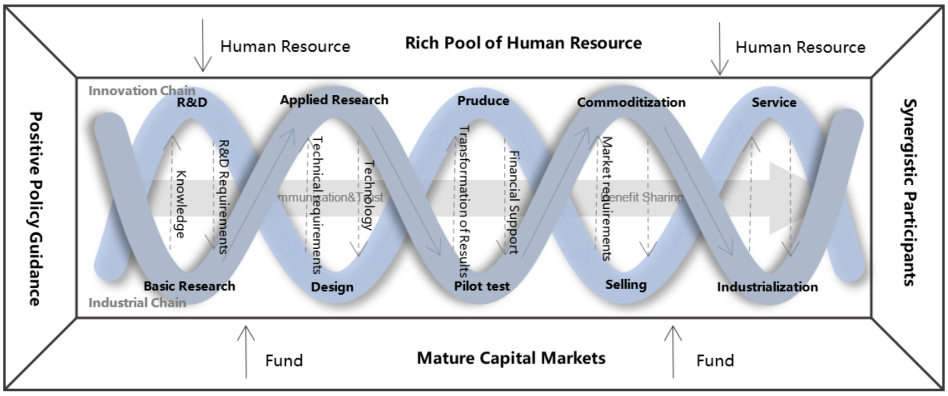

Fig. 1. Schematic Diagram of "Dual Chains" Fusion.

3.Identification of Fusion Influencing Factors and Construction of the DEMATEL-ISM Model for "Dual Chains" Fusion

3.1 Identification of Fusion Influencing Factors

Based on the fusion mechanism of the dual chains, 17 influencing factors were identified by analyzing three aspects: participating entities, resource elements, and institutional mechanisms, as shown in Table 1:

Table 1. Influencing Factor System for the Fusion of the "Dual Chains"

Classification	Si	Influencing Factors	Specific Explanation
Participating Entities	S1	Top-Level Design	The specific planning and design of the integration of the dual chains driven by leading enterprises and relevant entities
	S2	Supporting Policies	Relevant government policies promoting the integration of the dual chains, including preferential policies, investment policies, etc
	S3	Resource Integration and Coordination Capability	The ability of leading enterprises to integrate and coordinate resources in the industrial and innovation chains
	S4	Research Capability	The comprehensive research and innovation level of universities and research institutes
	S5	Maturity of Intermediary Markets	Including the diversification of technology intermediary entities, the breadth of business scope, and flexibility in innovation response
	S6	Goal Consistency	Consistency between the innovation goals of research entities and the innovation goals of industrial entities
Resource Elements	S7	Scale of R&D Personnel	The total scale of research and development personnel involved in innovation in both the innovation and industrial chains
	S8	Scale of Leading Talent	The scale of talent within the R&D personnel who play a leading role in the relevant field
	S9	Efficiency of Information Transmission	Timeliness and effectiveness of information/data transmission between the industrial and innovation chains
	S10	Scale of R&D Funding Investment	The quantity of funding invested in technological innovation research and development
	S11	Smoothness of Financing Channels	Smooth access of technology-based enterprises to financing channels such as stocks, bonds, loans, etc
	S12	Completeness of Financing Markets	Capital markets providing diversified financing options for enterprises
Safeguard Mechanisms	S13	Benefit Distribution Mechanism	Including technology transaction mechanisms and profit distribution mechanisms
	S14	Communication and Coordination Mechanism	Information communication mechanism among entities in the dual chains
	S15	Technology Transfer Platforms	Platforms utilizing digital technology to promote the transformation of technological achievements
	S16	Innovation Incentive Mechanism	Including talent incentive mechanisms, compensation incentive systems, innovation environment, and innovation culture
	S17	Talents Flow Mechanism	A mechanism within the dual chains where entities are unified to promote innovation through talent mobility

3.2 DEMATEL Method

1.Determination of the Direct Influence Matrix S

Establish the semantic scale for expert evaluation of the influencing factors (Table 2). Utilize the Delphi method to assess the strength of the relationships between the various influencing factors of the fusion of the "dual chains" and obtain the initial direct influence matrix S.

Table 2. Semantic Scale for Expert Evaluation.

Semantic Variable	No Influence	Minor Influence	Moderate Influence	Strong Influence
Scale	0	1	2	3

2.Computation of the Comprehensive Influence Matrix T

Normalize the initial direct influence matrix S to obtain the normalized influence matrix N. The specific computation formula is shown in Equation (1):

$$N = \frac{S}{\max\left(\sum_{j=1}^{n} s_{ij}\right)} \tag{1}$$

Consider both the direct and indirect influences between the influencing factors. Utilize the summation of direct and indirect influences. According to Equation (2), compute the comprehensive influence matrix T.

$$T = (N + N^2 + N^3 + \cdots + N^k) = \sum_{k=1}^{\infty} N^K = N(I - N)^{-1} \tag{2}$$

3.Calculate the Impact and Being Impacted Degrees of Each Influencing Factor

Calculate the impact degree Di and being impacted degree Ci of each influencing factor according to Equations (3) and (4). Where the impact degree Di is the sum of the corresponding row for factor Ti, and the being impacted degree Ci is the sum of the corresponding column for factor Ti.

$$D_i = \sum_{j=1}^{n} t_{ij}, (i = 1,2,3,\cdots,n) \tag{3}$$

$$C_i = \sum_{j=1}^{n} t_{ji}, (i = 1,2,3,\cdots,n) \tag{4}$$

4.Compute the Centrality and Causality of Each Influencing Factor

Calculate the centrality Mi and causality Ri of each influencing factor according to Equations (5) and (6). Where the centrality Mi is the sum of impact degree Di and being impacted degree Ci. The causality Ri is the difference between the impact degree Di and being impacted degree Ci. Based on the principle that a causality Ri greater than 0 is a causal factor and less than 0 is a result factor, determine the causal attributes of each factor and sort them accordingly.

$$M_i = D_i + C_i \tag{5}$$

$$R_i = D_i - C_i \tag{6}$$

3.3 ISM Method

1.Calculate the Overall Relationship Matrix Z

To simplify the system structure, introduce the threshold λ ($\lambda \in [0,1]$), and calculate the direct relationship matrix B based on the comprehensive impact matrix T according to Equation (7).

$$\begin{cases} b_{ij} = 1, t_{ij} \geq \lambda \\ b_{ij} = 0, t_{ij} < \lambda \end{cases} \tag{7}$$

Where, $\lambda = \bar{x} + \sigma$, $\bar{x}$ is the mean of the factors of the matrix T, σ is the standard deviation.

Further, considering the influence of the factor itself, calculate the overall relationship matrix Z according to Equation (8).

$$Z = B + I \tag{8}$$

Based on Equation (9), perform consecutive multiplication on the overall relationship matrix Z to obtain the reachable matrix K.

$$K = Z^{k+1} = Z^{k} \neq Z^{k-1} \tag{9}$$

Based on Equation (10) and the reachable matrix K, establish the reachable set R(Si), antecedent set A(Si), and intersection set C(Si) for each factor Si. If C(Si)=R(Si), then this element is a high-level element. Elements that meet this condition are on the same level. Repeat this process to obtain different hierarchical levels.

$$\begin{cases} R(S_i) = \{S_i \mid S_i \in S, k_{ij} = 1\} \\ A(S_i) = \{S_i \mid S_i \in S, k_{ji} = 1\} \\ C(S_i) = R(S_i) \cap A(S_i) = \{S_i \mid S_i \in S, k_{ij} = 1, k_{ji} = 1\} \end{cases} \tag{10}$$

Based on the hierarchy analysis results and incorporating the ranking results of centrality and causality, create a multi-level hierarchical structure model.

3.4 Model Construction Results

Based on the Delphi method, the direct impact matrix S of each factor was identified.

$$S = \begin{bmatrix}
0 & 0 & 0 & 3 & 2 & 3 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 3 & 0 & 0 \\
3 & 0 & 0 & 1 & 1 & 2 & 3 & 0 & 0 & 3 & 2 & 1 & 0 & 0 & 2 & 1 & 2 \\
0 & 0 & 0 & 0 & 0 & 3 & 0 & 2 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 3 & 0 & 0 & 3 & 0 & 2 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 2 & 0 & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 3 & 3 & 1 & 0 & 2 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 3 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 2 & 0 & 2 & 3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 3 & 2 \\
0 & 0 & 1 & 1 & 2 & 3 & 0 & 0 & 3 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 2 \\
0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 2 & 0 & 1 & 2 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 3 & 2 & 0 & 1 & 3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

The direct impact matrix was normalized according to Equation (1), and the comprehensive impact matrix T was calculated based on Equation (2). Using the impact matrix T and Equations (3), (4), (5), and (6), the influence degree, being-influenced degree, centrality, and causality of each influencing factor were calculated. The centrality was taken as the horizontal coordinate and causality as the vertical coordinate to plot the cause and effect diagram as shown in Figure 2.

Fig. 2. Cause-Effect Relationships of Various Influencing Factors.

Based on the comprehensive impact matrix T, calculate the reachable matrix K according to Equations (7), (8), (9), and (10). With the reachable matrix K as the basis, perform hierarchical division of each factor according to Equation (10), and the final hierarchical division result is shown in Table 3.

Table 3. Final Hierarchical Division Result.

Level	Fcators
L1	4,6,7,8
L2	3,5,9,10,11,16
L3	12,15,17
L4	1,13,14
L5	2

Based on the hierarchy division analysis results and the centrality and causality ranking results, a multi-level hierarchical structure model was constructed, as shown in Figure 3.

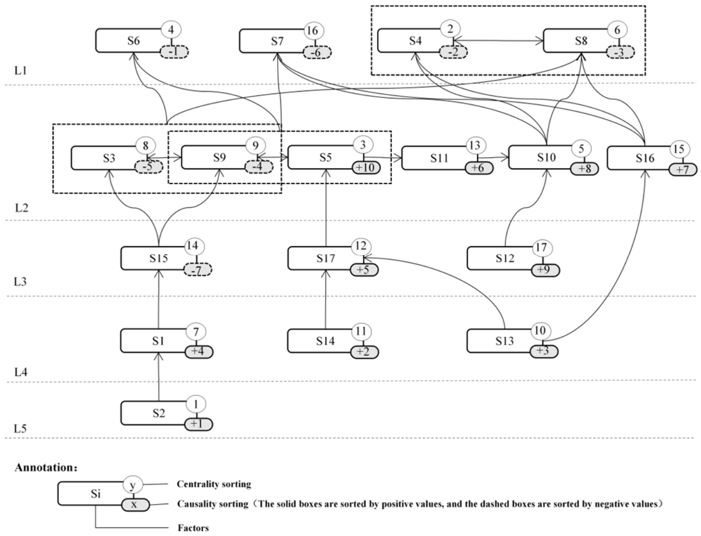

Fig. 3. Multi-Level Hierarchical Structure Model of "Dual Chain" Fusion Influencing Factors based on DEMATEL-ISM.

4.Model Analysis

4.1 Hierarchical and Causal Analysis

From Figure 3, it can be seen that the influencing factors of "Dual Chain" fusion form a five-level directed hierarchical structure, where the influencing factors gradually transition from fundamental causes to surface causes from bottom to top. The causal relationships between factors are reflected in the multi-level hierarchical structure diagram as directed arrows between factors. If the arrows are bidirectional, it indicates a mutual causal relationship between the factors. In Figure 3, there are three sets of mutually causal relationships in the "Dual Chain" fusion system: resource integration and dispatch capability (S3) and information transmission efficiency (S9), research capability (S4) and leading talent scale (S8), and maturity of the intermediary market (S5) and information transmission efficiency (S9). These groups of factors are closely connected internally, and when optimizing management, they need to be considered collectively to enhance management effectiveness. From a hierarchical perspective, policy support (S2) is the fundamental cause influencing the "Dual Chain" fusion. It directly affects the direction and intensity of top-level planning (S1) formulated by industry-leading enterprises and related entities, which in turn affects the mechanism of interest distribution (S13) and communication coordination (S14) among participating entities. On the other hand, the overall research capability (S4) of universities and research institutes, the consistency between the innovation goals of research entities and industry entities (S6), and the scale and quality of research talent (S7, S8) are surface-level factors affecting "Dual Chain" fusion and are influenced by other factors.

4.2 Analysis of Causality and Centrality

Centrality is a commonly used concept tool in social network analysis, representing the importance of a node in the network. Centrality is a measurement of centrality and is a positive indicator; that is, the larger the value, the more important it is. From the ranking in Figure 3, it can be seen that factors such as policy friendliness, market maturity, capabilities of participating entities, and resources such as funding size (S10) that affect "Dual Chain" fusion are relatively important and should be given more emphasis.

Causality reflects the causal attribute of factors, with two indicators: positive and negative causality. A positive causality indicates a causative factor, and the larger the value, the easier it is to influence other factors and the higher the ranking. A negative causality indicates a resulting factor, and the larger the absolute value, the more easily it is influenced by other factors and the higher the ranking. From Figure 3, it can be seen that the main causative factors are policy support (S2), communication coordination mechanism (S14), interest distribution mechanism (S13), top-level planning (S1), and talent flow mechanism (S17). These factors need to be closely monitored. The resulting factors that rank higher are goal consistency (S6), research capability (S4), leading talent scale (S8), information transmission efficiency (S9), and resource integration and dispatch capability (S3). When optimizing and enhancing these elements, attention should be given to the management of upstream factors connected to them.

4.3 Comparative Analysis of the Two Model Methods

Based on the analysis in the two aspects above, it can be seen that the centrality calculated by the DEMATEL method, as it comprehensively combines the attributes of influence and being-influenced, does not show an obvious correlation with the hierarchical division obtained by the ISM method. However, causality has a significant correlation with the hierarchical results; this is because the ISM model reflects the relationship between factors from root to surface in a hierarchical way, which is consistent with the logic of factor causality in the DEMATEL method. This also indicates that the causality and centrality properties of factors obtained by the two methods can mutually support and explain each other.

In conclusion, based on the analysis results of the DEMATEL-ISM model, starting from the factors with higher centrality rankings, which indicates higher importance, and finding the root cause factors that affect these factors through the hierarchical hierarchical structure, strategies and recommendations to optimize the fundamental influencing factors can be formulated, thus achieving the goal of deepening fusion.

5.Conclusion

"Dual Chain" integration involves multiple participating entities on both the industrial chain and the innovation chain. It requires the smooth flow of elements such as talent, funds, and information within and between the chains. This necessitates the formulation of various management mechanisms to ensure and promote collaboration and integration among the entities, making it a complex system. This study established the mechanism of "Dual Chain" fusion and used it as the theoretical basis to identify the influencing factors of "Dual Chain" fusion. We employed a systems engineering approach and the Delphi method to analyze the mutual relationships between various factors. Through the DEMATEL-ISM method, we obtained a clear hierarchical structure diagram of influencing factors. This visually displays the importance of the relationships affecting "Dual Chain" fusion. The analysis results show that to smoothly promote the integration of the industrial chain and the innovation chain, the key lies in government agencies providing active policy support, the industry formulating clear top-level planning, and having interest distribution mechanisms that align with the interests of various participating entities, smooth communication coordination mechanisms for the smooth flow of elements, and mechanisms for the interaction and exchange of innovative R&D talents, along with a mature capital financing market. The research results provide a new reference and basis for further deepening the integration of the "Dual Chain."

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