Influencing Factors and Mechanism of Enterprise Technological Innovation Capability Based on Interpretative Structural Model

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Abstract. The technological innovation capability of enterprise can be regarded as the synthesis of the internal conditions for an enterprise to implement the technological innovation behavior. It is a comprehensive ability system composed of various elements, reflecting the performance of its technological innovation, and is an important reference index to measure the growth potential of an enterprise. In order to clarify what these elements are and how they influence the technological innovation capability of enterprise, this paper does the following work. Based on the technology process theory and technology system theory, 28 elements that could affect the technological innovation capability have been chosen to construct a index system in this paper. Then using the ISM model, the structure, levels and the relationship between the indexes of the index system has been explored to build a hierarchical structure figure. 28 elements could be divided into 4 progressive layers: macro-layer, industrial-layer, enterprise-layer, target-layer. Then the action mechanism of the 4 layers to the technological innovation capability of enterprise has been researched. The results show that macro-layer is the underlying driving force factor, the industrial layer is the pressure factor, and the enterprise-layer is the strategic factor.

Keywords: Interpretative Structural Modeling; Technological innovation capability; innovation mechanism

1 Introduction

Scholars have began to study the technological innovation capability of enterprises since the 1980s. There is still not a unified definition of technological innovation capability owing to the the different perspectives and understandings of their research. However in general, the same substance involved in the different definitions can not be separated from the concept that the technological innovation capability of the enterprise can be regarded as a synthesis of the internal conditions for the enterprise to carry out the technological innovation behavior and a comprehensive capability system composed of various elements at the same time[1].The technological innovation capability of an enterprise reflects its ability and the possibility to achieve the performance of technological innovation, which is also an important reference index to measure the growth potential of an enterprise.Scholars decompose the enterprise technological innovation system from different perspectives, and evaluate the constituent elements of the enterprise technological innovation ability.According to the different angles of

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decomposition, it can be divided into the following three views: element view, process view and system view.

According to element view, the total quantity and quality of the many internal conditions needed for enterprises to implement innovation behavior can reflect the technological innovation ability of enterprises. The components of enterprise technology innovation ability include: enterprise available resources, the ability to interpret technology and industry competition, changes in organizational structure and culture, and strategic management ability and so on.

According to the process view, the process of technological innovation includes multiple links from creativity to technology, technology to sample, sample to product commercialization. Each link is connected with and influences each other, forming a complete process of technological innovation. The stronger the ability of each link, the stronger the overall technological innovation ability of the enterprise will be[2]. The technological innovation ability of the enterprise includes: the enterprise's technology and market opportunity selection ability, technology design and development ability, sample manufacturing capacity, pilot test capacity, scale production capacity, sales and market development ability, market information feedback and product update ability and so on.

According to the system view, technological innovation performance can be used to measure the technological innovation ability of enterprises. The performance of technological innovation could reflect the input-output efficiency of enterprise technological innovation, or the impact of technological innovation activities on the operational efficiency and efficiency of enterprises[3]. The higher the input-output ratio of an enterprise is, the higher its technological innovation performance is, and the stronger its technological innovation ability is[4].

On the basis of the literature research, relying on the system view, integrating the element view and the process view, considering the internal factors and external environment of enterprise, the influence factors of the enterprise technology innovation ability is analyzed in this paper. Using ISM model the logical relationship and development framework between these elements is clarified to explore the mechanism of the enterprise technology innovation ability.

2 Selection of indexes

The technological innovation process of an enterprise is a complex comprehensive system process, which has many influencing factors and is not independent from each other. It plays a major role in different sub-processes, and jointly determines the level of the technological innovation ability of an enterprise[5]. Referring to the evaluation index system of enterprise technology innovation ability proposed by Dong Gang et al[6]., basing on the time line of process view, the horizontal elements are analyzed at different time points, and selects 28 elements in 8 stages.

Stage 1:Technology and market opportunity selection

1-Market analysis capability: the ability that enterprise could plan and make decisions on production and management by analyzing historical experience data, normal market situation and government policies and regulations.The stronger the market analysis capability of the enterprise is, the clearer understanding of the market supply and demand the enterprise have, and the more accurately the enterprise could find the further development direction.

2-Resource endowment: the capital and non-capital resources enterprise holds, including capital, labor, patent and so on; the stronger the resource endowment capability of the enterprise is, the more support for the subsequent production and innovation.

Stage 2:Technical design and development and pilot

3-R&D personnel: human resources input to research and development.

4-R & D funding: capital resources input to research and development.

5-Patent quantity: Technological innovation can be realized by improving existing technology or creating new technology. The quantity of patents determines the basic resources for enterprises to achieve innovation through improving existing technology. The more patents they already have, the higher possibility of improvement on this basis is[7].

6-New technology development: the capability that creating a new technology from zero is difficult, but it affect enterprises' technological innovation more directly and significantly.

Stage 3:Scale production

7-Equipment level: whether the equipment could match the innovation of product determines the transformation of new technology.

8-Production personnel quantity and quality: production personnel do not participate the research and development process, therefore their understanding of the technology affects the transformation results of technology.

9-Modernization level: the modernization level of enterprises shows the level of efficiency of production mode and production structure of enterprises.

10-Raw material utilization: the improvement of raw material utilization ratio is the process of process improvement.

11-Product quality standards: the quality standard of the product is the rule that the enterprise must follow, and its limitation determines whether the product can be put into the market.

12-Product life cycle: the product life cycle determines the output level in different life cycle stages.

Stage 4: Sales and market development stage

13-Trading platform supply chain: the level of trading platform and supply chain determine the maturity of the market and the market support in market developing process.

14-Internal and external communication: the success of product in the market is a important symbol of the success of technological innovation. How products performance in the market can not be separated from a marketing strategy, which comes from the internal communication and realizes by external communication.

Stage 5:Market information feedback

15-Utilization of information resources: After the product is put into the market, its sales situation and customer evaluation will feedback back to the enterprise[8], according to which the enterprise could adjust the output of the product. Also the customer's evaluation feedback may become the source of product improvement[9].

16-Market forecasting capability: production process is not a short term period, which means that a production plan should be made in advance. What kind and amount of products is going to be produced next? What amount of the new product is gonging to be produced? To answer these questions, a prior market prediction is really necessary.

Stage 6:Product update

17-Technological improvements: the capability that enterprise could improve the existing technology[10].

18-Green product development: the product can save resources,reduce pollution and health injury to workers.

Stage 7:Internal environment

19-Innovation spirit of entrepreneur: the innovation spirit of entrepreneurs directly determines how valued the technological innovation is taken by the strategy maker of the enterprise, and indirectly determines the investment of innovation elements.

20-Innovative strategies: the innovation strategies arrange the structure and steps of the innovation activities of the enterprise.

21-Innovative mechanism: the innovation mechanism arranges the organizations and functions of the innovation activities of the enterprise.

22-Organizational culture: the organizational culture of the enterprise determines the incentive level.

23-Innovation environment: the innovation atmosphere of the enterprise determines the flow efficiency of the innovation elements within the enterprise.

24-Informatization level of enterprise: development of information technology in enterprise could improve the efficiency of production and operation and reduce the risk and cost, and thus improve the overall management level and sustainable management ability of enterprises[11].

Stage 8:External environment

25-Government policies and strategies: the national strategy determines the position and importance of the industry in the economy; the national policies guide the direction of the industry for the enterprise[12].

26-Market and industrial environment: the market and industrial environment determines the market competition situation, the innovation capability of enterprise determines whether it can get success among many competitors in the market.

27-Laws and norms: the national laws, regulations and industry standards supervise the innovation and management process of the enterprise.

28-Social culture and technology: the cultural environment has a direct impact on the demand and evaluation of products, and indirectly on the strategy choice of marketing and promotion.

3 Interpretative Structural Modeling

Intermediate Structural Modeling（ISM） is a kind of structural modeling technology, which can transform a system with many ineractional discrete elements into a multi-layer progressive structural model through logical operation. The relationship between the variables of the disordered system could be structured. Structure model formed by ISM method describes the relationship between the system elements with a directed graph, in which the nodes represent the elements and the arrow represents direction[13]. Operational process of ISM methods for hierarchical analysis is as follows:

Step1: Set system elements $X_i(i=1,2,...n)$.

Step2: Construct adjacency matrix: according to the relationship between system elements. Boolean value could be used to describe the relationship(if two elements are correlated , 0 or not), to get the adjacency matrix. The value of element a_{ij} is 1 if X_i and X_j are correlated, or else a_{ij} is 0 .

Step3: Operate matrix A_i to get the reachability matrix $M=\{\mathrm{m_{ij}}\}_{\mathrm{n*n}}$. The reachablility matrix comes from a logical operation of the matrix (I represents the identity matrix) that reflects the path through which the element X_i could reach the element X_j. It is also a matrix which represents the relationship between the variables with 0-1 variables. The operation process is as equation(1) shows:

$$\text{If } (A+I)^k=(A+I)^{k+1}\neq(A+I)^{k-1} \;;\quad \text{Then } M=(A+I)^k \tag{1}$$

Step4: Partition the reachability matrix hierarchically structure the index system and resequence the reachability matrix. And mapping the hierarchical structure of the system then.

4 Analysis of Enterprise's Technological Innovation Capability

Step 1: Set the enterprise technological innovation capability as X_0; Set the indexes of the Enterprise's Technological Innovation Capability index system as $X_i(i=1,2,...n)$,i is the serial number of the 28 elements in chaper .

Step 2: According to chapter 3 in this paper, construct adjacency matrix: $A_i=\{X_{ij}\}_{29*29}$; then operate the reachability matrix and merging the ranks of the same elements to obtain the reduced reachability matrix as **Table 1.** The number “1” in the reduced matrix represents a submatrix composed by strongly connected elements. Similarly, the number”13” represents the submatrix composed by elements $X_{13}\sim X_{17}$. The number”19” represents the submatrix composed by elements $X_{19}\sim X_{24}$.

Step 3: Relay to **Table 1**, reachability set P1, antecedent set Q1, and intersection set S1 could be find out as **Table 2** shows. According to the principle of equal reachable set and common set, the indicators of each layer are selected in turn, and the factors influencing the enterprise's technological innovation ability are decomposed horizontally, and “Ln” represents the number of layers.

Table 1. Reduced reachability matrix

i	1-10	11	12	13-17	18	19-24	25	26	27	28
1*（1-10）	1	0	0	1	1	1	0	0	0	0
11	1	1	1	1	1	1	0	0	0	0
12	1	0	1	1	1	1	0	0	0	0
13*（13-17）	1	0	0	1	1	1	0	0	0	0
18	0	0	0	0	1	0	0	0	0	0
19*（19-24）	1	0	1	1	1	1	0	0	0	0
25	1	1	1	1	1	1	1	1	1	0
26	1	0	0	1	1	1	0	1	0	0
27	1	1	1	1	1	1	0	0	1	0
28	1	0	1	1	1	1	0	0	0	1

Table 2. Reachability set, antecedent set and intersection set.

i	P_1	Q_1	S_1	L_n
1*	1,13,18,19	1,11,12,13,19,25,26,27,28	1,13,19	3
11	1,11,12,13,18,19	11,25,27	11	5
12	1,12,13,18,19	11,12,19,25,27,28	12,19	4
13*	1,13,18,19	1,11,12,13,19,25,26,27,28	1,13,19	3
18	18	1,11,12,13,18,19,25,26,27,28	18	2
19*	1,12,13,18,19	1,11,12,13,19,25,26,27,28	1,12,13,19	3
25	1,11,12,13,18,19,25,26,27	25	25	7
26	1,13,18,19,26	25,26	26	4
27	1,11,12,13,18,19,27	25,27	27	6
28	1,12,13,18,19,28	28	28	5
0	0	0	0	1

Step 4：A general structure of the enterprise technology innovation ability evaluation system can be obtained from **Table 2**. The strongly connected submatrix 1*,13*, 19* could also use ISM method to find out their structure. Finally, the structure of the influencing factor system of the technological innovation ability of enterprises can be shown in **Figure 1**.

The two factors located in the sixth and seventh layers come from external of the enterprise and belong to the macro-level factor uncontrollable by the enterprise, which are set as the "macro layer". The four factors in the fifth and fourth floors come from the industry situation in which the enterprise is located, which are set as "industrial layer". In the third layer, the factors directly related to the production and operation of the enterprise are set as "enterprise layer"; the factor matrix involved shows strong connectivity characteristics, respectively as "production factors", "market factors" and "non-physical factors". In the production factor 1 *,

some factors show further strong connectivity characteristics, which are classified as "R & D process". Factors located in the second and first layers can be understood as the "target layer" of enterprise technological innovation.

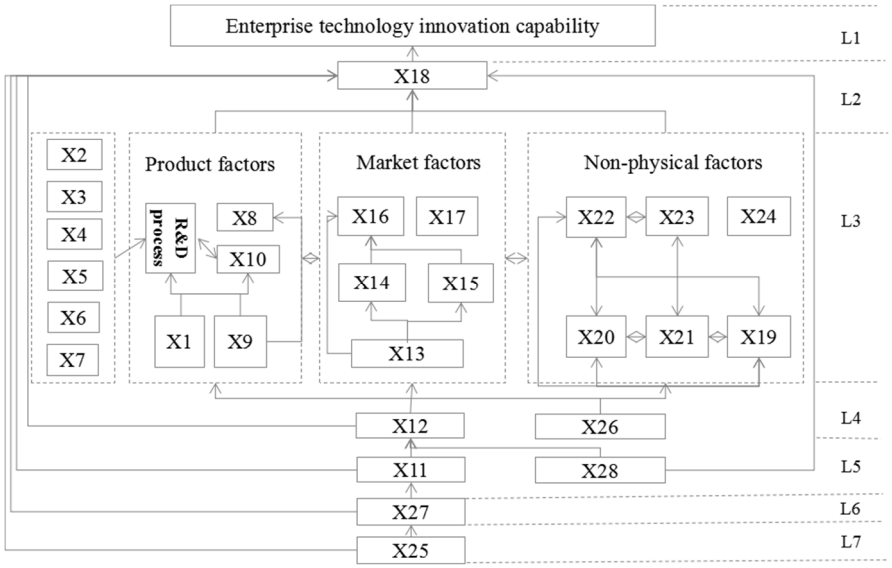

Figure 1. Hierarchical structure of the technological innovation capability factors

5 Conclusions

(1) Macro-level factors are the underlying driving force of enterprise technological innovation.

The ultimate goal of enterprise operation is to maximize profit, and the motivation of technological innovation is to pursue new profit points. Meanwhile, enterprise technological innovation requires cost input, so the enterprise lacks the motivation of technological innovation. The guidance of national innovation strategy, the promotion of economic and industrial policies, and the norms of relevant laws and regulations promote enterprises to carry out technological innovation.

(2) Industrial layer factor is the pressure factor of enterprise technological innovation.

The industrial layer factor is the direct response of the industry in which the enterprise is located to the macro-level factors, which determines the competition situation of the enterprise's products in the market. The changes of the product life cycle, quality standard and consumer preference caused by the cultural environment will affect the market share of the enterprise's products, and then affect the profit of the enterprise. But the controllable range of industrial factors is very small, and the enterprise passively adjusts its itself according to the industrial factors. Therefore, the goal of improving the market competitiveness of products, improving the market share of products and maintaining the profits of enterprises makes enterprises must carry out technological innovation.

(3) Enterprise layer factor is the strategic factor of enterprise technology innovation.

The three blocks of enterprise layer factors well reflect the three directions of technological innovation of enterprises. The three blocks influence each other, and enterprises can choose the innovation direction according to their own advantages. Production factors and market factors correspond to the production innovation and process innovation of enterprises, and the non-entity elements include the factors that affect the implementation of innovation activities in the process of innovation. Enterprise technology innovation can help enterprises to obtain higher profits by developing new products, improving production efficiency and reducing cost; the development factors affect the development of new products. The production personnel and modernization improvement can improve production efficiency, while increasing the resource utilization corresponds to reduce cost.

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