Application Research of Fuzzy Comprehensive Evaluation Model in Evaluation of Technological Innovation Ability of Innovative Small and Medium-sized Sci-tech Enterprises

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Abstract: The fuzzy comprehensive evaluation method has unique advantages in dealing with various complex system problems that are difficult to describe with precise mathematical methods. The fuzzy comprehensive evaluation model is used to conduct empirical research on the scale and technological innovation capability of innovative small and medium-sized technology enterprises. The research shows that the technological innovation ability of medium-sized innovative technology enterprises is higher than that of small-scale innovative technology enterprises. The advantages and disadvantages of medium-sized and small-scale innovative technology enterprises in technological innovation are different.

1. Introduction

Technological innovation is the lifeline of innovative small and medium-sized technology companies, and determines the quality and speed of the growth of innovative small and medium-sized technology companies. Innovative small and medium-sized technology enterprises are characterized by their own core intellectual property rights and relying on technological innovation to achieve sustainable development [1-2]. There are two views on the relationship between enterprise scale and technological innovation capability [3]: First, the theory of technological innovation of large enterprises, which holds that large enterprises have strong technological innovation capabilities, because large enterprises have more funds and the ability to take risks. Stronger, more able to discover the market value of innovation, and have economies of scale, the main representatives are Xiong Biao, Galbraith, Vals, Camien, Schwarz, Nelson, Scherrer, etc.; Innovation theory, this view is that SMEs are conducive to technological innovation, because SMEs have a simple management structure, flexible and flexible organization, and are more conducive to making innovative decisions based on market changes, and their innovation efficiency is high, mainly Representative figures are: Roswell, Arcos, Liu Deping [4], Chi Renyong [5] and so on.

In summary, the research on the relationship between enterprise scale and technological innovation capability still has no consensus in the theoretical circle, and there are not many researches on the technological innovation capability of innovative small and medium-sized technology enterprises of different scales. In order to deepen the research on the technological innovation ability of innovative small and medium-sized technology enterprises of different scales, and at the same time, the fuzzy comprehensive evaluation model can combine the qualitative analysis with the quantitative analysis, and the analysis and evaluation methods are unified with precision and non-precision. This paper uses fuzzy comprehensive evaluation model to evaluate the technological innovation ability of innovative small and medium-sized technology enterprises of different scales, in order to reveal the status quo and advantages and disadvantages of innovative small and medium-sized technology enterprises of different scales, so as to be innovative small and

medium-sized technology enterprises. The improvement of innovation ability provides theoretical and practical guidance.

2. Indicator system and data source

2.1 Indicator system

The evaluation index of technological innovation ability of innovative small and medium-sized technology enterprises should be examined from multiple angles to comprehensively reflect the technological innovation capability of innovative small and medium-sized technology enterprises of different scales, revealing the differences and advantages and disadvantages of their technological innovation capabilities. Under the guidance of the above ideas, and following the basic principles of purpose, science, comprehensiveness and adaptability, the following index system is constructed [6-7]:

Table. 1. Evaluation index system of technological innovation ability of innovative small and medium-sized technology enterprises of different scales

Target layer	Factor layer
Main target	Enterprises undertake research projects
	Get reward levels and times
	Proprietary technology and number of patents
	Number of new technologies or new products
	New product development cycle
	New product sales as a percentage of revenue
	Employees' education level
	Annual staff training cost growth rate
	The proportion of scientific research personnel
	Market conversion rate of research results
	R&D funding annual growth rate
	R&D investment accounts for the proportion of sales revenue
	Main technical source of the enterprise
	Advanced technology
	The autonomy of corporate intellectual property
	Enterprise knowledge management system construction

2.2 Data source

According to the established innovative small and medium-sized technology enterprise technology innovation capability evaluation index system, design innovative small and medium-sized technology enterprise technology innovation capability questionnaire, and obtain the data by issuing questionnaires. 200 innovative small and medium-sized technology enterprises in Jinan City and Qingdao City of Shandong Province were randomly selected as survey objects. A total of 200 questionnaires were issued and 120 were returned, of which 97 were valid questionnaires. 97 innovative small and medium-sized technology enterprises are used as sample enterprises. The scale classification standard adopts the “Statistical Large, Medium, Small and Micro Enterprises Division Method (2017)” promulgated by the National Bureau of Statistics, based on indicators such as employees, operating income, total assets or surrogate indicators. Classification, including 51 medium-sized enterprises and 46 small-scale enterprises.

3. Research methods

The fuzzy comprehensive evaluation method is a method of analyzing and evaluating fuzzy systems using the principle of fuzzy transformation. It is an analytical and evaluation method that combines qualitative and quantitative, fuzzy and non-precise, which is based on fuzzy reasoning. It

has unique advantages in dealing with various complex system problems that are difficult to describe with precise mathematical methods.

The fuzzy comprehensive evaluation model includes a single-level fuzzy comprehensive evaluation model and a multi-level fuzzy comprehensive evaluation model. In view of the multi-level and multi-factor characteristics of the evaluation index system of innovative small and medium-sized technology enterprises' growth ability, the research selects the multi-level fuzzy comprehensive evaluation model, and the steps are as follows [8]:

(1) For the evaluation factor set U, according to a certain attribute c, divide it into m subsets to satisfy:

$$\begin{cases} \sum_{i=1}^{m} U_i = U \\ U_i \bigcap U_j = 0 (i \neq j) \end{cases} \tag{1}$$

This gives the second level of evaluation factors:

$$U / c = \{U_1, U_2, ...U_m\} \tag{2}$$

In Equation 2, $U_i = [u_{ik}]$ (i = 1, 2, ..., m; k = 1, 2, ..., n) indicates that there are k evaluation factors in the subset U_i.

(2) For each of the k evaluation elements in each subset U_i, the evaluation is based on the single-level fuzzy comprehensive evaluation model. If the weights of the factors are assigned as $\overline{A}_i$, and the judgment decision matrix is R_i, then the comprehensive evaluation result of the i-th subset U_i is obtained.

$$\overline{B}_i = \overline{A}_i \cdot R_i = [b_{i1}, b_{i2}, ..., b_{in}] \tag{3}$$

(3) A comprehensive evaluation of the m subset U_i of evaluation factors U / c (i = 1, 2, ..., m), and the judgment decision matrix is

$$R = \begin{Bmatrix} \overline{B}_1 \\ \overline{B}_2 \\ ... \\ \overline{B}_m \end{Bmatrix} = \begin{Bmatrix} b_{11} & b_{12} & ... & b_{1n} \\ b_{21} & b_{22} & ... & b_{2n} \\ ... & ... & ... & ... \\ b_{m1} & b_{m2} & ... & b_{mn} \end{Bmatrix} \tag{4}$$

If the weight of each subset of the judgement factors U / c is assigned as $\overline{A}$, then the comprehensive evaluation result is obtained.

$$\overline{B} = \overline{A} \cdot R \tag{5}$$

In Equation 5, $\overline{B}$ is both the comprehensive evaluation result of the pair and the comprehensive evaluation result of all the evaluation factors in U.

The above is a simple two-level model building step. If there are still many factors in U / c, it should be divided again to obtain a multi-level model. For example, based on the extraction of the principal components, a three-level fuzzy comprehensive evaluation model should be established. The multi-level model can be regarded as the superposition of multiple two-level models, and the specific evaluation steps are the same as the two-level evaluation model.

In addition, in this study, the decision matrix is R_i judged as the form of the membership matrix. Combined with the characteristics of the evaluation index system of innovative small and medium-sized technology enterprises, the method of obtaining membership degree is as follows:

Let $a_{ij}^{*}=\left[u_{ij}^{*}-u_{ij}^{*(\min)}\right]/\left[u_{ij}^{*(\max)}-u_{ij}^{*(\min)}\right]$, then a_{ij}^{*} is the degree of membership of the superior indicator for the evaluation indicator U_{ij}^{*}. Where $u_{ij}^{*(\max)}$ is the upper limit of the three-level indicator U_{ij}^{*} and $u_{ij}^{*(\min)}$ is the lower limit. For the 5-point quantitative indicator, the upper and lower limits are the maximum and minimum values of the indicator; for the direct observation indicators, based on the comparison of the technological innovation capability level of the sample enterprises with the national average level and the opinions of the consulting experts, this paper uses the indicators. The average value is taken as the upper limit value and the minimum value of the index is used as the lower limit value.

4. Conclusion

4.1 Main conclusions

According to the above data processing steps, the following conclusions are drawn: the medium-sized innovative technology enterprises have a technical innovation capability score of 51.3, and the small-scale innovative technology enterprises have a score of 47.6. The medium-sized technology enterprises have better technological innovation capabilities than the small-scale technology enterprises, but the technologies of the two. The innovation ability is not strong; the medium and small innovative technology enterprises have different advantages and disadvantages in technological innovation capabilities. The former's dominant factors are technological innovation foundation, technological innovation transformation, and technological innovation level. The inferior factors are technological innovation achievements, technological innovation investment, The potential of technological innovation; the latter's dominant factors are technological innovation investment, technological innovation foundation, and the inferior factors are technological innovation achievements, technological innovation transformation, technological innovation potential, and technological innovation level.

4.2 Analysis of the main reasons

Related main reasons are as follows:

1) Insufficient input factors for technological innovation. Capital and scientific and technological talents are the main factors for small and medium-sized technology enterprises to carry out technological innovation activities, and are important conditions for ensuring the normal operation of the entire innovation activities such as design, research and development and transformation of technology. However, the survey shows that a large number of innovative small and medium-sized technology companies lack certain funds and talents in technological innovation, which seriously affects the enthusiasm for technological innovation and the improvement of innovation capabilities.

2) Narrow financing channels .According to the survey, the technological innovation funds of a large number of innovative small and medium-sized technology enterprises mainly come from their own funds, private lending and Internet borrowing. Innovative small and medium-sized technology enterprises still face problems such as shortage of funds, difficulty in financing, and fewer financing channels when they are innovating.

3) Low management capacity and credit level. According to the survey, innovative small and medium-sized technology enterprises are generally small in scale, low in management and management, non-standard financial systems, lack of real financial statements and good continuous business records, and lack of credit or lack of credit, directly affecting their technological innovation capabilities [9].

4) The technology innovation service system is not perfect. The innovative technology service system of innovative small and medium-sized technology enterprises is not perfect, mainly on the one hand: lack of public technical service institutions in the high-tech park to build common technology and key technology research and development platforms, provide technical support, technology transformation and project management consulting. On the other hand, there is a lack of

various training institutions that can organize technical talents for innovative small and medium-sized technology companies.

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