Design and Application of Evaluation Model on Technical Innovation Ability of SMEs Based on AHP and FCE*

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Abstract The evaluation model on technical innovation ability of small and medium enterprises is set up based on analytic hierarchy process and fuzzy comprehensive evaluation methods, which takes quantitative index as main parts and considers reality so that better practicability is obtained. Meanwhile, technical innovation ability of small and medium enterprises in Heilongjiang Province of China are objectively evaluated according to investigation, and the conclusion is that the comprehensive innovation level is not so high that should be strengthened as quickly as possible.
Key words Small and medium enterprises; Technical innovation ability; Analytic hierarchy process; Fuzzy comprehensive evaluation

1 Introduction

Looking around the world, small and medium enterprises have become important pillars of the national economy and its contribution to economic growth is increasingly significant. However, the majority of small and medium enterprises in China are semi-mechanized and labor-intensive enterprises, and the proportion of high-tech enterprises is less than 10%. With the fierce international competition after entering WTO and the influence of international financial crisis, small and medium enterprises are difficult to survive without carrying out technical innovation.

At present, the problem of evaluation on technical innovation ability has been paid more attention to, and the research is focused on the definition of technical innovation, indicators of technical innovation ability evaluation and models of technological innovation ability evaluation. The definition of technical innovation was studied from 80s of the 20th century, but no uniform definition is made until now. Most studies about indicators of technical innovation ability evaluation are similar, and the selected indicators are decision-making capacity, research and development capabilities, marketing ability, resource input capacity, management capacity, production capacity, etc. Models of technical innovation ability evaluation are researched mainly by using fuzzy mathematics, but without unified standard. To sum up, problems existing in evaluation system are concluded as following: firstly, the objects of studies are general enterprises but not medium-size and small businesses; secondly, all elements included in technical innovation ability are considered respectively and the relationships between different elements are neglected; thirdly, in previous studies, though evaluation was done by using fuzzy method, the subjectively-judged weights of indicators made result lack accuracy and applicability.

There are two important questions in evaluation on technical innovation ability of small and medium enterprises. One is the determination of indicators' weights, which directly determines evaluation results. AHP is the method to decide importance degree of elements in same unit by comparing calculated eigenvectors of the matrix based on multi-objective hierarchical structure, and then determine more suitable weights in accordance with the order from the bottom to up in sequence. Other is that technological innovation ability evaluation indicator system reflects a set of complex relationships within the enterprise, which has the characteristics of fuzziness. Particularly for qualitative analysis, specific evaluation values of these factors are difficult to be determined with statistical methods in the influence of evaluator' subjective judgment, therefore, fuzzy comprehensive evaluation method (FCE) is suitable to information processing and evaluation.

2 Evaluation Model Design on Technical Innovation Ability with AHP and FCE

* The paper is the production of a humanities and social sciences project sponsored by department of education in Heilongjiang Province, and the name of the project is "Research on Technological Innovation Strategy of SMEs in Heilongjiang Province". The paper is also sponsored by the research start-up project for doctors in northeast agricultural university, whose name is "Research on Technological Innovation Capability of SMEs in Heilongjiang Province".

2.1 Establish hierarchy

This paper selects six first-grade indicators including innovative resource input capacity (A_1), research and development capabilities (A_2), production capacity (A_3), innovation marketing ability (A_4), innovation management capacity (A_5), innovation output capacity (A_6) and twenty-five second-grade indicators including R&D input intensity (A_{11}), technology absorption and import intensity (A_{12}), the proportion of technical professionals (A_{13}), quality and numbers of technical staff (A_{14}), R&D expenditures per capita (A_{21}), the proportion of professional R&D staff (A_{22}), R&D speed (A_{23}), R&D success rates (A_{24}), research results into-production rate (A_{25}), patents and patent numbers per capita (A_{26}), independent innovation rate (A_{27}), the level of production equipment (A_{31}), comprehensive level of production personnel (A_{32}), labor productivity per capita (A_{33}), intensity of investment in marketing costs (A_{41}), intensity of advertising expenditures (A_{42}), network coverage (A_{43}), innovation incentive mechanism (A_{51}), rate of project cooperated by academia and industries (A_{52}), innovation preference (A_{53}), innovation strategy (A_{54}), risk prediction assessment of innovation (A_{55}), market share of new product (A_{61}), profit ratio of new production (A_{62}), technical trade index (A_{63}), innovation output efficiency (A_{64}). The hierarchy as shown in figure 1 is established according to the composition of target system.

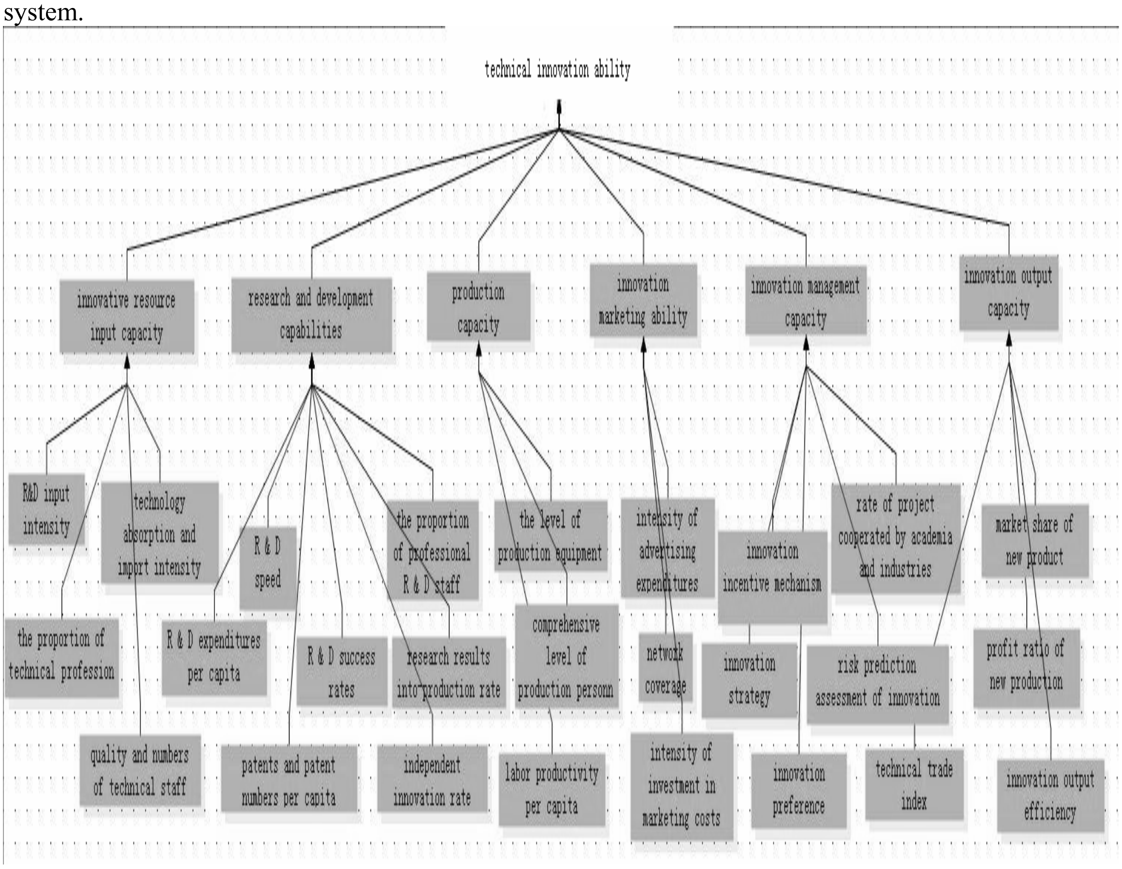

Figure 1 Hierarchy of Technical Innovation Ability Evaluation Model

2.2 Determine fuzzy set

Comprehensive evaluation on technical innovation of small and medium enterprises need to be determined grade-domains V= {V_1, V_2,…, V_m} , that is, to determine reviews set of each indicators, herein v_i indicates domain of i-grade in m grades. In the paper, the grade-domains are divided into five levels including excellent, good, middle, general and poor according to evaluation target, that is, V={V_1, V_2, V_3, V_4, V_5}={ excellent, good, middle, general, poor }, which reflects the feature of fuzzy evaluation.

2.3 Determine the weights of evaluation indicators

Because the evaluation of weights is greatly affected by types and sectors of different enterprises and evaluators' opinions, resultant weight vectors of target indicators in evaluation model should be calculated according to comprehensive views of the weight matrixes judged by different experts. Here, suppose weight coefficient of various experts' evaluation is equal, the method of geometric mean is used to determine weight vectors by calculating judgment matrixes and then resultant weight vectors are obtained.

2.4 Make evaluation indicators dimensionless

In the evaluation indicator system of technological innovation ability, different measure-units of various indicators make analysis deviate from exact results so that it is necessary to make indicators dimensionless. Dimensionless is to make data standardized and normalized, which could eliminate the impact of the original variables with mathematical transformation.

2.5 Determine evaluation matrix

In the paper, evaluation matrixes of qualitative indicators and quantitative indicators are determined respectively. The evaluation matrixes of qualitative indicators require experts judge the grade of certain indicator from multiple perspectives, and then calculate the ratio from numbers in every grade to total numbers of evaluators, that is r_{ij}, which is evaluation matrix. The evaluation matrixes of quantitative indicators are divided in five levels including excellent, good, middle, general and poor, which is in respective range as (100~90), (90~80), (80~70), (70~60) and (60~50). After quantitative indicators' dimensionless, the corresponding value could be acquired. To avoid unreasonable reviews caused by evaluation value in the boundary, degree-of-membership is determined according to fuzzy function.

2.6 Comprehensive evaluation

According to the calculated weight vector $\boldsymbol{W}$, select the appropriate composition-factors and compose W and membership degree $\boldsymbol{R}$, then fuzzy evaluation result Z is obtained. Because AHP is used to determine weights, the total of weights in any target level is 1, that is $\sum \boldsymbol{W}_j=1$, therefore, the composite-factor is general mathematical factor, which is M (•, +). So the evaluation results could be calculated by using the formula $\boldsymbol{Z} = \boldsymbol{W}*\boldsymbol{R}$.

3 Empirical Analysis of Technological Innovation Ability of SMEs in Heilongjiang Province

3.1 Determine indicators' weights

The judgment matrixes of different levels including indicators' layer, rule layer, target layer and decision-making layer are obtained by using the method of AHP to calculate data acquired from questionnaires and interviews to experts, business managers and department managers. Because the weights play an important role in evaluation, the judgments of individual experts are considered comprehensively so that more objective weights could be acquired.

Table 1 Indicators' Weights in Each Levels

A_1	0.1450	A_{11}	0.3219
		A_{12}	0.1614
		A_{13}	0.1749
		A_{14}	0.3418
A_2	0.2942	A_{21}	0.1064
		A_{22}	0.1052
		A_{23}	0.0913
		A_{24}	0.2276
		A_{25}	0.2174
		A_{26}	0.1361
		A_{27}	0.1160
A_3	0.0953	A_{31}	0.3819
		A_{32}	0.3819
		A_{33}	0.2363
A_4	0.1675	A_{41}	0.3824
		A_{42}	0.2739
		A_{43}	0.3437
A_5	0.1863	A_{51}	0.2378
		A_{52}	0.2213
		A_{53}	0.1370
		A_{54}	0.1826
		A_{55}	0.2213
A_6	0.1117	A_{61}	0.3320
		A_{62}	0.1700
		A_{63}	0.2946
		A_{64}	0.2034

3.2 Acquisition and standardization of data

Fifty enterprises selected from “Growing Small and Medium Enterprises in Heilongjiang Province” are taken as samples, which are distributed in machinery, metallurgy, construction and building materials, textiles, chemicals, food, medicine, electronics, processing and other industries, and the machinery industry is 20%, metallurgical industry is 5%, construction and building materials industry is 20%, textile industry is 5%, chemical industry is 10%, food sector is 10%, pharmaceutical industry is 10%, electronics industries is 5 %, processing and other industries is15%.

3.2.1 Determination on degree-of-membership of quantitative indicators

The determination of degree-of-membership of quantitative indicators is achieved in accordance with the method described above, which is shown as in table 2. From table 2, it is shown that the proportion of technical professionals, research results into-production rate, the level of production equipment, comprehensive level of production personnel, intensity of investment in marketing costs, network coverage, rate of project cooperated by academia and industries and profit ratio of new production are in the level of “good”, and technical trade index and independent innovation rate are in the level of “general”, and others are in the level of “middle”

Table 2 Quantitative Indicators’ Degree-of-membership

		U_{ij}	r_{v1} E	r_{v2} GD	r_{v3} M	r_{v4} GE	r_{v5} P
A_1	A_{11}	73	0	0	0.8	0.2	0
	A_{12}	77	0	0.2	0.8	0	0
	A_{13}	82	0	0.7	0.3	0	0
	A_{14}	78	0	0.3	0.7	0	0
A_2	A_{21}	78	0	0.3	0.7	0	0
	A_{22}	80	0	0.5	0.5	0	0
	A_{23}	72	0	0	0.7	0.3	0
	A_{24}	76	0	0.1	0.9	0	0
	A_{25}	85	0	1	0	0	0
	A_{26}	75	0	0	1	0	0
	A_{27}	61	0	0	0	0.6	0.4
A_3	A_{31}	81	0	0.6	0.4	0	0
	A_{32}	83	0	0.8	0.2	0	0
	A_{33}	79	0	0.4	0.6	0	0
A_4	A_{41}	83	0	0.8	0.2	0	0
	A_{42}	80	0	0.5	0.5	0	0
	A_{43}	82	0	0.7	0.3	0	0
A_5	A_{51}	76	0	0.1	0.9	0	0
	A_{52}	86	0.1	0.9	0	0	0
	A_{53}	78	0	0.3	0.7	0	0
A_6	A_{61}	78	0	0.3	0.7	0	0
	A_{62}	85	0	1	0	0	0
	A_{63}	60	0	0	0	0.5	0.5
	A_{64}	73	0	0	0.8	0.2	0

3.2.2 Determination on degree-of-membership of qualitative indicators

There are only two qualitative indicators, and the degree-of-membership is shown in table 3. From table 3, it is concluded that indicators are concentrated in the level of “good” and “middle”.

Table 3 Qualitative Indicators’ Degree-of-membership

		r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_5	A_{54}	0	0.6	0.2	0.2	0
	A_{55}	0	0.2	0.6	0.2	0

3.3 Analysis and evaluation

According to the evaluation of each indicator, following vectors are drawn: fuzzy evaluation vector of innovative resource input capacity is $\boldsymbol{Z}_1 = (0 \quad 0.257 \quad 0.678 \quad 0.065 \quad 0)$, fuzzy evaluation vector of research and development capabilities is $\boldsymbol{Z}_2 = (0 \quad 0.3247 \quad 0.5319 \quad 0.097 \quad 0.0464)$, fuzzy evaluation vector of production capacity is $\boldsymbol{Z}_3 = (0 \quad 0.6292 \quad 0.3708 \quad 0 \quad 0)$, fuzzy evaluation vector of innovation marketing ability is $\boldsymbol{Z}_4 = (0 \quad 0.6835 \quad 0.3165 \quad 0 \quad 0)$, fuzzy evaluation vector of innovation management capacity is $\boldsymbol{Z}_5 = (0.0221 \quad 0.3775 \quad 0.5196 \quad 0.0808 \quad 0)$, fuzzy evaluation vector of innovation output capacity is $\boldsymbol{Z}_6 = (0 \quad 0.2696 \quad 0.3951 \quad 0.1880 \quad 0.1473)$. The fuzzy evaluation matrix

R is calculated by combining six indicators' degree-of-membership vectors in sequence.

$$\boldsymbol{R}=\begin{bmatrix} 0 & 0.257 & 0.678 & 0.065 & 0 \\ 0 & 0.3247 & 0.5139 & 0.097 & 0.0464 \\ 0 & 0.6292 & 0.3708 & 0 & 0 \\ 0 & 0.6835 & 0.3165 & 0 & 0 \\ 0.0221 & 0.3775 & 0.5196 & 0.0808 & 0 \\ 0 & 0.2696 & 0.3915 & 0.1880 & 0.1473 \end{bmatrix}$$

According to table 1, six indicators' weight vector is $\boldsymbol{W}$ = (0.1450 0.2942 0.0953 0.1675 0.1863 0.1117), and fuzzy evaluation vector of technical innovation ability is $\boldsymbol{Z}$ = $\boldsymbol{W}$*$\boldsymbol{R}$, that is, $\boldsymbol{Z} = [0.004 \quad 0.408 \quad 0.484 \quad 0.074 \quad 0.03]$.

From the fuzzy evaluation vector, technical innovation ability of small and medium enterprises' degree-of-membership in "middle" is maximal, but α=0.44＜0.5, so data standardization should be done by using the method of sorting by score, then $\boldsymbol{Z}$= 81.2. According to score, technical innovation ability belongs to "good" grade.

In summary, technological innovation ability of small and medium enterprises in Heilongjiang Province is in the level between "good" and "middle", while co-existents between five levels. And innovative resource input capacity is in "middle" grade, research and development capabilities are in "middle" grade, production capacity is in "good" grade, innovation marketing ability is in "good" grade, innovation management capacity is in "middle" grade and innovation output capacity is in "middle" grade but close to "good" grade.

4 Conclusion

The objective evaluation on technological innovation ability is done by using AHP and FCE in this paper, and the conclusion is that the comprehensive innovation level of small and medium enterprises in Heilongjiang Province is not high, especially innovative resource input capacity, research and development capabilities, innovation management capacity and innovation output capacity need to be strengthened greatly.

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