Application of improved analytic hierarchy process in SME's competitiveness evaluation

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Received 1 October 2014, www.cmnt.lv

Abstract

With small and medium-sized enterprises (SMEs) becoming a significant engine for regional economic development, it is extremely important to evaluate SME's competitiveness in an appropriate way. So far, many scholars have explored theories and introduced practice on this, yet the theoretical system of the evaluation of SME's competitiveness in China still needs perfection. Therefore, this paper tries to establish an evaluation model of SME's competitiveness in China based on their features and former theories. Also, it proposes an improved analytic hierarchy process (IAHP) with consideration of expert weight applicable to the evaluation. After brought into test, the process can well apply to the evaluation of the competitiveness of SMEs in China..

Keywords: SMEs; competitiveness evaluation; improved analytic hierarchy process (IAHP); evaluation model

Introduction

As the Chinese economy grows rapidly, employment pressure and demand insufficiency have made people embrace the dynamism of SMEs, a situation that gives them an increasing prominence. Throughout the world, SMEs play a unique part in national economic structure: the major source of jobs, and of the institutional and technological innovation of enterprises. Since 1990s, in both OECD countries and newly industrialized countries (or regions) in Asia, the average scale of the enterprises has become smaller while the contribution they have made to GDP keeps growing enormously. In China, there is no exception. Statistics show that in 2013, SMEs in China accounts for 95% of the total enterprises, offering 75% jobs and contributing to more than 50% of GDP. Against such background and using the improved analytic hierarchy process (IAHP) with expert weight, this paper proposes a competitiveness evaluation model of SMEs in China. In light of that, we can gain a comprehensive understanding of current SMEs in China, and find the main factors that hinder their development.

2 Literature Review

As global economies compete intensely and openly, there have emerged various theoretical schools on studying the competitiveness of enterprises, providing different perspectives on analyzing the concept. Firstly, the international comparative school represented by World Economic Forum (WEF) and Swiss International Institute for Management Development in Lausanne (IMD)[1]. It has offered relatively comprehensive principles and method system of international competitiveness, released international reports on national competitiveness evaluation and revealed international competition from nations' perspective. Secondly, the industrial competitiveness study represented by M.E.Potter[2]. It believes that six factors influence the international competitiveness of a country's industries: factors of production, demand of the market, the development of related and supporting industries, the strategic structure and rivals of an enterprise, opportunities and the government policies. Based on these, it builds up a basic analysis framework of the enterprise's international competitiveness. Thirdly, the enterprise resources school represented by Birger Wernerfelt and Edith Penrose. It advocates that enterprises differ in their tangible human resources, intangible resources and accumulated knowledge and information. The resource advantages produce competitiveness advantages. Fourthly, the concept of core enterprise capacity raised by C.K.Prahalad and Cary Hamel in 1990[3]. It creates the core period of the theoretical study on the competitiveness of enterprises.

In light of the theory, method, and empirical analysis of the evaluation of SME's competitiveness[4-8], Chinese scholars have also done a lot of research. Fu Jianhua studied SME's competitiveness in Shanghai; Sheng Shihao analyzed the main factors affecting SME's competitiveness; Chen Deming and Zhou Sanduo created 21 indicators to analyze SME's competitiveness in Suzhou from the perspective of development ability, innovative ability, resource integration ability and market expansion ability; Chen Jiagui and Wu Jun did a regional competitiveness evaluation on SMEs in China's 30 provinces, municipalities and autonomous regions from three respects of regional influence, operative management, and development using 6 indicators; Lin Hanchuan and Guan Hongxi did a regional comparative study of SME's competitiveness in East, Central and West China[9-14].

The literature review shows that in the existing theories, most methods and empirical analysis focus on

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international comparison or big enterprises while lay minor importance to SME's competitiveness. Even some research touch upon SME's competitiveness, they center on regional comparison instead of their competitiveness evaluation. Built on the existing researches mentioned above, this paper considers the competitiveness characteristics of different SMEs and explores the comparison method and the indicator system of competitiveness evaluation in SMEs[15]. Moreover, it evaluates and compares the sample data of different SMEs, tests the feasibility and effectiveness of the method system and finally proposes an improving strategy for different SMEs in China[16].

3 Evaluation model of SME's competitiveness

3.1 STRUCTURE OF EVALUATION MODEL

The competitiveness of SMEs in China is evaluated in three respects: core resources, core competence and the external environment of an enterprise. Firstly, core resources possessed by enterprises, including all kinds of property, knowledge and information in forms of tangible human resources and intangible resources. Despite the type, it is the scarce resources which can bring exceeding profits that breed competitiveness of enterprises, and also demand strategic development and management. These resources include special equipment, patents and special techniques held by high-tech human resources and management personnel, well-known trademark, goodwill, enterprise culture and so on. Secondly, core competence of an enterprise[17]. It is mainly reflected in efficiency and effectiveness, two concepts concerning production. It evaluates organizational competence of an enterprise. Such competence involves overall and departmental organizational capability, and is reflected in the achievement of the capability of materials and human resources, the capacity of its departments and external environment, as well as the inter-departmental integration capability by different sectors or groups working together. It represents not only the efficiency of material distribution in achieving the target, but also its effectiveness and innovation.

Thirdly, the production and market environment of enterprises. The different external environment essential to enterprises influences the initial state of their logistics, information flow and human resources as well as their input, transformation and output, finally resulting in the difference of the competitiveness of enterprises[18]. If the environment is favorable to the enterprise, it can gain or sustain its competitive advantage easily. If it is unfavorable, there will be many bad factors including market mechanism, macro-economic, political and social culture, natural resources and environment. Natural resources feature the longest time. Once destroyed, it is hardly restored. Social culture also demands long-term cultivation to yield any improvement. These two factors have long and profound influence on competitiveness of enterprises. Some mid-term factors are political and economic systems, infrastructure, legal infrastructure and financing system. Besides, market structure and the government's un-institutional intervention influence the competitiveness directly and rapidly. Based on all the principles above, this paper constructs the following evaluation model according to analytic hierarchy process (AHP)[19]:

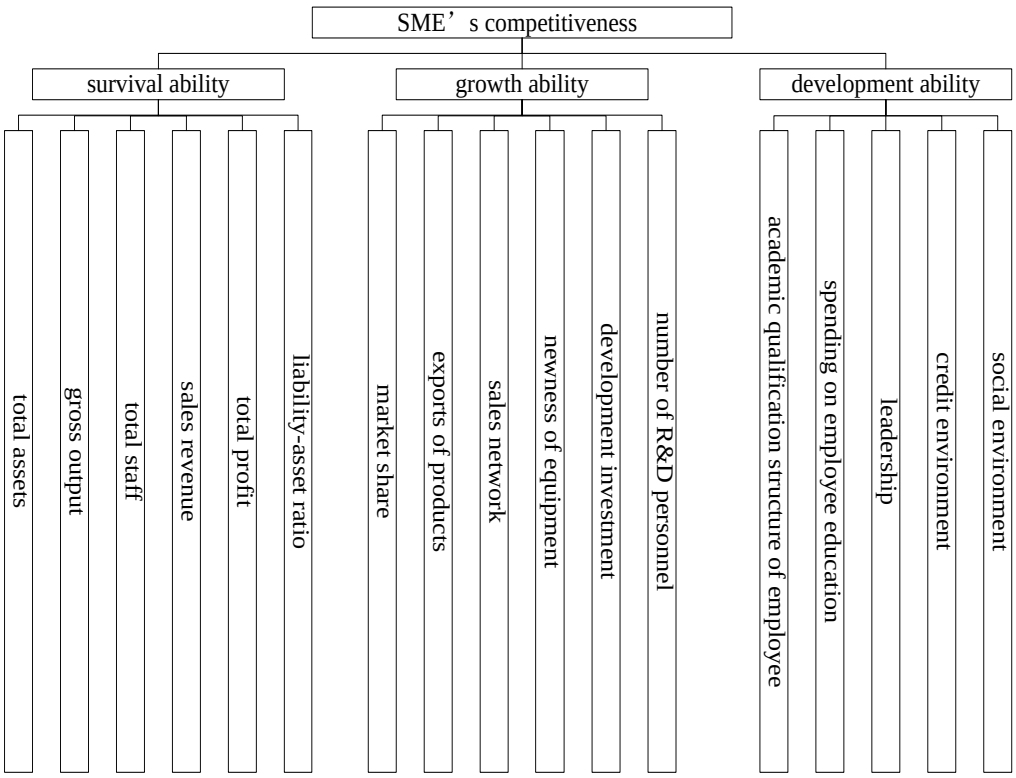

FIGURE 1 Evaluation model of SME’s competitiveness.

In this model, criteria layer consists of survival ability, growth ability and development ability, evaluating SME' s competitiveness from different perspectives. Survival ability is the ability to sustain an SME' s normal operation faced with fierce competition in practical market. Growth ability is the ability to increase its scale and extend its industrial chains. Development ability is the ability to expand to know the operational risks according to its own strategic materials and core competence.

3.2 EVALUATION INDICATOR MEASUREMENT

This model breaks the factors affecting survival ability, growth ability and development ability down to 17 sub-factors. Then qualitative study on total value, ratio and qualitative questionnaire gains the value of the indicators influencing SME's competitiveness and then standardizes them. The definitions and measurements of indicators are shown in Table 1.

TABLE 1 Indicator definition and measurement of SME's competitiveness evaluation

Indicator	Category	Definition	Measurement
Total assets	total value	Enterprise's year-end total assets	Average year-end total assets of the last three years
Gross output	total value	Enterprise's annual gross output	Average annual gross output of the last three years
Work force	total value	Enterprise's year-end work force	Average year-end total work force of the last three years
Sales revenue	total value	Enterprise's annual sales revenue	Average annual sales revenue of the last three years
Total profit	total value	Enterprise's annual after-tax profit	Average annual profit of the last three years
leverage	ratio	Liability-asset ratio	Average year-end liability of the last three years / Average year-end assets of the last three years
Market share	qualitative value	Market share of main products	qualitative questionnaire evaluation (high, relatively high, fair, relatively low, low)
Exports of products	ratio	Proportion of exports revenue in total sales revenue	Last year's exports volume/ last year's total sales revenue
Sales network	qualitative value	Marketing channels of main products	qualitative questionnaire evaluation (very good, good, fair, poor, very poor)
Newness of equipment	ratio	Proportion of equipment in different times	Net value of the equipment/original values of the equipment
Input of product development	total value	Annual R&D cost	Last year's R&D cost
Number of R&D personnel	total value	Total number of full-time R&D personnel	Current number of full-time R&D personnel
Academic qualification structure of employee	ratio	Academic qualification structure of employee	The number of employees above college education/total number of the employees
Spending on employee education	total value	Enterprise's annual spending on employee training	Last year's spending on employee training
leadership	qualitative value	Entrepreneurs' ability in planning, arrangement, controlling, coordination and communication	qualitative questionnaire evaluation (very good, good, fair, poor, very poor)
Credit environment	qualitative value	The timeliness of the withdrawal of payment for goods , seriousness of inter-company arrears	qualitative questionnaire evaluation (very good, good, fair, poor, very poor)
Social environment	qualitative value	Dis-proportionality of inter-company share-out; services provided by local government	qualitative questionnaire evaluation (very good, good, fair, poor, very poor)

The measurement gains different dimensions of evaluation value including total index, ratio index and qualitative index. To gain comparability, these indexes need to be made dimensionless. Given no reliable standards for the indexes of the evaluation of SME' s competitiveness, this paper uses the improved efficacy coefficient method to process the total and ratio index. The method is as follows[20]:

Suppose E={E1, E2, ⋯, En} is the sample enterprise of this evaluation, I={I_1, I_2, ⋯, I_m} is a set of total and ratio indexes. M_{ij} is the value of the I_j index of enterprise E_i: $E_i \in A$, $I_j \in I$. The dimensionless utilized value is ξ_{ij}. It is the function of M_{ij} with the following formula:

$$\xi_{ij} = f(M_{ij}) = \frac{M_{ij} - M_j^s}{M_j^h - M_j^s} \times 40 + 60, i = 1,...,n; j = 1,...,m$$

M_j^s, M_j^h is the minimum and maximum of the j index in the sample enterprise respectively. ξ_{ij} is actually the evaluation score corresponding to M_{ij}. $\xi_{ij} \in [60,100]$.

Similarly, the evaluation value of qualitative index can also be shifted to corresponding scores[21]. Their mapping relation is:

[Very good (High), Good (Relative high), Fair, Poor, Very poor]→[100, 90, 80, 70, 60]

4 Application of improved analytic hierarchy process (IAHP) in the evaluation of SME's competitiveness

4.1 THE CHOICE OF AN AGGREGATION METHOD

The existing evaluation indicator system has three layers, making it very convenient for measurement software to calculate the consistency ratio CR of judgment matrices. Therefore, we invite several experts to provide judgment

matrices of all layers for the evaluation indicator system in equipment manufacturing industry. Those mismatching the consistency ratio (CR>0.1) will be rejected[22]. This paper applies the method of Accumulated Individual Judgment matrix (AIJ) and its mathematical method is weighted geometric mean method(WGMM).

4.2 FIXING EXPERT WEIGHT

Different from the traditional analytic hierarchy process (AHP), this paper fixes expert weight according to the degree of similarity of the expert judgment matrices. Suppose the evaluation layer is shown in chart 2, then expert weight can be fixed by the following steps:

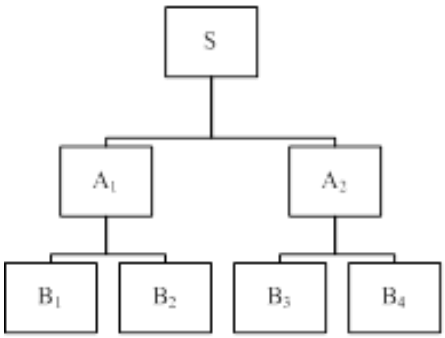

FIGURE 2 Supposed evaluation layer

Suppose after the consistency test, the judgment matrices for all layers given by the i expert who passes the test are shown in table 2, table 3, table 4:

TABLE 2. Judgment matrix in S layer

S	**A_1**	**A_2**
A_1	1	a_i
A_2	$1/a_i$	1

TABLE 3. Judgment matrix in A_1 layer

A_1	**B_1**	**B_2**
B_1	1	b_i
B_2	$1/b_i$	1

TABLE 4. Judgment matrix in A_2 layer

A_2	**B_3**	**B_4**
B_3	1	c_i
B_4	$1/c_i$	1

This paper uses 17-scale measurement and a_i, b_i, c_i are a scale. The experts' judgment matrices are the principle behind the determination of expert weight. Therefore, the matrices in table2, table 3 and table 4 are the standards to measure the similarity degree of the experts' judgment matrices. However, to reduce the work load, we only use a part of the information in the matrices which can represent the whole to fix expert weight. Finally, we choose the upper triangular matrix excluding the numbers in the main diagonal to conveniently represent the whole information.

Following this, we accumulate all valid information in all the experts' judgment matrices which forms a judgment matrix of expert weight shown in table 5.

TABLE 5. Judgment matrix of expert weight

expert	**Indicator 1**	**Indicator 2**	**Indicator 3**	**Indicator 4**
expert 1	a_1	b_1	c_1	…
expert 2	a_2	b_2	c_2	…
…	…	…	…	…
expert n	a_n	b_n	c_n	…

According to the judgment matrix of expert weight as shown in Table 5, this paper assumes that an index will gain heavier weight if it is closer to the average of the experts' measurement values. After fixing every expert's weight in every index, we accumulate all the weights and have the expert weight.

$$a_i^* = \frac{\min\limits_n\{a_i, \bar{a}\}}{\max\limits_n\{a_i, \bar{a}\}} \quad (0 \le a_i^* \le 1)$$

We work out the averages of indexes in table 5 as $\bar{a}$, $\bar{b}$ and $\bar{c}$ according to our assumption. Then we give greater measure for the index to the expert which is closer to the averages. Suppose for index 1, we calculate the weight of expert *i* according to the following formula:

$$a_i^* = \frac{\min\limits_n\{a_i, \bar{a}\}}{\max\limits_n\{a_i, \bar{a}\}} \quad (0 \le a_i^* \le 1)$$

The evaluation measure for index 1 of expert *i* shifts to a number between 0 and 1. If the number is closer to 1, the expert's evaluation is more similar to the average of the whole experts. Thus, we get a judgment matrix of expert weight on changing measurements shown in table 6.

TABLE 6. The judgment matrix of expert weight on changing measurements

expert	**Indicator 1**	**Indicator 2**	**Indicator 3**	**Indicator 4**
Expert 1	a_1^*	b_1^*	c_1^*	…
Expert 2	a_2^*	b_2^*	c_2^*	…
…	…	…	…	…
Expert n	a_n^*	b_n^*	c_n^*	…

In table 6, we add up all the judgment measures of an expert. The bigger the summation is, the heavier weight we give to the expert. After that, we get the comprehensive expert value as shown in Table 7

TABLE 7. Comprehensive indicator judgment matrix of expert

Expert	**Comprehensive indicator**
Expert 1	$I_1 = a_1^* + b_1^* + c_1^*$
Expert 2	$I_2 = a_2^* + b_2^* + c_2^*$
…	…
Expert n	$I_n = a_n^* + b_n^* + c_n^*$

Then we normalize the indexes in table 7 and calculate the objective weight of all experts. The formula of normalization is $\omega_i = \frac{I_i}{\sum\limits_{i=1}^{n} I_i}$ and we get the expert weight shown in table8.

TABLE 8. expert weight

Expert	expert weight
Expert 1	ω_1
Expert 2	ω_2
…	…
Expert n	ω_n

These weights satisfy $\sum_{i=1}^{n}\omega_i = 1$. Then we get the weights of the experts and process them to gain a final judgment matrix using weighted geometric mean method to accumulate the experts' judgment matrices. With the final judgment matrix, we can work out the weight of the economic indexes. Then the scores of SME's competitiveness can be calculated through measurement weights and dimensionless measures. Then we can rank the SMEs' performance according to the scores, have a comprehensive and wholistic view of the competitiveness of SMEs in China, and finally propose suggestion on improving their competitiveness.

Here, it is better to consider expert weight in the analytic hierarchy process (AHP) because the accumulated matrices will be more consistent. Suppose five experts provide the following matrices:

$$A^1=\begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ 3 & 1 & 1 & 1 & 1 & 3 \\ 3 & 1 & 1 & 1 & 1 & 3 \\ 3 & 1 & 1 & 1 & 1 & 3 \\ 3 & 1 & 1 & 1 & 1 & 3 \\ 3 & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & 1 \end{bmatrix},\quad A^2=\begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{5} & \frac{1}{5} & \frac{1}{7} & 1 \\ 5 & 1 & \frac{1}{3} & 3 & \frac{1}{5} & 5 \\ 5 & 3 & 1 & 1 & 1 & 5 \\ 5 & \frac{1}{3} & 1 & 1 & \frac{1}{3} & 3 \\ 7 & 5 & 1 & 3 & 1 & 5 \\ 1 & \frac{1}{5} & \frac{1}{5} & \frac{1}{3} & \frac{1}{5} & 1 \end{bmatrix},\quad A^3=\begin{bmatrix} 1 & 3 & \frac{1}{3} & 3 & 5 & 7 \\ \frac{1}{3} & 1 & 7 & 7 & 5 & 3 \\ 3 & \frac{1}{7} & 1 & 3 & 3 & 5 \\ \frac{1}{3} & \frac{1}{7} & \frac{1}{3} & 1 & 7 & 7 \\ \frac{1}{5} & \frac{1}{5} & \frac{1}{3} & \frac{1}{7} & 1 & 3 \\ \frac{1}{7} & \frac{1}{3} & \frac{1}{5} & \frac{1}{7} & \frac{1}{3} & 1 \end{bmatrix},$$

$$A^4=\begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & \frac{1}{5} & 3 \\ 3 & 1 & 1 & \frac{1}{3} & \frac{1}{3} & 3 \\ 3 & 1 & 1 & 1 & \frac{1}{3} & \frac{1}{3} \\ 5 & 3 & 1 & 1 & 3 & 1 \\ 5 & 3 & 3 & \frac{1}{3} & 1 & 7 \\ \frac{1}{3} & \frac{1}{3} & 3 & 1 & \frac{1}{7} & 1 \end{bmatrix},\quad A^5=\begin{bmatrix} 1 & 1 & \frac{1}{5} & \frac{1}{3} & 1 & 1 \\ 1 & 1 & \frac{1}{5} & \frac{1}{5} & \frac{1}{3} & 1 \\ 5 & 5 & 1 & 3 & 5 & 3 \\ 3 & 5 & \frac{1}{3} & 1 & 1 & 1 \\ 1 & 3 & \frac{1}{5} & 1 & 1 & 1 \\ 1 & 1 & \frac{1}{3} & 1 & 1 & 1 \end{bmatrix}.$$

Then the five experts weights are 0.231, 0.193, 0.203, 0.186, 0.187 respectively. Then we use the weighted geometric mean method to accumulate and calculate the five matrices, and get the judgment matrix consistency ratio CR_1=0.0009. If we use geometric mean method instead of calculating the expert weights, the average random consistency index of judgment matrices is CR_2=0.0011. We can see that $CR_1<CR_2$. Therefore, the judgment matrix obtained through the expert weight method proposed in this paper is more consistent and makes the evaluation more accurate and reliable.

5 Conclusions

This paper designs an evaluation model of SME' s competitiveness in China, improves the analytic hierarchy process (AHP) and uses it to evaluate SME' s competitiveness. The test above proves this method is more applicable to the evaluation of SME' s competitiveness in China. This paper is significant because it provides a new method for the evaluation of SME' s competitiveness, and makes up for the deficiency of China's study on this issue.

Acknowledgments

This paper is sponsored by Key Program of Anhui Provincial Humanities and Social Science Fund (No.SK2013A028).

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