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

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Abstract
With small and medium-sized enterprises (SMEs) becoming a significant engine for regional economic development, it is extremely important to evaluate SMEs' 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.Pralalahad 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.](image-url)
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>
<thead>
<tr>
<th>Indicator</th>
<th>Category</th>
<th>Definition</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total assets</td>
<td>total value</td>
<td>Enterprise’s year-end total assets</td>
<td>Average year-end total assets of the last three years</td>
</tr>
<tr>
<td>Gross output</td>
<td>total value</td>
<td>Enterprise’s annual gross output</td>
<td>Average annual gross output of the last three years</td>
</tr>
<tr>
<td>Work force</td>
<td>total value</td>
<td>Enterprise’s year-end work force</td>
<td>Average year-end total work force of the last three years</td>
</tr>
<tr>
<td>Sales revenue</td>
<td>total value</td>
<td>Enterprise’s annual sales revenue</td>
<td>Average annual sales revenue of the last three years</td>
</tr>
<tr>
<td>Total profit</td>
<td>total value</td>
<td>Enterprise’s annual after-tax profit</td>
<td>Average annual profit of the last three years</td>
</tr>
<tr>
<td>Leverage</td>
<td>ratio</td>
<td>Liability-asset ratio</td>
<td>Average year-end liability of the last three years / Average year-end assets of the last three years</td>
</tr>
<tr>
<td>Market share</td>
<td>qualitative value</td>
<td>Market share of main products</td>
<td>Qualitative questionnaire evaluation (high, relatively high, fair, relatively low, low)</td>
</tr>
<tr>
<td>Exports of products</td>
<td>ratio</td>
<td>Proportion of exports revenue in total sales revenue</td>
<td>Last year’s exports volume / last year’s total sales revenue</td>
</tr>
<tr>
<td>Sales network</td>
<td>qualitative value</td>
<td>Marketing channels of main products</td>
<td>Qualitative questionnaire evaluation (very good, good, fair, poor, very poor)</td>
</tr>
<tr>
<td>Newness of equipment</td>
<td>ratio</td>
<td>Proportion of equipment in different times</td>
<td>Net value of the equipment/original values of the equipment</td>
</tr>
<tr>
<td>Input of product development</td>
<td>total value</td>
<td>Annual R&amp;D cost</td>
<td>Last year’s R&amp;D cost</td>
</tr>
<tr>
<td>Number of R&amp;D personnel</td>
<td>total value</td>
<td>Total number of full-time R&amp;D personnel</td>
<td>Current number of full-time R&amp;D personnel</td>
</tr>
<tr>
<td>Academic qualification structure of employee</td>
<td>ratio</td>
<td>Academic qualification structure of employee</td>
<td>The number of employees above college education/total number of the employees</td>
</tr>
<tr>
<td>Spending on employee education</td>
<td>total value</td>
<td>Enterprise’s annual spending on employee training</td>
<td>Last year’s spending on employee training</td>
</tr>
<tr>
<td>Leadership</td>
<td>qualitative value</td>
<td>Entrepreneurs’ ability in planning, arrangement, controlling, coordination and communication</td>
<td>Qualitative questionnaire evaluation (very good, good, fair, poor, very poor)</td>
</tr>
<tr>
<td>Credit environment</td>
<td>qualitative value</td>
<td>The timeliness of the withdrawal of payment for goods, seriousness of inter-company arrears</td>
<td>Qualitative questionnaire evaluation (very good, good, fair, poor, very poor)</td>
</tr>
<tr>
<td>Social environment</td>
<td>qualitative value</td>
<td>Dis-proportionality of inter-company share-out; services provided by local government</td>
<td>Qualitative questionnaire evaluation (very good, good, fair, poor, very poor)</td>
</tr>
</tbody>
</table>

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 \( E\{E_1, E_2, \cdots, E_n\} \) is the sample enterprise of this evaluation, \( I\{I_1, I_2, \cdots, I_m\} \) is a set of total and ratio indexes. \( M_{ij} \) is the value of the \( I_j \) index of enterprise \( E_k \). \( E_k \in A, I_j \in I \). The dimensionless utilized value is \( \xi_{ij} \). It is the function of \( M_{ij} \) with the following formula:

\[
\xi_{ij} = f(M_{ij}) = \frac{M_{ij} - M_{ij}^\mu}{M_{ij}^\nu - M_{ij}^\mu} \times 40 + 60, i = 1, \ldots, n; j = 1, \ldots, m
\]

\( M_{ij}^\mu, M_{ij}^\nu \) is the minimum and maximum of the \( j \) index in the sample enterprise respectively. \( \xi_{ij} \) 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:

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

**TABLE 2. Judgment matrix in S layer**

<table>
<thead>
<tr>
<th>Expert</th>
<th>Indicator 1</th>
<th>Indicator 2</th>
<th>Indicator 3</th>
<th>Indicator 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td>a1</td>
<td>b1</td>
<td>c1</td>
<td>...</td>
</tr>
<tr>
<td>Expert 2</td>
<td>a2</td>
<td>b2</td>
<td>c2</td>
<td>...</td>
</tr>
</tbody>
</table>

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:

\[
a_i^* = \frac{\min\{a_i, \bar{a}\}}{\max\{a_i, \bar{a}\}} \quad (0 \leq a_i^* \leq 1)
\]

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.

Then we normalize the indexes in table 7 as \( \omega_j \) and calculate the objective weight of all experts. The formula of normalization is \( \omega_j = \frac{I_j}{\sum_{i=1}^{n} I_i} \) and we get the expert weight shown in table 8.
TABLE 8. expert weight

<table>
<thead>
<tr>
<th>Expert</th>
<th>expert weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td>$\omega_1$</td>
</tr>
<tr>
<td>Expert 2</td>
<td>$\omega_2$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Expert n</td>
<td>$\omega_n$</td>
</tr>
</tbody>
</table>

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:

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

Then the five expert 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.

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References


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