

The Small and Medium-sized Enterprises Performance Evaluation Model based on DEA and AHP Method

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Abstract

Traditional Methods of enterprises performance evaluation are often complex. In this paper, a new method combined with data envelopment analysis (DEA) and analytic hierarchy process (AHP) model to evaluate the performance of the small and medium enterprises is proposed. The principle of the new method is through the judgment matrix analysis, screens out performance evaluation input, output indexes, then using AHP to reflect evaluators' subjective preferences ability to improve scientificness and effectiveness of DEA when selecting input and output indexes. A simulation using deap2.1 software to test the new model is applied. Results show conjunction of DEA and AHP method has good applicability and feasibility.

Keyword: model, performance evaluation, small and medium-sized enterprises

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1. Introduction

The developing China has a unique development environment, but the opportunities and challenges co-exist in it. For all enterprises, especially small and medium ones it is a rare opportunity. Whether policy makers can seize this opportunity to go forward in the economy flood is much depends on their unique vision and courageous decision. But for the enterprise itself, its own performance level is an important factor that is deciding how long and how far it can go. In the process of economic development, any large-scale leading enterprise is starting from small businesses. Therefore, the problem of survival and development of small and medium-sized enterprises (SME) has long been placed in government officials, experts and scholars' desk [1]. Solutions to SMEs' project management and daily operations inefficiencies have become the focus of the problem for Chinese sustained economic development. However, these Chinese SMEs' problems and contradictions in the process of development have exist long time.

Enterprise performance evaluation is to make a final reasonable judgment by using scientific evaluation methods for qualitative and quantitative analysis of business operating situation [2]. For SME, which through standardized management system, establish incentive and restraint mechanisms to improve their management level and overall competitiveness. As a result, performance evaluation has long been considered as the most important means of management. Since the 1990s, China's SME targeted Western companies to learn about the experiences and system of performance evaluation, with its own conditions, and establish the existing applicable Chinese enterprise performance evaluation system. At present, the most widely used enterprise performance evaluation methods in China are as follows: economic value added (EVA), balanced score card (BSC), analytical hierarchy process (AHP), data envelopment analysis (DEA) [3], etc.

2. Research Ideas of The Model

Method enterprises choose for performance evaluation is often effected by a lot of subjective factors, and algorithms are also relatively complex [4]. DEA rule omit the step of estimating parameters, so since not only simplifies the algorithm, but also reduce the influence of subjective factors. Therefore, more and more experts, scholars and business people are more

likely to choose DEA method for enterprise performance evaluation. Of course, DEA method also has some deficiencies, on the one hand it requires relatively high accuracy of the data, if the data is not accurate enough, the evaluation result is clearly wrong; on the other hand, when choosing evaluation index, DEA method is often more casual, not through scientific judgment to obtain a reasonable choice. The AHP and DEA are exactly complementary. Therefore, this article on innovative choose DEA method and AHP method as a combination for SME performance evaluation. Includes the following three steps: The first step, using AHP to build judgment matrix when screening evaluation index; Second, using DEA method to evaluate enterprise based on screened out evaluation index; the third step, obtain evaluation results, based on conclusions of analysis results give enterprise applicable and effective advice. On the one hand, this approach can improve objectivity, rationality and scientificness of their own performance evaluation, on the other hand, SMEs are easy to implement improvements.

3. Based on The Combination of DEA and AHP Analysis Performance Evaluation Model

3.1. AHP Model Introduction

Analytic Hierarchy Process (AHP), AHP is first time raised by a well-known University of Pittsburgh operational research professor T. L. Saaty in the early 1970s. This method is more efficiently used to solve multiple complex problems. Its main operating principle is to make full use of systems engineering thinking to combine qualitative analysis and quantitative analysis together to solve practical problems. Through quantitative analysis of qualitative issues, it is a very practical and flexible multi-criteria decision making method. The reason why the AHP method is applied to enterprise performance evaluation is that complex decision problems can be layered separately to be analyzed. In this stratified analysis process, obtains all levels' decision-making principles. Namely evaluation index weights, screen out several the greatest impact factors from the results. Implementation of AHP can be divided into three steps:

First, form hierarchical structure model according to specific problems to be solved. The specific problems to be solved were stratified firstly. After further decomposition of the problem first, then on the basis of certain criteria based on decomposition of various elements that impact the problem to be solved. And then divide the problem into different levels according to the analysis results. Factors in same level are usually derived from an upper hierarchy, and it caused main influence to the upper layer's factors and the next layer's factors are dominated by factors of upper layer.

Second, using evaluation index screened by AHP method to build evaluation judgment matrix. Judgment matrix expression is as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

n: the number of evaluation index

The i-th row and the i-th column corresponds to the same evaluation index,

And the matrix should satisfy the conditions: $a_{ij} > 0, a_{ij} = 1/a_{ji}, a_{ii} = 1, i = 1, 2, \dots, n, j = 1, 2, \dots, n$.

Third, consistency test. If it does not pass the consistency test, then they would have to re-construct the judgment matrix in order to conduct the next step; however, if the test result is passed consistency test, the weight vector obtained is the result.

$$\text{Coincident indicator } C.I. = \frac{\lambda_{\max} - n}{n - 1}$$

$$\text{Random consistency index } CR = \frac{CI}{RI}$$

Average random consistency index (RI) size is determined by the number of decision making units (DMU) "n".

3.2 DEA Model Introduction

DEA method was first proposed in 1978 by a well-known professor A. Charnes at the University of Texas and famous operational research expert Cooper. W W. Its main features are that in a given period, DEA method by measuring the input and output indicators established cross-choice array, then the decision-making unit is divided into valid and invalid. It now appears that this method can be seen as a new statistical method, widely used in evaluation of multi-objective decision making unit relative effectiveness. Using DEA method for enterprise performance evaluation can make up the defects of principal component analysis and financial index evaluation. It's, more scientific, objective and fair reflect business's operating efficiency.

Most used CCR model can be described this way:

Equation assumes that evaluate n SMEs' enterprise performance. X_i, Y_i , are firm "i" inputs, outputs respectively. $X_i = (x_{i1}, x_{i2}, \dots, x_{il})$, $Y = (y_{i1}, y_{i2}, \dots, y_{is})$; v, u are weights of Inputs and outputs respectively. Then the CCR model that calculate β_i implement performance of firm i can be expressed as [7]:

$$\beta_i = \max \frac{u^T Y_i}{v^T X_i}$$

$$s.t. \begin{cases} \frac{u^T Y_j}{v^T X_j} \leq 1, j = 1, 2, \dots, n \\ u \geq 0, v \geq 0 \end{cases}$$

Transform nonlinear programming problem into linear programming problem, it is necessary to satisfy that:

$$t = \frac{1}{v^T X_i}, \omega = t \times v, \eta = t \times u, \beta_i = \max \eta^T Y_i$$

$$s.t. \begin{cases} \omega^T X_j - \eta^T Y_j \geq 0, j = 1, 2, \dots, n \\ \omega^T X_i = 1 \\ u \geq 0, v \geq 0 \end{cases}$$

When $\beta_i = 1$, indicating that the performance of firm i reached the DEA efficient; if $\beta_i \leq 1$, it is called enterprise performance does not meet the DEA efficient. However, DEA method just simply divides evaluation result into valid and invalid. These will be more likely to cause a situation that numbers of companies reach efficient and can not conduct further comparison. Meanwhile, subjective choice of the weight may also lead to efficiency is overrated, make effective decision making units are above normal. However, DEA method application still has some limitations, mainly because of its own avoidless defects. For example, the method can not determine incidence of evaluation index impact on efficiency. Thus it can not achieve the expected increase relative effectiveness of decision making units. So, if we only use DEA method, it is not scientific enough.

3.3. DEA/AHP Model

Based on research the AHP model and DEA model respectively, combine characteristics of each model together, we propose a DEA/AHP model. This method can be divided into three steps: first, using AHP build judgment matrix, screening out evaluation index; Second, evaluate enterprise using evaluation index screened out by DEA method; third step, analyze the results obtain from performance evaluation and get the conclusions. Give enterprise reasonable suggestions or comments. This approach on the one hand can improve their own

objectivity, rationality and science of performance evaluation; on the other hand, SMEs are easy to implement improvement suggestions, and improve their own efficiency.

4. Examples of SME Performance Evaluation

4.1. Using AHP to Construct Input-output System

First, each of the SMEs to be evaluated as a decision-making unit (DMU_j, $j = 1, \dots, n$). Based on actual needs and their own characteristics of SMEs' performance evaluation, combined with previous similar performance evaluation practices, summarize the input and output index project. After identify indicators, ask specialized people to grade these input and output index, establish judgment matrix according to the score:

Table 2

INPUT	Total cost	Total assets	Capital assets	Number of employees	Main business cost	Weight
Total cost	1	1/3	1/2	1/3	1/5	0.066
Total assets	3	1	4	3	1/2	0.302
Capital assets	2	1/4	1	2	1/3	0.135
Number of employees	3	1/3	1/2	1	1/2	0.127
Main business cost	5	2	3	2	1	0.369

Table 3

OUTPUT	Retained profits	Gross profit	Operating profit	Taking	Weight
Retained profits	1	1/4	1/3	1/5	0.071
Gross profit	4	1	3	2	0.438
Operating profit	3	1/3	1	1/4	0.139
Taking	5	1/2	4	1	0.352

Calculate CR value. Test consistency for these two judgments matrix by calculating the results. These two judgment matrix CR values are 0.04 and 0.08 respectively, both of them are less than 0.1. It can be inferred that standby input index judgment matrix and standby output index judgment matrix both have consistency.

Because limitations of DEA model itself, sum of selected input and output indexes is less than the number of DMU. In comparison the result of weight, select two relative greater weight indexes as final input and output indexes. From the results of Table 2 and Table 3 we can clearly see that the total assets and main business cost have greater weight; in output indexes, total profits and main business profit have relatively larger weights. So we select relative larger total assets, main business costs, and total profits, main business income as input and output indexes.

4.2. Solving Efficiency Evaluation Value using DEA

After investigation, we collected basic information of eight SMEs' output value between 10 million and 50 million yuan, used the software deap2.1 computing enterprise involved, and the outcome are as follows:

As data derived from Table 4, we see that in the performance evaluation of the eight participating SMEs, there are four companies' technical efficiency reached DEA efficient standards. But only one company's overall efficiency reaches DEA effective. So does scale efficiency. While only DMU4 achieves technical efficiency, scale efficiency and overall efficiency at the same time. Among them, technical efficiency meet DEA efficient but overall efficiency did not are DMU5, DMU6, DMU7. DMU4 achieves not only scale efficiency and overall efficiency, but also technical efficiency standards. This result shows that business situation of DMU4 is good, no further investment structure and size adjustments. We can also intuitively see this from input and output data of the enterprise. You can improve their overall operational efficiency by improve enterprise management level for effective DMU1, DMU2, DMU3, DMU8 which did not meet the technical efficiency standard. And the three companies DMU5, DMU6, DMU7 although

reach DEA efficient technical efficiency, but overall efficiency does not reached, indicates that they also need to carry out further improve for their overall efficiency in order to improve their business performance levels. Only DUM4's scale efficiency meet DEA efficient company, indicates that the company's existing scale is more reasonable, no need to expand or reduce. While all scale efficiency of the remaining seven companies are less than one, indicates that they can expand the operation scale to get more revenue. DMU1, DMU2, DMU3, DMU8 these four companies do not meet technical efficiency effectively. We recommend that they can adjust the input and output data to achieve technical efficiency effectively. Therefore, we use deap2.1 software, using the projection method to calculate target value which these four companies to achieve technical efficiency valid state need to be adjusted, provide specific and clear recommendations for these four companies management. There are still four companies indexes need to improve, namely refined value that does not reach DEA technology effectively is shown in Table 5.

Table 4. Data Output Result

DMU (Decision Making Unit)	Input		Output		Overall efficiency	Technical efficiency	Scale efficiency
	Total assets(100 thousands)	Main business cost (100 thousands)	Total profits (100 thousands)	Main business income (100 thousands)			
DMU1	1653.1	1531.3	192.8	1724.1	0.932	0.971	0.960
DMU2	2186.6	2013.4	218.1	2231.5	0.918	0.938	0.979
DMU3	2356.7	1964.6	28.8	1993.4	0.840	0.849	0.989
DMU4	1568.4	1486.7	308.9	1795.6	1.000	1.000	1.000
DMU5	4361.8	4026.5	189.9	4216.4	0.867	1.000	0.867
DMU6	3486.5	3241.5	288.1	3529.6	0.902	1.000	0.902
DMU7	2513.7	2361.8	384.3	2746.1	0.963	1.000	0.963
DMU8	1865.4	1654.3	207.2	1861.5	0.932	0.935	0.996

Table 5. Refined Value of the 4 Companies that Does Not Reach DEA Technology Effectively

DMU	Input		Output	
	Total assets (10 thousands)	Main business cost (10 thousands)	Total profits (10 thousands)	Main business income (10 thousands)
DMU1	1568.400	1486.700	308.900	1795.600
DMU2	2001.915	1888.022	343.478	2231.500
DMU3	1765.118	1668.809	324.591	1993.400
DMU8	1633.939	1547.372	314.128	1861.500

5. Conclusion and Outlook

Small and medium-sized enterprises are growth cradles for the future backbone large and medium-size enterprises of our country, which play a special and important role in economic development of our country. For SMEs, enterprise performance evaluation is an irreplaceable part to upgrade and form the soul of itself in growth road. It also plays an important role for business management and internal environment improvement. It is of great practical significance an integral part of the enterprise. As a result, we should pay proper attention to small and medium enterprises performance evaluation studies to provide a favorable environment for their developments. This article first time comprehensively and in-depth analysis home and abroad SMEs' performance evaluation research status and the latest results of. Then propose DEA and AHP Method Performance Evaluation Model for SMEs based on their special circumstances and actual demands. The principle of this model is mainly through the judgment matrix analysis, screens out performance evaluation input, output indexes, then using AHP to reflect evaluators' subjective preferences ability to improve scientificness and effectiveness of DEA when selecting input and output indexes. Then it uses DEA model to solve the performance evaluation value, and deap2.1 software realization. Through empirical analysis, we can reach a conclusion that conjunction of DEA and AHP method has good science, applicability and feasibility.

Although this article uses AHP method to analysis judgment matrix which is build by input and output indicators to let it has a certain scientific. But it is still in reference to a large number of alternative indexes based on existing study. There are still many subjective factors. How to make alternative indexes more scientific, more rational, is a problem to be further considered. Meanwhile, the DEA/AHP model is dependents on the use of numbers of basic data, and this lead to a relatively high requirement for basic data selection. If the basic data has errors or is improper selected, then the conclusion is clearly unreasonable. Therefore, in the application process, be sure to pay attention to the accuracy and reasonableness of original data collection.

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