DEA Comprehensive Evaluation on Enterprise's Technology Innovation Capacity

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Abstract: As evaluation factors of enterprise technology innovation capacity are very complicated, evaluation methods commonly used do not consider interrelationships between every capacity element, which results in subjectivity of evaluation results. Because non-parametric methods can be used to deal with evaluation problems with many input and output, this thesis proposes DEA evaluation idea and establish DEA evaluation module. Through practical case study, optimum value analysis of sample enterprise, returns to scale analysis and projection analysis, relatively efficient enterprises are identified and adjustment proposals are put forth for inefficient enterprises. Case study shows that: DEA evaluation method is an efficient method to evaluate enterprise technology innovation capacity.

Keywords: enterprise, technology innovation, evaluation, DEA (Data Envelopment Analysis)

1. Introduction

There are 4 major methods commonly used to evaluate technology innovation capacity. Below is the brief introduction about them.

Firstly, enterprise innovation capacity is decomposed to establish evaluation module; then, artificial neural network method is employed to evaluate it.[1] Apply basic theory of fuzzy mathematics through membership function of grade fuzzy subset to acquire degree of membership.[2] The greater degree of membership, the stronger innovation capacity of every indexis. For qualitative indicators, experts will make a judge and decide the evaluation value, thus obtain strength order of every enterprise's technology innovation capacity.[3] Apply grey evaluation theory to process distributed information from evaluators into a weight vector, which describes different grey digress, and which should be single-valued processed to acquire comprehensive evaluation value from evaluators. [4]

These evaluation methods only take every capacity element of technology innovation capacity into consideration, excluding interrelationship between every capacity element. That's to say, coordination between every capacity element has an influence on overall technology innovation capacity. Comprehensive evaluation module that processes very sub-capacity by linear superposition simplifies a systematic problem into a linear one, which will result in subjectivity of evaluation results.

As non-parametric DEA method is greatly applicable to complicated systems that have many input indices and output indices, and can be used to work out evaluation problems about many inputs and outputs, its restrictions are relatively few, and it's more practical in study. Therefore, this thesis in tentatively applies DEA method to evaluate enterprise technology innovation capacity.[5]

2. Basic content of DEA module evaluation

Data Envelopment Analysis is called DEA for short. DEA is an efficiency evaluation method, which was developed by scholars, including Charnes and Cooper in 1978, on the basic of the concept of relative efficiency. DEA is to use mathematic programming model to evaluate relative efficiency (called DEA efficiency) between "departments" or "units" (called Decision-making Unit, DMU for short), which have many inputs and outputs. All the DMU are ranked according to relative efficiency. Relatively efficient DMU is identified. Reasons for lack of efficiency of other DMU and its degree should be pointed out in order to provide competent departments with information for management decision-making.

Provided the number of comparable DMU is n, the number of input and output in every DMU is m and s respectively. Of which,

$X_j = \left(x_{1j}, x_{2j}, \cdots, x_{mj} \right)^T, j = 1, 2, \ldots, n$ is the input vector of DMU,

$Y_j = \left(y_{1j}, y_{2j}, \cdots, y_{sj}\right)^T, j = 1, 2, \ldots, n$ is the output vector of DMU,

λ is the n dimensional vector composed of weights of n DMU.

so, CCR model of DEA evaluation is (D), through calculating the values of θ, S^+ and S^-, DEA efficiency[6]can be obtained. The expression is as shown in (1):

$$(D)\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta\, X_0 \\ \quad . \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, j = 1, 2 \cdots\cdots, n \\ S^+ \geq 0, S^- \geq 0 \end{cases} \qquad (1)$$

(1) If $\theta = 1$, and $S^{*-}=0$, $S^{*+}=0$, then DMU_{j0} is DEA efficient;

(2) If $\theta = 1$, and $S^{*-}\neq0$, or $S^{*+}\neq0$, then DMU_{j0} is weak DEA efficient;

(3) If $\theta < 1$, then DMU_{j0} is DEA inefficient.

3. Empirical research

During the study, considering complexity of enterprise technology innovation evaluation system and availability of related index data, this thesis selected 5 indices as DEA model input indices, including R&D investment intensity, R&D labor force input intensity, innovation (inspiration) mechanism, number of patents and self-owned technology as well as marketing expense ratio. Two indices: new product sales quota and product market share are selected to be DEA model output indices. The number of input and output indices is 7. It is required that the number of DMU should be two times more than the amount of input and output indices, or otherwise more, DEA calculation method with respect to experience. Therefore, this thesis selected 14 sample enterprises to evaluate.[6]

3.1 Optimum value analysis

Optimum value calculation results of sample enterprises are as shown in Table 1.

Table 1. Optimum value calculation results of sample enterprises

DMU \ Results	θ	S_1^-	S_2^-	S_3^-	S_4^-	S_5^-	S_1^+	S_2^+
1	1.000000	0	0	0	0	0	0	0
2	0.7481614	0	0.007483	0	0.427463	0	0	0.012365
3	1.000000	0	0	0	0	0	0	0
4	0.8388867	0.002803368	0	46.03846	0.82467	0.067101	0	0
5	0.3693661	0.008652319	0	0	0	0.0332	0	0
6	0.7492386	0	0.0111	6.581439	5.850213	0	0	0
7	1.000000	0	0	0	0	0	0	0
8	1.000000	0	0	0	0	0	0	0
9	0.4124471	0.0312	0	17.96013	1.33113	0	0	0
10	0.6301064	0	0.00621	0	5.417831	0	0	0.00106
11	1.000000	0	0	0	0	0	0	0

12	0.6798677	0	0	13.76034	2.719929	0	0	0.00613
13	1.000000	0	0	0.0131	0.00217	2.456063	24.93766	0
14	0.7282899	0.0898	0.00016	0	0	0	0	0

(1) According to analysis in Table 1, enterprises with efficient DEA are 1, 3, 7, 8 and 11. Technology innovation efficiency of each of these enterprises is relative efficiency. On basic of previous input, output has reached the optimum value. It indicates that each of such enterprises has made full use of current input in the field of technology innovation, and has excreted its own potential. Their technology innovation capacities are relatively high.

(2) According to analysis in Table 1, weak DEA efficient Enterprise 13 indicates that for any of these enterprises, there is a DMU combination, which can be used to reduce partial input with the same output, or increase partial output (not total) with the same input.

(3) According to analysis in Table 1, enterprises with no DEA efficiency are 2, 4, 5, 6, 9, 10, 12 and 14, as their optimum values θ are all lower than 1. It suggests that for any of these enterprises, there is a DMU combination, which will achieve an output at least equal to that of the evaluated enterprise with every input lower. That's to say, the enterprise evaluated is not DEA efficient. The smaller θ is, the less efficient the enterprise is.

3.2 Returns to scale analysis

Table 2. Weight calculation results

Enter \ λ_i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\sum_{i=1}^{n}\lambda_i$
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0.313259	0	0	0	0	0	0	0	0	0	0.240875	0	0.384637	0	0.938771
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
4	0.14647	0	0	0	0	0	0	0	0	0	0.361303	0	0	0	0.507773
5	0.129576	0	0	0	0	0	0	0.0467	0	0	0.0449	0	0.0528	0	0.273976
6	0.192948	0	0	0	0	0	0	0.0561	0	0	0	0	0.533893	0	0.782941
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
9	0.056	0	0	0	0	0	0	0	0	0	0.166123	0	0.0913	0	0.313423
10	0	0	0.282542	0	0	0	0	0	0	0	0.275962	0	0.264351	0	0.822855
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
12	0.306742	0	0	0	0	0	0	0	0	0	0.574568	0	0.0201	0	0.90141
13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
14	0.245136	0	0	0	0	0	0	0.0508	0	0	0.135036	0	0.355594	0	0.786566

(1) If $\sum_{j=1}^{n}\lambda_j^{*}=1$, then the returns to scale DMU_{j0}, and itremainsthe same. According to analysis in Table 2, enterprises with the same returns to scale are 1, 3, 7, 8, 11 and 13, which means these enterprises have reached the maximum output.

(2) If $\sum_{j=1}^{n}\lambda_j^{*}<1$, then the returns to scale DMU_{j0} increases, and the smaller $\sum_{j=1}^{n}\lambda_j^{*}$ is, the greater the tendency for scale to increase. Among these 14 enterprises, those with increasing tendency of returns to scale are 2, 4, 5, 6, 9, 10, 12 and 14. These 8 enterprises should somewhat increase input to realize a higher proportion of output.

(3) If $\sum_{j=1}^{n}\lambda_j^{*}>1$, then the returns to scale DMU_{j0} decreases, and the larger $\sum_{j=1}^{n}\lambda_j^{*}$ is, the greater tendency for scale

to decrease. It suggests that on the basic of input, it is impossible to obtain a higher proportion of output with an increase of input, and at this moment, it is unnecessary to increase DMU input.

3.3 Projection analysis of DMU

The projection of DMU that falls short of DEA efficiency at production frontier surfaces DEA efficient, which means through coordinating input value and output value in non-efficient DMU to reach DEA efficiency.

The projection of ($\hat{X}_0, \hat{Y}_0$) at the relative efficiency surface of DEA is to construct a new ($\hat{X}_0, \hat{Y}_0$) with the following formula (2) on the basic of the original DMU$_j$. Adjustment scheme of Enterprise 2 is as in Table 3.

$$\begin{cases} \hat{X}_0 = \theta X_0 - S^- = \sum_{j=1}^{n} X_j \lambda_j \\ \hat{Y}_0 = Y_0 + S^+ = \sum_{j=1}^{n} Y_j \lambda_j \end{cases} \tag{2}$$

Table 3. Adjustment scheme of Enterprise 2

Indices	Before Indices Adjustment	Slack Variables	After Indices Adjustment
R&D investment intensity X1	0.021	0	0.015711
R&D labor force input intensity X2	0.036	0.007483	0.019451
innovation (inspiration) mechanism X3	70	0	52.3713
number of patents and self-owned technology X4	10	0.427463	7.054151
marketing expense ratio X5	0.15	0	0.112224
new product sales quota Y1	0.0365	0	0.027308
product market share Y2	0.030	0.012365	0.03481

Take Enterprise 2 for example, adjustment scheme as shown in Table 3 can be obtained. From the table, it can be seen that the projection points of this enterprise at the production frontier surface are x1=0.015711, x2=0.019451, x3=52.3713, x4=7.054151, x5=0.112224, y1=0.027308, y2=0.03481. It indicates that if the enterprise wants to realize DEA efficiency, it should reduce somewhat input of R&D investment intensity and number of patents and self-owned technology. Similarly, through adjustment, the most efficient schemes for enterprise technology innovation of other enterprises can be obtained.[7]

4. Conclusion

Through case study, DEA is proved to be a very efficient method to evaluate enterprise technology innovation capacity. By using DEA method to evaluate enterprise technology innovation capacity, an enterprise can understand disparity in management efficiency, identify status of technology innovation, determine the orientation to improve, which is good for enterprise managers to propose countermeasures for technology innovation and thus strengthen enterprise competitiveness. According to evaluation results, enterprise managers can select DEA efficient enterprises as rival benchmark management enterprise. Through comparing with external excellent enterprises, an enterprise can identify its position, management effects and shortcomings. This is beneficial to establish suitable and efficient development strategy; constantly trace and control development and changes of the external environment. In this way, enterprise innovation capacity can be continuously improved, and enterprise competitiveness can also be enhanced. DEA method can also be applied in annual vertical comparison of an enterprise to distinguish efficient year from inefficient one, which reflects alteration situation of enterprise economic profitability in a period. It enables enterprise to further identify situation of technology innovation, adjust input of innovation resources, increase input of essential and efficient resources while decrease input of inefficient resources, in order to improve resource deployment and enterprise technology innovation capacity.

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