An IDEA-BCC Model for Performance Management of Scientific Research

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Abstract. Aiming at the practical problems in the performance management of scientific research, an IDEA-BCC model based on the combination of kernel function mapping and the BCC model in the traditional DEA method is proposed in this paper. Taking the annual research input and output data of the scientific research institution as an example, the IDEA-BCC application model is established and the validity of the method is illustrated by the experimental data.

Introduction

DEA (data envelopment analysis, DEA) [1] method is a non-parametric statistical method which is to the concept of relative efficiency as the basis, to the convex analysis and linear programming as a tool for evaluation a prolific DMU (decision making unit, DMU) whether has the same type of multi input is the "technology" or not. The basic idea of DEA is to each unit to be assessed as a DMU, again by many DMU constitute the group evaluation, through the comprehensive analysis of input and output ratio, DMU each input and output index weights for variable operations, determine the efficient production surface, and according to each DMU and efficient surface distance state to determine the DMU is DEA efficient, and gives various meanings of evaluation index. DEA is widely used in production [2] [3], finance [4] [5], business [6] [7], research & development [8] and other fields [9] [10]. The better results have been obtained by providing a scientific basis for decision makers.

DEA has developed many models and the most basic is the two models BCC and CCR. In this paper, an IDEA-BCC model based on the combination of kernel function mapping and the BCC model in the traditional DEA method is proposed. Taking the annual research input and output data of the scientific research institution as an example, the IDEA-BCC application model is established and the validity of the method is illustrated by the experimental data.

Design of the IDEA-BCC model

Step1:

There are n decision making units, DMU_j ($j=1,...,n$), their input and output vectors are respectively:

$X'_j=(x'_{1j},x'_{2j},...,x'_{mj})^T>0$, $Y_j=(y_{1j},y_{2j},...,y_{sj})^T>0$, $j=1,...,n$.

The weight vectors of input and output are respectively $v=(v_1,v_2,...,v_m)^T$, $u=(u_1,u_2,...,u_s)^T$.

Step2:

The weight vector of input $X'j$ is mapped to the data analysis space X_j.

$$X_j = \Phi(x'_{mj} - c) = e^{-(x'_{mj}-c)^2/2\sigma^2} \tag{1}$$

$$c = \frac{1}{n*m}\sum_{k=1}^{n}\sum_{l=1}^{m} x'_{lk} \tag{2}$$

$$\sigma = 1\Big/\sqrt{\frac{1}{m*n}\sum_{j=1}^{n}\sum_{i=1}^{m}(x'_{ij} - c)} \tag{3}$$

Step3:

Get BCC model.

$$\begin{aligned} & Maximize \quad \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} = \theta_o \\ & subject\ to \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ j = 1, 2, \cdots, n, \\ & \qquad u_r \ge 0, v_i \ge 0,\ \forall r, i. \end{aligned} \tag{4}$$

Step4:

The linear programming model is obtained by using the Charnes-Cooper transform.

$$\begin{aligned} & Maximize \quad \sum_{r=1}^{s} \mu_r y_{ro} - u_o, \\ & subject\ to \quad \sum_{i=1}^{m} \omega_i x_{io} = 1, \\ & \qquad \sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \omega_i x_{ij} - u_o \le 0,\ \ j = 1, \dots, n, \\ & \qquad \mu_r, \omega_i \ge 0, \qquad r = 1, \dots, s;\ i = 1, \dots, m. \end{aligned} \tag{5}$$

Step5:

According to the basic theory of linear programming, get the form of the dual problem of the model (5).

$$\begin{aligned} & Maximize \quad \theta_{\mathbf{o}} - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\ & subject\ to \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_o x_{io},\ i = 1, \dots, m \\ & \qquad \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro},\ \ r = 1, \dots, s \\ & \qquad \sum_{j=1}^{n} \lambda_j = 1 \\ & \qquad \lambda_j, s_i^-, s_r^+ \ge 0,\ \ \forall i, j, r \end{aligned} \tag{6}$$

Experiment and Results

The 5 scientific research institutions (DMU1-DMU5) in 2012 research performance related data, are obtained in the experiment. Set up the index system of scientific research investment as number of scientific researcher, research funding, research equipment, the number of scientific research subjects. Set up the index system of scientific research output as achievement award, work completion score. The investment and output index data are standardized, as shown in Table 1.

The results of DEA analysis based on the IDEA-BCC model proposed in this paper are calculated as shown in Table 2. The results are analyzed as follows.

DMU1:

The total efficiency of DMU1 θ=1, it is not necessary to adjust the scientific research investment.

Tab.1. The investment and output index data

	number of scientific researcher	research funding	research equipment	the number of scientific research subjects	achievement award	work completion score
DMU1	84	506	36	18	8	94
DMU2	46	422	28	6	3	92
DMU3	38	406	32	6	5	96
DMU4	41	60	12	2	1	86
DMU5	39	85	25	2	1	92

Tab.2. The results of DEA analysis

	total efficiency θ	number of scientific researcher	research funding	research equipment	the number of scientific research subjects	achievement award	work completion score
DMU1	1	0	0	0	0	0	0
DMU2	0.976	0	8.42	8.220	3.83	8.19	4.32
DMU3	1	0	0	0	0	0	0
DMU4	0.92	3.40	0	0	1.04	6.9	5.3
DMU5	0.96	1.95	1.2	1.42	0	2.67	3.88

DMU2:

Total efficiency of DMU2 is "technology" invalid, the reason is scientific research investment slack variable S_{inv}=(0, 8.42, 8.22, 3.83), so the number of scientific researcher are not enough, cause other resources are unused and wasted.

The method for improving efficiency of DMU2 is as follows:

$$\hat{x}_0 = \theta x_0 - S_{inv}$$

$$\hat{x}_0 = 0.976 \times (46, 422, 28, 6) - (0, 8.42, 8.22, 3.83)$$

$$\hat{x}_0 = (58, 420, 26, 6)$$

$$\hat{y}_0 = \theta y_0 + S_{out}$$

$$\hat{y}_0 = 0.976 \times (3, 92) + (8.19, 4.32)$$

$$\hat{y}_0 = (11.2, 95.86)$$

That means the investment of DMU2 can be adjust to (58, 420, 26, 6), the output can be raised to (11.2, 95.86).

DMU3:

The total efficiency of DMU3 θ=1, it is not necessary to adjust the scientific research investment.

DMU4:

Total efficiency of DMU4 is "technology" invalid, the reason is scientific research investment slack variable S_{inv}=(3.4, 0, 0, 1.04), so the research funding and research equipment are not enough, cause other resources are unused and wasted.

The method for improving efficiency of DMU4 is as follows:

$$\hat{x}_0 = \theta x_0 - S_{inv}$$

$$\hat{x}_0 = 0.976 \times (41, 60, 12, 2) - (3.4, 0, 0, 1.04)$$

$$\hat{x}_0 = (38, 59, 11, 3)$$

$$\hat{y}_0 = \theta y_0 + S_{out}$$
$$\hat{y}_0 = 0.976 \times (1,86) + (6.9,5.3)$$
$$\hat{y}_0 = (7,93)$$

That means the investment of DMU4 can be adjust to (38, 59, 11, 3), the output can be raised to (7, 93).

The analytical method of DMU5 is the same as the DMU4.

Conclusion

In this paper, an IDEA-BCC model based on the combination of kernel function mapping and the BCC model in the traditional DEA method is proposed. Taking the annual research investment and output data of five scientific research institutions as an example, get the results of scientific research performance evaluation, find the reasons of the invalid DEA from the analysis of the results, give the rectification recommendations. The validity of the IDEA-BCC model is illustrated by the experimental data.

References

[1] Banker R D, Charnes A, Cooper WW. Some models for estimating technical and scale efficiencies in data envelopment analysis [J]. Management Science, 1984, 30: 1078-1092.

[2] Wang G Z, Wu J R. Empirical Analysis on Input-Output Efficiency of Advanced Equipment Manufacturing Industry Based on DEA Method[J]. Proceedings of the 2012 International Conference on Wavelet Analysis and Pattern Recognition, 2012:321-326.

[3] Kuo C L, Lin C L. The Management Performance Assessment of Taiwan's Camping Park Based on DEA Technique[C]. SI International 2011, 2011:768-771.

[4] Cong Sui, Guo tai Chi. Loan Pricing Model of Commercial Bank based on DEA[C]. 2009 International Conference on Electronic Commerce and Business Intelligence, 2009:378-381.

[5] Joseph C P, Sandra S, Claire S C. Knowledge Worker Performance Analysis Using DEA: An Application to Engineering Design Teams at Bell Canada[J]. IEEE Transactions on Engineering Management, 2002, 49(1):161-172.

[6] Li Y M, Li C Sh. Evaluation of the Efficiency of the Supermarket Chain Based on the DEA Method[C].2011 International Conference on Management and Service Science, 2011:1-4.

[7] Rezaie K, Haeri A, Amalnick M S, Ansarinejad A. Using Augmented DEA to Calculate Efficiency Scores of Organizational Resources[C]. 2011 UKSim 13th International Conference on Modelling and Simulation, 2011:365-369.

[8] Li R P, Cui H D. DEA Evaluation and Analysis of Input and Output Efficiency about Regional R&D Resource[C]. 2012 Fifth International Joint Conference on Computational Sciences and Optimization, 2012:531-534.

[9] Huang C, Huang M R, Chang S H, Chung R G. Quality Improvement of On-Job-Training: Using DEA method[C]. 2010 International Symposium on Computer, Communication, Control and Automation, 2012:455-458.

[10] Xie N B, Xiao J. The Efficiency Evaluation of the College which Based on DEA[C]. 2009 First International Workshop on Education Technology and Computer Science, 2009:168-172.