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Guarantee Agency Efficiency Evaluation Based on Super-Efficiency DEA-AHP Model

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Abstract

In order to evaluate the efficiency of the guarantee agencies and achieve the purpose of identifying there competitive advantages, through the analysis of advantages and disadvantages of previous DEA-AHP methods, this paper puts forward a Super-efficiency DEA-AHP model, which cannot only completely and more accurately rank the guarantee agencies but also comprehensively reflect the weights of the importance of each index which influence the efficiency of the guarantee agencies. Through the case analysis and the comparison with other models, the model shows its validity.

Keywords: *guarantee institutions, efficiency evaluate, DEA, AHP, super efficiency model,*

1. Introduction

Efficiency evaluating of guarantee agencies can promote its healthy growth, it is helpful in a country or region to solve the financial distress for its Small and Medium-sized Enterprises so that economic strength of enterprises is improved and social economic benefit is increased [1]. There are many methods to research the efficiency of security agencies at home and abroad [2], including the cost-benefit method [3], the financial ratio analysis [4], the linear regression analysis [5] and so on. But the most popular methods are analytical hierarchical process method (AHP) [6], the data envelopment analysis method (DEA) [7] and the DEA-AHP method [8-10].

Data envelopment analysis (DEA) [11], developed by Charnes in 1978, has become one of the most widely used methods in operations research and management science. A reason for this success is that DEA is a task-oriented approach and focuses on an important task: to evaluate the relative (technical) efficiency of comparable Decision Making Units (DMU) essentially performing the same task. Based on information about existing data on the performance of the units and some preliminary assumptions, the purpose of DEA is to empirically characterize the so-called Efficient Frontier based on the set of available DMUs, and to project all DMUs onto this frontier. If a DMU lies on the frontier, it is referred to as an efficient unit, otherwise inefficient.

Analytic Hierarchy Process (AHP) [12], developed by an American Operations Research Professor SaatyT.L in 1970s. In the condition of complex target structure and more qualitative information, AHP method makes the decision-making process hierarchically and quantitatively, it is suitable for solving the complexity decision problem with multi-objective and multi-criteria [13].

Therefore, many scholars combine these two methods to solve efficiency issues, the combined ones cannot only distinguish between the advantages and disadvantages of effective decision-making units in the efficient frontier, which DEA method could not, but also avoid the drawbacks of subjective matrix which is judged by experts with different knowledge structure and different determine level, which AHP method could not.

However, DEA-AHP model still has drawback, most scholars use the DEA method directly to get the judgment matrix of every two comparison [14]. There are only two decision-making units are considered in the efficiency comparison, which is contrary to the formula of Charnes's experience [15]:

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$$n \geq \{ms, 2(m+s)\} \quad (1)$$

Here, n is the number of decision-making units. m, s are respectively the numbers of inputs and outputs.

Some other scholars calculate the efficiency values of each DMU and the weights of each input and output indicator with single input index and single output index [16]. However, using with basic CCR DEA model leading to that the effective units could not be reasonably distinguished.

Based on the above analysis, this paper proposed a Super-efficiency DEA-AHP method. This method has abandoned the disadvantage of the former ones and has improved accuracy of efficiency assessment.

2. Super-Efficiency DEA-AHP Evaluation Model

In the traditional DEA model, all efficient DMUs are considered equally “good” and it cannot distinguish between the pros and cons. It is necessary to somehow incorporate other method into the analysis if the efficient units are needed to sort. Anersen [17] put forward to the so-called Super-efficient DEA model which can solve the issue.

The basic principle of super-efficiency DEA is the same with that of traditional DEA. Their difference lies as follows: when the efficiency of DMU0 is evaluated, the restriction of less than or equal to 1, which is the proportion between output and input of DMU0, shall be removed. In other words, DMU0 is excluded, while the traditional DEA model is included. Therefore, an effective DMU may lead to an increase in output and input ration, which is an extra-efficiency value and may be greater than 1.

But utilizing the super-efficiency DEA alone does not reflect the importance of the differences among the various properties. This article will be on the basis of the super-efficiency model with referencing to XU Guangye’s interactive DEA-AHP one[16], propose the super-efficiency DEA-AHP model. Concrete steps are as follows:

Step 1.

Consider n decision making units (DMU_j) with m inputs and s outputs, the input and output vectors of DMU_j ($j = 1, 2 \ldots, n$) are: $X_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T \geq 0$, $Y_j = (y_{1j}, y_{2j}, \ldots, y_{sj})^T \geq 0$.

Firstly, considering only one input indicator and excluding other ones, utilize Super-efficient CCR model to calculate the decision-making units’ relative efficiency θ_{kj}, where $k \in \{1, 2 \ldots, m\}$, $j = (1, 2, \ldots, n)$.

Based on the above assumptions, referencing to Charnes, Cooper's input-oriented CCR model [18], this paper puts forward the new input-oriented Super-efficiency model $D_{C^2R}^{I_k}$ (consider only one input index x_{kj}; When the DMU0 is evaluated, the DMU0’s restriction is removed.):

$$\begin{cases} \min \theta \\ \sum_{\substack{j=1 \\ j \neq 0}}^{n} x_{kj} \lambda_j \leq \theta x_{k0} \\ \sum_{\substack{j=1 \\ j \neq 0}}^{n} Y_j \lambda_j \geq Y_0 \\ \lambda_j \geq 0,\ j = 1, 2, \cdots, n, k \in \{1, 2 \ldots, m\} \end{cases} \quad (2)$$

Under the condition of only one input indicator x_{kj}, the efficiency ratio of the DMU p and the DMU q can be arrived by formula: $a_{pq}^{k} = q_k^p / q_k^q$, the pairs comparison judgment matrix can be drawn:

$$A^k = \begin{bmatrix} 1 & a_{12}^k & \cdots & a_{1n}^k \\ a_{21}^k & 1 & \cdots & a_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^k & a_{n2}^k & \cdots & 1 \end{bmatrix} \quad (3)$$

The efficiency ratio of the decision-making units, under the condition of input indicator x_{kj}, can be derived by AHP algorithm:

$$v_i = [v_{i1},\ v_{i2},\ \ldots,\ v_{im}] \quad (4)$$

Step2.

Considering only one output indicator and excluding other ones, utilize Super-efficient CCR model to calculate the decision-making units' relative efficiency Z_{tj}, where $t \in \{1, 2\ldots,\ s\}$, $j = (1, 2, \ldots,\ n)$.

Based on the above assumptions, referencing to Charnes, Cooper's output-oriented CCR model, this paper puts forward the new output-oriented Super-efficiency model $D_{C^2R}^{O_t}$ (consider only one output index y_{tj}; When the efficiency of DMU0 is evaluated, the restriction of DMU0 is removed.):

$$\begin{cases} \max Z \\ \sum_{\substack{j=1 \\ j\neq 0}}^{n} X_j \lambda_j \le X_0 \\ \sum_{\substack{j=1 \\ j\neq 0}}^{n} y_{tj} \lambda_j \ge Z y_{t0} \\ \lambda_j \ge 0, t \in \{1, 2\ldots,\ s\}, j = 1, 2, \cdots, n \end{cases} \quad (5)$$

Under the condition of only one output indicator y_{tj}, the efficiency ratio of DMU p and DMU q can be arrived by formula: $b_{pq}^{t} = 1/Z_{tp} \left(1/Z_{tq} \right)^{-1}$, the pairs comparison judgment matrix can be drawn:

$$B^t = \begin{bmatrix} 1 & b_{12}^t & \cdots & a_{1n}^t \\ b_{21}^t & 1 & \cdots & b_{2n}^t \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1}^t & b_{n2}^t & \cdots & 1 \end{bmatrix} \quad (6)$$

The efficiency ratio of the decision-making units, under the condition of output indicator y_{tj}, can be derived by AHP algorithm:

$$v_o = [v_{01},\ v_{02},\ \dots,\ v_{0s}] \tag{7}$$

Step 3.

As the efficiency ratios of the decision-making units for each input indicator have been calculated in the first step, the importance weight of each input indicator $c_{k_1k_2}$ can be arrived by formula: $c_{k_1k_2} = \frac{1}{n}\sum_{j=1}^{n}\theta_{k_1}^{j}\left(\frac{1}{n}\sum_{j=1}^{n}\theta_{k_2}^{j}\right)^{-1}$,so pairs comparison judgment matrix between every two input indicator is constructed:

$$C = \begin{bmatrix} 1 & c_{12} & \cdots & c_{1m} \\ c_{21} & 1 & \cdots & c_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ c_{m1} & c_{m2} & \cdots & 1 \end{bmatrix} \tag{8}$$

The importance weight of each input indicator can be derived by AHP algorithm:

$$W_i = [w_{1i},\ w_{2i},\ \dots,\ w_{mi}] \tag{9}$$

Step 4.

As the efficiency ratios of the decision-making units for each output indicator have been calculated in the second step, the importance weight of each output indicator $d_{t_1t_2}$ can be arrived by formula: $d_{t_1t_2} = \frac{1}{n}\sum_{j=1}^{n} 1/Z_{t_1j}\left(\frac{1}{n}\sum_{j=1}^{n} 1/Z_{t_2j}\right)^{-1}$, so pairs comparison judgment matrix between every two output indicator is constructed:

$$D = \begin{bmatrix} 1 & d_{12} & \cdots & d_{1s} \\ d_{21} & 1 & \cdots & d_{2s} \\ \vdots & \vdots & \ddots & \vdots \\ d_{s1} & d_{s2} & \cdots & 1 \end{bmatrix} \tag{10}$$

The importance weight of each output indicator can be derived by AHP algorithm:

$$W_o = [w_{1o},\ w_{2o},\ \dots,\ w_{so,}] \tag{11}$$

Step 5.

As the importance weights of each input and each output indicator have been calculated in the second and the third steps, The importance ratio between the integral inputs and the integral outputs e_{io} can be derived by the formula: $e_{io} = \frac{1}{mn}\sum_{k=1}^{m}\sum_{j=1}^{n}\theta_k^j\left(\frac{1}{sn}\sum_{t=1}^{s}\sum_{j=1}^{n}\frac{1}{Z_t^j}\right)^{-1}$. So the judgment matrix of integral inputs and the integral outputs is constructed:

$$E = \begin{bmatrix} 1 & e_{io} \\ e_{oi} & 1 \end{bmatrix} \tag{12}$$

The importance weight between integral inputs and the integral outputs can be derived by AHP algorithm:

$$W_{12} = [w_1, w_2] \tag{13}$$

Step 6.

Individual decision-making unit's efficiency ratio in every input and output indicator can be calculated through above steps:

$$v_{i0} = [v_{i1}, \ \ldots, \ v_{im}, \ v_{o1}, \ \ldots, \ v_{os,}] \tag{14}$$

The importance weights between each input and output indicator:

$$W_{io} = \left[W_i \cdot w_1, W_o \cdot w_2\right] = [w_{1i}, \ \ldots, \ w_{mi}, w_{1o}, \ \ldots, \ w_{so,}] \tag{15}$$

Integrate the efficiency ratios into the comprehensive weights of indicators, then the comprehensive rank of decision-making units can be received.

$$w = v_{io} \cdot W_{io}{}^{T} \tag{16}$$

As a result, it is possible to obtain a composite score for each decision-making unit, the pros and cons can also be judged according to the score level.

3. Model Application

3.1. Index Selection

Considering the profitability、 credit ability and the guarantee compensatory ability which can reflect the efficiency of the guarantee institutions, we selected 5 input indicators, including the Actual Magnification (AM), the ratio of intermediate and senior management persons with professional certificate (MWCR), the Capital Adequacy ratio (CAR), the Capital Scale (CS), the Debt Asset ratio (DAR). 4 output indicators including the Guarantee Business Margin (GBM), the Return on Equity (ROE), the Credit Quality ratios (CQR), the Total Assets Compensatory rate (TACR).

Here, the Capital Scale reflects the scale of total investment made by the guarantee agency while the ratio of intermediate and senior management persons with professional certificate reflects the level of administrators in the guarantee agency. The Credit Quality Ratio reflects the profitability and the management benefit of the guarantee agency while the Total Assets Compensatory rate and Actual Magnification reflect the guarantee compensatory capability of the guarantee agency. The nine indicators can reflect the actual inputs and outputs of the guarantee institutions comprehensively and reasonably, so as to the actual operational efficiency of each guarantee.

3.2. Verification with Instance

Selecting 16 guarantee institutions in Jiangsu Province as the analytical objects. The input and output data of the16 guarantee companies are shown in Table 1.

The operating efficiency of the 16 guarantees companies calculated by the traditional CCR model as shown in Table 2.

It can be found obviously that 8 guarantee companies' efficiency value is less than 1, so they are inefficient. The 8 inefficient guarantee companies can be ranked as the follow:

DMU14>DMU 11>DMU 3>DMU 15>DMU 10 > DMU 12>DMU 13>DMU 7

To calculate the remaining 8 with new model, the assessment results are shown in the Table 3.

The first column of Table 3 shows the 8 DMUs' ultimate efficiency scores, the sort is shown in the Figure 1.

Table 1. The Input-output Data of 16 Guarantee Companies in Jiangsu Province in 2011

	(I) AM	(I)M WCR	(I) CAR	(I) CS	(I) DAR	(O) GBM	(O) ROE	(O) CQR	(O) TACR
DMU1	0.0824	1	0.1691	10055	0.2645	0.6001	0.0623	0.0203	5.8751
DMU2	0.0585	0.25	0.2544	10016	0.4401	0.8875	0.0922	0.0114	5.4645
DMU3	0.0439	1	0.3254	30000	0.4678	0.7953	0.074	0.0145	3.6524
DMU4	0.0326	0.5	0.1524	10000	0.192	0.8033	0.0476	0.0293	2.2979
DMU5	0.0246	0.1	0.5052	5000	0.1527	0.6261	0.0265	0.0175	1.8752
DMU6	0.0328	0.3	0.4399	7000	0.1488	0.8696	0.0811	0.0474	2.7158
DMU7	0.0482	0.63	0.3202	9990	0.1521	0.6051	0.0548	0.035	2.7372
DMU8	0.0534	0.33	0.2381	10060	0.2637	0.306	0.0188	0.025	3.4596
DMU9	0.0528	0.1	0.2201	5000	0.0836	0.3404	0.0088	0.0173	1.0122
DMU10	0.016	0.43	1.2856	5000	0.0412	0.5517	0.0314	0.0225	1.1798
DMU11	0.058	0.35	0.2905	8000	0.2179	0.5653	0.0305	0.0297	2.66
DMU12	0.0226	0.48	0.7421	6000	0.0604	1.1102	0.0403	0.0189	1.5355
DMU13	0.0361	0.63	0.667	6200	0.182	1.2819	0.0783	0.0331	2.0436
DMU14	0.0256	0.34	0.6392	8050	0.0449	0.7338	0.021	0.0435	1.9966
DMU15	0.0326	0.8	0.5786	10000	0.0784	0.6327	0.0205	0.0171	2.6748
DMU16	0.0205	0.5	0.5163	5000	0.0537	0.3081	0.0067	0.0625	1.7058

Table 2. Efficiency of the 16 Guarantees Companies

DMU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Efficiency	1	1	0.904	1	1	1	0.812	1	1	0.87	0.909	0.862	0.822	0.932	0.901	1

Table 2. Super-efficiency DEA-AHP-based Model of Efficiency Assessment Results

	AM (0.0804)	MWCR (0.0974)	CAR (0.0977)	CS (0.0778)	DAR (0.1119)	GBM (0.1486)	ROE (0.1339)	CQR (0.1351)	TACR (0.1113)
DMU(10.1141)	0.09	0.0395	0.2514	0.1291	0.0853	0.0774	0.1376	0.0628	0.1811
DMU2(0.1397)	0.132	0.1971	0.145	0.128	0.0548	0.1569	0.2342	0.0356	0.2042
DMU4(0.1228)	0.109	0.05	0.2358	0.0757	0.0733	0.1857	0.1314	0.1532	0.0842
DMU5(0.1198)	0.1126	0.2556	0.035	0.1187	0.0718	0.1919	0.0973	0.1036	0.0986
DMU6(0.1661)	0.1977	0.1396	0.0856	0.1917	0.2251	0.1454	0.2963	0.1137	0.1111
DMU8(0.0672)	0.0828	0.0756	0.0942	0.0749	0.0441	0.0408	0.0356	0.0754	0.0913
DMU9(0.0775)	0.0285	0.1409	0.0602	0.0645	0.0714	0.0979	0.0382	0.1033	0.083
DMU16(0.1928)	0.2474	0.1018	0.0928	0.2173	0.3742	0.1041	0.0295	0.3524	0.1465

Obviously, the efficiency sort of 8 guarantee companies is:

$$DMU16 > DMU6 > DMU2 > DMU4 > DMU5 > DMU1 > DMU9 > DMU8$$

The first line of Table 3 shows relative importance weights of 9 input and output indicators. It can be seen that the maximum proportion, owned by the Guarantee Business Profit, is 0.1486, followed by the Credit Quality ratios and the Return on Equity. It can prove that the profit margin is important to the guarantee company. The minimum proportion, owned by the Capital Scale, is 0.0778, indicating that the Scale of Capital is not the main factor to affect the guarantee efficiency. Such as DMU3, its capital is 300 million, while the CCR model determined it to be invalid, because its Relative Credit Quality ratio is too low.

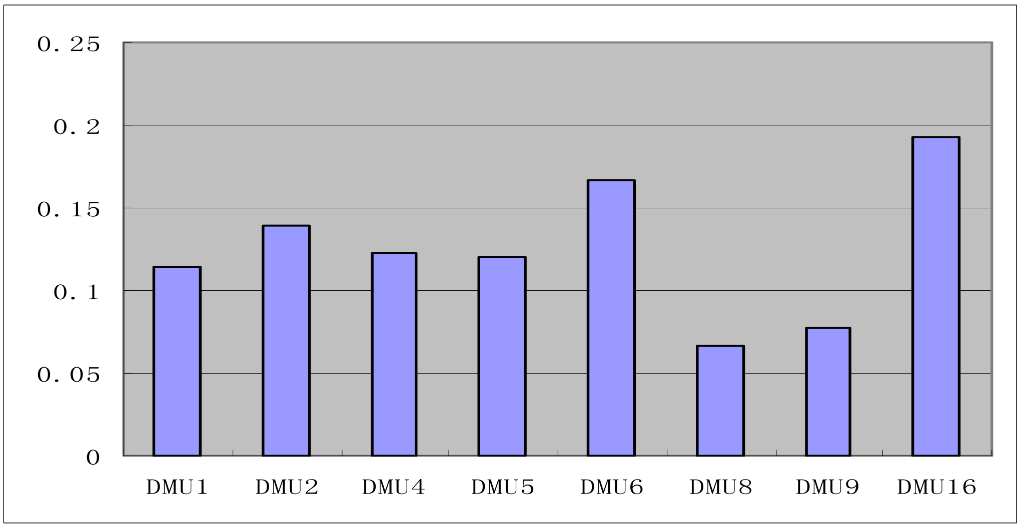

Figure 1. Efficiency Ranking of 8 Guarantee Companies (the new model)

3.3. Comparison with Other Models

In order to better illustrate the validity and accuracy of the new model, we will give a comparison with some other models. Utilizing the DEA-AHP method with Basic CCR model which is proposed by Ref. 14, the efficiency ranking of the 8 guarantee companies, mentioned in the previous section, can be received. It is shown in Figure 2.

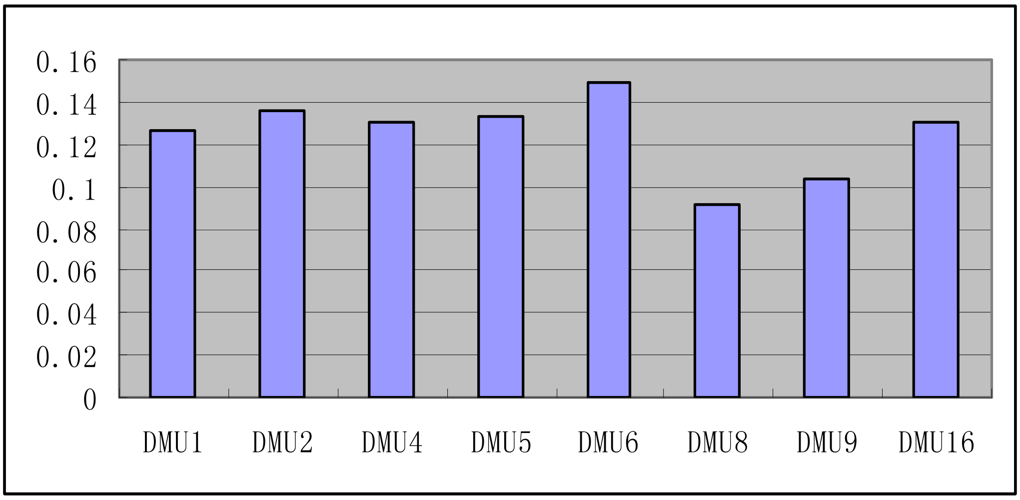

Figure 2. Efficiency Ranking of 8 Guarantee Companies [14]

First, it is clearly that the efficiency values, calculated by this model, have no obvious distinction. It cannot sort the pros and cons of each DMU accurately and reasonably. Second, by comparing with the new super-efficiency model, this model has not only reversed the DMU4 and DMU5, but also replaced the highest efficiency DMU16 into DMU6. However, the DMU16 comes in the 5th.

Using the super-efficient DEA to analysis DMU4, DMU5, DMU6 and DMU16, the result is shown at Table 3.

Table 3. The efficiencies of DMU4, DMU5, DMU6 and DMU16 calculated by super-efficient DEA

DMU	DMU6	DMU5	DMU4	DMU16
Score	2.6664119	2.1599586	2.4171798	3.6536784

Obviously, DMU16 has the highest score, followed by DMU6、DMU4、DMU5, the result is consistent with the new model, and has verified the accuracy of the new model.

4. Conclusion

Traditional DEA method can only divide decision-making units into effective and ineffective while the effective units cannot be reasonably distinguished. Utilizing the super-efficiency DEA alone cannot reflect the importance of the differences among the various properties. Simultaneously, efficiency values, calculated by former DEA-AHP method, have no obvious distinction. What's worse, it is contrary to the formula of Charnes's experience sometimes. However, the super-efficiency DEA-AHP model could not only sort the decision-making units completely, but also accurately calculate the attribute difference between inputs and outputs. It could provide decision makers with basis to judge the competitive advantages and disadvantages of each decision-making unit, which is just the true value of efficiency assessment.

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