Efficiency Analysis of China's Commercial Banks Based on DEA: Negative Output Investigation

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Abstract: This paper focuses on the shortcomings of the extensively-used method of DEA in evaluating the efficiency of bank, i.e., the DEA method cannot make further comparisons to the efficient units and it does not take into account the situation of negative input or output value. We use the BCC model in DEA to measure the fourteen Chinese commercial banks' efficiency in 1999. Since BCC model has the property of transformation invariance, the problem of negative input or output value is thus resolved. We also use the super-efficiency DEA model to rank all the efficient units completely.

Key words: commercial banks; DEA; efficiency; super-efficiency

1. Introduction

Bank efficiency reflects the comprehensive evaluation of all the input and output projects, including the operating achievements that can be inferred from various kinds of financial reporting and the operating outcome that cannot be taken into account in financial analysis. Bank efficiency is not only the manifestation of a bank's comprehensive competitive strength, but also, up to now, the most comprehensive evaluation index of achievements. Therefore, the efficiency analysis of China's commercial banks would benefit the managerial and administrative personnel a lot in that they could have a clear understanding of their status in the national and international banking industry and the gap between their own banks and other banks through the analysis so as to adopt the measures with a clear aim and what is more, improve management and administration and realize sustainable development.

The approaches to bank efficiency analysis can be divided into two categories: parameter approach and non-parameter approach. The former includes SFA, DFA and TFA while the latter includes DEA and FDH. Compared with parameter approach, the advantages of non-parameter approach with DEA as its representative lie in the following four aspects: (1) it is unnecessary to find out the concrete form of production function and is with less restrictions; (2) it is easier to deal with the situation with multiple inputs and multiple outputs; (3) the technology efficiency analysis could enable the enterprises to find out what input is not efficiently utilized so as to look for the best way to improve the efficiency, in addition to know the input efficiency of the evaluated structure in question compared to the most outstanding enterprises; (4) through the non-parameter approach, one could not

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only arrive at a conclusion about the technology efficiency, but also calculate the economic efficiency, allocation efficiency and pure technology efficiency, which makes it possible to conduct a comprehensive evaluation and should be regarded as a comprehensive assessment index of achievements. Therefore, DEA has been widely used by a large number of scholars in analyzing the efficiency of banks and their affiliated agencies (Sherman & Gold, 1985; Casu, 1999; Sathye, 2003).

However, as far as the existing researches on bank efficiency through DEA are concerned, there are still some shortcomings. To begin with, the current researches mainly focus on making use of DEA to line up the efficiency value of different banks, but they do not take a step further in arranging the order of efficient banks (whose efficiency value is 1). Secondly, DEA model requires that the input and output value should not be negative, but in real situation, negative input and negative output are quite likely to appear. For instance, when a bank is in deficit, the profit would be negative. In the light of this, it is of practical significance to make use of DEA dealing with the negative input and negative output situations, which has been neglected in current researches. As for the first shortcoming mentioned above, this paper utilizes the improved form of DEA, that is, the super-efficiency DEA model to fully line up all the sample banks. While for the second shortcoming, this paper makes use of the "constancy" nature of DMU in BCC to calculate the BCC model (The "constancy" nature of DMU means that when there is negative or zero input or output in DMU, the changed input and output value could be adopted).

2. DEA Model

In this section, we will introduce the DEA models that will be used to evaluate the efficiency of commercial banks in China.

2.1 CCR model

DEA is an effective non-parameter approach for the DMU efficiency evaluation. Since the first DEA model—CCR model was established in 1978, it has been regarded as a new approach to efficiency evaluation and has been extensively investigated and utilized.

Suppose there are n DMU_j $(j = 1, 2, ..., n)$ and the input and output value of DMU_j are as follows:

$$X_j = (x_{1j}, x_{2j}, ..., x_{mj})^T > 0,\ j = 1, 2, ..., n$$

$$Y_j = (y_{1j}, y_{2j}, ..., y_{sj})^T > 0,\ j = 1, 2, ..., n$$

While the weights vector of input and output are $v = (v_1, v_2, ..., v_m)^T$ and $u = (u_1, u_2, ..., u_s)^T$, and suppose $h_j = \frac{u^T y_j}{v^T x_j} = \frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}},\ j = 1, ..., n.$ is the efficiency evaluation index of the DMU_j.

Roughly speaking, the larger the h_{j_0} value is, the more output DMU_{j_0} would gain with relatively less input. Therefore, if we want to make sure whether DMU_{j_0} is the "excellent" one among n DMUs is, we could conduct an investigation on what the largest value of h_{j_0} is when *u* value and *v* value are in constant changes. In this way, if we want to make an evaluation on DMU_{j_0}, the so-called CCR model could be established as follows:

$$\begin{cases} Max\ h_{j_0} = \sum_{k=1}^{s} u_k y_{kj_0} \\ s.t.\ \sum_{i=1}^{m} v_i x_{ij_0} = 1 \\ \sum_{k=1}^{s} u_k y_{kj} - \sum_{i=1}^{m} v_i x_{ij} \le 1,\ j = 1,...,n \\ u_k \ge 0 \quad k = 1,...,s; v_i \ge 0 \quad i = 1,...,m \end{cases} \tag{1}$$

We can solve the linear programming (1) respectively with different j_0, then get the each DMU's efficiency value: $0 < h_j \le 1,\ j = 1,...,n.$, h_j is the relative efficiency value of the $DMU_{j.}$, which represents the distance from $DMU_{j.}$ to the production frontiers. $h_j = 1$ means the DMU is on the production frontiers, and works effectively; if $h_j < 1$, the DMU works ineffectively.

However, one defect of the CCR model lies in its incapability in further evaluation of all the efficient units. Andersen and Petersen (1993) later put forward super-efficiency evaluation model, which makes it possible to fully line up all the efficient units. The super-efficiency DEA model is different from ordinary DEA model in which their collections of evaluated units for reference are not the same. In evaluating a certain decision unit, the collection of evaluated units for reference of traditional DEA－CCR model is, as a matter of fact, the linear combination of all the evaluated units. If we eliminate the evaluated unit itself from the collection for reference, that is, make a comparison between the evaluated unit and the linear combination of all the other evaluated units, and we could get the improved DEA model—the super-efficiency DEA model. For schema (1),

$$\begin{cases} Max\ h_{j_0} = \sum_{k=1}^{s} u_k y_{kj_0} \\ s.t.\ \sum_{i=1}^{m} v_i x_{ij_0} = 1 \\ \qquad \sum_{k=1}^{s} u_k y_{kj} - \sum_{i=1}^{m} v_i x_{ij} \le 1, \\ \qquad j = 1,...,n. j \ne j_0 \\ \qquad u_k \ge 0 \quad k = 1,...,s \\ \qquad v_i \ge 0 \quad i = 1,...,m \end{cases} \tag{2}$$

In evaluating the j_0 evaluation target, it is possible that the effective targets might increase their input proportionately while their efficient nature remains unchanged. The super-efficiency DEA model considers the largest proportionate value of a certain effective evaluation target to be its new efficiency value in the situation that in spite of the increasing input, the evaluation itself still remains relatively efficient. It is obvious that as far as an efficient evaluation target in the ordinary DEA model is concerned, its new efficiency value remains unchanged in super-efficiency DEA model. As for the efficient evaluation targets in ordinary DEA model, their new efficiency value in super-efficiency DEA model might exceed 1. Therefore, the super-efficiency DEA model would be able to make further evaluation and arrangement for the effective evaluation targets.

2.2 BCC model

The above-mentioned CCR model bases on the weight that possible production set satisfy is convex, while sometimes the convexity cannot be satisfied, and BCC model was proposed. Suppose there are n DMUs: $(x_j, y_j), x_j \in R_m^+, y_j \in R_s^+, j = 1,...,n$, then the envelopment form of BCC model can be written as:

$$(D)\begin{cases} Min\theta = V_D \\ s.t.\ \sum_{j=1}^{n} \lambda_j x_j \le \theta x_0 \\ \quad \sum_{j=1}^{n} \lambda_j y_j \ge y_0 \\ \quad \sum_{j=1}^{n} \lambda_j = 1 \\ \quad \lambda_j \ge 0, j = 1,...,n. \end{cases} \tag{3}$$

And the Duality of (D) is:

$$(P)\begin{cases} Max(\mu^T y_0 + \mu_0) = V_P \\ s.t.\ \omega^T x_j - \mu^T y_0 - \mu_0 \ge 0, j = 1,...,n \\ \quad \omega^T x_0 = 1 \\ \quad \omega \ge 0, \mu \ge 0 \end{cases} \tag{4}$$

Where $\omega \in R_m, \mu \in R_s$.

Definition 1: If ω^*, μ^*, μ_0^*, the optimization of the linear programming (P), satisfies the equation $V_P^* = \mu^{*T} y_0 + \mu_0^* = 1$, we consider DMU_{j_0} is weak DEA-Efficient (BCC).

Definition 2: If the linear programming (P) not only satisfies the equation $V_P^* = 1$, but also has the restriction $\omega^* > 0, \mu^* > 0,$ we consider DMU_{j_0} is DEA-Efficient (BCC).

In BCC model, we have the following theorem:

Theorem: In BCC model, the division of DMU is characterized by the "constancy" nature, namely, the division of DMU and its frontier is free from the influence of input and output value variation.

This theorem gets rid of the bound that the DMU value (input/ output) should not be negative, thus expanding the application domain of DEA. Therefore, when the input or output value of DMU is zero or negative, the changed input or output value could be taken into the BCC model.

3. Results and Discussions

This paper, by making use of the crossed-evaluation approach, makes a comprehensive evaluation of the efficiency of China's four state-owned commercial banks and ten joint-stock commercial banks in 1999.

3.1 Selections of research samples

The selected samples are 14 commercial banks in 1999, including ten joint-stock commercial banks. The total capital of the 14 commercial banks accounts for more than 90% of that of all China's commercial banks and therefore, their efficiency could amply reflect the overall efficiency of China's commercial banks. The statistics originate from the "Financial Yearbook of China" and the annual reports of various banks in 1999.

3.2 Selection and analysis of input and output index

This paper selects the following input and output index according to foreign specifications on bank input and output and the characteristics of China's commercial banks.

Input: The selection of input index begins with the cost of commercial banks, which, for the most part, includes managerial expenditure, labor cost, and invested capital and so on. Firstly, labor cost is the invested capital for bank operation and therefore, the average number of workers at a particular period of time is selected as the first input index (X_1). Secondly, bank capital is motive force for banks to create profits, so the net amount of fixed capital is selected as the second input index (X_2). Last but not the least, the various kinds of costs at a particular period of time (the total amount of costs in the loss-and-gain table, including the cost of interests) are selected as the third input index (X_3).

Output: Banks in China do not impose any charge on depositing businesses. This kind of intermediate behavior would exert positive external effects on our society, so it is reasonable to regard deposit as part of the output of commercial banks in China and select the total amount of deposit as the first output index (Y_1). In addition, loan is a major channel for commercial banks to gain profit and the amount of loan reflects a bank's operating scale to certain extent, so the total amount of loan is selected as the second output index (Y_2). Giving that banks, as commercial organizations, should take the largest profit as the operating target and profit, as the bank's eventual operating outcome, could be regarded as the output, the total amount of profit before paying tax is chosen as the third output index (Y_3).

In short, the selected index structure in this paper is as follows: input index—the average number of persons (X_1), the net amount of the fixed capital (X_2) and various costs (X_3); the output index—the total amount of deposit (Y_1), the total amount of loan (Y_2) and the total amount of profit before paying tax (Y_3).

3.3 Result and analysis

Table 1 Input and output value of 14 commercial banks in 1999

	Input			Output		
	X1(people)	X_2(billion)	X_3(billion)	Y_1(billion)	Y_2(billion)	Y_3(billion)
DMU1	549038	59.385	177.35	2982.4	2427.1	4.126
DMU2	539298	46.491	95.495	1588.867	1589.665	-0.355
DMU3	197534	40.003	117.4	1276.5	1249.7	4.341
DMU4	431959	66.507	97.853	1759.4	1150.9	7.366
DMU5	46453	4.75	20.645	338.5	243.5	2.785
DMU6	6664	2.674	5.728	130.996	75.875	1.139
DMU7	5334	1.481	5.015	111.19	77.8	0.677
DMU8	3345	0.822	2.931	50.798	30.143	0.512
DMU9	1733	0.506	1.213	29.06	16.82	0.361
DMU10	10707	2.108	5.786	75	55.1	0.215
DMU11	3724	1.4	1.788	37.617	26.553	0.605
DMU12	8721	2.482	6.03	132.08	91.61	1.521
DMU13	4660	1.08	1.653	32.142	23.34	0.438
DMU14	4149	2.225	3.589	80.873	54.719	1.177

Data source: *China Statistical Yearbook*, 2000.

Note: DMU1: Industrial and Commercial Bank of China; DMU2: Agricultural Bank of China; DMU 3: Bank of China; DMU4: Construction Bank of China; DMU5: Bank of Communications; DMU 6: China CITIC Bank; DMU 7: Everbright Bank of China; DMU 8: Huaxia Bank; DMU 9: China Minsheng Bank Corporation, Ltd.; DMU 10: Guangdong Development Bank; DMU11: Shenzhen Development Bank; DMU12: Merchants' Bank; DMU 13: Fijian Industrial Bank; DMU14: Pudong Development Bank.

According to Table 1 which lists out the input and output value of 14 commercial banks in 1999, the author finds out that the total amount of profit before paying tax of Agricultural Bank of China is negative or in other words, it is in deficit. In the light of the "constancy" nature of BCC model mentioned above, we add 4 to the total amount of profit before paying tax of all banks, thus making this index become positive. Based on the processed input and output value in Table 1, we come to Model 4 by making use of MATLAB as the second row in Table 2 shown. What is more, we also line up the efficiency value of all banks (the third row).

Table 2 Efficiency and ranking of 14 commercial banks in 1999

	BCC efficiency	Ranking	Super-efficiency	Ranking
DMU1	1.0000	1	Infeasibility	1
DMU2	1.0000	1	1.2139	11
DMU3	1.0000	1	1.6249	5
DMU4	1.0000	1	Infeasibility	1
DMU5	1.0000	1	3.2068	3
DMU6	1.0000	1	1.2823	9
DMU7	1.0000	1	1.4208	8
DMU8	1.0000	1	1.0704	12
DMU9	1.0000	1	2.0418	4
DMU10	0.7777	3	0.7777	14
DMU11	1.0000	1	1.2289	10
DMU12	1.0000	1	1.5823	7
DMU13	0.9673	2	0.9673	13
DMU14	1.0000	1	1.6025	6

According to Table 2, the efficiency value of most of the 14 commercial banks in question is 1, which suggests that these banks are relatively effective among the 14 banks. In other words, among the 14 commercial banks, these banks have already been the excellent ones as far as their ratios of input to output are concerned.

On the contrary, Guangdong Development Bank and Fijian Industrial Bank are irrelatively effective, that is, we could reduce their input proportionately while maintaining the output value so as to make the fund become relatively effective. The reason why the Guangdong Development Bank is ineffective is that its capital is on a large scale and its total amount of profit before paying tax is not sufficient. While the reason for Fijian Industrial Bank also lies in two aspects: one attributes to the excessive number of people and the other, its total amount of profit before paying tax is not enough, either.

Since most of the 14 banks are effective, we are unable to make a comparison between them and arrange them in order through ordinary DEA model. Therefore, we make use of the super-DEA model to fully line up the super-efficiency of each bank. The super-efficiency value is in the fourth row in Table 2 and the super-efficiency order of all banks is shown in the last row in Table 2. According to the order, the efficiency value of the ineffective

Guangdong Development Bank and Fijian Industrial Bank do not change and rank 13 and 14 respectively. While the efficiency value of all the other effective banks do change. What is more, there are situations that the super-DEA model is unable to explain in Industrial and Commercial Bank of China and Construction Bank of China according to the super-efficiency value, which suggests that the two banks both perform well and therefore, both rank the first in the list.

4. Conclusion

This paper, aiming at the shortcomings of the extensively-used DEA approach in analyzing the bank efficiency, that is, its incapability to make a further comparison between the effective banks and its negligence of the situation with negative input and output value, adopts the BCC model to conduct an evaluation of the 14 commercial banks from 1999 to 2001. By making use of its "constancy" nature, this paper succeeds in solving the problem with negative input and output value. What is more, this paper also utilizes the super-efficiency DEA model to fully line up all the effective banks. The results show that most of the banks are effective while Guangdong Development Bank and Fijian Industrial Bank are ineffective. We find there are situations that the super-DEA model is unable to explain in Industrial and Commercial Bank of China and Construction Bank of China according to the super-efficiency value, which suggests that the two banks both perform well and therefore, both rank the first in the list.

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