Measuring Efficiency of Chinese Commercial Listed Banks Based on Data Envelopment Analysis

YE Qian
School of Finance, Zhejiang University of Finance & Economics, Hangzhou, China.
docterye@yahoo.com.cn

Abstract
This paper presents CRS and VRS of DEA model that is used to measure efficiency. It uses data set on 11 Chinese commercial listed banks over the period 2004 to 2009, and estimates these banks’ Technical efficiency (TE), Pure technical efficiency (PTE) and Scale efficiency by using Data Envelopment Analysis techniques. Contrast to efficiency of the listed Banks and non-listed banks, in analyzing the Efficiency and its change characteristics of the listed Banks, Results show that efficiency of Commercial banks-listed in china increase year by year. In addition, those joint-stock commercial banks are more efficient than the large state-owned commercial banks. However, it increases faster and their gap is narrowing.

Keywords: Measuring Efficiency, Data Envelopment Analysis, the DEA Model, Chinese Commercial Listed Banks

1. Introduction

Efficiency is an important comprehensive indicator used to measure the achievement of operating behavior, resources allocation and technology exertion in financial institutions. Also, banking efficiency level has a direct impact on the effect of social resources allocation as well as the degree of financial resources utility (Battes G. and Coelli T., 1995; Berger A.N., Hancock D., and Humphrey D.B., 1997; Yano, Go and Shiraishi, Maho, 2012). With the full open of financial industry in china, the entrance of foreign banks has led to the dramatic competition in Chinese financial industry. Thus, the urgent problem domestic banking sector faces is that how to improve the efficiency and competitive power, especially those listed ones (Berger A.N. and Mester L.J., 1997; Huang Xuping and Zhang Xiekui, 2005; Ye Qian, 2007).

Generally, studies on banking efficiency throughout the world can be divided into 2 phases: before the 1990s, banking efficiency was commonly evaluated from the perspectives of economies of scale and economies of scope; afterwards, it turned to use frontier efficiency, including X-efficiency, cost efficiency and profit efficiency (Stavros Peristiani, 1997; Kun Chang and Jia Shouqiao, 2006; Yuan Jiang, Lusheng Wu, Dongming Jiang, 2011).

There are in general two methodologies in measuring commercial banks’ efficiency: financial indicators and frontier analysis (Li Xiaqin and Liu Xiangbin, 2005; Halkos, George & Tzeremes, Nickolaos, 2012). The former evaluates banks’ operating efficiency by utilizing those financial indexes such as average Return on Assets, Turnover ratio of loan and Capital adequacy ratio. Although it can be used conveniently, the result is unable to reflect the total operating performance. As a result, frontier analysis is adopted more often as evaluating the banking efficiency (Chen Xiaoang, Michael Skully and Kym Brown, 2005). The frontier analysis is clearly divided between parametric and non-parametric estimation methods. Thick Frontier Analysis (TFA), commonly used as the parametric estimation method, still has a typical drawback. It requires a functional form specification for the best efficient frontier, which may introduce errors into calculation. Therefore, this study adopts Data Envelopment Analysis (DEA) which is in the category of non-parametric techniques.
So far, no similar studies on relative efficiency of the different ownership modes in China have been done (Chen Guozhong and Liu Zhiying, 2005; Yi Huiman, 2006). This study discusses the relative efficiency between inputs and outputs for the different ownership mode of commercial banks in China.

The rest of the paper is organized as follows: Section 2 provides a summary of Data Envelopment Analysis. Section 3 covers the methodological aspects with the empirical results presented in Section 4. Finally, the conclusions are contained in Section 5.

2. Data Envelopment Analysis

Data Envelopment Analysis (DEA), being one of the non-parametric frontier analysis methods, can be used to measure production efficiency in corporations. It was originally developed by Charnes et al. (1978) and then applied into the evaluation of banking efficiency by Sherman and Gold (1985). By connecting all the best sample points, it empirically characterizes a piecewise curve combination and forms the convex production possibility set. DEA calculates and compares the relative efficiency of each unit in relation to all other units by using the actual observed values for the inputs and outputs of each DMU. At present, many researchers who use the Data Envelopment Analysis (DEA) have adopted the concept of efficiency brought up by Farrell, that is the comprehensive efficiency (cost efficiency, economic efficiency and X-efficiency), made of Allocation efficiency and technology efficiency. DEA serves as an excellent method to analyze small scale of samples for it is a non-parametric technique. Because those Chinese commercial banks haven’t been listed for a long time and lack data, the DEA methodology is much more feasible.

2.1 DEA Model

Data Envelopment Analysis (DEA) model, firstly developed by Charnes et al. (1978) is based on the concept of efficiency brought up by Farrell (1957). By assuming constant returns to scale, this model can be also called CRS or CCR model. Afterwards, Banker et al. (1984) brought up the VRS (BCC) model for the broader condition of variable returns to scale. Both CRS and VRS models, though, can not analyze the interval in which such as the increasing or decreasing marginal productivity, the inefficient DUM is, they are still able to recognize those inefficient DUMS. Thus, this study adopts Constant Returns to Scale (CRS)-DEA model and variable returns to Scale (VRS)-DEA model for the measurement of technical efficiency (TE) and pure technical efficiency (PTE) respectively.

2.1.1 Constant returns to scale model

Constant Returns to Scale model (CRS-DEA). It is assumed that there is data on m inputs (x) and s outputs (y) for each of N states (the Decision Making Units). For the jth state, its ith input and rth output data can be represented by $x_{ij}$ and $y_{rj}$ respectively; $v_i$ is the weight of ith input and $\mu_r$ is the weight of rth output.

$$x_{ij} > 0; y_{rj} > 0; \quad i = 1, 2, \cdots, m; r = 1, 2, \cdots, s; j = 1, 2, \cdots, n)$$

$$v = (v_1, v_2, \cdots, v_s); \quad \mu = (\mu_1, \mu_2, \cdots, \mu_m)$$

The efficiency evaluation index for each Decision Making Unit (DUM) can be expressed as:

$$h_j = \frac{\sum_{r=1}^{s} \mu_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}; \quad j = 1, 2, 3, \cdots$$
To select optimal weights, subjecting to $h_j \leq 1; j = 1, 2, \cdots, n$. Aiming at the efficiency of $j_0$th DUM, we make $v$ and $\mu$ as variables and all states' efficiency $h_j \leq 1; j = 1, 2, \cdots, n$ as a constraint, so the CCR model can be expressed as

$$
\text{max } \frac{\sum_{j=1}^{n} \mu_j y_{i,j}}{\sum_{i=1}^{n} v_j x_{i,j}}
$$

Subject to:

$$
\sum_{j=1}^{n} v_j x_{i,j} \leq 1, \quad j = 1, 2, 3 \ldots n
$$

$$
v = \left(v_1, v_2, \ldots, v_m\right)^T \geq 0; \quad \mu = \left(\mu_1, \mu_2, \ldots, \mu_m\right)^T \geq 0
$$

Where, $x_j = (x_{ij}, x_{2j}, \cdots, x_{mj})^T$ is a vector of input for $j$th state and $y_j = (y_{ij}, y_{2j}, \cdots, y_{mj})^T$ is a vector of its output, and $X_0 = X_{j0}, Y_0 = Y_{j0}$.

We can judge whether the $j_0$th DUM is efficient by comparing with other DUMs in the equations. However there is a difficulty in getting the answer to the equations in practice for the Objective function is nonlinear and sub-formula. Therefore, we can use the Charnes—Cooper transformation to transform the equations into an ordinary linear programming model problem:

$$
\text{max } \mu_j, Y_0
$$

Subject to:

$$
w_j^T X_j - \mu_j^T Y_j \geq 0, \quad j = 1, 2, 3, \ldots n
$$

$$
w_j^T X_0 = 1; \quad w \geq 0, \mu \geq 0
$$

So the dual programming of the equations above can be expressed as:

$$
\text{min } \theta
$$

Subject to:

$$
\sum_{j=1}^{m} \lambda_j x_j \leq \theta X_0
$$

$$
\sum_{j=1}^{m} \lambda_j y_j \leq \theta Y_0; \quad \lambda_j \geq 0, j \geq 0, j = 1, 2, 3, \ldots n
$$

The meaning of this model is: from the input–oriented perspective, we can research the inputs efficiency by finding a combination which subjects to minimizing inputs while producing at least the $j_0$th output levels. Similarly, we can also analyze the efficiency of outputs from the output–oriented perspective.

Then we introduce the slack variables $s^-$ and $s^+$:

$$
s^+ = (s_1^+, s_2^+, s_3^+, \ldots, s_m^+)^T \in E^+_m; \quad s^- = (s_1^-, s_2^-, s_3^-, \ldots, s_m^-)T \in E^-_m
$$

To change the constraint conditions into equations, and leads to linear programming:
\[
\min \theta \\
\sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_0 \\
\sum_{j=1}^{n} \lambda_j y_j - s^+ = \theta y_0; \ \lambda_j \geq 0, j \geq 0, j = 1, 2, 3, \ldots, n \\
s^- \geq 0, s^+ \geq 0
\]

Where, \( s^- \) and \( s^+ \) are slack variables and \( \lambda_j \) is the weight of \( j \)th state.

The economic meaning of this model is:

If \( \theta = 1 \) and \( s^- = s^+ = 0 \), it means state \( j_0 \) lies on the efficient frontier and it is labeled as DEA efficiency. That is, in this economic system of \( n \) states, the value of output \( y_0 \) has reached to the optimal condition based on the original input \( x_0 \);

If \( \theta = 1 \) and \( s^- \neq 0 \) or \( s^+ \neq 0 \), this unit is called weak DEA efficiency. That is, in this economic system of \( n \) states, investing \( x_0 \) can help to reduce \( s^- \) while contain the value of original output \( y_0 \), or improve \( s^+ \) without adding the original \( x_0 \);

If \( \theta < 1 \), the state \( j \) is labeled as DEA inefficiency.

### 2.1.2 Variable returns to scale model

This CRS model above implies the premise of constant returns to scale which means the output of the given state will increase by the same percentage as the input increases, vice versa. In fact, there is imperfect competition in most conditions. Thus, the premise of constant returns to Scale is hard to realize. Considering the given DUM may be in the internal of increasing returns to scale or decreasing returns to scale, we can introduce the constraint condition \( \sum_{j=1}^{n} \lambda_j = 1 \) based on the CCR model, which lead to the modified model VRS-DEA model, namely the variable returns to Scale DEA model:

\[
\begin{align*}
\min & \quad \theta \\
\text{s.t.} & \quad \sum_{j=1}^{n} \lambda_j x_j \leq \theta x_0 \\
& \quad \sum_{j=1}^{n} \lambda_j y_j \geq y_0 \\
& \quad \sum_{j=1}^{n} \lambda_j = 1; \quad \lambda_j \geq 0, j = 1, 2, 3, \ldots, n
\end{align*}
\]

The optimal value of this model is called pure technology efficiency and it excludes the impacts of a DUM for its own scale change. The scale efficiency of this given DUM can be obtained from technical efficiency dividing pure technical efficiency. So the formula is: Scale Efficiency (SE) = Technical Efficiency (TE)/Pure Technical Efficiency (PTE). Thus we can use this relationship to measure DEA scale efficiency of those DMUs (listed banks).
2.2 Input and output indicators selection

When evaluating the banking efficiency, the first thing is to select the proper input and output indicators. Unlike some companies which produce concrete and tangible productions, banks are widely known as monetary intermediaries. Its operating process can be expressed as cash inflow and outflow, while it is difficult to define the inputs and outputs. It is accepted by academic circle around the world that there are three ways of choosing the input and output indicators. They are production, intermediary and capital methods: (1) production method. Bank is regarded as the producer of deposit and loan accounts. The output items are those which can make profit, such as the number of all types of deposit accounts, volume of loan business provided; if the net disbursement is needed in one item, it is the input item, such as capital labor as well as operation cost; (2) intermediary method. Bank will be regarded as the monetary intermediary between depositors and investors. In this way, this deposit and loan balances are classified as the output items, and the operating cost and interest cost, on the other hand, go into the category of input items; (3) capital method. Bank is still regarded as the monetary intermediary in this method. However, only the capital items in the balance sheet are regarded as output items, and the deposit item of liability is excluded.

Due to the specific characteristics of banking sector, each of the three methods above has flaws. According to the DEA researches on the banking efficiency throughout the world, some references are constantly discussing how to improve the way to select effective inputs and outputs indicators. Recently, BiGongbin and Lianliang (2009) brought up the new method depending on the theory of cash-added to select the proper indicators when evaluating the banking DEA efficiency. This method can tell the item, being input or output item by whether all the items in the balance sheet create or destroy value. The specific steps are:

Step 1: By taking the cash flow of commercial banks as dependent variable and other items on the balance sheet as independent variables, we can do the statistic regression analysis to find out those factors which can influence the cash flow and market value of commercial banks.

Step 2: Make the statistical test. First, by using T test, we can illustrate the factors influencing cash flow; then we can demonstrate there is no auto correlation among these cash flow factors through the D-W test.

Step 3: Determine input and output indicators, do the collinear analysis according to the indicators above and confirm the final input and output indicators.

This study integrates the way of indicators selection in this reference and chooses asset, salary, welfare as input indicators while deposit, loan, inter-bank lending/borrowing as output indicators

3. Measuring Result of DEA

To take 11 listed banks in China as the research sample, including 4 state-owned banks and 7 nationwide shareholding banks, we gather and organize the 66 groups of financial data in all of these banks from 2004 to 2009. Most of the information is referred to annual report, Finance Yearbook of China, CBRC and Securities Times.

Since the inputs element is unattainable, we got TE, PTE and SE, except AE of these listed banks from 2004 to 2009 using DEPA version2.1 software and the results are shown.
Table 1. Ranking of relative indicators among 11 listed commercial banks

<table>
<thead>
<tr>
<th>Listed banks</th>
<th>Technical Efficiency</th>
<th>Profit per person</th>
<th>Asset managed per person</th>
<th>Rank of cost in managing every 1 billion asset</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICBC</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>CCB</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>BOC</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>BOCOM</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>CITIC</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>HuaXia Bank</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>CMBC</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>SPDB</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>SDB</td>
<td>9</td>
<td>9</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>IB</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>CMB</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

The comparisons form measuring result of DEA show that the ranking of TE of inputs outputs measure index which filtered by cash accretion value method has consistency with the rankings of average profits, average managing assets and management expense of every million RMB. Specifically, the banks with higher TE value also rank ahead in other three indexes, like Hua Xia Bank, Shanghai Pudong Development Bank, CMBC and CCB and vice versa, such as ICBC, BOC and CBC. These indexes all reflect operation behavior effect, resource utilization and technology level of banks, showing the efficiency value adopted by the cash accretion value method precisely reflect the resource utilization ability of listed banks. Ranking of relative indicators among 11 listed commercial banks are shown in table 1.

4. Results

To do the horizontal and vertical analysis on the different efficiencies among 11 listed commercial banks.

4.1 Vertical comparative analysis on listed banks efficiency

Generally, China’s listed banks show high efficiency level. Between 2004 and 2009, distribution extent of TE value is [0.766, 1.000] with an annual figure higher than 0.89 while of PTE value is [0.896, 1.000] with an annual figure higher than 0.9. Both TE and PTE values present a tendency of going-up. The difference of TE value narrowed from 0.211 to 0.055 and of PTE value narrowed from 0.092 to 0.002 from 2004-2009. With the development of listed banks, most banks have achieved remarkable success at reinforcing cost control, decreasing recourse waste and raising ability of resource collocation.
Figure 1. The trend of average efficiency of listed banks from 2004 to 2009

Figure 1 shows increase of TE value by a large margin during 2004-2006, suggesting that the joint-stock revolution takes initial effect and the TE of state-owned banks will absolutely affect the whole efficiency of commercial banks. Listed banks performed better these years since PTE was going up all along while SE descended firstly then ascended which shows scale expansion style of China’s listed banks reformed from extensive to intensive, uneconomically to economically. At the same time, it, to some extent, promotes the improvement of TE.

Figure 2. TE differences between two types of listed banks from 2004-2009

TE of state-owned commercial banks increased largely from 2004 to 2007, suggesting the re-organization took its effect and the consummation of bank management is the key to whether TE is able to promote continually in the future. On the other hand, PTE of state-owned commercial banks descended firstly then ascended and grew slower than shareholding commercial banks’ due to oversize issue even though state-owned banks possess absolute advantages in whatever total asset scale or deposits and loans scale. Joint-stocks banks have realized the fact that they can only develop by raising operation efficiency, bringing creativity and nurturing comparison competition superiority instead of competing with state-owned banks on traditional services. We can see from Figure 3 that both TE and PTE move up during these years and take the lead in other indexes within banks in China.
4.2 Horizontal comparative analysis on listed banks efficiency

From the TE average value of state-owned listed banks we can see that TE is going up with polarization. During 2004-2009, TE of state-owned commercial banks moved up year after year of which CCB’s and BOC’s were clearly higher than ICBC’s and BC’s. CCB and ICBC led the head in the ranking of TE, ranked as the fourth and fifth, while CCB and BOC were the bottom two suggesting the difference in cost control ability. However, the increment speed of BOC and BC was faster than that of ICBC and CCB which shows the gap was narrowed down with better overall resource collocation and utilization abilities.

Through analyzing the levels of shareholding commercial banks efficiency, 7 listed national shareholding commercial banks have higher TE than average level, and their mean value is higher than state-owned commercial banks. From the form 1, we can observe the mean values of annual TE are all higher than 0.9 in these 6 years. Hua Xia Bank has the highest average TE value, which is followed by Shanghai Pudong Development Bank and CMB, and the last is SDB. It reveals that although those shareholding commercial banks have outstanding ability in cost controlling, there are still gaps among different banks in operating management as well as efficiency.
By comparing the efficiency between these two types of banks, all the indicators in shareholding commercial banks are better than those of state-owned banks. Also the mean values of three efficiencies in the 6 years from 2004 to 2009 show TE and SE of shareholding commercial banks are 0.056 and 0.048 higher respectively than the values of stated-owned banks whose PTE, however, shows 0.008 lower than that of shareholding commercial banks, suggesting the fact that although there is no obvious difference in inner management efficiency between two kinds of banks, it can be credited to the scale efficiency, which is an advantage to the shareholding commercial banks. As a result, the overall TE is higher. Apart from that, the SE of listed banks declined before showing an upward trend in 2004, which demonstrates all of them have been improving the operating management capacity, helping them adapt to its own operating scale. The operating pattern, aiming at enlarging quantities, described as being extensive, has been changed.

5. Conclusion

Based on the relative theory of commercial banks efficiency, this study uses the Data Envelopment Analysis (DEA), chooses those representative indicators of listed banks, measures efficiency of 11 domestic listed banks, analyses horizontally among them and gets the conclusions as follows:

(1) With the advancement of structural reform in Chinese banking sector, the efficiency of commercial banks gradually increased year by year; some banks’ efficiency inclined remarkably after being listed.

(2) Among the listed commercial banks, average efficiency of the state-owned commercial banks is lower than that of shareholding commercial banks whose speed of efficiency growth, however, is slower than that of state-owned commercial banks. Thus, with the constant improvement of
Shareholding system reform in state-owned commercial banks, the gap between these two will be narrowing.

(3) There is obvious gap among state-owned commercial banks. The efficiency of CCB and ICBC is higher than BCM’s and BOC’s. Also the efficiency difference can be found in shareholding commercial bank. SDB, CMBC and CMB all have high banking efficiency whereas Industrial Bank is not as good as them.

6. References