Performance Evaluation in Bank branch with Two Stage DEA Model

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Abstract

Data Envelopment Analysis (DEA) has been applied in many efficiency studies in the banking sector. Conventional DEA models consider the system as a single-process black box. There are however a number of so-called network DEA approach that consider the system as composed by distinct processes or stages, each one with its own inputs and outputs and with intermediate flows among the stages. In this paper some of these approaches that have been applied to banking sector are reviewed and in particular applications of two-stage DEA to Iranian banking branches are presented and discussed. The conclusions of this research is that two-stage DEA models have a greater discriminate power than conventional, single-process DEA and since they allow a more fine-grained analysis their results are generally more valid and useful. The main drawback are the need for more detailed data (i.e. at the process level) and the greater complexity of the resulting models, especially if there are inputs or outputs that are shared among the processes.

Keyword:
Data envelopment analysis, two-stage network model, bank performance, efficiency.
1. Introduction

The improvement of performance for the banks in public or private sectors is an important way for any country’s progress. Measuring and evaluating the operating efficiency of bank branches require analytic techniques that provide insights beyond those available from accounting ratio analysis. Banks have aggressively sought to improve their performance by improving cash management and marketing new services that attract additional funds.

Evaluating the economic performance of banks, however, is a complicated process. Often a number of criteria such as profits, liquidity, asset quality, attitude toward risk, and management strategies must be considered. The changing nature of the banking industry has made such evaluations even more difficult, increasing the need for more flexible alternative forms of financial analysis.

Therefore, evaluating the efficiency requires employing different approaches for determining the efficiency frontier; and there are many researches in this field. Two competing methods for constructing frontiers are parametric and non-parametric methods.

Data Envelopment Analysis (DEA) is a non-parametric mathematical tool for assessing the relative efficiency of homogeneous Decision Making Units (DMU). DEA has been applied in many sectors (education, health care, finance, transportation, etc). In particular, there are many applications of DEA in banking sector.

Most of these DEA studies in Iranian bank sectors consider the units under assessment as a single process and assume that this aggregate process consumes all the different inputs and produces all the different outputs (some of them perhaps undesirable). No modeling of the inner structure of the system is performed. No sub-process or stages are considered and intermediate products produced and consumed within the system are recognized. This black box approach is the most common one in DEA.

This paper describes a particular methodology called Two-stage Data Envelopment Analysis (DEA), that has been used previously to analyze the relative efficiencies of industrial firms, universities, hospitals, military operations, baseball players and, more recently, commercial banks.

Data envelopment analysis (DEA) is an approach for measuring the relative efficiency of peer decision making units (DMUs) that have multiple inputs and outputs. As discussed in many DEA studies, DMUs can have a two-stage structure where the first stage uses inputs to generate outputs that then become the inputs to the second stage. The second stage thus utilizes these first-stage outputs to produce its own outputs. We call the first stage outputs intermediate measures. For example, banks use labor and assets to generate deposits which in turn used to generate loan income (Chen and Zhu, 2004). Kao and Hwang (2008) consider a set of Taiwanese non-life insurance companies with a two-stage process of premium acquisition and profit generation. A closer examination of Kao and Hwang (2008)’s approach reveals that (i) their overall efficiency is defined as the product of efficiencies of the two stages, (ii) their models assume constant returns to scale (CRS), and (iii) their models assume that the weights (or multipliers) on the intermediate measures are the same for the two stages.

In this paper, in section 2, literature review in banking sector is reviewed. In section 3, proposal model are presented and in section 4 the empirical study of these approaches are provided. Finally, in section 5, conclusions are drawn and further research outlined.

2. Literature review

Major local Iranian banks continue to pursue all the opportunities available to enhance their competitiveness. Consequently, performance analysis in the banking industry has become part of their management practices. Top bank management wants to identify and eliminate the underlying causes of inefficiencies, thus helping their firms to gain competitive advantage, or, at least, meet the challenges from other banks. Therefore, it is critical to determine how to measure organizational performance in a multi-dimensional structure. In comparison with techniques of assessing organization performance, the method of data envelopment analysis (DEA) proposed by Charnes et al. (1978) is a better way to organize and analyze data since it allows efficiency to change over time and requires no prior assumption on the specification of the efficient frontier. Thus, DEA is an excellent approach for the performance analysis in banking industry in literature.

Data envelopment analysis (DEA) is a non-parametric, linear programming technique to identify best practices of peer decision making units (DMUs) that use multiple inputs to generate multiple outputs. The
efficiency score of any DMU is determined by comparison with the DMU located on the efficient frontier as a benchmark.

DEA has been applied in many sectors such as education (Thanassoulis and Dunstan, 1994), forest management (Kao et al., 1993), insurance (Mahajan, 1991), library management (Hammond, 2002), life insurance companies (Cummins et al., 1999), transportation companies (Kerstens, 1996), mutual funds (Basso and Funari, 2001), nursing (Nunamaker, 1983), airlines (Schefczyk, 1993), telecommunications (Uri, 2001), hospitals (Chilingerian and Sherman, 1990), transportation companies (Kerstens, 1996), hotels (Barros, 2005) etc. There are also many studies have used DEA to examine the performance of the banking industry. Drake and Howcroft (2002) assessed the relative efficiency of UK clearing bank branches using DEA method. This paper utilized the basic efficiency indices and extended the analysis by examining the relationship between size and efficiency. Aly, Grabowski, Pasurka, and Rangan (1990) evaluated the technical efficiency, scale efficiency, and allocative efficiency of 322 independent USA banks in 1986. Results indicated that 35% of cost inefficiency was attributed to technical inefficiency, that is, input waste or use insufficiency was greater than input combination incorrectness and technical inefficiency was due to pure technical efficiency slump but not scale inefficiency; a bank’s scale in terms of total deposit or number of branches had a positive impact on pure technical efficiency, Yildirim (2002) evaluated the efficiency of Turkish commercial banks between 1988 and 1999 using DEA method. Results suggest that over the sample period both pure technical and scale efficiency measures showed a great variation and the sector did not achieve sustained efficiency gains. Using a bootstrapping DEA technique, Elyasiani and Mehdian (1995) used the DEA to compare the technical efficiency between big and small banks. It is found that in the efficiency analysis using single production frontier, small and large banks had very similar efficiency in 1979, while in 1986, the efficiency of large banks was higher than that of small banks and efficiency variation reached the significant level of 1%; in the efficiency analysis building individual production frontier with scale cluster, the efficiency variation of small banks from 1979 to 1986 was greater than that of larger scale banks, and after releasing control, the efficiency of both large and small banks tended to slip but small banks slipped in greater magnitude, Lin (2002) studied 43 commercial banks in Taiwan, analyzed the cost efficiency between merged banks and non-merged banks. The result indicated that the operating inefficiency of each bank after acquisition was lower than that of each bank without acquisition except in 1999.Yang, and Liang (2006) integrated DEA and neural networks (NNs) to examine the relative branch efficiency of a large Canadian bank. Findings suggest that the predicted efficiency using the DEA–NN model has good correlation with that calculated by DEA, which indicates that the predicted efficiency using the DEA–NN approach is a god proxy to classical DEA approach.

In many real world scenarios, DMUs have a two-stage network process and due to this reason, DEA has been extended to examine the efficiency of two-stage processes, where all the outputs from the first stage are intermediate measures that make up the inputs to the second stage. Wang et al. (1997) present a two-stage process in the banking industry where the banks use inputs (to the first stage) of fixed assets, labor and information technology (IT) investments to generate deposits. The banks then use the deposits (intermediate measure) to generate loans and profits (as the outputs). Seiford and Zhu (1999) examined the performance of the top 55 US banks using a two-stage DEA approach. Results indicated that relatively large banks exhibit better performance on profitability, whereas smaller banks tend to perform better with respect to marketability. Kao and Hwang (2008) develop a different approach where the entire two-stage process can be decomposed into the product of the efficiencies of the two sub-processes. As a result, both the overall efficiency and each stage’s efficiency are obtained. Sexton and Lewis (2003) propose a two-stage process for evaluating Major League Baseball performance. Chilingerian and Sherman (2004) describe another two stage process in measuring physician care. Bhattacharya, Lovell, and Sahay (1997) used a two-stage DEA approach to examine the impact of liberalization on the efficiency of the Indian banking industry. In the first stage a technical efficiency score was calculated, whereas in the second stage a stochastic frontier analysis was used to attribute variation in efficiency scores to three sources: temporal, ownership and noise component.

One of the drawbacks of traditional DEA models is the ignorance of intermediate measures or linking activities. To resolve this drawback, we apply relational network DEA proposed by Kao (2009) to construct a performance evaluation model for the Iranian bank. The proposed model provides not only an overall efficiency score of entire process but evaluates the individual stages.
3. Proposal model

The performance of banks is aggregated from the efforts of different stages, but also relies on the bank as a whole. For example, the bank performance depends on the combination of marketability and profitability. Evaluating the efficiency of multiple inputs and outputs using a single process, as is the case in most DEA papers on bank performance evaluation, will be problematic because this single process evaluation ignores the efficiency of internal structure within the bank. Furthermore, the results cannot explain the relationships between the efficiency of each stage and the efficiency of the organization as a whole.

To resolve the drawback mentioned above, we apply the two-stage network DEA model by Kao (2009) to construct a performance evaluation model, which aims to evaluate the bank based on efficiency of different stages.

The bank can be viewed as an entity in which two inter-related operations are performed shown in Fig. 1. At the first stage, funds are collected from the customers in the form of deposits by consuming the bank resources such as fixed assets, number of employees, and IT budget. At the second stage, banks use the value of exchange deposits for investing other activities and loan benefits to get more profit (Wu et al., 2006, 2007; Wang et al., 1997).

This study aims to evaluate the efficiency of "marketability" and "profitability" stages and overall organization, and furthermore, to discover the relative contributions of efficiency of each stages to the overall performance of the bank.

In the phase of "marketability", the model aims to measure the ability of bank to transform fixed assets, employee and IT budget into deposits. Therefore, this research uses fixed assets ($x_1$), No. of employees ($x_2$), and IT budget ($x_3$) as inputs, and uses deposits ($z_1$) as intermediate output to measure the marketability of the bank.

In the phase of "profitability", we measure the ability to transform deposits into profit and loans for the bank. We use the intermediate output from the "marketability" as input and the profit ($y_1$) and fraction of loan recovered ($y_2$) as outputs to measure the "profitability" of bank. Finally, "bank performance" represents the overall performance of the bank.

The proposed network performance evaluation model for banks is described by the following linear program:

\[ \text{Max} \sum_{j=1}^{n} u_j y_j \]

Subject to

\[ \sum_{j=1}^{n} v_j x_j = 1 \]  

\[ \sum_{j=1}^{n} w_j z_j = y_j \]  

\[ \sum_{j=1}^{n} u_j y_j - \sum_{j=1}^{n} v_j x_j \leq 0 \]  

\[ \sum_{j=1}^{n} w_j z_j - \sum_{j=1}^{n} u_j y_j \leq 0 \]  

Fig 1. Two-stage network performance evaluation model for bank
Note that Eq. (1.2) is redundant in Kao and Hwang's (2008) model, since Eq. (1.3) and (1.4) imply Eq. (1.2). Model (1) provides the overall efficiency of the "marketability" and "profitability" stages.

The dual format of above model can be formulated as follows:

\[ E_0^{\text{centralized}} = \min \theta \]

Subject to

\[ \begin{align*}
\sum_{n} \lambda_n x_n &\leq \theta x_{01} & t = 1, \ldots, m \\
\sum_{n} (\lambda_n - \mu_n) x_{nj} &\geq 0 & d = 1, \ldots, D \\
\sum_{n} \mu_n y_{nj} &\geq y_{1j0} & r = 1, \ldots, F \\
\lambda_n, \mu_n &\geq 0 & j = 1, \ldots, n
\end{align*} \]
So, according to above model (3), the minimum of $E_0^{(2)}$ is yielded as follow:

$$E_0^{(2)} = \frac{E_{centrized}}{E_0^{(2)+}}$$

(3.6)

And the maximum value of $E_0^{(2)+}$ can be determined by the following linear program:

$$E_0^{(2)+} = \text{Max } \sum_{i=1}^{n} u_i y_{i0}$$

Subject to

$$\sum_{a=1}^{m} w_a x_{a0} = 1$$

(4.1)

$$\sum_{i=1}^{n} u_i y_{i0} - \sum_{a=1}^{m} w_a x_{a0} = 0$$

(4.2)

$$\sum_{i=1}^{n} u_i y_{i0} - \sum_{a=1}^{m} w_a x_{a0} \leq 0$$

(4.3)

$$\sum_{i=1}^{n} u_i y_{i0} - \sum_{a=1}^{m} w_a x_{a0} \leq 0$$

(4.4)

$u_i \geq 0, i = 1, ..., n; x_{a0} \geq 0, a \in 1, ..., m; w_a \geq 0, d = 1, ..., D$

(4.5)

The minimum of $E_0^{(1)}$ is also calculated as follow:

$$E_0^{(1)} = \frac{E_{centrized}}{E_0^{(1)+}}$$

(4.6)

Note that $E_0^{(1)} = E_0^{(1)+}$ if and only if $E_0^{(2)} = E_0^{(2)+}$. Note also if $E_0^{(1)} = E_0^{(1)+}$ or $E_0^{(2)} = E_0^{(2)+}$, then $E_0^{(1)+}$ and $E_0^{(2)+}$ are uniquely determined by model (1). If $E_0^{(1)} = E_0^{(1)+}$ or $E_0^{(2)} = E_0^{(2)+}$, (Liang et.al 2008) develop a procedure to gain an alternative decomposition of $E_0^{(1)+}$ and $E_0^{(2)+}$.

The aim of performance decomposition is to understand the relative contribution of "marketability" and "profitability" to overall bank performance. According to the decomposition results, bank managers could improve the component with a weaker contribution to enhance the overall performance of the bank. When compared with the conventional DEA model, we find that the two-stage network DEA model is more stringent. The evaluation results of two-stage network DEA model could provide managerial insights for increasing efficiency.

4. Empirical study

Based on the proposal model which described above, we apply the two-stage network DEA model to evaluate the performance of Iranian bank in 2010. In this study, Iranian bank is comprised of 17 branches.
divided into "marketability" and "profitability" stages. At the first stage, this research uses fixed assets ($x_1$), No. of employees ($x_2$), and IT budget ($x_3$) as inputs, and uses deposits ($z_1$) as intermediate output to measure the marketability of the bank, and at the second stage, we use the intermediate output from the "marketability" as input and the profit ($y_1$) and fraction of loan recovered ($y_2$) as outputs to measure the "profitability" of bank.

The overall efficiency score is calculated based on model (1), and the maximum achievable value of first stage and the minimum value of second stage are determined by model (3)(see Table 1). From the calculation of performance decomposition using model (3), we obtained the optimal multipliers and the relative contribution of each stage to the overall performance of the bank. Decomposition results are shown in Table 1.

Table 1. Performance measures of 17 Iranian banks.

<table>
<thead>
<tr>
<th>DMU</th>
<th>Network efficiency</th>
<th>Stage efficiency</th>
<th>Profitability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bank performance ($E_{centralized}$)</td>
<td>Marketability ($E_{1}$)</td>
<td>Profitability ($E_{2}$)</td>
</tr>
<tr>
<td>DMU 1</td>
<td>0.9437391</td>
<td>0.9437391</td>
<td>1.000000</td>
</tr>
<tr>
<td>DMU 2</td>
<td>0.6524879</td>
<td>0.6524879</td>
<td>1.000000</td>
</tr>
<tr>
<td>DMU 3</td>
<td>0.8227826</td>
<td>1.000000</td>
<td>0.8227826</td>
</tr>
<tr>
<td>DMU 4</td>
<td>0.3756259</td>
<td>0.4788037</td>
<td>0.7845092</td>
</tr>
<tr>
<td>DMU 5</td>
<td>0.4143179</td>
<td>1.000000</td>
<td>0.4143179</td>
</tr>
<tr>
<td>DMU 6</td>
<td>0.8919605</td>
<td>1.000000</td>
<td>0.8919605</td>
</tr>
<tr>
<td>DMU 7</td>
<td>0.5402622</td>
<td>0.8408439</td>
<td>0.6425238</td>
</tr>
<tr>
<td>DMU 8</td>
<td>0.7139614</td>
<td>0.8244984</td>
<td>0.8659343</td>
</tr>
<tr>
<td>DMU 9</td>
<td>0.3325799</td>
<td>0.4154540</td>
<td>0.8005216</td>
</tr>
<tr>
<td>DMU 10</td>
<td>0.5406739</td>
<td>0.9067353</td>
<td>0.5962864</td>
</tr>
<tr>
<td>DMU 11</td>
<td>0.2986603</td>
<td>0.3482161</td>
<td>0.8576866</td>
</tr>
<tr>
<td>DMU 12</td>
<td>0.3132749</td>
<td>0.5385341</td>
<td>0.5817179</td>
</tr>
<tr>
<td>DMU 13</td>
<td>0.3045385</td>
<td>1.000000</td>
<td>0.3045385</td>
</tr>
<tr>
<td>DMU 14</td>
<td>0.2893826</td>
<td>0.7733808</td>
<td>0.3741787</td>
</tr>
<tr>
<td>DMU 15</td>
<td>1.000000</td>
<td>1.000000</td>
<td>1.000000</td>
</tr>
<tr>
<td>DMU 16</td>
<td>1.000000</td>
<td>1.000000</td>
<td>1.000000</td>
</tr>
<tr>
<td>DMU 17</td>
<td>0.2921690</td>
<td>0.5007433</td>
<td>0.5834707</td>
</tr>
</tbody>
</table>
5. Conclusion

This paper is the first application of relational network DEA proposed by kao (2009) to construct a network performance evaluation model for banking sector in Iran. The proposed model evaluates the performance of different network branches of Iranian bank. Comparing with previous branch studies, this two-dimensional efficiency analysis shows a signifiically more comprehensive evaluation of bank branches performance, that is also likely to better accepted by branch level management.

The empirical study considers 17 bank branches in Iranian bank and provides detailed resulted on the overall efficiency and efficiency of each stages separately. In addition the ranking of the branches across their ability to marketing and making profit could be provided as benchmarks for branches to adopt in order to improve their performance. Overall, the present study may provide a starting point for further investigation and validation into the efficiency of Iranian bank sector. we hope that branches improve their overall performance through comprehensive performance evaluation, and this leads to an increase in competitiveness of banking sector in Iran.

Conventional DEA models for measuring the efficiency of a system treat systems as a black-box, disregarding its internal structure. more reprehensive and informative result can be obtained if interactions of the component processes within the system are taken into account. Black-box DEA models estimate the efficiency of DMUs by assuming that inputs are used to produce only final outputs, in this paper we go inside the black-box and allow for a two-stage structure to production where inputs in first stage produce intermediate outputs are transformed in second stage of production to final outputs. We argue that a two-stage is a superior to traditional DEA if applied in a banking sector that largely depends on primary deposits.
6. Reference


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