

**Application of DEA and Malmquist Indexes, Empirical Model and Data Envelopment Analysis: A Measure of Performance and Efficiency of Commercial Banks in Taiwan**

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**ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)**

**Aims:** This paper examines the performance of commercial banks in Taiwan, in terms of their ability to provide maximum outputs by the given input utilization. There seems to be important concern hanging on the ability of commercial banks to provide output-base for the available input utilization in Taiwan.

**Study design:** This study has been divided into four parts to investigate the DEA model such as efficiency analysis, return to scale analysis, slack variable analysis, and sensitivity analysis.

**Place and Duration of Study:** The data used in the study are from the reports of the Bank Sector Statistics published by the Central Bank, Taiwan from 2006 to 2010.

**Methodology:** The Data Envelopment Analysis (DEA) and Malmquist Index methods have been employed to determine the effects of variable returns on the operational performance and efficiency. The variables used in the study include inputs: (1) numbers of branches, (2) number of employee per branch, (3) share in total assets, (4) share in total loans, and (5) share in total deposits and outputs: (1) ROA, (2) ROE, (3) net interest income/total assets, (4) net interest income/total operating income, and (5) non-interest income/total assets.

**Results:** The DEA efficiency scores can be interpreted to illustrate that individual bank may increase its outputs without changing the input utilization if the technical efficient is as good as the best practice bank. Regarding the change on the technical efficiency, the change rate in the period of 2007-2008 is 0.949, which shows that the technical efficiency has declined. Moreover, the following periods, 2008-2010 have declined further. For the change of scale efficiency in the period of 2006-2007 is 0.931 whilst the rate is 1.008 in the following period (2007-2008).

**Conclusion:** It is found that the operation of commercial banks in Taiwan is not on the optimal scale. For resource consumption, there should be some rooms for improvement.

**Keywords:** Bank, Performance, Data Envelopment Analysis, Malmquist Index

**1. INTRODUCTION**

Financial markets in Taiwan have remarkable transformation over the last two or three decades due to globalization. This paper examines the performance of commercial banks in Taiwan, in terms of their ability to provide maximum outputs. There seems to be important concern hanging on the ability of commercial banks to provide output-base for the available

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input utilization in Taiwan. This paper examines the performance of commercial banks in Taiwan, in terms of their ability to provide maximum outputs by the given input utilization. This study has been divided into four parts to investigate the DEA model such as efficiency analysis, return to scale analysis, slack variable analysis, and sensitivity analysis. The data used in the study are from the reports of the Bank Sector Statistics published by the Central Bank, Taiwan from 2006 to 2010. The Data Envelopment Analysis (DEA) and Malmquist Index methods have been employed to determine the effects of variable returns on the operational performance and efficiency. The variables used in the study include inputs: (1) numbers of branches, (2) number of employee per branch, (3) share in total assets, (4) share in total loans, and (5) share in total deposits and outputs: (1) ROA, (2) ROE, (3) net interest income/total assets, (4) net interest income/total operating income, and (5) non-interest income/total assets. This paper is organized as follows: section two reviews the relevant literature on banking industry using DEA and Malmquist Index. Section three introduces DEA and Malmquist Index in brief. Section four discusses methodology and sample. Section five presents findings and discussions. Conclusions are presented in the final section.

## 2. LITERATURE REVIEW

Banking sector has undergone significant changes in the past decades. Liberalization in financial market has been adopted by many countries worldwide such as Financial Service Action Plan in the European Union. Facing extreme competition, commercial banks require evaluating their efficiency and performance. There are a variety of research studied in the field of banking performance using different methodologies, such as DEA or Malmquist Index to examine the operational performance and efficiency (Chang and Chiu, 2006; Pasiouras, 2008; Sufian, 2009). Facing high competition, commercial banks need to evaluate their efficiency and operational performance worldwide. Consequently, empirical research on performance evaluation and efficiency of the banking industry is much studied. However, there is a shortage of relevant research in the region of Eastern Asia (Sufian, 2012). Regarding the competitiveness of banks across countries, empirical research on performance evaluation and efficiency of the banking industry is much studied. However, there is a shortage of relevant research in the region of Eastern Asia (Sufian, 2012). Additionally, few studies have compared banking efficiency across countries, comparative research can offer valuable information in an increasingly harmonized financial world (Dietsch and Lozano-Vivas, 2000, Lim and Randhawa, 2005).

A variety of techniques have been used to examine the efficiency and performance of commercial banks. It is found that the selection of technique have a crucial role in evaluating efficiency and operational performance. DEA technique allows an evaluation of the efficiency and performance relative to a best practice technology (Charnes et al., 1978; Sekhri, 2011). Efficiency is a wider perception and involves choosing optimum levels. Bank efficiency can be divided into scale, scope, technical efficiency and so on. As contrasting to parametric techniques such as regression or Structure Equation Model (SEM), DEA technique does not assume that the same optimized regression equation relates to all Decision Making Units (DMUs).

Farrell (1957) published a paper entitled "the Measure of Productive Efficiency" to pre-estimate efficiency value with non-predetermined production function to replace predetermined function. This establishes the basic theory of the data envelopment analysis. Firstly, Farrell proposed the concept of production frontier to measure efficiency and with mathematical programming method to find the deterministic non-parametric efficiency frontier and efficiency production function. The concept of determinism refers to all the DMU at the same level and face the same production frontier. But, non-parametric efficiency frontier between the input and output need not predetermined specific production function. Farrell (1957) with the concept of the non-predetermined production function built mathematical programming model to evaluate agricultural technical efficiency among 48 states in USA. Its evaluation method mainly lies in the relative concept. To find the most efficiency sample from 48 states, use it to represent the most efficiency frontier. For the other states, weighted average of its most efficiency sample for each unit production to find optimal sample combination. Take contrary of the sum of its coefficient. This inverse coefficient is called efficient. Farrell established a framework of the DEA with non-predetermined function to measure it. But this method only deals with the single output case. Charnes et al. (1978) based on the concept established by Farrell (1957) to create a mathematical model and formally named it the DEA. It applies the envelope theory built by Farrell and Fieldhouse (1962) and deterministic nonparametric method built by Farrell (1957) to develop a method to measure relative efficiency for multiple outputs and multiple inputs.

### 3. DEA THEORY AND EMPIRICAL MODEL

This study used the DEA to explore the operational performance of commercial banks in Taiwan. DEA is a non-stochastic and non-parametric programming to assess the comparative efficiency of DMUs with ordinary inputs and outputs. As to the DEA theoretical basis, we can divide this into basic principle of the DEA and the Malmquist Index. This method can identify the most efficiency decision making unit (DMU) among all the decision units. It does not need to preset a weighted index, but can handle multiple inputs and multiple outputs. It can also offer the contribution of each kind of input and output to the relative efficiency. In addition, this method can offer improvement suggestions for the inefficiency decision units and with equality and objectivity to measure the efficiency (Sufian, 2012). The DEA estimate compares each of the commercial banks in the sample with the one that is the best practice DMU in this study.

This study has been divided into four parts to investigate the DEA model such as efficiency analysis, return to scale analysis, slack variable analysis, and sensitivity analysis. First, efficiency analysis; Farrell (1957) defines the overall efficiency as the product of technical efficiency and allocate efficiency. Afterwards Banker et al. (1984) decomposed the technical efficiency into the product of the pure technical efficiency and the scale efficiency. Second, return to scale analysis; With the DEA to calculate the sum of the aggregate parameter ( $\lambda$ ) for each DMU, it can be identified which scale level stayed for the DMU. It shows that the production of this DMU is over the optimal scale as  $\sum \lambda > 1$ . It belongs to the increasing return to scale. If  $\sum \lambda < 1$ , it shows that the production of this DMU is below the optimal scale. It belongs to the decreasing return to scale. If  $\sum \lambda = 1$ , it shows that the production of this DMU is on the optimal scale. It belongs to the constant return to scale. In the BCC (Banker et al., 1984) model, it adds  $u_0$ . If  $-u_0$  (negative  $u_0$ ) is greater than 0 (i.e.  $u_0$  itself is negative), then it corresponds to the line of the production frontier belonging to the increasing return to scale (IRS). If  $-u_0$  equals to 0, then it corresponds to the line of the production frontier belonging to the constant return to scale (CRS). If  $-u_0$  is less than 0, then  $-u_0$  corresponds to the line of the production frontier belonging to the decreasing return to scale (DRS).

Third, slack variable analysis; Slack variable analysis can provide the information of the resource utilization. It is not only for the basis of target setting, but also for understanding of how much improvement for the evaluated DMU is. For an inefficient evaluated DMU is called  $k$ . Its input set is  $(X_{ik}, Y_{rk})$ . If the optimal solution is  $(\theta^*, \lambda^*, S_r^{**}, S_i^*)$ ,  $(\lambda_1^*, \lambda_2^*, \dots, \lambda_n^*)$ , then the projection of the  $(X_{ik}, Y_{rk})$  on the efficiency frontier is would be as following:

$$X_{ik}^* = \theta^* X_{ik} - S_i^*, i=1, \dots, m$$

$$Y_{rk}^* = Y_{rk} + S_r^*, r=1, \dots, s$$

It can be found that the difference of  $(X_{ik}, Y_{rk})$  to the compare object as follows:

$$\Delta X_{ik} = X_{ik} - X_{ik}^*, i=1, \dots, m$$

$$\Delta Y_{rk} = Y_{rk} - Y_{rk}^*, r=1, \dots, s$$

i.e. the evaluated DMU  $k$  can improve its efficiency by reducing input of  $\Delta X_{ik}$  and increasing output of  $\Delta Y_{rk}$ .

Forth, sensitivity analysis; the efficiency measured by the DEA is a relative efficiency. If the number of the evaluated DMU changes, its relative efficiency will be changed along. When input items changed, it has to rerun the DEA and to examine the efficiency value for the evaluated DMU. Thus any factor value changed it has to re-execute the programming model. Farrell (1957) proposed a method to measure efficiency. The main assumption is production technique fixed to measure the distance of the DMU to the production frontier. Use this production efficiency index as a criterion to evaluate firm operational performance. If add time factor into the model, it belongs to multiple period model. Production technique will change as time variation. Therefore on evaluating production efficiency, it should consider the variation of the production technique. Fare et al. (1992) defined Malmquist production index (MPI). It can solve the aforementioned problem. Productivity change can be decomposed into efficiency change (EC) and technical change (TC). Use distant function to calculate these two components of the MPI. Then use it to explore the reasons of the firm productivity change.

### 4. METHODOLOGY AND DATA ANALYSES

It is an advantage to employ DEA and Malmquist Index in measuring performance of the bank since the techniques do not need to use specified functional form such as guarantees, foreign exchange, trusts, credit cards, cash cards, securities, debentures, and proprietary dealing in futures. This paper aims to examine the long-term trend in efficiency changes of twelve commercial banks, which are subsidiaries of financial holding companies listed in Taiwan Stock Exchange (see Table 1).

The data used in the study are from the reports of the Bank Sector Statistics published by the Central Bank, Taiwan from 2006 to 2010. Table 2 shows that the variables used in the study include inputs: (1) numbers of branches, (2) number of employee per branch, (3) share in total assets, (4) share in total loans, and (5) share in total deposits and outputs: (1) ROA, (2) ROE, (3) net interest income/total assets, (4) net interest income/total operating income, and (5) non-interest income/total assets (Primorac and Zvonimir, 2005; Sakar, 2006; Sekhri, 2011). First, we calculate simple correlation coefficients as a criterion to check productivity initially and use it to analyze variable relationships. Second, based on the relationship between inputs and outputs to find optimal production frontier, use it to evaluate the operational performance of commercial banks in Taiwan. Based on the slack variable analysis provide the criteria to improve operational

performance. For all input and output variables standard deviation is a value comparable to the variable mean (Färe et al. 1992).

The correlations between inputs and outputs are presented in the Table 3. There are strong correlations between the input variables. For instance, IP1 (Number of branches) affect the IP3 (Share in total assets), IP5 (Share in total deposits). However, the correlation between inputs and outputs is either too weak or not in existence. OP1 (ROA) and OP2 (ROE) are highly correlated. Table 3 shows that all the coefficients with a positive between inputs and outputs. It indicated that relational output quantity will increase as quantity of input increased. Therefore, it is not necessary to remove the variables of input or output with a lower correlation coefficient.

5. RESULTS

The DEA efficiency scores can be interpreted to illustrate that individual bank may increase its outputs without changing the input utilization if the technical efficient is as good as the best practice bank. The Table 4 shows that total efficiency indicated a steady improvement on the commercial banks in Taiwan during 2006 to 2007. However, from 2009 to 2010, total efficiency showed a decline. This showed that the operation of commercial banks in Taiwan is not on the optimal scale. For resource consumption, there should be some rooms for improvement.

Regarding the change on the technical efficiency, the change rate in the period of 2007-2008 is 0.949, which shows that the technical efficiency has declined. Moreover, the following periods, 2008-2010 have declined further. For the change of scale efficiency in the period of 2006-2007 is 0.931 whilst the rate is 1.008 in the following period (2007-2008). This indicates that production scale is more near constant return to scale. Regarding the change on the productivity, the rate drops from 1.03 (2006-2007) to 0.774 (2009-2010). It indicates that productivity has constantly declined during the five years (see Table 4).

6. CONCLUSION

The paper aimed to use DEA and Malmquist Index to study the performance and efficiency of commercial banks listed in Taiwan Stock Exchange. Two sets of results were found from the period of five years between 2006 and 2010. Bank performance can be evaluated by these efficiency scores so that banks with dreadful performance may identify and prioritize their resources and enhance efficiency only by improving their outputs. We can identify relative efficient and inefficient commercial banks and understand the result of each output variable under the efficiency performance analysis by the empirical results. We study how to achieve optimal efficiency for the bank operation by changing inputs or outputs. In addition, those results are expected to offer suggestions for commercial banks in planning its performance.

First of all, just 1(8.3%) bank shows an increase in total efficiency during 2005-2009, 4(33.3%) banks remain steady, and 7(58.3%) banks demonstrate a decline. Second, regarding technical efficiency, only 1(8.3%) bank shows an increase, 1(8.3%) bank keeps constant, and 10(83.3%) banks show a decline. This indicates that most of the commercial banks in Taiwan are not in their best operation. Finally, with regard to total factor productivity, all 12(100%) banks show a decrease. It indicates the bank sector was deeply in financial crisis in 2008 and has not fully recovered. This study has a limitation in terms of the number of banks. The product of the multiple inputs and outputs should be less than the number of banks and it is better to have more than 25 samples. Further research should be aware of this criterion and gather an adequate amount of samples.

Table 1 Sample of Commercial Bank and its Financial Holding Company

| DMU | Commercial Bank                           | Financial Holding Company            |
|-----|-------------------------------------------|--------------------------------------|
| 1   | Hua Nan Bank (HNB)                        | Hua Nan Financial Holdings Co., Ltd. |
| 2   | Taipei Fubon Commercial Bank (TFCB)       | Fubon Financial Holdings Co., Ltd.   |
| 3   | Cathay United Bank (CUB)                  | Cathay Financial Holdings Co., Ltd.  |
| 4   | E.SUN Commercial Bank (ESCB)              | E. SUN Financial Holdings Co., Ltd.  |
| 5   | Yuanta Commercial Bank (YCB)              | Yuanta Financial Holdings Co., Ltd.  |
| 6   | Mega International Commercial Bank (MICB) | Mega Financial Holdings Co., Ltd.    |

|    |                                  |                                                |
|----|----------------------------------|------------------------------------------------|
| 7  | Taishin International Bank (TIB) | Taishin Financial Holdings Co., Ltd.           |
| 8  | Shin Kong Bank (SKB)             | Shin Kong Financial Holdings Co., Ltd.         |
| 9  | Bank SinoPac (BSP)               | SinoPac Financial Holdings Co., Ltd.           |
| 10 | CITIC Bank International (CITIC) | Chinatrust Financial Holding Co., Ltd.         |
| 11 | First Commercial Bank (FCB)      | First Financial Holding Co., Ltd.              |
| 12 | Taiwan Cooperative Bank (TCB)    | Taiwan Cooperative Financial Holding Co., Ltd. |

**Table 2 Variable of Inputs and Outputs in the Model**

| Inputs         |                                            | Mean    | Std.    |
|----------------|--------------------------------------------|---------|---------|
| Input 1 (IP1)  | Number of branches                         | 158.017 | 1.579   |
| Input 2 (IP2)  | Number of employee (per branch)            | 106.792 | 153.969 |
| Input 3 (IP1)  | Share in total assets                      | 29.459  | 0.568   |
| Input 4 (IP1)  | Share in total loans                       | 18.341  | 0.347   |
| Input 5 (IP1)  | Share in total deposits                    | 22.632  | 1.214   |
| Outputs        |                                            |         |         |
| Output 1 (OP1) | ROA (Return on Assets)                     | 0.018   | 0.002   |
| Output 2 (OP2) | ROE (Return on Equity)                     | 0.263   | 0.146   |
| Output 3 (OP3) | Net interest income/total assets           | 0.421   | 0.912   |
| Output 4 (OP4) | Net interest income/total operating income | 1.430   | 2.049   |
| Output 5 (OP5) | Non-interest income/total assets           | 0.006   | 0.003   |

**Table 3 Correlations between inputs and outputs**

|     | IP1   | IP2   | IP3   | IP4   | IP5   |
|-----|-------|-------|-------|-------|-------|
| OP1 | 0.14  | -0.19 | -0.53 | 0.04  | -0.53 |
| OP2 | -0.38 | 0.24  | -0.93 | -0.57 | -0.86 |
| OP3 | 0.41  | -0.25 | 0.88  | 0.66  | 0.75  |
| OP4 | 0.08  | -0.17 | -0.18 | -0.33 | 0.25  |
| OP5 | 0.88  | -0.92 | -0.15 | 0.22  | 0.47  |

**Table 4 Malmquist Index Summary of Annual Means**

| Period    | Efficiency change | Technical change | Pure technical change | Scale efficiency change | Total factor productivity change |
|-----------|-------------------|------------------|-----------------------|-------------------------|----------------------------------|
| 2006-2007 | 0.889             | 1.158            | 0.931                 | 0.955                   | 1.03                             |
| 2007-2008 | 1.021             | 0.949            | 1.008                 | 1.014                   | 0.969                            |
| 2008-2009 | 1.022             | 0.831            | 1.012                 | 1.01                    | 0.849                            |
| 2009-2010 | 0.983             | 0.787            | 0.992                 | 0.991                   | 0.774                            |
| Mean      | 0.977             | 0.921            | 0.985                 | 0.992                   | 0.9                              |

**Table 5 Banks ranking by total factor productivity change of Malmquist Index**

| DMU                           | Bank  | Efficiency change | Technical change | Pure technical change | Scale efficiency change | Total factor productivity change |
|-------------------------------|-------|-------------------|------------------|-----------------------|-------------------------|----------------------------------|
| 6                             | MICB  | 0.913             | 1.067            | 0.937                 | 0.975                   | 0.974                            |
| 7                             | TIB   | 1                 | 0.973            | 1                     | 1                       | 0.973                            |
| 2                             | TFCB  | 0.959             | 1                | 0.983                 | 0.976                   | 0.959                            |
| 12                            | TCB   | 0.994             | 0.949            | 1                     | 0.994                   | 0.943                            |
| 8                             | SKB   | 1                 | 0.935            | 1                     | 1                       | 0.935                            |
| 10                            | CITIC | 1                 | 0.911            | 1                     | 1                       | 0.911                            |
| 3                             | CUB   | 0.959             | 0.94             | 0.976                 | 0.983                   | 0.902                            |
| 9                             | BSP   | 1.05              | 0.85             | 1                     | 1.05                    | 0.893                            |
| 1                             | HNB   | 0.959             | 0.913            | 1.001                 | 0.958                   | 0.876                            |
| 5                             | YCB   | 1                 | 0.857            | 1                     | 1                       | 0.857                            |
| 11                            | FCB   | 0.938             | 0.86             | 0.947                 | 0.991                   | 0.807                            |
| Mean                          |       | 0.977             | 0.921            | 0.985                 | 0.992                   | 0.900                            |
| Number of Efficient ratio > 1 |       | 1(8.3%)           | 1(8.3%)          | 1(8.3%)               | 1(8.3%)                 | 0(0%)                            |
| Number of Efficient ratio = 1 |       | 4(33.3%)          | 1(8.3%)          | 6(50%)                | 4(33.3%)                | 0(0%)                            |
| Number of Efficient ratio < 1 |       | 7(58.3%)          | 10(83.3%)        | 5(41.7%)              | 7(58.3%)                | 12(100%)                         |

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