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Full Length Research Paper

Measuring super-efficiency of financial and non-financial holding companies in Taiwan: An application of DEA models

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Data Envelopment Analysis (DEA) has been widely used to assess the efficiency of various manufacturers, but for some specific natural industries, there is a problem of the same efficiency score being 1. Taiwanese banks are all small in scale and their numbers abound. Hence, the efficiency scores of Taiwanese banks turn out many efficient decision making units (DMUs) and create a ranking problem. This paper implements four kinds of DEA models to solve the rating problem and calculates the correct efficiency scores. This paper hypothesizes four kinds of super-efficiency in DEA models as our estimates are based on information obtained from 37 Taiwanese banks for the period from 2004 to 2006. The results show that: (1) Traditional DEA presents more efficient DMUs when estimating Taiwan banking, and in order to solve the problem of ranking, adopting the Modified-Super model is more suitable. (2) The performances of financial holding companies' subsidiary banks are better than the independent banks. (3) The total loans to total asset ratios, ROA, bank share of market loans, number of branches, and group play important roles in efficiency. (4) Banks should segment their own attributes and clients to offer diversified services or specialized businesses, so as to satisfy the needs of different groups of customers.

Key words: Data envelopment analysis, super-efficiency, efficiency rating, efficiency.

INTRODUCTION

As the global economy and financial investment services move towards liberalization and globalization, the operation patterns of financial institutions have turned more diversified. Financial innovation can promote the development of an economy, and therefore pursuing a solid and efficient financial system is the target for most countries. Since the 1980s, Taiwan's financial market has experienced a number of changes in financial liberalization - for example, interest rate and exchange rate controls were lifted, private commercial banks were allowed to set up, and trust investment companies and credit cooperatives helped the restructuring of commercial banks. The internal and external conditions of its domestic economic environment are very different from before, resulting in the banking industrial structure having undergone many changes. Bank managers need to develop diversified investment in order to maintain the survival of their entity.

Has the establishment of financial holding companies really helped increase the overall financial system's efficiency? As a financial holding company (FHC) and non-FHC are different in characteristics, what impact has Taiwan's financial system operating efficiency brought about upon their ranking? These issues are becoming more and more important and should be attended to carefully by authorities. This study estimates bank efficiency scores and uses the Tobit regression to investigate the bank efficiency effect.

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Efficiency is seen as the result of a set of inputs being transformed into outputs. Data Envelopment Analysis (DEA) is a non-parametric method without setting a function form and adopts the envelopment technique to substitute for the production function in general microeconomics. DEA has been widely used to estimate the performance of various industries, projects every input and output of the decision making units (DMUs) onto a space, and displays the frontier for these DMUs. At the same time, this method takes specific productive efficiencies as a basis and allocates each DMU a relative performance index. The efficiency score is a relative performance indicator ranging from 0 to 1, and DMUs can be ranked according to the score. When there are many efficient DMUs, one is unable to rank and compare the efficiency of performances correctly. In recent years, super efficiency DEA models have become an interesting research subject that discriminates between these efficient DMUs.

Banks in Taiwan can be divided into two types. The first group includes private banks that opened up in the early 1980s and they are smaller in size. The other one makes up old public sector banks and private banks of large consortiums. The sizes of old public sector banks are generally similar to each other and larger than the smaller private banks. Under such circumstances, using the traditional DEA to estimate the efficiency scores of Taiwan's banks turns out many efficient DMUs and creates a ranking problem. In addition, as most Taiwanese banks are small in scale and are many in number, their efficiency scores do not differ greatly. Based on the above reasons, there is a problem in producing estimates of the same efficiency rate as 1, and thus one cannot rank and compare the efficiency of the performances correctly. To solve the ranking problem, Andersen and Petersen (1993) proposed a super-efficiency model to estimate the efficiency of the DMUs' performance. This resulted in a super-efficiency score larger than 1, and so we can rank the efficiency values smoothly. However, Thrall (1996) found that the super-efficient model has an infeasible problem in varying returns to scale. Therefore, how to improve the ranking problem has come to the wide attention of many scholars. Thanassoulis (1999), Tone (2002), and Lovell and Rouse (2003) used different models to solve the infeasible problem, but there are no comprehensive discussions about various models to solve the efficiency score as 1. Moreover, there are no papers that compare the advantages and disadvantages of these models. Hence, this study conducts a DEA based on different estimation models, in which they estimate a comparison of the efficiency.

This study intends to improve the unsolvable problem put forward by scholars in order to value the rankings when the efficiency rate is 1 and estimates the efficiency scores of Taiwanese banks. We also use the Tobit regression to investigate what factors affect the efficiency scores. The structure of this study is as follows: The first part of this study is Introduction, section 2 is literature review, section 3 presents empirical models, section 4 is empirical results, and section 5 is conclusion.

LITERATURE REVIEW

The methodology for efficiency estimation can be divided into parametric and non-parametric methods. DEA is a non-parametric method without setting the function form and adopts the envelopment technique to substitute the production function in general microeconomics. Compared to other approaches, DEA is a better way to organize and analyze data since it allows efficiency to change over time, does not require any prior determination of function types, and also has the characteristics of measurable multiple-inputs and multiple-outputs (Ferrier and Lovell, 1990; Thanassoulis, 1993; Favero and Papi, 1995; Bhattacharyya et al., 1997; Fukuyama et al., 1999; Yang, 2009). Although DEA has many advantages, its disadvantage is that the outlier has a great influence on the frontier and affects the estimation result.

DEA was advanced by Charnes et al. (1978) and its discussion of constant returns to scale is called the CCR model. Thereafter, Banker et al. (1984) developed the BCC model under the variable return to scale. For the ranking of DMUs that have original efficiency values the same as 1, scholars have put forth more stringent definitions and criteria. Andersen and Pertersen (1993) used the super-efficiency measures of these efficient firms to resolve the efficient ranking problem. However, the problem of feasibility arises in a super-efficiency model when an efficient bundle fails to satisfy the input attainability assumption with respect to the modified production possibility set (Thrall, 1996).

According to Charnes et al. (1986), Seiford and Thrall (1990), Seiford and Zhu (1999), and Xue and Harker (2002), the efficiency of DMUs can be divided into three subsets: weakly efficient DMUs, the efficiency of efficient DMUs, and strongly efficient DMUs. Some scholars have proposed solutions for the efficiency with a value of other means (Zhu, 1996; Thrall, 1996; Seiford and Zhu, 1999; Harker and Xue, 2002; Bogetoft and Hougaard, 2004). The super-efficiency model can identify DMUs that are strongly efficient or weakly efficient. Lovell and Rouse (2003) proposed a modification of the standard DEA model that overcomes the infeasibility problem. Chen (2004, 2005) replaced observations found to be inefficient under the variable returns to scale assumption in a conventional DEA evaluation by their efficient projections onto the frontier and used the revised dataset to perform super-efficiency. Ray (2008) implemented the directional distance function and the resulting Nerlove-Luenberger measure of super-efficiency. Cook et al. (2009) provided the VRS super-efficiency model whereby the scores are equivalent to those arising from the VRS super-efficiency model when feasibility is present.

Most scholars before 1990 focused on economies of scale and scope of economic analysis, classifying different sizes of banks by assets. Some scholars believe that the banking industry does not present a conditional existence of economies of scale (Kaparakis et al, 1994; Mitchell and Onvural, 1996; Vennet, 1996), while other scholars propose economies of scale in the banking industry (Shaffer, 1993; Clark, 1996). Since 1990, scholars have seen more impact on the inefficiency factors of the financial sector (Kaparakis et al, 1994; Favero and Papi, 1995).

Researchers have recently focused on the relationship between bank efficiency and risk when studying a bank's efficiency. There are two issues of bank efficiency and risks. One treats risk as exogenous so as to analyze efficiency effects (Cebenoyan et al., 1993; Elyasiani et al., 1994; Berger and DeYoung, 1997; Chang, 1999) and the other way is to implement risk indicators into the production process (Mester, 1996; Hughes, 1999; Altunbas et al., 2000; Hughes et al., 2001; Chang and Chiu, 2006; Chiu and Chen, 2009). In the above research literature, environmental variables include a common number of ATMs, number of branches, operating time, operating patterns, exclusiveness of operating, and diversification. The most common risk variables are the capital adequacy rate, lending ratio, debt ratio, and the lenders' proportion of the total assets.

Many scholars have also compared the efficiency of the banking sector before and after a change in mergers. More recently, scholars have discussed banks' operating efficiency before and after the establishment of financial holding companies. As a result, some scholars believe that an acquisition helps banks to improve their efficiency (Berger et al., 1997; Resti, 1998; Cavallo and Rossi, 2001), while other scholars think that acquisitions do not help to improve the efficiency of banking (Rhoades, 1999; Peristani, 1997; Garden and Ralston, 1999). With the adoption of the Financial Holding Law, Taiwanese scholars have begun to discuss efficiency ever since the establishment of financial holding banks. Sheu et al. (2006) proposed that the relation between the diversification strategy and performance of a FHC is not a single dimension, as with the degrees and types of diversification. Lo and Lu (2006) offered that large-scale FHCs are more efficient than small-scale FHCs, and insurance firms as the mainstay of FHCs are more efficient than banks and securities as their main business unit. FHCs that continue to make acquisitions will contribute to economies of scale.

Looking at past research, there has been no comprehensive discussion of the various models for solving the ranking problem and no relevant empirical data for a validation comparison. Therefore, this study targets to improve the problem with the efficiency of the rankings for one and to estimate the correct value of the efficiency of Taiwan's banks. This helps further analyze the performance of banking consolidation effects.

EMPIRICAL MODELS

DEA is used to establish best practice group units and to determine which units are inefficient compared to best practice groups as well as to show the magnitude of the inefficiencies present. For solving the ranking problem, there are two types of estimation methods (Banker and Chang, 2005). The first category to be excluded from the decision-making reference collection is the estimate of the DMUs for the value of super-efficiency. The second category is a part of the efficient DMUs as outliers. Methods involve some difficulties with an extreme value in that there is no objective standard. Andersen and Petersen (1993), Thanassoulis (1999), Tone (2002), and Lovell and Rouse (2003) compared the differences in such a model.

This study adopts a two-stage approach, DEA and Tobit regression, to investigate the bank efficiency index and the factors affecting the efficiency. In the first stage we use four models to estimate bank cost efficiency. The second stage employs a Tobit regression model to estimate efficiency effects.

Andersen and Petersen (1993)'s Super-BCC Model (AP Model)

Assume there are m inputs, s outputs, and n DMUs. Andersen and Petersen (1993) excluded DMU_j from the decision-making reference collection, and the super-efficiency score of DMU_j is estimated as follows.

super-BCC Model

$$
\begin{aligned}
&\min_{E_j,\lambda_1,\lambda_2,\dots\lambda_n} \quad E_j \\
&s.t. \quad E_j X_j - \sum_{\substack{k=1 \\ k\neq j}}^{n} z_k X_k \geq 0 \\
&\qquad -Y_j + \sum_{\substack{k=1 \\ k\neq j}}^{n} z_k Y_k \geq 0 \\
&\qquad \sum_{\substack{k=1 \\ k\neq j}}^{n} z_k = 1 \\
&\qquad z_k \geq 0, k = 1,\dots,n \\
&\qquad E_j \quad is \quad free
\end{aligned}
\qquad (1)
$$

In Formula (1), E_j is the super-efficiency score of DMU_j estimated by the AP model; X_j is the input vector of DMU_j; Y_j is the output vector of DMU_j; z_k is the intensity of DMU_k. This model's feature is to exclude the DMU out of the reference set. If the DMU is inefficient, then the reference set does not change in this model. On the other hand, the frontier will change if the DMU is efficient and the score of efficiency is larger than 1.

This says that the AP model does not change an inefficient DMU's score, but an efficient DMU's score in this model is larger than 1. Therefore, this model seems to solve for the efficiency with a value of the rankings, but follow-up scholars find that this model cannot be estimated (infeasible). In practice, they are still unable to model all efficient DMUs and do the right value rankings.

Thanassoulis (1999)s' Threshold model

Thanassoulis deleted the extreme value from the reference set and re-evaluated the efficiency score. The advantage of this model is to find the appropriate DMU to avoid the condition which cannot be estimated. This model estimates the efficiency score by the same way as the original DEA, but the model sets three percentage subjective parameters ($p_1\%, p_2\%, r_1$) which meet the following two conditions to exclude the extremes from the reference set.

(1) If the efficiency score of DMU is between $(100 - r_1)\%$ to 100%, then it need not preclude the efficient DMU and can proceed to (2).

(2) If more than $p_2\%$ of the DMUs have been removed from the reference set, then it is not required to remove any DMUs; otherwise, the infeasible DMUs should be removed or deleted to the highest efficiency until (1).

After the completion of the above steps, one then re-estimates the value of the DMUs. Assume there are m inputs, s outputs, and n DMUs. The VRS threshold model is as follows.

Threshold Model—

$$\begin{aligned}
&\min_{\theta_j, \lambda_1, \lambda_2, \ldots, \lambda_H} \quad \theta_j \\
&s.t \quad \theta_j X_j - \sum_{k \in G - \Im}^{n} \lambda_k X_k \geq 0, \\
&\qquad -Y_j + \sum_{k \in G - \Im}^{n} \lambda_k Y_k \geq 0, \\
&\qquad \sum_{k \in G - \Im}^{n} \lambda_k = 1 \\
&\qquad \lambda_k \geq 0, k \in G - \Im; \\
&\qquad \theta_j \quad is \quad free
\end{aligned} \tag{2}$$

In Formula (2), θ_j is the super-efficiency score of DMU_j estimated by the Threshold model; X_j is the input vector of DMU_j; Y_j is the output vector of DMU_j; λ_k is the intensity of DMU_k. The above G is the full DMU set and $\Im$ is the extreme set to meet the parameters' set percentage of extreme value.

Tone (2002)'s super SBM model

Tone (2001, 2002) proposed the SBM model which is in a manner of a non-ray efficiency of the estimated value, and it will not incur a problem that cannot be estimated. Assume there are n DMUs, m inputs, and s outputs. The production possibility set is defined as $P = \{(x, y) | x \geq X\lambda, y \leq Y\lambda, \lambda \geq 0\}$ in which $X = (x_{ij}) \in R^{m \times n}$ is the input matrix and $Y = (y_{rj}) \in R^{s \times n}$ is the output matrix. The index δ_j for the DMU_j is from (x_0, y_0) so as to average distances $(\bar{x}, \bar{y}) \in \bar{P} \setminus (x_0, y_0)$. The VRS super SBM is as follows.

Super-SBM Model—

$$\begin{aligned}
&\min_{\delta_j, \lambda_1, \lambda_2, \ldots, \lambda_n} \quad \delta_j = \frac{\frac{1}{m}\sum_{i=1}^{m} \bar{x}_{ij} / x_{i0}}{\frac{1}{s}\sum_{r=1}^{s} \bar{y}_{rj} / y_{r0}} \\
&s.t. \quad \bar{x}_j \geq \sum_{k=1, \neq 0}^{n} \lambda_k x_k \\
&\qquad \bar{y}_j \leq \sum_{k=1, \neq 0}^{n} \lambda_k y_k \\
&\qquad \bar{x}_j \geq x_0 \quad and \quad \bar{y}_j \leq y_0 \\
&\qquad \bar{y}_j \geq 0, \quad \lambda_k \geq 0
\end{aligned} \tag{3}$$

The VRS super-SBM model can solve the efficiency ranking problem and the infeasible problem caused by the AP model.

Lovell and Rouse (2003)'s modified super-efficiency model

Lovell and Rouse (2003) proposed the modified super-efficiency model which uses inputs or outputs as the deflator to estimate the DMUs' efficiency scores. The merit of this approach is not having priori exclusions, and all DMUs are estimated and ranked successfully. The shortcoming is that the efficiency score of the DMUs estimated is not accurate.

There are n DMUs, m inputs, and s outputs. Assume Y is an s × (n-1) output matrix excluding DMU_j, X is an m × (n-1) input matrix excluding DMU_j, and λ is an (n-1) dimensional intensity variable vector of DMU_K ($k = 1,2,\ldots,n$ and $k \neq j$). If Y_j and X_j are the output and input vectors of DMU_j, then λ_j is the intensity variables vector of DMU_j. The modified super-efficiency score of DMU_j is estimated as follows.

Modified Super-Efficiency Model—

$$\begin{aligned}
&\min_{\theta_{ij}, \lambda, \lambda_j} \quad \theta_{1j} \\
&s.t. \quad Y\lambda + y_j \lambda_j \geq y_j
\end{aligned}$$

$$X\lambda + x_j\lambda_j \leq x_j\theta_{1j}$$
$$\sum \lambda + \lambda_0 = 1 \qquad (4)$$
$$\lambda, \lambda_0 \geq 0, \quad \theta_{1j}\ is \quad free$$

From a comparison of the modified super-efficiency model (4) with the traditional super-efficiency model (1), the biggest difference between them is that the modified super-efficiency model estimates the efficiency score without excluding the DMU from the reference set t. Both may see a number of efficient decision-making units. Therefore, the score of efficient DMUs estimated in model (4) is multiplied by large parameters of $\alpha > 1$. In the following (5), they become an inefficient DMU $\theta_2^* < 1$.

$$\min_{\theta_2,\rho,\rho_j} \quad \theta_{2j}$$
$$s.t. \quad Y\rho + y_j\rho_j \geq y_j$$
$$X\rho + \alpha_j x_j \rho_j \leq \alpha x_j \theta_{2j} \qquad (5)$$
$$\sum \rho + \rho_j = 1$$
$$\rho, \rho_j \geq 0, \quad \theta_{2j}\ is \quad free$$

The parameters α_j of each DMU_j ($j = 1,.....,n$) are selected for a minimum $x_{ij} > 0$, and we calculate $\alpha_j = \max\ x_{ij} \big/ \min\ x_{ij}$, and finally let $\alpha = \max(\alpha_1,.....,\alpha_m) + 1$.

Tobit method

In order to identity factors impacting bank efficiency, we regress efficiency on a set of characteristic and financial variables, including eight independent variables. The functional form of the econometric model is as follows.

T = *f* (NPL, CAP_RA, LOAN_TA, ROA, LOAN_share, BRANCH, AGE, GROUP), (6)

where T is the efficiency index; NPL is non-performing loans to total loans; CAP_RA is the total qualifying capital to the risky asset ratios; LOAN_TA is total loans to total asset ratios; ROA is ratio of net income before tax to total assets; LOAN_share is the bank's share of market loans; BRANCH is the number of bank branches at the end of each year; AGE is the number of years that the bank has been operating; and GROUP means the bank belongs to a financial holding company.

The relationships of the dependent variable and various independent variables in Equation (6) are summarized as follows. CAP_RA: The coefficient of CAP_RA is predicted to be positive in the regressions and CAP_RA is included to account for capital adequacy. According to moral hazard theory, CAP_RA should be positively related to efficiency (Mester, 1993). LOAN_TA: The relationship between efficiency and LOAN_TA is ambiguous; a positive relationship of specialization leads to higher efficiency; otherwise, the lower the ratio, the more diversified the bank's asset portfolio will be. According to portfolio theory, a lower ratio of LOAN_TA in the bank results in lower risk to the bank and this increases the bank's efficiency (Chang and Chiu, 2006). The expected sign for the ROA coefficient is positive since higher efficiency correlates with better performance (Mester, 1993). A positive relationship between LOAN_share and bank efficiency is expected. LOAN_share proxies for the bank's market power and the relationship of market power with efficiency is positive if concentration leads to higher profits (Chang and Chiu, 2006). The control variables are BRANCH, AGE, and GROUP.

DATA SOURCE AND EMPIRICAL RESULTS

DEA has been widely used to assess the efficiency of various manufacturers, but for some of the more specific natures of an industry, the use of traditional DEA makes it unable to estimate efficiency successfully. Using DEA to assess the efficiency of Taiwan's banking industry will be a problem. This study looks to improve the ranking problem by four models. The DEA-Frontier is applied to estimate the efficiency scores of the super-BCC model, super-Threshold model, and Modified Super-Efficiency model. The DEA-Slover is applied to estimate the efficiency scores of the super-SBM model. Finally, we adopted Eviews to regress the Tobit model.

Data source

This study uses panel data of 37 Taiwanese banks for the three-year period from 2004 to 2006 and examines a bank's efficiency. The data of 37 banks include annual reports released by the Securities and Futures Commission of the Republic of China. Table 1 describes the pertinent definitions of the variables, as well as the original data and explanations of the data. There are three input factors, including (1) Number of employees (persons), (2) Total deposits (NT$ million), and (3) Fixed assets (NT$ million), and three output factors, including (1) Total amount of loans (NT$ million), (2) Total investment (NT$ million), and (3) Non-interest revenue (NT$ million)

Efficiency results

This study discusses the performance of Taiwanese banks in 2004-2006. Tables 4-2 show the positive results estimated by the four models.

The performance of Taiwanese banks in 2004

The Super-BCC model presents the results in 2004 where the worst performance is Seventh Bank with an efficiency value of 59.09. The second worst is Hwa Tai Bank, and the third worst is Bowa Bank. The best efficient performances are by Chinatrust, Land Bank, and Cooperative Bank, but we were not able to estimate the

Table 1. Definitions and resources of input/output factors.

Input factors	Definition	Unit
Number of employees	Number of employees at the end of the year	Persons
Total deposits	Demand deposit, time deposit, foreign exchange deposit	NT$ million
Fixed assets	Structures and equipment	NT$ million
Output factors	**Definition**	**Unit**
Total amount of loans	Short, medium, and long-term loans	NT$ million
Total investment	Government bonds and other investments	NT$ million
Non-interest revenue	Operating revenue minus interest revenue	NT$ million

Data resources: 1. Static report of financial institution from the Central Bank of China. 2. The financial and operating ratios from the Central Bank of China. 3. Taiwan Economic Journal (TEJ). 4. Annual report of each bank.

Table 2. Efficiency scores estimated by four super-efficiency models in 2004~2006.

FHC	Bank	2004				2005				2006			
		Super-BCC	Super-SBM	Super-Threshold	Modified-Super	Super-BCC	Super-SBM	Super-Threshold	Modified-Super	Super-BCC	Super-SBM	Super-Threshold	Modified-Super
*	First Bank	89.53	60.70	100.00	89.53	88.06	61.07	94.52	88.06	76.93	64.17	118.08	76.93
*	Huanan Bank	87.60	58.80	89.70	87.60	85.27	59.21	90.33	85.27	76.54	61.88	131.73	76.54
*	CDI Bank	160.80	136.72	165.25	160.80	271.06	161.96	278.24	271.06	361.27	221.02	361.27	361.27
*	Mega Bank	112.34	106.08	146.10	112.34	137.12	114.76	231.22	137.12	214.42	123.96	214.99	214.42
*	Chinatrust	infeasible	132.93	infeasible	12500.00	infeasible	133.72	infeasible	10500.00	infeasible	127.45	infeasible	11200.00
*	Cathay Bank	119.73	104.72	138.51	119.73	111.76	103.17	136.21	111.76	86.59	71.37	129.02	86.59
*	TaipeiFubon Bank	113.98	107.57	129.63	113.98	114.59	104.86	139.31	114.59	137.37	113.70	161.90	137.37
*	SinoPac Bank	90.76	75.66	95.10	90.76	88.87	81.89	144.80	88.87	83.68	54.67	128.65	83.68
*	E.Sun Bank	96.37	69.29	113.16	96.37	92.04	67.51	114.85	92.04	78.83	62.62	104.88	78.83
*	Fuhwa bank	94.63	73.40	97.16	94.63	96.92	71.71	115.91	96.92	87.55	67.68	100.00	87.55
*	Taishin Bank	145.07	111.44	148.88	145.07	155.14	113.34	158.34	155.14	110.20	102.87	111.98	110.20
*	Jih Sun Bank	86.78	64.14	100.00	86.78	83.75	60.52	93.62	83.75	70.98	58.01	77.21	70.98
*	Shin Kong Bank	72.32	51.83	101.62	72.32	71.04	47.69	100.00	71.04	67.68	42.89	100.00	67.68
	Changhwa Bank	97.76	52.41	101.33	97.76	92.99	50.81	100.00	92.99	79.85	45.65	100.00	79.85
	King's Town Bank	78.44	37.61	79.97	78.44	61.66	33.93	100.00	61.66	52.56	27.94	100.00	52.56
	Taichung Bank	81.08	29.55	103.92	81.08	71.38	35.84	112.57	71.38	60.08	29.72	100.00	60.08
	The Chinese Bank	126.29	108.88	126.29	126.29	156.30	114.18	178.95	156.30	150.83	112.81	163.42	150.83
	Taiwan Business Bank	98.32	53.90	136.06	98.32	97.03	55.22	141.96	97.03	81.36	39.24	100.00	81.36
	Bank of Kaohsiung	78.55	41.88	94.83	78.55	69.96	33.89	93.99	69.96	68.22	40.91	94.71	68.22

Table 2. Cont'd

	Cosmos Bank	121.60	106.07	170.94	121.60	105.76	101.69	105.76	105.76	103.79	100.99	133.56	103.79
	Union Bank	124.60	105.16	132.53	124.60	69.82	59.92	89.55	69.82	74.31	54.60	93.20	74.31
	Far Eastern Bank	108.98	105.89	115.23	108.98	148.19	119.99	166.04	148.19	116.75	106.81	205.25	116.75
	Tachong Bank	100.79	100.25	108.38	100.79	92.17	78.39	95.70	92.17	102.96	101.70	148.40	102.96
	Entie Bank	154.63	110.83	226.95	154.63	94.99	77.26	147.74	94.99	73.50	65.23	117.55	73.50
	IBT Bank	178.20	126.07	178.20	178.20	192.26	130.75	192.26	192.26	197.93	132.64	197.93	197.93
	Bowa Bank	62.99	35.76	100.00	62.99	60.27	50.95	66.94	60.27	45.86	39.09	73.78	45.86
	Bk. of Overseas Chinese	70.35	47.98	100.00	70.35	70.46	43.42	100.00	70.46	55.21	41.72	100.00	55.21
	Cooperative Bank	89.66	67.31	100.00	89.66	93.80	62.70	100.00	93.80	infeasible	110.24	101.70	11200.00
	Chinfon Bank	90.03	68.84	100.19	90.03	80.10	65.70	110.04	80.10	59.06	42.82	82.15	59.06
	Hualien Bank	100.13	8.29	100.13	100.13	67.73	5.47	69.38	67.73	82.15	7.65	100.00	82.15
	Sunny Bank	82.49	34.47	100.00	82.49	73.39	26.97	100.00	73.39	62.23	29.70	100.00	62.23
	Shanghai Bank	74.46	64.22	100.28	74.46	73.24	65.27	100.00	73.24	75.33	66.62	69.49	75.33
	Seventh Bank	59.09	8.05	64.92	59.09	54.57	9.07	68.61	54.57	66.73	10.58	102.16	66.73
	Hwa Tai Bank	61.71	21.37	65.90	61.71	55.55	28.27	67.01	55.55	54.82	26.06	63.52	54.82
	Cota Bank	71.18	42.33	71.18	71.18	83.17	45.80	83.93	83.17	60.74	41.57	133.30	60.74
	Land Bank	infeasible	114.41	infeasible	12500.00	infeasible	116.73	infeasible	10500.00	112.78	102.31	infeasible	112.78
	Bank of Taiwan	infeasible	100.13	infeasible	12500.00	infeasible	103.91	infeasible	10500.00	infeasible	102.20	infeasible	11200.00
MAX		178.20	136.72	226.95	12500.00	271.06	161.96	278.24	10500.00	361.27	221.02	361.27	11200.00
MIN		59.09	8.05	64.92	59.09	54.57	5.47	66.94	54.57	45.86	7.65	63.52	45.86
STDEV		31.71	37.71	39.01	3811.82	43.90	37.13	46.69	2878.57	60.25	42.91	55.64	3073.09
	Average	105.83	85.03	118.76	105.83	116.30	87.31	141.45	116.30	121.00	87.07	144.98	121.00
FHCs	MAX	160.80	136.72	165.25	160.80	271.06	161.96	278.24	271.06	361.27	221.02	361.27	361.27
	MIN	72.32	51.83	89.70	72.32	71.04	47.69	90.33	71.04	67.68	42.89	77.21	67.68
	Average	95.97	62.60	112.60	95.97	89.31	58.89	108.66	89.31	82.11	55.43	113.26	82.11
Non-FHCs	MAX	178.20	126.07	226.95	178.20	192.26	130.75	192.26	192.26	197.93	132.64	205.25	197.93
	MIN	59.09	8.05	64.92	59.09	54.57	5.47	66.94	54.57	45.86	7.65	63.52	45.86

* means financial holding company (FHC).

value of efficiency (infeasible) and so the three tied for first.

The Super-Threshold model estimates of the results for 2004 show the worst performance is Seventh Bank with an efficiency value of 64.92. The second worst is Hwa Tai Bank, and third worst is Cota Bank. The best efficient performance is Chinatrust, and then Land Bank and Cooperative Bank, but the three could not estimate the value of efficiency (infeasible).

The modified-super model estimates the results in 2004 and the worst performance is Seventh Bank with an efficiency value of 59.09. The second worst is Hwa Tai Bank, and the third worst is Bowa Bank. The best efficient performances are Chinatrust, Land Bank, and Cooperative Bank, but the efficiencies of the three are all 12,500 - far higher than the other banks.

The Super-SBM model estimates of the results show the worst performance is Seventh Bank with an efficiency value of 8.05. The second worst is Hualien Bank, and the third worst is Hua Tai Bank. The best performance is CDI Bank with an efficiency value of 136.72, followed by Chinatrust with an efficiency value of 132.93, and third is IBT with an efficiency value of 126.07.

The performance of Taiwanese banks in 2005

The Super-BCC model estimates of the results in 2005 show that the worst performance is Seventh Bank with an efficiency value of 54.57. The second worst is Hwa Tai Bank with efficiency value 55.55, and the third worst is Bowa Bank with efficiency value 60.27. The best performances for efficiency are Chinatrust, Land Bank, and Bank of Taiwan tied for first, but the three are not able to estimate the value of efficiency (infeasible).

The super-threshold model estimates show that in 2005 the worst performance is Bowa Bank with efficiency value 66.94. The second worst is Hwa Tai Bank with efficiency value 67.01, and the third worst is Seventh Bank with efficiency value 68.61. The best efficient performances are Chinatrust, Land Bank, and Bank of Taiwan, but the three tied for first and cannot be estimated (infeasible).

The Super-Modified model estimates show that the worst performance is Seventh Bank and its efficiency value is estimated at 54.57. The second worst is Hwa Tai Bank with efficiency value 55.55, and the third worst is Bowa Bank with efficiency value 60.27. The three best efficient performances are tied for first with Chinatrust, Land Bank, and Bank of Taiwan having an efficiency of 10,500, or far higher than that of other banks.

The Super-SBM model shows that the worst performance is Hualien Bank with efficiency value 5.47. The second worst is Seventh Bank with efficiency value 9.07, and the third worst is Cota Bank with efficiency value 26.97. The best performance is CDI Bank with efficiency value 161.96, followed by Chinatrust with efficiency value 133.72, and then Bank of Taiwan with efficiency value 130.75.

The performance of Taiwanese banks in 2006

The Super-BCC model estimates show that in 2006 the worst performance is Bowa Bank and its efficiency value is estimated at 45.86. The second worst is Hwa Tai Bank with efficiency value 54.83, and the third worst is Bank of Overseas Chinese with efficiency value 55.21. Though the best performances and tied for first are Chinatrust, Bank of Taiwan, and Cooperative Bank, the three are not able to be estimated (infeasible).

The Super-Threshold model estimates show that the worst performance is Hwa Tai Bank with an estimated 63.52, the second worst is Shanghai Bank with efficiency value 69.49, and the third worst is Bowa Bank with efficiency value 73.78. The best efficiency performances are Chinatrust, Land Bank, and Bank of Taiwan, but the three are not able to be estimated (infeasible).

The Modified-Super model estimates show that the worst performance is Bowa Bank at 45.86, the second worst is King's Town Bank with efficiency value 5.256, and the third worst is Hwa Tai Bank with efficiency value 54.82. The best efficiency performances are Chinatrust, Cooperative Bank, and Bank of Taiwan with efficiency value 11,200, and then followed by CDI Bank with efficiency value 361.27, and third best is Mega Bank with estimated efficiency value 214.42.

The Super-SBM model estimates show that the efficiency score of Hualien Bank is the worst at 7.65, the second worst is Hwa Tai Bank with efficiency value 26.02, and the third worst is Cota Bank with efficiency value 29.2. The best performance is CDI Bank with efficiency value 221.02, followed by Bank of Taiwan with efficiency value 132.64, and third is Chinatrust with efficiency value 127.45.

Comparison of the efficiency scores estimated by the four models

A comparison of the efficiency scores estimated by the four models shows that the Modified Super model estimates of the maximum value are much higher than the other models, and the Super-SBM model estimates of the minimum are below the other models. For the average score of efficiency, the Super-SBM model estimates the minimum average value of efficiency, and the modified super model estimates the maximum average value and variance of efficiency. As mentioned above, the Super-BCC model based on the BCC model excludes the DMU from the reference set so as to further distinguish the value of super-efficiency, while the Super-Threshold model is improved for the Super–BCC model and the difference is in the setting of parameters. The Super-Threshold model excludes the extreme value from the reference set, and so the estimated results of two similar models for extreme efficiency are infeasible. The Super-SBM model and Modified-Super model can estimate the efficiency value of all DMUs, but the Modified Super model has a greater degree of variability.

Using the traditional DEA model presents that there are 16, 12, and 13 efficient banks (efficiency score of 1) in 2004, 2005, and 2006, respectively. Therefore, it is not suitable to estimate the efficiency scores of Taiwanese banks through traditional DEA. In this paper the efficiency of Taiwan's banking sector shows that the Super-BCC model and Super-Threshold model have an infeasible problem, while the Super-SBM model and Modified-

Table 3. Pearson correlation coefficients of efficiency score.

	Super-BCC	Super-SBM	Super-Threshold	Modified-Super
Super-BCC	1	0.873	0.908	1
Super-SBM	0.873	1	0.833	0.873
Super-threshold	0.908	0.833	1	0.908
Modified-super	1	0.873	0.908	1

Table 4. Spearman correlation coefficients of efficiency ranking.

	Super-BCC	Super-SBM	Super-Threshold	Modified-Super
Super-BCC	1	0.871	0.781	1
Super-SBM	0.871	1	0.754	0.871
Super-threshold	0.781	0.754	1	0.781
Modified-super	1	0.871	0.781	1

Super model are successful in estimation. Thus, the Super-SBM model and Modified-Super model have better results. In other words, when the DMUs have a closer performance, there will be many efficient DMUs and will cause the ranking problem by traditional DEA. Using the Super-SBM Model and Modified-Super model is therefore a good choice.

The correlation analysis

The four DEA models were calculated with the Pearson correlation coefficient of efficiency score and Spearman correlation coefficients of efficiency ranking as shown in Tables 3 and 4. The tests of the correlations are significantly positively correlated, and the estimated results show model consistency.

As shown in Tables 3 and 4, the Modified–Super model and super-BCC model are perfectly positively correlated. The DEA estimates the relative efficiency of the numerical, and therefore all elements of the DMUs to a fixed percentage do not affect the relative efficiency performance. Thus, the Modified-super model multiplies the inputs at a specific ratio, but it does not change the efficiency score, and the two estimated results are entirely relevant. However, the Modified-Super model provides all the efficiency score of DMUs and facilitates further analysis of the slack variables or economies of scale. For a practical application, the Modified-super model seems to be better than the Super-BCC model.

FHC comparison with the non-FHC

The samples are divided into financial holding companies and non-financial holding companies, and then the four models compare the estimated results. Because the super-BCC model and Super-Threshold model are infeasible, the statistics cannot be compared. The statistics are in Tables 2 and 5.

Table 2 shows that the financial holding companies perform better than the non-financial holding companies. From further testing the differences (Table 5), the performances of FHCs are significantly better than non-FHCs, aside from the Super-Threshold model, which causes a different organizational structure. We further analyze the efficiency performance of the top 10, which include five FHCs and five non-FHCs. Banks can have a better ranking by joining an FHC, which may improve their performance or scales of economies. Therefore, the organizations of banks should tie in the attributes and customers' demand for segmentation choices in providing diversified services or specialized services and in order to satisfy the needs of different groups of customers.

The result of the Tobit method

In this section we first establish A, B, C, and D models (Super-BCC model, Super-SBM Model, Super-Threshold Model, and Modified Super-Efficiency Model) and use the Tobit regression model to compare the differences between them.

From Table 4-6, we find that the coefficients of LOAN_TA are statistically significant at the 1% level with efficiencies in models A, B, and C, but not in model D. This implies that the higher ratio of LOAN_TA in a bank results in specialized operations, decreasing bank efficiency. The ROA coefficients are statistically significant at the 1% level in efficiencies in models A, B, and C. The term LOAN_share (market concentration power) has a significantly positive influence on efficiencies in model B. A high concentration of market power can increase efficiency. The BRANCH coefficient is statistically

Table 5. The test of efficiency scores of FHCs and non-FHCs.

	Super-BCC	Super-SBM	Super-threshold	Modified-super
T value	2.343*	3.683*	2.235	2.343*
P-value	0.023334	0.000452	0.02981	0.023334

Table 6. The Tobit regression results of efficiency scores.

Dependent variable	Super-BCC model(A)	Super-SBM model(B)	Super-threshold model (C)	Modified -super model(D)
Constant	155.2829***	115.3564***	170.6483***	-435.9534
	(9.7946)	(8.8334)	(10.1527)	(-0.9763)
NPL	0.1138	-0.8287	-0.2128	25.6532
	(0.1174)	(-1.0342)	(-0.2063)	(0.9362)
CAP_RA	-0.0182	-0.0244	-0.0174	0.2294
	(-0.5726)	(-0.9241)	(-0.5128)	(0.2541)
Loan_TA	-81.6643***	-62.6225***	-67.0729***	32.2073
	(-4.2186)	(-3.8820)	(-3.2304)	(0.0584)
ROA	11.5247***	7.8104***	10.3507***	49.0466
	(5.8365)	(4.7745)	(4.9161)	(0.8768)
Loan_share	313.5776	494.1241*	535.0435	7868.657
	(1.1028)	(1.9877)	(1.6722)	(0.9257)
Branch	-0.2234	-0.1765	-0.2828*	8.5667**
	(-1.7303)	(-1.6602)	(-2.0667)	(2.3562)
Age	-0.1707	-0.3065	-0.2033	-5.0105
	(-0.7945)	(-1.7209)	(-0.8869)	(-0.8226)
Group	19.6573**	16.8579**	16.1076	-499.1738**
	(2.4932)	(2.5937)	(1.9255)	(-2.2459)

z value in parenthesis. *, **, and *** denote significance at the 10, 5, and 1% levels, respectively.

significant at the 10% level in efficiencies in model C, but the BRANCH coefficient is statistically significant positive in the efficiencies in model D. The coefficients of GROUP are significantly, positively correlated with efficiencies in models A and B, but the coefficient of GROUP is significantly, negatively correlated with efficiencies in model D.

In model A the major factors with a significant impact on efficiencies consist of total loans to total assets ratios, ROA, and group. In model B the major factors with a significant impact on efficiencies consist of the total loans to total asset ratios, ROA, bank share of market loans, and group. In model C the major factors with a significant impact on efficiency consist of the total loans to total asset ratios, ROA, and the number of branches. In model D the major factors with a significant impact on efficiency consist of the number of branches and group.

Conclusion

Taiwan's financial market has changed its industrial structure through financial innovations, and coupled with global capital markets' rapid changes and different economic environment external conditions, banks need to operate and develop diversified investment channels to maintain their survival. In order to construct an internationally competitive financial environment and management mechanism, Taiwan in 2001 implemented the Financial Holding Company Law, which permits financial operators to conduct business in inter-banking, securities, and the insurance industry, because the purpose of this was to push financial institutions towards equity decentralization and to become larger. So far, there are 14 financial holding companies and they were set up before 2004. This paper has estimated the efficiency scores of Taiwan's banks for 2004-2006 and compared the different organizational structures under banks' operating performances.

If Taiwan's banks are estimated by the traditional DEA, then there is an infeasible problem, because of their small size and number of banks. The result is not being able to rank a correct performance for comparison. To improve this problem, the paper has adopted scholars' different models to avoid such a problem and has taken the Tobit regression to investigate bank efficiency effect. The results of this paper are discussed and compared below.

1. Traditional DEA shows more efficient decision making units in estimating Taiwan's bank, and in order to solve the problem of ranking, adopting the Modified-Super model is more suitable.
2. The Modified Super model's scores are higher than the other models, and the Super-SBM model's scores are lower than the other models.
3. The Super-BCC model and Super-Threshold model are still unable to estimate the infeasible problem. The Super-SBM model and Modified Super model can fully estimate the efficiency scores of DMUs, but the Modified-Super model has a greater degree of variability.
4. The efficiency scores or efficiency ranking show that the four models are significantly positively correlated, and the estimated results of the four models show consistency.
5. Except for the Super-Threshold model, the banks of financial holding companies are significantly better than those in non-financial holding companies.
6. The results of the Tobit regressions show that total loans to total asset ratios, ROA, bank share of market loans, the number of branches, and group play important roles in efficiency.

The empirical results from the above say that when the performances of the decision-making unit get closer, then using the Super-SBM model and Modified-Super model is a better option. The Modified-Super model is based on the Super-BCC model, but as the Modified-Super model provides all the efficiency scores of DMUs, the Modified-Super model seems to be better than the Super-BCC model for practical application.

The banks of financial holding companies on average perform better than those of non-financial holding companies. Further analysis of the top-10 banks (five each in FHCs and non-FHCs) found this phenomenon for efficiency ranking: banks in FHCs operate by upgrading in addition to providing diversified financial products and enjoying economies of scale, while banks of non-FHCs can improve efficiency through specialized business practices. Therefore, banks should tie in their attributes and customers' demand for segmentation in choice by providing diversified services or specialized services and this should help satisfy the needs of different groups of customers.

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