1. Introduction

There has been a worldwide trend for financial institutions to become larger in scale and more diversified in terms of their scope. The emergence of the financial holding company (FHC), which has already become popular in the United States, Europe, and Japan, is one of the classic ways in which financial service institutions have begun to operate across industries. In referring to the financial reform experiences of other countries, the Taiwan government successively passed legislation to enable local financial institutions to merge with or acquire other financial institutions in order to cope with the problems of over-competition in this small economy. Fourteen financial holding companies (FHCs) have each begun to function as a management umbrella in Taiwan by investing in different types of financial services such as banking, insurance, and securities. This paper focuses on this local financing issue from an integrated methodological perspective by model innovations proposed in several earlier studies. For example, the efficiency of profitability and marketability are combined to evaluate the FHCs’ performance. To conduct a valid and reliable evaluation process while applying the FHC’s case in Taiwan, we integrate the slacks-based measure (SBM) and slacks-based measure of super efficiency (super-SBM) models in order to directly handle the slacks and identify the best performers. A new scheme that deals with the negative output data in the SBM/super-SBM is also introduced. Inter-temporal efficiency change, which is decomposed into ‘catch-up’ and ‘frontier-shift’ effects, is analyzed by means of the SBM-based Malmquist index.

There has been a worldwide trend for financial institutions to become larger in scale and more diversified in scope, with Taiwan being no exception. Fourteen financial holding companies (FHCs) have each begun to function as a management umbrella in Taiwan by investing in different types of financial services such as banking, insurance, and securities. This paper focuses on this local financing issue from an integrated methodological perspective by model innovations proposed in several earlier studies. For example, the efficiency of profitability and marketability are combined to evaluate the FHCs’ performance. To conduct a valid and reliable evaluation process while applying the FHC’s case in Taiwan, we integrate the slacks-based measure (SBM) and slacks-based measure of super efficiency (super-SBM) models in order to directly handle the slacks and identify the best performers. A new scheme that deals with the negative output data in the SBM/super-SBM is also introduced. Inter-temporal efficiency change, which is decomposed into ‘catch-up’ and ‘frontier-shift’ effects, is analyzed by means of the SBM-based Malmquist index. A decision-making matrix is also presented to help the FHCs’ managerial authorities position themselves in the industry. The above techniques show with a high degree of consistency that large-sized FHCs perform better than small-sized ones.
Efficiency has for a long period of time been an important topic in banking research. Data envelopment analysis (DEA) is one of the techniques commonly used to measure bank efficiency. Major academic journals have published special issues on banking efficiency using the DEA technique, including the *European Journal of Operational Research* in 1997, the *Journal of Economics and Business* in 1998, and *Management Science* in 1999. Most previous studies placed emphasis on the efficiency of profitability using the production approach (Sherman and Gold, 1985; Ferrier and Lovell, 1990) or the intermediation approach (Miller and Noulas, 1996; Haslem et al., 1999). One can refer other approaches in Golany and Storbeck’s (1999), Sherman and Rupert’s (2006), Bergendahl and Lindblom’s (2008), García-Cestona and Surroca’s (2008) studies. However, while the efficiency of profitability is important for an FHC, marketability is also crucial, because the value of an FHC is ultimately assessed by the stock market. This viewpoint is representative of Taiwan’s financial service industries, for once a financial institution is merged with or acquired by another as part of an FHC, its stock should be exchanged in the stock market with that of the FHC in accordance with a certain ratio. In a way that differs from previous research, we integrate the profitability as well as the efficiency of marketability to evaluate the FHCs’ performance based on Seiford and Zhu’s (1999) model. Seiford and Zhu (1999) initially employed the DEA technique to propose a two-stage production process that examined the efficiency of the top 55 US commercial banks. The value-creating process of an FHC consists of two stages as shown in Fig. 1. The first, involving the profitability performance model (Stage-1), measures an FHC’s ability to generate revenues and profits and consists of three inputs (assets, stockholders’ equity, and employees) and two outputs (revenues and profits). The marketability performance model (Stage-2) measures an FHC’s attractiveness in the stock market, and consists of two inputs (revenues and profits) and two outputs (market value and earnings per share (EPS)). This two-stage model is also applied in other industries in the US (Zhu, 2000; Luo, 2003).

DEA, which was first developed by Charnes et al. (1978) (CCR model), is a methodology for constructing a best practice frontier, which tightly envelops observed data on producers’ inputs and outputs. Expanded DEA models were subsequently established, such as the BCC model (Banker et al., 1984), the Russell measure (Russell, 1985), and the range-adjusted measure (Aida et al., 1998). From a methodological point of view, however, these traditional DEA techniques fail to achieve our purpose in examining the FHCs in Taiwan for the following reasons:

- First, traditional DEA techniques directly assign ‘input-oriented’ or ‘output-oriented’ models that may lack objectivity in terms of reflecting the real input/output conditions for each decision-making unit (DMU). As in the two-stage production model used in this study, it is hard to assign input/output-oriented models without being subjective. In other words, non-radial measures, instead of radial measures, which deal directly with the input excesses and the output shortfalls of the DMUs, should be a main concern when seeking to achieve more realistic results.

- Secondly, a crucial issue is concerned with how to deal with negative output/input data in the slacks-based measure models. As in the case of the two-stage production model used in this study, profit is a negative output in the first stage and a negative input in the second stage. Therefore, when engaging in performance evaluations for the 14 FHCs in Taiwan, advanced techniques are needed to deal with the negative output/input data in the slacks-based measure models.

- Third, while forming an efficiency frontier to determine the efficiency score for each DMU, the results could be biased due to extreme values. For example, a small-sized DMU may have to refer to the input/output allocation experiences of some super large-sized DMUs, which cannot be achieved in reality. This technical problem should be taken care of in this study since the assets of the largest FHC are more than ten times as large as those of the smallest FHC in Taiwan. Inefficient FHCs are more likely to make progress by learning from their peers that are similar in size.

- Fourth, in most DEA models, while the number of DMUs may be small, there will be multiple DMUs exhibiting an ‘efficient’ status with a score of one. Engaging in DEA with a small number of DMUs compared to the number of criteria used for evaluation can lead to problems in determining which DMUs are the best performers. Therefore, when conducting a performance evaluation of 14 FHCs in Taiwan, advanced techniques are needed to identify which are the best performers.

To overcome the methodological shortfalls referred to above when evaluating the performance of FHCs in Taiwan, we adopt advanced DEA techniques, slacks-based measures (SBM) and slacks-based measures of super efficiency (super-efficiency-SBM), as proposed by Tone in 2001 and 2002, respectively. In contrast to the CCR and BCC measures, which are based on the proportional reduction in input vectors or the increase in output vectors without taking slacks into account, the SBM deals directly with input excesses and output shortfalls (slacks). The SBM reports an efficiency

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1 Variable ‘stock price’ is also included as an output in Seiford and Zhu’s (1999) model. Since stock price is more meaningful when multiplied by the number of shares to get the market value variable, which is already included, we therefore abandon this variable in this study.

2 This two-stage model is also applied in Seiford and Zhu’s (1999) model. Since stock price is more meaningful when multiplied by the number of shares to get the market value variable, which is already included, we therefore abandon this variable in this study.
measure of between 0 and 1, and gives an efficiency score of one if and only if the DMU concerned is on the frontier of the production possibility set with no input/output slacks. Furthermore, the SBM model possesses several desirable properties that can properly handle our research interests. For instance, this measure is unit invariant and monotone decreasing with respect to input excesses and output shortfalls; it is determined only by consulting the reference-set of the DMUs and is not affected by statistics over the whole data set; and it is closely connected with other measures, e.g., those in the CCR and BCC models and the Russell measure. On the other hand, the super-efficiency-SBM is particularly useful in distinguishing efficient DMUs when the number of DMUs is small compared with the number of evaluation criteria. The application of the SBM and super-SBM models is expected to produce more valid results and more persuasive investigation into the efficiency of the FHCs in converting multiple inputs into multiple outputs. Cross-period efficiency analysis is also presented to decompose the inter-temporal efficiency change into ‘catch-up’ and ‘frontier-shift’ in accordance with the SBM-based Malmquist index.

In addition to this introductory section, there are five more sections in this paper. Section 2 defines the performance model used in this study. Section 3 introduces the sample and data collection. Section 4 provides the literature review on various advanced DEA models. Section 5 presents the empirical results and analysis. Finally, the concluding remarks are given in the last section.

2. Performance models

Since a company’s performance is a complex phenomenon that cannot be characterized by just a single criterion, a number of studies have argued that a multi-factor performance measurement model may be used (Bagozzi and Phillips, 1982; Chakravarthy, 1986), Seiford and Zhu (1999), Zhu (2000) and Luo (2003) develop a multi-factor performance measure model for US companies. This study adopts Seiford and Zhu (1999) two-stage transformation process (Fig. 1) to design two performance models, namely, a profitability performance model and a marketability performance model.3

From Fig. 1, it can be seen that the profitability performance model (Stage-1) measures an FHC’s ability to generate revenue and profit consists of three inputs (assets, stockholders’ equity, and employees) and two outputs (revenues and profits). The marketability performance model (Stage-2) that measures an FHC’s attractiveness in the stock market consists of two inputs (revenues and profits) and two outputs (market value and earnings per share (EPS)). The output and input factors (seven financial measures) used in this study are defined as follows:

- Employees comprise all staff members in an FHC.
- Revenues include those of consolidated subsidiaries and exclude excise taxes.
- Profits are after taxes, after extraordinary credits or charges, and after the cumulative effects of accounting charges.
- Assets are the company’s year-end total.
- Equity is the sum of all capital stock, paid-in capital, and retained earnings at the company’s year-end.
- Market value is obtained by multiplying the number of common shares outstanding by the price per common share at the last exchange date end of the year.
- The EPS for each company is the primary earnings per share appearing in the income statement.

3. Sample and data

This paper uses a sample of 14 FHCs in Taiwan. Each of these FHCs is treated as a decision making unit (DMU) in the DEA analysis. At the end of 2004, there were 14 FHCs operating, and we therefore include all of these in our investigation. Since 14 FHC licenses had been issued by the end of 2003 in Taiwan, we use the data for two years, namely, 2003 and 2004. The input and output data were extracted from the Taiwan Economic Journal (TEJ) data bank, which is generally regarded as being valid, reliable, and available to the public. The complete data set is presented in Table 1. Table 2 presents the descriptive statistics for our data set in 2004. From this table, we can observe that the deviations in the variables used are quite large because of the various sizes of the FHCs.

The DEA technique presumes the existence of a relationship among the input and output data, and a correlation analysis is therefore performed in Table 3. It can be observed that most input factors are highly correlated with output factors with score larger than 0.2. implying that the FHC that employs more input resources will increase its revenue and market value. According to Golany and Roll (1989), the number of FHCs should be at least twice the total number of input and output factors considered when using the DEA model. In this study the number of FHCs is 14, which is at least twice the five factors selected for the profitability performance model. We hence conclude that the DEA model developed based on the profitability performance model has met construct validity requirement. By following the same rules, the marketability model in this study is also found on required validity issue.

4. DEA models

This section briefly introduces the DEA models used to assess the relative efficiency in the current period (the year 2004) and the efficiency variation in the cross-period (from 2003 to 2004). Detailed descriptions of the specific evaluation model used in this study are also presented. The procedures adopted are as follows. First, we employ Tone (2001)’s slacks-based measure (SBM) model to evaluate the performance of the FHCs in the current period. The super-efficiency-SBM model (Tone, 2002) is then used to rank the best performers from those exhibiting an efficiency score of one. Finally, we use the SBM-based Malmquist approach (Tone, 2005) that combines the SBM model and super-efficiency-SBM model to measure the variation in efficiency in the cross-period for FHCs in Taiwan.

4.1. Slacks-based measure (SBM) model

As described in Cooper et al. (2000), there are a variety of DEA models that can be categorized into two forms. The first one consists of radial models, such as the CCR model by Charnes et al. (1978), and the BCC model by Banker et al. (1984). The second form includes the non-radial models that are characterized by the additive model (Charnes et al., 1985a), the Russell measure (Russell, 1985), the range-adjusted measure (Aida et al., 1998), and the SBM model (Tone, 2001).

We choose the SBM model as the appropriate version of DEA for the purposes of this study. The SBM model possesses some desirable features which are suitable for investigating the efficiency of the process of converting multiple inputs into multiple outputs. These features include: (1) a scalar measure that deals directly
The non-oriented SBM model evaluates the efficiency of the target DMU, by solving the following fractional programs:

\[
\begin{align*}
\text{Min } & \quad \eta_o = \left(1 - \frac{1}{m} \sum_{i=1}^{m} s_i \right) \left(1 + \frac{1}{s} \sum_{r=1}^{s} y_r / y_{ro} \right) \\
\text{subject to } & \quad x_{io} = \sum_{j=1}^{n} y_j x_{ij} + s_i^-, \quad i = 1, \ldots, m, \\
& \quad y_{ro} = \sum_{j=1}^{n} y_j x_{ij} + s_i^+, \quad r = 1, \ldots, s, \\
& \quad \sum_{j=1}^{n} y_j x_{ij} = 1, \\
& \quad y_j \geq 0, s_i^- \geq 0, s_i^+ \geq 0.
\end{align*}
\]

where \( n \) is the number of DMUs; \( x_{io} > 0 \) and \( y_{ro} > 0 \) are the level of the \( i \)th input and \( r \)th output, respectively, at the \( j \)th DMU; and \( y_j \) is the weight of the \( j \)th DMU. Here the target DMU is the DMU being evaluated. Eq. (1) requires that the sum of the weights must be equal to one. This suggests that the constructed best practice frontier exhibits variable returns to scale technology, i.e., the frontier permits increasing, constant, and decreasing returns to scale. Hence, the efficiency score obtained from Eq. (1) reflects the DMU’s current scale of operations and is referred to as “pure” technical efficiency, thus representing the ability of management to transform inputs in order to produce outputs. A DMU is regarded as ‘SBM efficient’ if

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Data set of 14 FHCs from 2003 to 2004 in Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assets (NT$100 million)</td>
</tr>
<tr>
<td>2003 FHC</td>
<td></td>
</tr>
<tr>
<td>Cathay</td>
<td>23416.96</td>
</tr>
<tr>
<td>Shin Kong</td>
<td>7205.94</td>
</tr>
<tr>
<td>Fubon</td>
<td>12583.94</td>
</tr>
<tr>
<td>Mega</td>
<td>17579.80</td>
</tr>
<tr>
<td>First</td>
<td>14787.02</td>
</tr>
<tr>
<td>Chinatrust</td>
<td>12132.11</td>
</tr>
<tr>
<td>Hua Nan</td>
<td>14654.86</td>
</tr>
<tr>
<td>Taishin</td>
<td>6309.14</td>
</tr>
<tr>
<td>SinoPac</td>
<td>5716.97</td>
</tr>
<tr>
<td>E.SUN</td>
<td>3344.61</td>
</tr>
<tr>
<td>Fuhwa</td>
<td>3120.23</td>
</tr>
<tr>
<td>Chian development</td>
<td>2961.11</td>
</tr>
<tr>
<td>Jhsun</td>
<td>2713.13</td>
</tr>
<tr>
<td>Waterland</td>
<td>416.56</td>
</tr>
<tr>
<td>2004 FHC</td>
<td></td>
</tr>
<tr>
<td>Cathay</td>
<td>26500.78</td>
</tr>
<tr>
<td>Shin Kong</td>
<td>9313.44</td>
</tr>
<tr>
<td>Fubon</td>
<td>15130.88</td>
</tr>
<tr>
<td>Mega</td>
<td>21290.05</td>
</tr>
<tr>
<td>First</td>
<td>15025.42</td>
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<tr>
<td>Chinatrust</td>
<td>14289.79</td>
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<tr>
<td>Hua Nan</td>
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</tr>
<tr>
<td>Taishin</td>
<td>8647.55</td>
</tr>
<tr>
<td>SinoPac</td>
<td>5949.51</td>
</tr>
<tr>
<td>E.SUN</td>
<td>4978.83</td>
</tr>
<tr>
<td>Fuhwa</td>
<td>3665.23</td>
</tr>
<tr>
<td>Chian development</td>
<td>2603.77</td>
</tr>
<tr>
<td>Jhsun</td>
<td>3228.51</td>
</tr>
<tr>
<td>Waterland</td>
<td>2187.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Descriptive statistics for the 14 FHCs in 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Mean</td>
</tr>
<tr>
<td>Assets (NT$100 million)</td>
<td>10961.90</td>
</tr>
<tr>
<td>Equity (NT$100 million)</td>
<td>848.83</td>
</tr>
<tr>
<td>Employees</td>
<td>9085</td>
</tr>
<tr>
<td>Revenues (NT$100 million)</td>
<td>1047.71</td>
</tr>
<tr>
<td>Profits (NT$100 million)</td>
<td>95.24</td>
</tr>
<tr>
<td>EPS (NT$)</td>
<td>1.81</td>
</tr>
<tr>
<td>Market value (NT$100 million)</td>
<td>159286.79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Correlation coefficients among inputs and outputs in 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>Equity</td>
</tr>
<tr>
<td>Assets</td>
<td>1.000</td>
</tr>
<tr>
<td>Equity</td>
<td>0.799</td>
</tr>
<tr>
<td>Employees</td>
<td>0.746</td>
</tr>
<tr>
<td>Revenues</td>
<td>0.717</td>
</tr>
<tr>
<td>Profits</td>
<td>0.783</td>
</tr>
<tr>
<td>EPS</td>
<td>0.730</td>
</tr>
<tr>
<td>Market value</td>
<td>0.861</td>
</tr>
</tbody>
</table>
and only if \( \eta_i^o = 1 \). The value of \( \lambda_j \) indicates whether the \( j \)th DMU serves as an exemplar from which the target DMU can learn.

Eq. (1) can be transformed into the program by introducing a positive scalar variable \( t \) (Charnes and Cooper, 1962).

\[
\text{Min } \tau_o = t - \frac{1}{m} \sum_{i=1}^{m} t \xi_i^o / x_{io} \\
\text{s.t. } 1 = t + \frac{1}{s} \sum_{r=1}^{s} t \xi_{r}^o / y_{ro} \\
x_{io} = \sum_{i=1}^{n} x_i \xi_j^o + S_i^-, \quad i = 1, \ldots, m, \\
y_{ro} = \sum_{j=1}^{n} y_j \xi_j^o - S_r^+, \quad r = 1, \ldots, s, \\
\sum_{j=1}^{n} \xi_j^o = 1, \\
\lambda_j \geq 0, S_i^- \geq 0, S_r^+ \geq 0, t > 0.
\]

Now let us define
\[
S_i^o = t \xi_i^o, \quad S^+ = t \xi_{r}^o, \quad \Gamma = t \lambda_j.
\]

Then Eq. (2) becomes the following linear program in \( t, S_i^o, S^+, \) and \( \Gamma \):

\[
\text{Min } \tau_o = t - \frac{1}{m} \sum_{i=1}^{m} S_i^o / x_{io} \\
\text{s.t. } 1 = t + \frac{1}{s} \sum_{r=1}^{s} S_r^+ / y_{ro} \\
x_{io} = \sum_{j=1}^{n} x_j \Gamma_j + S_i^-, \quad i = 1, \ldots, m, \\
y_{ro} = \sum_{j=1}^{n} y_j \Gamma_j - S_r^+, \quad r = 1, \ldots, s, \\
\sum_{j=1}^{n} \Gamma_j = t, \\
\Gamma_j \geq 0, S_i^- \geq 0, S_r^+ \geq 0, t > 0.
\]

Note that \( t > 0 \) by virtue of the first constraint. This means that the transformation is reversible. Thus let an optimal solution of Eq. (3) be

\((\tau_o^*, t^*, \Gamma^*, S_i^{o*}, S^*, \cdot^*)\).

We then have an optimal solution of Eq. (1) defined by

\[\eta_i^o = \tau_o^*, \quad \lambda_j^* = \Gamma_j^*/t^*, \quad S_i^{o*} = S_i^*/t^*, \quad S^* = S^*/t^*\] 4.2. Super-efficiency-SBM model

In most DEA models, the best performers share the fully efficient status denoted by a score of one. From experience, it is possible that multiple DMUs usually exhibit ‘efficient’ status. The super-efficiency model can distinguish ‘real’ benchmarks among these efficient DMUs. The basic concept is that the efficient observed DMU concerned is taken out from the production possibility set (PPS). The distance from the observed DMU to the point located on the remaining PPS is therefore to be measured. If the distance is small, the super-efficiency of the DMU is high compared to the remaining DMUs. Hence, we can rank the efficient DMUs in the order of the super-SMB scores obtained. However, the main problem is how to define the ‘distance’ between an efficient DMU and the PPS formed by excluding the DMU. The non-oriented super-SBM model proposed by Tone (2002) is a proper solution for evaluating the super-efficiency of the observed DMU, \( (x_{io}, y_{ro}) \) by solving the following fractional programs:

\[
\text{Min } \pi_o = \left( \frac{1}{m} \sum_{i=1}^{m} \xi_i / x_{io} \right) \left( \frac{1}{s} \sum_{r=1}^{s} \gamma_r / y_{ro} \right) \\
\text{s.t. } \xi_i \geq \sum_{j=1}^{n} x_j \gamma_j, \quad i = 1, \ldots, m, \\
\gamma_r \leq \sum_{j=1}^{n} y_j \gamma_j, \quad r = 1, \ldots, s, \\
\sum_{j=1}^{n} \gamma_j = 1, \\
\xi_i \geq x_{io}, \gamma_r \leq y_{ro}, \gamma_r \geq 0, \lambda_j \geq 0.
\]

The point \((\xi_i, \gamma_r)\) is located on the remaining PPS. The numerator of the objective function is a weighted \( l \) distance from \( x_{io} \) to \( \xi_i (\geq x_{io}) \), and hence it expresses an average expansion rate of \( x_{io} \) to \( \xi_i \) of the point \((\xi_i, \gamma_r)\). The denominator of the objective function is a weighted \( l \) distance from \( y_{ro} \) to \( \gamma_r \leq y_{ro} \), and hence is an average reduction rate for \( y_{ro} \) to \( \gamma_r \) of the point \((\xi_i, \gamma_r)\). The smaller the denominator is, the farther \( y_{ro} \) is positioned relative to \( \gamma_r \). Its inverse can be interpreted as an index of the distance from \( y_{ro} \) to \( \gamma_r \). Therefore, \( \pi_o \) is a product of two indices: one is the distance in the input space, and the other is the distance in the output space.

Let us introduce \( \phi = \Phi / \Theta \) and \( \theta \in R^n \) such that \( \xi_i = x_{io} / (1 + \phi_i) \) and \( \gamma_r = y_{ro} / (1 + \theta_r) \). Then, this program can be equivalently stated in terms of \( \phi_i, \theta_i, \) and \( \lambda_j \) as follows:

\[
\text{Min } \pi_o = \frac{1 + \frac{1}{m} \sum_{i=1}^{m} \phi_i}{1 + \frac{1}{s} \sum_{r=1}^{s} \theta_r} \\
\text{s.t. } \sum_{j=1}^{n} x_j \gamma_j - x_{io} \phi_i \leq x_{io}, \quad i = 1, \ldots, m, \\
\sum_{j=1}^{n} y_j \gamma_j + y_{ro} \theta_r \geq y_{ro}, \quad r = 1, \ldots, s, \\
\sum_{j=1}^{n} \gamma_j = 1, \\
\phi_i \geq 0, \theta_i \geq 0, \lambda_j \geq 0.
\]

Eq. (5) can be transformed into the program by using a positive scalar variable \( t \) (Charnes and Cooper, 1962).

\[
\text{Min } \pi_o = t + \frac{1}{m} \sum_{i=1}^{m} t \phi_i \\
\text{s.t. } t - \frac{1}{s} \sum_{r=1}^{s} t \theta_r = 1 \\
\sum_{j=1}^{n} x_j \gamma_j - x_{io} \phi_i \leq x_{io}, \quad i = 1, \ldots, m, \\
\sum_{j=1}^{n} y_j \gamma_j + y_{ro} \theta_r \geq y_{ro}, \quad r = 1, \ldots, s, \\
\sum_{j=1}^{n} \gamma_j = 1, \\
\phi_i \geq 0, \theta_i \geq 0, \lambda_j \geq 0, t > 0.
\]

Now let us define
\[t \phi_i = \Phi_i, \quad t \lambda_j = \Lambda_j, \quad t \theta_r = \Theta_r \]

Then Eq. (6) becomes the following linear program in \( \Phi_i, \Lambda_j, \) and \( \Theta_r \).
Min \( \delta_0 = t + \frac{1}{m} \sum_{i=1}^{m} \Phi_i \)

s.t. \( t - \frac{1}{S} \sum_{j=1}^{S} \Theta_j = 1 \)

\[
\begin{align*}
\sum_{j=1}^{n} x_{ij} \lambda_j - x_{io} \Phi_l & \leq d_{io}, & i = 1, \ldots, m, \\
\sum_{j=1}^{n} y_{ij} \lambda_j + y_{io} \Theta_r & \geq d_{yo}, & r = 1, \ldots, s, \\
\sum_{j=1}^{n} \lambda_j & = t, \\
\Phi_l & \geq 0, \Theta_r & \geq 0, \lambda_j & \geq 0, t > 0.
\end{align*}
\]

Let an optimal solution of Eq. (7) be \((\delta_0^*, \Phi_l^*, \Theta_r^*, \lambda_j^*, t^*)\). Then we have an optimal solution of Eq. (5) expressed by

\[
\pi^*_o = \delta_0^*, \quad \lambda_j^* = A_j^*/t^*, \quad \phi_l^* = \Phi_l^*/t^*, \quad \theta_r^* = \Theta_r^*/t^*
\]

Furthermore, the optimal solution of Eq. (4) is given by

\[
x^*_o = x_o(1 + \phi_l^*) \quad \text{and} \quad y^*_o = y_o(1 - \theta_r^*).
\]

4.3. Non-positive output/input data in the SBM/super-SBM models

In the case of the SBM/super-SBM models, it is crucial to deal with negative outputs in the evaluation of efficiency, since negative data should play an important role in measuring efficiency. If neglected, a large deficit (loss) is worse than a small one, especially for profit (loss) in this case. We therefore employ a new scheme (Tone, 2004; Dützkin and Dützkin, 2007) to solve this problem:

Suppose \( y_{io} < 0 \). We define \( y_i^* \) and \( y_j^* \) by

\[
\begin{align*}
y_i^* & = \text{Max}_{j=1,\ldots,n}(y_{ij}/y_{io} > 0) \\
y_j^* & = \text{Min}_{j=1,\ldots,n}(y_{ij}/y_{io} > 0)
\end{align*}
\]

we replace the term \( s_i^*/y_{io} \) in the objective function in the following way (notice that we never change the value \( y_{io} \) in the constraints). If \( y_i^* > y_j^* \), the term is replaced by

\[
s_i^* / y_{io} - y_j^* / y_{io}.
\]

In any case, the denominator is positive and strictly less than \( y_j^* \). Furthermore, it is in inverse proportion to the distance \( y_j^* - y_{io} \). This scheme positively takes into account the magnitude of the non-positive output. The score obtained is also unit invariant, i.e., it is independent of the units of measurement used.

If the input variable is not positive, a positive amount is added to the negative value so that the value of that particular input variable becomes positive. This same adjustment must be made to the same input value for all DMUs included in the data in order to not alter the efficiency frontier. The modification may violate ‘translation invariant’ in SBM model, which affect the efficiency scores. However, the relative performances of DMUs are still to be unchanged (Bowlin, 1998).

4.4. Cross-period efficiency analysis – testing the SBM-based Malmquist index

The Malmquist index (MI) evaluates the change in efficiency of a DMU between two time periods. It is defined as the product of the ‘Catch-up’ and ‘Frontier-shift’ terms. The catch-up term is related to the amount of effort that a DMU makes to improve its efficiency, and the frontier-shift term reflects the change in the efficient frontiers surrounding a DMU between the two time periods \( t_1 \) and \( t_2 \).

Since the ‘Malmquist index’ is obtained as the product of \( \text{Catch-up} \) and \( \text{Frontier-shift} \), it can be presented as

\[
\text{Malmquist index} = \text{(Catch-up)} \times \text{(Frontier-shift)}.
\]

It is an index representing the total factor productivity (TFP) of a DMU, in that it reflects progress or regress in the efficiency of the DMU along with the progress or regress of the frontier technology.

We now employ the following notation for the efficiency score of the DMU \((x_o, y_o)^t\) measured by the frontier technology \( t_2 \):

\[
\delta^{t_2}((x_o, y_o)^{t_1})
\]

Using this notation, the ‘catch-up’ effect can be expressed as

\[
\text{Catch up} = \frac{\delta^{t_2}((x_o, y_o)^{t_2})}{\delta^{t_2}((x_o, y_o)^{t_1})}.
\]

The frontier-shift effect is described as

\[
\text{Frontier-shift} = \left[ \frac{\delta^{t_2}((x_o, y_o)^{t_1})}{\delta^{t_2}((x_o, y_o)^{t_2})} \right]^{1/2}
\]

As the product of Eqs. (12) and (13), we obtain the following formula for the computation of MI:

\[
\text{MI} = \left[ \frac{\delta^{t_2}((x_o, y_o)^{t_1})}{\delta^{t_2}((x_o, y_o)^{t_2})} \right]^{1/2}
\]

This last expression gives another interpretation of MI, i.e., the geometric means of the two efficiency ratios: one is the efficiency change measured by the technology in period \( t_1 \), and the other is the efficiency change measured by the technology in period \( t_2 \).

As can be seen from these formulae, the MI consists of four terms: \( \delta^{t_2}((x_o, y_o)^{t_1}), \delta^{t_2}((x_o, y_o)^{t_2}), \delta^{t_1}((x_o, y_o)^{t_2}) \) and \( \delta^{t_2}((x_o, y_o)^{t_1}) \). The first two are related to the measurements within the same time period, while the last two are used for intertemporal comparison. MI > 1 indicates the progress made in the total factor productivity of the DMUs from period \( t_1 \) to \( t_2 \), while MI = 1 and MI < 1 indicate, respectively, the status quo and decay in the total factor productivity.

In the non-parametric framework, the MI is constructed by means of DEA technologies. Färe et al. (1992, 1994a,b), utilized the input/output-oriented radial DEA model to compute MI. However, as discussed before, the radial model suffers from a shortcoming in that it neglects slacks. Therefore, the slacks-based non-oriented Malmquist index is employed in this study. The [Non-Oriented SBM] and [Non-Oriented Super-SBM] models used for computing \( \delta^{t_2}((x_o, y_o)^{t_1}) \) are represented by the following fractional programs:[Non-Oriented SBM]

\[
\delta^{t_2}((x_o, y_o)^{t_1}) = \text{Min} \left( \frac{1 - \frac{1}{m} \sum_{i=1}^{m} s_i / x_{io}^*}{1 + \frac{1}{S} \sum_{r=1}^{S} s_r / y_{ro}^*} \right)
\]

s.t. \( x_{io}^* = \sum_{j=1}^{n} x_{ij}^* \lambda_j + s_i^* + \delta_i, \quad i = 1, \ldots, m, \)

\( y_{ro}^* = \sum_{j=1}^{n} y_{ij}^* \lambda_j - s_r^*, \quad r = 1, \ldots, s, \)

\( \sum_{j=1}^{n} \lambda_j = 1, \)

\( \lambda_j \geq 0, s_i^* \geq 0, s_r^* \geq 0. \)

(15)
5. Results and analysis

5.1. Performance analysis for the current period

The evaluation of the FHCs’ profitability and marketability efficiencies is conducted for the year 2004. The non-oriented SBM model is applied to assess the relative performances of the 14 FHCs in Taiwan. To distinguish those efficient FHCs that can be treated as real benchmarks, the super-SBM model is used as a ranking measure. All of the results are shown in Table 4. The order (No.) of the FHCs is coded based on the respective sizes of the total assets.

The average scores computed from the SBM models based on the profitability and marketability models are 0.686 and 0.862, respectively. About half of the FHCs are inefficient in the profitability performance model. In the marketability performance model, six out of the 14 FHCs are inefficient. Even though some FHCs do not perform that well in generating profit or revenue compared to the resources invested, the stock market still responds positively to the super-SBM model. In the marketability performance model, FHCs with insurance as their main focus are also better performers. The reason for this result is that most large-sized FHCs are insurance companies in Taiwan.

5.2. Identification of benchmarks

Distinguishing among these efficient FHCs and identifying the benchmarks has become an interesting research subject. Several authors have proposed methods for ranking the best performers, including Andersen and Petersen (1993), Doyle and Green (1994), Tofallis (1996), Seiford and Zhu (1999), Zhu (2001), and Tone (2002). We refer to this problem as the ‘super-efficiency’ problem. The super-SBM model first proposed by Tone (2002) is an appropriate version of DEA for ranking these efficient FHCs in this study. Several characteristics of the super-SBM model have been discussed before, especially its ability to cope with a small number of DMUs compared to the number of evaluation criteria.

A FHC with higher super-SBM efficiencies reveals to be different in the input/output space, and thus to be either referenced by very few DMUs, or just by itself. From managerial implication, the FHC is a self-evaluator (Charnes et al., 1985b), i.e. niche player. The super-SBM efficiencies are reported for both the profitability and marketability models in Table 4. There are six technically efficient FHCs under the SBM model for the profitability stage. The order of ranking in descending order is Cathay (01), Waterland (14), Shin Kong (07), Mega (02), Taishin (08), and Chinatrust (06). In profitability model, Cathay (01) is a niche player in large-sized group; and Waterland (14) is a niche player in small-sized group. The super-SBM efficiency for the eight technically efficient FHCs in the marketability performance model is also reported herein. The order of ranking in descending order is China Development (13), Waterland (14), Cathay (01), Chinatrust (06), Mega (02), E.SUN (10), Taishin (08), and Shin Kong (07). In marketability model, Cathay (01) is a niche player in large-sized group; and China Development (13) is a niche player in small-sized group. We can therefore rank the efficient FHCs from the highest to the lowest in order to rank the best performers based on the resulting list to determine niche player.

5.3. Cross-period efficiency analysis

This section uses the model described in Section 4.4 to analyze the performance of effectiveness variations from 2003 to 2004. The results of the cross-period efficiency analysis are shown in Table 6.
The catch-up and frontier-shift effects, spanning from 2003 to 2004, can be calculated by means of the four equations described earlier. The product of the catch-up and frontier-shift is the Malmquist index (MI). If $MI > 1$, this indicates an improvement in efficiency by which is meant that the productivity of a specific FHC increases over the previous year; if $MI < 1$, this indicates a reduction in efficiency which means that the productivity of a specific FHC decreases over the previous year.

By taking the profitability model into consideration, while many small FHCs exhibit growth in terms of the catch-up effect, most large FHCs show expansion in terms of the frontier-shift effect. Generally speaking, large FHCs develop quite rapidly with their Malmquist indices exceeding a score of one. Small FHCs, on the contrary, regress quite rapidly compared to the previous year.

In the marketability model, small FHCs perform better than the large FHCs in terms of the catch-up effect. However, this effect is dominated by the frontier-shift effect where large FHCs outperform small ones. Generally speaking, the trends in terms of the catch-up and frontier-shift effects found in large/small FHCs are consistent in both the profitability and marketability models.

We can conclude that small FHCs demonstrate a positive catch-up effect in devoting their efforts to catching up on the efficiency frontier. However, since most large FHCs are on the efficiency frontier in the previous year, there is little room for improvement. On the other hand, due to the advantageous frontier-effect, most large FHCs break through the previous frontier in 2003, implying that the frontier moves forward due to the FHCs’ better technological capability.

From the standpoint of the managerial implications, the productivity of the small FHCs lags far more behind that of the large FHCs because of their inferior frontier-shift effects. These small FHCs endeavor to overtake the leading group in terms of raising efficiency, but fail to integrate their resources to compete with the large-sized ones. While large FHCs currently exhibit growth and competitiveness, small FHCs chase after them.

By combining the results of the relative efficiency and productivity change analyses, we design a decision-making matrix to help the FHCs’ managerial authorities to position themselves in the industry and to provide directions for improving efficiency. By taking the profitability model as an example, we first of all take the results in regard to the relative efficiency of the current period (the year 2004) as the horizontal axis of this matrix. A larger value indicates better managerial efficiency currently and less urgency for improvement, while a smaller value on the contrary currently means worse managerial efficiency and an urgent need for improvement. The cutting point is the score of one derived from the SBM measure. Secondly, we take productivity change as the vertical axis. Here, a larger value means a positive utilization of resources, a higher degree of managerial efficiency in the previous year, and a greater development potential. By contrast, a smaller value means an ineffective utilization of resources in the previous years, a smaller change in productivity, and a decline in development potential. The cutting point is the score of one derived from the Malmquist-SBM measure.

The decision-making matrix and the results of the analysis are shown in Fig. 2. This matrix can be divided into four groups by means of these two criteria: the relative efficiency in the current period (the managerial efficiency) and the productivity change across periods (the growth potential). This matrix can serve as a managerial decision-making matrix for further improvement efforts. The four groups of FHCs are described below:

**Those in zone I:** These FHCs enjoy better contemporary efficiency and increasing variation in productivity. Four FHCs are included here: Cathay (01), Mega (02), Chinatrust (06), and Taishin (08). These FHCs are role models for the others and are currently achieving outstanding managerial efficiency as well as positive growth from the past. They will be able to stay in this leading position if they effectively control these suggested resource indices and avoid significant administrative mistakes.

**Those in zone II:** These FHCs experience worse contemporary efficiency, but an increasing variation in productivity. Three FHCs are included: Fubon (04), First (05), and SinoPac (09). Their current resource inputs do not generate efficient outputs, but the efforts they have invested over the two years have given rise to a positive productivity. It is possible for them to move up into the ‘star group’ in zone I if they make improvements in efficiency. It is suggested that the FHCs in this zone should place more emphasis on activities that are aimed at improving operational management.

**Those in zone III:** These FHCs perform worse both in terms of contemporary efficiency and variation in productivity. They include Hua Nan (03), E.SUN (10), Fuhwa (11), and Jhsun (12) and China Development (13). To catch up with the stars in zone I, these FHCs need to urgently start improving their efficiency now, and to expand their productivity hereafter.

**Those in zone IV:** These FHCs, which have better contemporary efficiency, but low productivity growth, are classified here. Two of them, Shin Kong (07) and Waterland (14), are in this zone. Although these two FHCs are on the frontier currently, they do not exhibit growth compared to the previous year. The adoption

### Table 6

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<tr>
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<tbody>
<tr>
<td></td>
<td>Catch-up</td>
<td>Frontier</td>
<td>Malmquist</td>
</tr>
<tr>
<td>Cathay (01)</td>
<td>1.000</td>
<td>1.053</td>
<td>1.053</td>
</tr>
<tr>
<td>Mega (02)</td>
<td>1.000</td>
<td>1.098</td>
<td>1.058</td>
</tr>
<tr>
<td>Hua Nan (03)</td>
<td>0.947</td>
<td>1.077</td>
<td>1.056</td>
</tr>
<tr>
<td>Fubon (04)</td>
<td>0.805</td>
<td>1.316</td>
<td>1.059</td>
</tr>
<tr>
<td>First (05)</td>
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<td>1.007</td>
<td>1.220</td>
</tr>
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<td>Chinatrust (06)</td>
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<td>1.113</td>
<td>1.986</td>
</tr>
<tr>
<td>Shin Kong (07)</td>
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<td>0.883</td>
</tr>
<tr>
<td>Taishin (08)</td>
<td>1.944</td>
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<td>2.002</td>
</tr>
<tr>
<td>SinoPac (09)</td>
<td>1.097</td>
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<td>1.049</td>
</tr>
<tr>
<td>E.SUN (10)</td>
<td>0.592</td>
<td>1.066</td>
<td>0.631</td>
</tr>
<tr>
<td>Fuhwa (11)</td>
<td>1.355</td>
<td>0.729</td>
<td>0.988</td>
</tr>
<tr>
<td>Jhsun (12)</td>
<td>1.213</td>
<td>0.681</td>
<td>0.826</td>
</tr>
<tr>
<td>China development (13)</td>
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<td>0.666</td>
<td>0.758</td>
</tr>
<tr>
<td>Waterland (14)</td>
<td>1.000</td>
<td>0.867</td>
<td>0.867</td>
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</table>
of strategies to actively expand their business in order to increase productivity is advised here.

6. Conclusions

This paper combines the efficiency of profitability as well as the efficiency of marketability to evaluate the FHCs’ performance in Taiwan based on Seiford and Zhu’s (1999) model. To overcome the shortfalls of traditional DEA techniques being applied to FHCs as in Taiwan, we adopt the slacks-based measure (SBM) and slacks-based measure of super efficiency (super-SBM) models initiated by Tone (2001, 2002). The application of the SBM and super-SBM models is expected to produce more valid results and a more persuasive investigation into the FHCs’ efficiency in terms of converting multiple inputs into multiple outputs. Cross-period efficiency analysis is also performed which decomposes the inter-temporal efficiency change into ‘catch-up’ and ‘frontier-shift’ effects based on the SBM-based Malmquist index.

Our main results are summarized as follows: (1) In the profitability model, the large-sized FHCs perform better than the small-sized ones, implying that they are more likely to generate relatively higher profits due to their large-scale assets. (2) In terms of marketability performance, large-sized FHCs also operate better than small-sized ones suggesting that large FHCs can more easily capture the attention of the investors even with comparable earning news. (3) The more efficient FHCs are ranked from the highest to the lowest where the best performers identified. (4) In the cross-period efficiency analysis, while many small FHCs exhibit growth in terms of the catch-up effect, most large FHCs exhibit expansion in terms of the frontier-shift effect in both the profitability and marketability models. (5) By combining the current efficiency and productivity change, a four-zoned decision-making matrix is presented to help the FHCs’ managerial authorities position themselves in the industry.

The FHCs in Taiwan would rather consolidate externally to enlarge their size since the momentum resulting from internal growth has its limitations in the short run. According to the international experiences of financial institutions, the synergy can only be observed at least two or three years after a merger. From this study, we perceive that large-sized FHCs perform better than small-sized ones two years after the introduction of financial consolidation legislation in Taiwan. The ‘Second-Stage Financial Reforms,4 directed by the president of Taiwan, has come to policy coherence that no more than about five financial holding companies should be established for the sake of the market’s scale in this small economy. Taiwan’s financial holding companies therefore urgently need to merge in order to reap the benefits from multi-business synergy and to raise the stockholders’ value in this highly competitive market place. From the evidence provided here, we can anticipate that large efficient FHCs will be more capable of merging with small inefficient ones due to their superior profitability and marketability performance. From a researcher’s point of view, it is hoped that the integration of the models and techniques proposed in this study can be used in the financial sectors of other countries with a similar environment. Topics on Asian FHCs’ efficiency evaluation in terms of their diversification strategies are promising research directions. Moreover, if the multi-period financial data of sub-systems under FHC become more transparent, and can be clearly cut from one to another in the future, it is worth adopting Golany et al.’s (2006) system to evaluate FHCs’ performance.

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References


The vision of the Second-Stage Financial Reforms is to promote the competitiveness of Taiwan’s financial institutions, and to build Taiwan as a regional financial service center. Reducing the number of FHCs is one of the major goals by cutting the number of financial institutions within a given period of time. However, some controversies arise from the point that the policy overrides the market mechanism.