Predicting bank performance with financial forecasts: A case of Taiwan commercial banks

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Abstract

Data envelopment analysis (DEA) has been used as a tool for evaluating past accomplishments in the banking industry. However, due to a time lag, the results usually arrive too late for the evaluated banking institutions to react timely. This paper makes advanced predictions of the performances of 24 commercial banks in Taiwan based on their financial forecasts. The forecasts based on uncertain financial data are represented in ranges, instead of as single values. A DEA model for interval data is formulated to predict the efficiency. The predictions of the efficiency scores are also presented as ranges. We found that all the efficiency scores calculated from the data contained in the financial statements published afterwards fall within the corresponding predicted ranges of the efficiency scores which we had calculated from the financial forecasts. The results also show that even the bad performances of the two banks taken over by the Financial Restructuring Fund of Taiwan could actually be predicted in advance using this study.

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1. Introduction

Over the past 30 years Taiwan has achieved high economic development while maintaining mild inflation and low unemployment. At the same time, the structure of its financial system has changed from a controlled system into a liberalized one. The financial system has played a key role in the process of Taiwan’s economic development (Yu, 1999). The widespread relaxation of the financial system has resulted in a more efficient financial market and enhanced financial technology. On the downside, however, the keener competition in financial markets has had a huge impact on various kinds of operating risk encountered by financial institutions. Since the Southeast Asian financial crisis of July 1997, most of the countries in that region have suffered from its impact. One of the main factors in that financial crisis was excessive risk-taking, especially after the finance liberalization in Southeast Asia. The major cause leading to excessive risk-taking is the inadequate regulatory system (Mishkin, 1999). An efficient financial system must have a sound regulatory system, not only to help financial institutions achieve expected development but also to prevent them from relying on risk-taking.

The most effective way to enforce financial rules and regulations in the financial supervisory system is to conduct financial examinations. In Taiwan, the principal government agencies responsible for the supervision of financial institutions are the Central Bank of China, the Ministry of Finance, and the Central Deposit Insurance Corporation. These three bank regulators use the CAMELS rating system, which consists of six categories, including Capital adequacy, Asset quality, Management, Earnings, Liquidity, and Sensitivity to market risk, to evaluate the banks in Taiwan. This system relies on various financial ratios obtained from periodic reports of the entities under their jurisdiction. The ratios are also aggregated into performance indices based on various weighting or scoring schemes. The aggregation of the ratios can be a complicated process involving subjective judgment. The changing economic conditions have made such aggregations even more difficult, increasing the need for a more reliable way to express a bank’s financial condition.

Data envelopment analysis (DEA) for efficiency measurement has seen extensive applications in the study of commercial banks (Bauer et al., 1998; Berger and DeYoung, 1997; Berger and Humphrey, 1997; Bhattacharyya et al., 1997; Elyasiani and Mehdian, 1990; Miller and Noulas, 1996; Rezvani and Mehdian, 2002; Sherman and Ladino, 1995; Yeh, 1996; Yue, 1992). Several authors have also proposed that DEA efficiency measures be used as the evaluative information for the management component of CAMELS (Barr et al., 1993, 1994; Brockett et al., 1997; Siems, 1992; Siems and Barr, 1998). In most studies the DEA approach has been used as a tool for evaluating accomplishments in the past. The results highlight the status of the operational performance and are helpful for planning future activities for improving the performance. However, this ex post facto evaluation might be a little late for an unsuccessful unit to find its weaknesses and make the appropriate amendments. In this paper we predict the performance of the commercial banks in Taiwan based on the forecasted financial data via DEA. The results are regarded as forward-looking information, which can be used for planning management activities in ad-
vance to enhance the operational performance. Since the input–output data are the financial forecasts of the banks, considerable uncertainty is involved. We thus develop a solution method to solve the problem of imprecise data encountered in measuring the relative efficiency.

The rest of this paper is organized as follows: first we discuss the input and output factors used to measure the efficiency of commercial banks, then we develop a solution method to calculate the relative efficiency of the banks with imprecise data under the DEA framework. Next, the case of Taiwan’s commercial banks is adopted for illustration, and finally, the results are discussed and some conclusions drawn from the discussion.

2. Inputs and outputs

Selecting proper inputs and outputs is probably the most important task in successfully applying DEA to measure the relative efficiency of the decision making units (DMUs) since they determine the context for comparison. In the banking industry, there are different viewpoints regarding inputs and outputs. According to the Banking Law of the Republic of China on Taiwan, the primary functions of commercial banks are to receive checking account deposits and to extend short-term credit. The regular operations include servicing checking accounts, demands, and time deposits; extending short-term and medium-term loans; engaging in domestic and foreign remittances and guaranty business; and underwriting government bonds, treasury bills, and corporate bonds. The detailed operations in which a commercial bank may engage can be found in the Banking Law of Taiwan (2000).

From looking at the operation contents of the commercial banks in Taiwan, one soon realizes that the availability of funds and the costs of deposits are not the major consideration of banks. The emphasis of bank management is to make proper decisions. Instead of offering competitive interest rates on saving accounts to attract stable deposits for credit applications, bank managers focus their attention on credit analysis to determine a borrower’s ability to repay loans, along with collateral evaluation and documentation screening to protect the bank’s financial profits and to be sure deposit payments are duly made. Another task is to adjust the interest rates paid on deposits and the interest rates charged to loans to secure more profit. In other words, the role played by the banks of Taiwan is primarily to mediate funds between depositors and borrowers. In this sense, the commercial banks in Taiwan can be regarded as financial intermediaries, whose main business is to borrow funds from depositors to lend to others (Yeh, 1996; Yue, 1992).

Based on the inter-mediation concept and the empirical study of Yeh (1996), three inputs are considered in evaluating a bank’s performance: total deposits, interest expenses, and non-interest expenses. Total deposits are composed of checking accounts and time deposits. Interest expenses include expenses for deposits and other borrowed money. Non-interest expenses include service charges and commissions, expenses of general management affairs, salaries, and other expenses. These inputs represent the costs of labor, administration, equipment and funds
purchased for bank operations, and the source of loanable funds for investment (Yeh, 1996).

Regarding the outputs in assessing bank performance, there are also three factors, viz., total loans, interest income, and non-interest income. Total loans consist of short-term and medium-term loans. Interest income includes interest on loans, income from government bonds and corporate bonds, and interest and dividend income on securities. Non-interest income includes service charges on loans and transactions, income from renting and fiduciary activities, commissions, and other operating income. These outputs represent bank revenue and the major profit-making business activities (Yeh, 1996). One thing to be noted is that according to the Banking Law of Taiwan, the total loans extended by a bank may not exceed its balance of total deposits. This makes the performance evaluation a little more complicated.

In Taiwan there are 48 commercial banks, with total assets of 422.76 billion US dollars. The average is 8.8 billion for each bank. Of the 48 banks, 30 (62.5%) are on the security list of Taiwan Stock Exchange Corporation (TSEC). Their total assets are 348.9 billion US dollars, which accounts for 82.53% of the total assets of the 48 banks, with an average of 11.63 billion. The total assets of the other 18 banks are 4.1 billion. These 30 commercial banks are the target of this study. The financial data for inputs and outputs are the source for measuring their relative efficiencies. In March 2000, questionnaires were sent to the general managers of the 30 banks to ask for their forecasts of the financial data. We asked that the forecasts for the three inputs and three outputs be expressed in intervals rather than single values due to their uncertain nature. Of the 30 banks, 24 provided all the data required for our analysis. Those 24 banks were also visited to make sure that they had provided the data we wanted. The banks that did not respond are all relatively small. The largest one has total assets of 9.43 billion dollars which is smaller than the average of the 30 listed banks–11.63 billion. Their total assets are 49.3 billion dollars, accounting for 14.13% of the total assets of the 30 listed banks. The average is 8.22 billion as opposed to the 12.48 billion average of the 24 banks which responded. Table 1 shows the input and output data of the 24 banks. The monetary values are in Taiwan dollars, where 1 US dollar is approximately equal to 35 Taiwan dollars.

According to the regulations of Taiwan’s Securities and Futures Commission, the commercial banks must publish their financial forecasts for the coming calendar year. The publication and reporting of the information regarding the financial forecast should also be submitted to the Securities and Futures Institute (SFI) for public inspection. This publication of financial information should be completed by the end of April. For this reason, we sent our questionnaires to ask the banks financial forecasts for the following calendar year in March 2000, and received their responses in April. Every bank has the forecasts available at the beginning of the year. They could actually have provided the forecasts earlier. However, it is obvious that the earlier the forecasts are made the less accurate they will be. Nonetheless, the methodology of this paper is still applicable. The regulators can decide the time they want to collect the forecasts. In Section 3, we shall develop a solution procedure for predicting bank performances using interval financial data.
<table>
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<tr>
<th>Bank</th>
<th>Total deposits</th>
<th>Interest expenses</th>
<th>Non-interest expenses</th>
<th>Total loans</th>
<th>Interest income</th>
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</table>
3. The solution procedure

Since the pioneer work of Charnes et al. (1978), DEA has been widely applied to measuring the relative efficiencies of a set of DMUs utilizing the same inputs to produce the same outputs. One form of their model for measuring the efficiency of DMU \(r\) is

\[
E_r = \max \sum_{k=1}^{t} u_k Y_{rk} \tag{1}
\]

s.t. \[
\sum_{j=1}^{s} v_j X_{rj} = 1,
\]

\[
\sum_{k=1}^{t} u_k Y_{ik} - \sum_{j=1}^{s} v_j X_{ij} \leq 0, \quad i = 1, \ldots, n,
\]

\[
u_k, v_j \geq 0, \quad k = 1, \ldots, t, \quad j = 1, \ldots, s,
\]

where \(X_{ij}\) and \(Y_{ik}\) represent the \(j\)th input and \(k\)th output, respectively, of the \(i\)th DMU, and \(e > 0\) is a small non-Archimedean quantity (Charnes et al., 1979; Charnes and Cooper, 1984). In this model all observations must be precise. However, the data used for all inputs and outputs in this study are imprecise, lying in the ranges of \([X_{ij}^L, X_{ij}^U]\) and \([Y_{ik}^L, Y_{ik}^U]\), respectively. We need to modify Model (1) to make it applicable to interval data.

Let \(\tilde{X}_{ij} = [X_{ij}^L, X_{ij}^U]\) and \(\tilde{Y}_{ik} = [Y_{ik}^L, Y_{ik}^U]\) denote the interval counterparts of \(X_{ij}\) and \(Y_{ik}\), respectively. Specifically, \(\tilde{X}_{i1}, \tilde{X}_{i2}, \text{ and } \tilde{X}_{i3}\) represent total deposits, interest expenses, and non-interest expenses of the \(i\)th DMU, respectively, and \(\tilde{Y}_{i1}, \tilde{Y}_{i2}, \text{ and } \tilde{Y}_{i3}\) represent total loans, interest income, and non-interest income of the \(i\)th DMU, respectively. Conceptually, the efficiency of Bank \(r\), \(E_r\), is calculated as

\[
\hat{E}_r = \max \sum_{k=1}^{3} u_k \tilde{Y}_{rk} \tag{2}
\]

s.t. \[
\sum_{j=1}^{3} v_j \tilde{X}_{rj} = 1,
\]

\[
\sum_{k=1}^{3} u_k \tilde{Y}_{ik} - \sum_{j=1}^{3} v_j \tilde{X}_{ij} \leq 0, \quad i = 1, \ldots, 24,
\]

\[
u_k, v_j \geq 0, \quad k = 1, 2, 3, \quad j = 1, 2, 3.
\]

If the observations are imprecise, then the efficiency measures will be imprecise as well. That is, the efficiency score \(\hat{E}_r\) should also appear in range. Cooper et al. (1999, 2001) propose a method that permits the mixtures of bounded data and exactly known data in a DEA model. However, their method provides only the upper bound of the efficiency scores. Kao and Liu (2000a,b) adopt the concept of membership function used in fuzzy set theory for representing imprecise data. A fuzzy
DEA model is developed to measure the fuzzy efficiencies. Recently, Despotis and Smirlis (2002) developed an approach for dealing with imprecise data in DEA. Their method is similar to that of Kao and Liu (2000a,b). In this study, we modify the method of Kao and Liu to calculate the efficiency intervals.

According to the Banking Law of the Republic of China, the total loans \( \hat{Y}_{il} \) should not exceed the total deposits \( \hat{X}_{il} \). All the banks have to obey this legal requirement. However, by applying the method of Kao and Liu (2000a) to calculate the minimum and maximum efficiencies, all input and output values in their corresponding ranges are considered. This total flexibility could violate the above-mentioned legal requirement. Hence, unlike previous studies, here we additionally require \( \hat{Y}_{il} \leq \hat{X}_{il} \). This constraint has nothing to do with the decision variables \( u_k \) and \( v_j \), which also makes the existing methods inapplicable. Therefore, we shall develop a new method to calculate the efficiency scores of the commercial banks with interval data.

Let \( E_r^L \) and \( E_r^U \) denote, respectively, the lower and upper bounds of the efficiency score \( E_r \) of Bank \( r \). Based on the concept of Pareto optimality, the minimal projected future efficiency \( E_r^L \) is calculated under the worst-case scenario for Bank \( r \). Specifically, the output levels are set at the low estimates and the input levels are set at the high estimates for Bank \( r \). At the same time, for the other banks, the output levels are set at the high estimates and input levels are set at the low estimates. Conversely, to calculate the maximal future efficiency \( E_r^U \), the most favorable scenario for Bank \( r \) is adopted, where the outputs are at the high and the inputs are at the low estimates for Bank \( r \), while for the other banks the outputs are at the low and inputs are at the high estimates. Note that this concept does not apply to \( \hat{X}_{il} \) and \( \hat{Y}_{il} \) because we need \( \hat{Y}_{il} \) to be smaller than \( \hat{X}_{il} \).

In mathematical forms, we require \( X_{il}^L \leq x_{il} \leq X_{il}^U \), \( Y_{il}^L \leq y_{il} \leq Y_{il}^U \), and \( y_{il} \leq x_{il} \) for \( i \neq r \), where \( x_{il} \) and \( y_{il} \) are the specific values for \( \hat{X}_{il} \) and \( \hat{Y}_{il} \), respectively, to calculate the efficiency score. The whole idea can be formulated by the following pair of two-level mathematical programs:

\[
\begin{align*}
E_r &= \max \sum_{k=1}^{3} u_k Y_{rk}^L \\
\text{s.t.} & \quad \sum_{j=1}^{3} v_j X_{rj}^U = 1, \\
& \quad \sum_{k=1}^{3} u_k Y_{rk}^L - \sum_{j=1}^{3} v_j X_{rj}^U \leq 0, \\
& \quad \left( u_l y_l + \sum_{k=2}^{3} u_k Y_{rk}^U \right) - \left( v_l x_l + \sum_{j=2}^{3} v_j X_{ij}^L \right) \leq 0, \\
& \quad i = 1, \ldots, 24, \quad i \neq r, \\
& \quad u_k, v_j \geq \varepsilon > 0, \quad k = 1, 2, 3, \quad j = 1, 2, 3.
\end{align*}
\]

(3a)
To derive $E^L_r$, it suffices to solve the following program:

$$E^L_r = \min \left\{ \begin{array}{l}
E_r = \min \quad \theta_r - \varepsilon \left[ \sum_{j=1}^{3} s^+_j + \sum_{k=1}^{3} s^-_k \right] \\
\text{s.t.} \quad \sum_{i=1}^{24} \lambda_i x_{i1} + \lambda_r x^U_{r1} + s^+_1 = \theta_r x^U_{r1}, \\
\sum_{i=1}^{24} \lambda_i x^U_{ij} + \lambda_r x^U_{rj} + s^+_j = \theta_r x^U_{rj}, \quad j = 2, 3, \\
\sum_{i=1}^{24} \lambda_i y_{i1} + \lambda_r Y^L_{r1} - s^-_1 = Y^L_{r1}, \\
\sum_{i=1}^{24} \lambda_i Y^U_{ik} + \lambda_r Y^L_{rk} - s^-_k = Y^L_{rk}, \quad k = 2, 3, \\
\lambda_i, s^+_j, s^-_k \geq 0, \quad \forall i, j, k,
\end{array} \right. \right. (4)$$

where $s^+_j$ and $s^-_k$ are slack and surplus variables, respectively. Now, since both level one and level two perform the same minimization operation, their constraints can be combined to form the following conventional one-level mathematical program:

$$E^L_r = \min \quad \theta_r - \varepsilon \left[ \sum_{j=1}^{3} s^+_j + \sum_{k=1}^{3} s^-_k \right] (5)$$

$$\text{s.t.} \quad \sum_{i=1}^{24} \lambda_i x_{i1} + \lambda_r x^U_{r1} + s^+_1 = \theta_r x^U_{r1}, \quad (5.1)$$
\[
\sum_{i=1 \atop i \neq r}^{24} \lambda_i X_{ij}^L + \lambda_r X_{r1}^U + s_j^+ = \theta_r X_{rj}^U, \quad j = 2, 3,
\]
\(\text{(5.2)}\)

\[
\sum_{i=1 \atop i \neq r}^{24} \lambda_i y_{i1} + \lambda_r Y_{r1}^L - s_1^- = Y_{r1}^L,
\]
\(\text{(5.3)}\)

\[
\sum_{i=1 \atop i \neq r}^{24} \lambda_i Y_{ik}^U + \lambda_r Y_{rk}^L - s_k^- = Y_{rk}^L, \quad k = 2, 3,
\]
\(\text{(5.4)}\)

\[
X_{i1}^L \leq x_{i1} \leq X_{i1}^U, \quad i = 1, \ldots, 24,
\]
\(\text{(5.5)}\)

\[
Y_{i1}^L \leq y_{i1} \leq Y_{i1}^U, \quad i = 1, \ldots, 24,
\]
\(\text{(5.6)}\)

\[
y_{i1} \leq x_{i1}, \quad i = 1, \ldots, 24,
\]
\(\text{(5.7)}\)

\[
\lambda_i, s_j^+, s_k^- \geq 0, \quad \forall i, j, k.
\]

Model (5) is a non-linear program with non-linear terms \(\lambda_i x_{i1}\) in (5.1) and \(\lambda_i y_{i1}\) in (5.3). This non-linear program can be linearized by multiplying Constraints (5.5), (5.6), and (5.7) by \(\lambda_i\) and substituting \(\lambda_i x_{i1}\) and \(\lambda_i y_{i1}\) by \(p_i\) and \(q_i\), respectively, to obtain the following linear program:

\[
E_r^L = \min \quad \theta_r - \epsilon \left[ \sum_{j=1}^{3} s_j^+ + \sum_{k=1}^{3} s_k^- \right]
\]
\(\text{(6)}\)

s.t. \[
\sum_{i=1 \atop i \neq r}^{24} p_i + \lambda_r X_{r1}^U + s_1^+ = \theta_r X_{r1}^U,
\]

\[
\sum_{i=1 \atop i \neq r}^{24} \lambda_i X_{ij}^L + \lambda_r X_{r1}^U + s_j^+ = \theta_r X_{rj}^U, \quad j = 2, 3,
\]

\[
\sum_{i=1 \atop i \neq r}^{24} q_i + \lambda_r Y_{r1}^L - s_1^- = Y_{r1}^L,
\]

\[
\sum_{i=1 \atop i \neq r}^{24} \lambda_i Y_{ik}^U + \lambda_r Y_{rk}^L - s_k^- = Y_{rk}^L, \quad k = 2, 3,
\]

\[
\lambda_i X_{i1}^L \leq p_i \leq \lambda_i X_{i1}^U, \quad i = 1, \ldots, 24,
\]

\[
\lambda_i Y_{i1}^L \leq q_i \leq \lambda_i Y_{i1}^U, \quad i = 1, \ldots, 24,
\]

\[
q_i \leq p_i, \quad i = 1, \ldots, 24,
\]

\[
\lambda_i, s_j^+, s_k^- \geq 0, \quad \forall i, j, k.
\]

The lower bound of the efficiency score \(E_r^L\) can then be solved without difficulty.
In Model (3b), the outer program is to maximize the inner program under some bound constraints. Since the inner program also has an objective function of maximization, we can combine the constraints of level one and level two to form the conventional one-level program as follows:

\[
E_r^U = \max \quad u_1y_{r1} + \sum_{k=2}^{3} u_k Y_{rk}^U
\]

s.t. \[
v_1x_{r1} + \sum_{j=2}^{3} v_j X_{rj}^L = 1,
\]

\[
\left( u_1y_{r1} + \sum_{k=2}^{3} u_k Y_{rk}^U \right) - \left( v_1x_{r1} + \sum_{j=2}^{3} v_j X_{rj}^L \right) \leq 0,
\]

\[
\sum_{k=1}^{3} u_k Y_{ik}^L - \sum_{j=1}^{3} v_j X_{ij}^U \leq 0, \quad i = 1, \ldots, 24, \quad i \neq r,
\]

\[
v_1^L x_{r1} \leq X_{r1}^L,
\]

\[
y_1^L y_{r1} \leq Y_{r1}^U,
\]

\[
y_{r1} \leq x_{r1},
\]

\[
u_k, v_j \geq \varepsilon > 0.
\]

Similar to Model (5), the non-linear terms \(v_1 x_{r1}\) and \(u_1 y_{r1}\) in Model (7) can be linearized by substituting variables \(p_r\) and \(q_r\), respectively, and replacing Constraints (7.4) and (7.5) with \(v_1 X_{r1}^L \leq p_r \leq v_1 X_{r1}^U\) and \(u_1 Y_{r1}^L \leq q_r \leq u_1 Y_{r1}^U\) accordingly. Regarding Constraint (7.6) \(y_{i1} \leq x_{i1}\), we multiply this constraint by \(u_1\) to become \(u_1 y_{r1} \leq u_1 x_{r1}\) and substitute \(u_1 x_{r1}\) with \(h_r\). This constraint is then transformed to \(q_r \leq h_r\). The resulting formulation becomes a linear program:

\[
E_r^U = \max \quad q_r + \sum_{k=2}^{3} u_k Y_{rk}^U
\]

s.t. \[
p_r + \sum_{j=2}^{3} v_j X_{rj}^L = 1,
\]

\[
\left( q_r + \sum_{k=2}^{3} u_k Y_{rk}^U \right) - \left( p_r + \sum_{j=2}^{3} v_j X_{rj}^L \right) \leq 0,
\]

\[
\sum_{k=1}^{3} u_k Y_{ik}^L - \sum_{j=1}^{3} v_j X_{ij}^U \leq 0, \quad i = 1, \ldots, 24, \quad i \neq r,
\]

\[
v_1 X_{r1}^L \leq p_r \leq v_1 X_{r1}^U,
\]

\[
u_1 Y_{r1}^L \leq q_r \leq u_1 Y_{r1}^U,
\]

\[
q_r \leq h_r,
\]

\[
u_k, v_j \geq \varepsilon > 0.
\]
The lower bound $E_r^L$ and upper bound $E_r^U$ of the efficiency score $\hat{E}_r$ are solved from Models (6) and (8), respectively.

4. The result

With the input–output data of Table 1, we apply Models (6) and (8) to calculate the lower and upper bounds of the efficiency scores of the commercial banks in Taiwan. The results are shown in the last column of Table 1. Consider Bank 1. The range of efficiency score is $[0.8630, 1.0]$, indicating that the efficiency score will never fall below 0.8630 and the best efficiency score possible is 1.0. All commercial banks except Banks 8 and 23 have an upper value of 1.0. Interestingly, Banks 6, 19, and 20 have a precise efficiency score of 1.0, although the input–output data of all banks are imprecise. This is a phenomenon of Pareto optimality. When the production frontier shifts due to variations in the input and output data, a DMU is always efficient as long as it lies on the production frontier. Most banks (19 out of 24) have a lower-bound efficiency score greater than 0.8 and three banks have a lower bound falling between 0.7 and 0.8. Only Banks 8 and 23 have a lower bound smaller than 0.6. They are far below the average of 0.8295. This is a warning to the management concerning the operations of these two banks.

To investigate how precise our predictions are, the real data of the 24 banks for Year 2000 were acquired from their financial statements published in Year 2001 as shown in Table 2. Most of the input–output data fall within the corresponding intervals shown in Table 1. There are only two input and one output values which fall outside of the forecasted ranges of Table 1. The true values of the non-interest expenses of Banks 1 and 18 are slightly higher than the upper forecasted bounds. This is because deregulation of the banking industry in 1990 has given banks in Taiwan much more operating flexibility, and many new banks were established at that time. These two banks planned to open up several new branches to increase market competitiveness. Additional bank staff and new buildings were required, which pushed up the operation costs. Regarding the value of the non-interest income of Bank 20, it is also higher than the upper bound of the forecasted value. The reason is that facing high pressure from free competition within the financial market and the trend toward electronic banking, the top management spent much time and budget to computerize technical operations. The improved services brought higher non-interest income in service charges on loans and transactions.

With the real financial data, the true efficiency scores of the 24 banks for Year 2000 can be calculated from Model (1), namely, the conventional DEA model, as shown in the last column of Table 2. As expected, all the true efficiency scores fall within the ranges of the predicted efficiencies shown in Table 1. Banks 8 and 23 have the smallest efficiency scores 0.7358 and 0.7584, respectively. These two banks had suffered from the Asian financial crisis and held many bad debts. It seems that the managers of Banks 8 and 23 were not cautious enough, and were unaware of the associated risks when new lending opportunities opened up following financial liberalization. With rapid growth in lending, those two banks could not increase the
necessary capital fast enough to enable themselves to screen and monitor these new loans appropriately. The results were huge losses and deterioration of their balance. Moreover, the financial reports for fiscal year 2000 showed the net worth of these two banks to be less than one-half of their paid-in capital. Under Taiwan’s Securities and Exchange Laws, TSEC had to terminate their stock trading on the market. To preserve financial stability, depositor interests, and social order, Banks 8 and 23 were taken over by the Financial Restructuring Fund, which is governed by the Executive Yuan of the Republic of China. The predicted efficiency scores calculated by the method proposed in this paper would have been able to provide warning of the abnormal operations of Banks 8 and 23.

In Taiwan the banking industry is very competitive. The general managers must foresee the weaknesses of their banks as compared with others and make appropriate adjustments before it is too late. For banks with a low predicted efficiency score, their inputs should be decreased and outputs be increased to have better performance. Table 1 shows that all banks except Banks 8 and 23 have a perfect upper-bound efficiency score. Therefore, we need to concentrate only on the lower-bound efficiency score to find the target inputs and outputs for each bank to raise efficiency. As revealed from Model (6), if $X_{rj}'$ is reduced to $(\theta X_{rj}' - s_{j+1})$ and $Y_{rk}'$ increased to

<table>
<thead>
<tr>
<th>Bank</th>
<th>Total deposits</th>
<th>Interest expenses</th>
<th>Non-interest expenses</th>
<th>Total loans</th>
<th>Interest income</th>
<th>Non-interest income</th>
<th>Efficiency score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>824107.208</td>
<td>42494.128</td>
<td>12473.007</td>
<td>741433.098</td>
<td>6298.027</td>
<td>7239.506</td>
<td>0.9984</td>
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<tr>
<td>2</td>
<td>980038.014</td>
<td>46845.139</td>
<td>16936.479</td>
<td>806428.970</td>
<td>68819.936</td>
<td>13291.902</td>
<td>0.9501</td>
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<td>3</td>
<td>938204.610</td>
<td>42376.809</td>
<td>13645.024</td>
<td>823782.076</td>
<td>61385.655</td>
<td>12504.515</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
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<td>31276.893</td>
<td>6563.065</td>
<td>447143.841</td>
<td>47438.004</td>
<td>6057.015</td>
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<tr>
<td>5</td>
<td>246440.892</td>
<td>8252.742</td>
<td>2953.079</td>
<td>181108.056</td>
<td>12221.894</td>
<td>1730.635</td>
<td>0.9913</td>
</tr>
<tr>
<td>6</td>
<td>268353.445</td>
<td>8999.696</td>
<td>1218.105</td>
<td>214366.484</td>
<td>12015.108</td>
<td>3043.514</td>
<td>1.0</td>
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<tr>
<td>7</td>
<td>113919.124</td>
<td>5677.476</td>
<td>1471.736</td>
<td>85624.323</td>
<td>8394.519</td>
<td>323.151</td>
<td>0.8959</td>
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<tr>
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<td>5320.945</td>
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<td>36626.140</td>
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<td>531555.261</td>
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<td>3903.575</td>
<td>426360.240</td>
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<td>11</td>
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<td>3791.665</td>
<td>151727.404</td>
<td>12109.135</td>
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<tr>
<td>12</td>
<td>191037.580</td>
<td>8717.023</td>
<td>1628.212</td>
<td>163439.178</td>
<td>12396.810</td>
<td>759.830</td>
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<tr>
<td>13</td>
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<tr>
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<tr>
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<td>5749.836</td>
<td>5159.511</td>
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<td>618.807</td>
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<tr>
<td>16</td>
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<td>7354.116</td>
<td>3207.729</td>
<td>130663.308</td>
<td>9783.182</td>
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<td>1.0</td>
</tr>
<tr>
<td>17</td>
<td>159399.890</td>
<td>8307.174</td>
<td>6263.270</td>
<td>131732.765</td>
<td>12846.278</td>
<td>809.854</td>
<td>0.9346</td>
</tr>
<tr>
<td>18</td>
<td>125692.640</td>
<td>4842.992</td>
<td>2931.299</td>
<td>135487.618</td>
<td>12650.628</td>
<td>2531.048</td>
<td>1.0</td>
</tr>
<tr>
<td>19</td>
<td>199134.585</td>
<td>9746.008</td>
<td>693.170</td>
<td>155294.627</td>
<td>14017.185</td>
<td>2168.116</td>
<td>1.0</td>
</tr>
<tr>
<td>20</td>
<td>227120.157</td>
<td>9962.417</td>
<td>2000.913</td>
<td>159534.846</td>
<td>13265.725</td>
<td>5091.513</td>
<td>1.0</td>
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<tr>
<td>21</td>
<td>137385.786</td>
<td>6802.984</td>
<td>4034.292</td>
<td>103615.346</td>
<td>9220.254</td>
<td>1642.579</td>
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</tr>
<tr>
<td>22</td>
<td>224619.732</td>
<td>11169.600</td>
<td>4871.093</td>
<td>185694.494</td>
<td>20698.487</td>
<td>3267.933</td>
<td>1.0</td>
</tr>
<tr>
<td>23</td>
<td>159179.571</td>
<td>9470.265</td>
<td>14765.248</td>
<td>100249.397</td>
<td>11698.965</td>
<td>1137.971</td>
<td>0.7584</td>
</tr>
<tr>
<td>24</td>
<td>164145.941</td>
<td>8184.584</td>
<td>1696.105</td>
<td>146801.986</td>
<td>11778.402</td>
<td>927.318</td>
<td>1.0</td>
</tr>
</tbody>
</table>
then Bank $r$ will be efficient. Banks 6, 19, and 20 have a perfect lower-bound efficiency score; thus, no improvement is needed. For other banks, their target inputs and outputs are calculated and shown in Table 3. Consider Bank 1 again. Its lower-bound efficiency score is 0.8630. To become efficient, the total deposits, interest expenses, and non-interest expenses should be controlled at the target values of 725807.485, 37718.950, and 10985.223 million Taiwan dollars, respectively. Regarding the output, the total loans, interest income, and non-interest income should be increased to the target values of 724380.137, 60822.392, and 8792.667 million Taiwan dollars, respectively. If some target values are too difficult for a bank to achieve, then other target values that are feasible to this bank can be generated by applying the model of Kao (1994).

### 5. Conclusion

Rapid changes in the economic environment has raised the need to evaluate the risks and returns involved in banking, especially after the financial liberalization in East Asia. DEA is able to measure the efficiency of the banking industry. However, because it is applied in an ex post facto manner, banks might not have time to react appropriately. Based on the financial forecasts of the 24 commercial banks in Taiwan, this paper predicts the efficiency scores in advance for providing look-ahead
information for bank operations. Since considerable uncertainty is involved in financial forecasts, a pessimistic and an optimistic estimate are supplied to represent the financial data. A DEA model for interval data is developed to calculate the efficiency scores. The results are also in ranges. As a matter of fact, a reliable interval estimation is more informative than an unreliable point estimation of the efficiency score for cases of imprecise data. Notably, even though all banks have imprecise observations, it is possible that some banks have precise efficiency scores. This happens when the whole ranges of the input–output data of a DMU lie on the production frontier.

There exist some differences in the input–output data between the financial forecasts and the real data shown in the financial statements published afterwards. However, the impact on efficiency measurement is not great. The true efficiency scores calculated from the real data all fall within the ranges of the predicted efficiency scores calculated from the financial forecasts. The predicted efficiency scores are able to disclose some operating problems for the banks in advance. These results show that the solution method proposed in this paper is able to predict the bank performance based on their financial forecasts. They also confirm that this study has selected proper input and output factors to measure the efficiencies of the banks.

Several financial ratios have been used to detect a possible financial crisis in a company. The popular ratios include (net worth)/(total assets), (total operating income)/(total assets), (net income)/(total assets), and (current assets)/(current liabilities). A problem with these ratios is that a company may perform differently in different ratios. In this study, we have calculated these four ratios for 24 banks based on their financial statements. As expected, every bank performs differently in each ratio. The ratio of (net worth)/(total assets) indicates that Banks 8 and 23 have the worst performance as concluded in the current study. However, for the other ratios the conclusions are different. It is difficult to derive a general consensus conclusion from these ratios.

Taiwan is gradually recovering from the Asian financial crisis and is currently performing a series of financial reforms to regulate banking operations. The evaluation of bank performance via DEA discussed in this paper might not be able to replace the on-site examination conducted by government agencies, however, it is able to provide part of the early-warning information needed in financial supervision beforehand. It is a tool worthy of consideration by bank managers and government officials for planning, operation, and control.

The proposed methodology has another application for future study. Every year, the input and output data for each bank fluctuate. Consequently, the efficiency score of each bank also fluctuates. The efficiency scores of a specific year only give a snapshot of the performance of the banks being evaluated. It will be more informative if we could have a more comprehensive picture of the performance of the banks. One possible way is to treat the banks data as imprecise, and use the smallest and largest observations for each factor for each bank as it appeared in the past as the lower and upper bound of the interval-valued data. With this interval-valued data, the model of this paper can be applied to calculate the minimum and maximum efficiency scores for each bank. The associated efficiency intervals would give a general idea of the relative performance of the banks in the past.
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References


