Measurement of Credit Risk Efficiency and Productivity Change for Commercial Banks in Taiwan

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Abstract

Efficiency measurement is based on the fact that the operational risks are important factors affecting the productivity of a bank. Particularly, the credit risk management of the banks has serious impact on productivity. In this paper, we use financial ratios to assess credit risk of 34 Taiwanese commercial banks over the period 2005-08, and investigate the productivity change based on the factors of credit risk with the Malmquist productivity index (MPI) approach, which is calculated from efficiency scores based on data envelopment analysis (DEA). Our results indicate that the productivity on credit risk of seventeen banks has been improving over the evaluated periods while seventeen banks have been declining. And according to the credit risk efficiency scores and credit risk MPI (CR-MPI), we classify the 34 banks into four groups. We find that different groups of banks should have different strategies of credit risk management to survive in this changing environment.

Keywords: Credit risk; Financial ratios; Data envelopment analysis; Malmquist productivity index.

I. Introduction

There has been an increasing interest in the relationship between operational risks and management [21] [54] [59]. Over the last few decades, there has been a dramatic increase in the number of publications on risk management. However, it is regretful that, on the issue of risk management, in spite of the large number of researchers, only a few studies in risk efficiency have been done. And it is important though, to understand the relationship between efficiency and productivity change based on the factors of operational risks.

In Taiwan, the banking industry plays an important role in Taiwan’s economic development. The last three decades have seen growing importance placed on research in evaluating the operating efficiency of banks. Since 1980s, the vast literature devoted to the study of a bank’s performance has been reviewed on occasions. And most of the studies on bank performance in the literature focus the issues on scale economies, scope economies, cost efficiency, allocative efficiency, and technical efficiency (TE). However, previous research has failed to consider the view of risk efficiency. The risk is an important factor affecting the profitability of the bank. Reference [54] indicated that while low risk decreases the expected profit, it prevents the bank from suffering harshly in case of unexpected events, such as economic crisis. On the other hand, high risk strategies would provide higher expected profits, but will also lead to higher expected returns and accordingly higher discount rates for future cash flows. The high risk plans, even though they provide higher expected profits, may lead to lower market values. Consequently, efficiency measurement by just looking at profit maximization while ignoring risks, may lead to wrong evaluations. This study considers that the risk is an important factor and should be taken into account in efficiency analysis.

The notion of risk which matters is central to all industries. It is not just a question of what kinds of products will be produced, or how much it will cost. Most of the studies on bank performance in the literature employ objective functions focusing on the economics of cost minimization, profit maximization or managerial utility maximization, where the performance equation denotes a cost function, a profit function or a managerial utility function. However, the main deficiency of these researches is their negligence of risk. Recently, regulators have begun to consider the evaluation of credit risk to estimate the effectiveness of the capital requirement regime. Furthermore, efficiency models are based on the fact that the elements of credit risk are important factors affecting the performance of a bank. Researchers in banks' strategic management have also considered credit risk assessment to be a major factor affecting key strategic decisions.

Credit risk is one of the oldest and most important forms of risk faced by banks as financial intermediaries. It is defined as the degree of value fluctuations in debt instruments and derivatives due to changes in the underlying credit quality of borrowers and counterparties. And, it is also measured as the uncertainty of future credit losses around their expected levels. In the literature, there is a basic model for corporate default risks, which is called a structural model of credit risk. It has been introduced by Black and Myron (1973) [14] and Merton (1974) [46]. While Merton's study on the pricing of risky debt was published, interest in pricing models for credit risk has been discussed extensively. About this setting, default of a firm occurs when the total market value of its assets falls below the value of its debts or a certain given threshold level. In order to manage this kind of risk, bank regulators select and monitor borrowers and create a diversified loan portfolio.

Furthermore, there are many researches on credit risk which relate on bankruptcy prediction. A pioneering contribution from the 1960s is Altman's study of bankruptcy prediction [4]. Following Altman, a number of authors have estimated various types of credit risk models based on cross-sectional resampling techniques (e.g. [5] [6] [30] [40] [43] [67]), multivariate discriminant analysis (e.g. [22] [15]), logistic regression (e.g. [45] [52]), and probit analysis (e.g. [74] [68]). Recently, there has been a flurry of developments in the field of evaluating credit risk based on firm performance. The latest work is Psillaki et al. (2010) [57] who investigates whether productive inefficiency measured as the distance from the industry's 'best practice' frontier is an important ex-ante predictor of business failure. It uses samples of French textiles, wood and paper products, computers and R&D companies to obtain efficiency estimates for individual firms in each industry. These efficiency measures are derived from a directional technology distance function constructed empirically using non-parametric data envelopment analysis (DEA) methods. By estimating binary and ordered logit regression models, it is found that productive efficiency has significant explanatory power in predicting the likelihood of default over and above the effect of standard financial indicators.

The literature on credit risk assessment is extensive and growing. A variety of analytical techniques have been used for credit risk assessment. They include statistical methods, models based on contingent claims and asset value coverage of debt obligations, neural networks, and operational research (OR) methods such as linear or quadratic programming and DEA. The bulk of this literature has concentrated on the use of financial factors such as liquidity, profitability and capital structure in risk evaluation [57].

DEA is a widely applied approach for measuring the relative efficiencies of a set of decision making units (DMUs), which use multiple inputs to produce multiple outputs. It has been proven to be an effective tool for performance evaluation and benchmarking since it was first introduced by Charnes et al. (1978) [19]. Charnes et al. (1978) based their work on the seminal paper by Farrell (1957) [27], and is a non-parametric method of efficiency analysis. It is used to evaluate the relative efficiency of a set of comparable entities with making simultaneous use of multiple inputs and outputs. And the method does not require assumptions regarding the shape of the production frontier. After Charnes, Cooper, and Rhodes' model (CCR), a number of different DEA models have been proposed (e.g. [11] [62] [70] [41]), and these models have wide applications in various performance evaluation problems. Recently, an important application of DEA technique is on analyzing the efficiency performance of the banking industry.

During the late 1980s and particularly in the 1990s, the DEA method has been widely accepted and applied in the field of performance evaluation of banking institutions. Table 1 summarizes the studies of DEA research in banks.

Table 1: A study of DEA research in banks

Study	Country	No. of banks	Inputs	Outputs
Sherman and Gold (1985) [65]	USA	14	Employees, expenses, space	Number of transactions
Parkan (1987) [55]	Canada	35	Employees, expenses, space, rent, terminals	Number of transactions, customer response, error corrections
Oral and Yolalan (1990) [53]	Turkey	20	Employees, terminals, number of accounts, credit applications	Number of transactions
Vassiloglou and Giokas (1990) [69]	Greece	20	Employees, suppliers, space, Computer terminals	Number of transactions
Giokas (1991) [32]	Greece	17	Employees, expenses, rent	Number of transactions
Al-Faraj et al. (1993) [2]	Saudi Arabia	15	Employees, location, expenses, acquired equipment	Net profit, balance of current accounts, savings account, loans, number of accounts
Fukuyama (1993) [31]	Japan	143	Employees, capital, funds from customers	Loan revenue, other revenues
Sherman and Ladino (1995) [66]	USA	33	Employees, expenses, rent	Number of transactions
Favero and Papi (1995) [28]	Italy	174	Employees, capital, loanable funds, deposits	Loans, investment in securities, non-interest income
Miller and Noulas (1996) [47]	US	201	Total transactions deposits, total non-transactions deposits, total interest expense, total non-interest expense	Commercial and industrial loans, consumer loans, real estate loans, investment, total interest income, total non-interest income
Athanassopoulos and Curram (1996) [8]	UK	250	ATMs, employees, counter transactions, potential market	Loans sales, liability sales, investments and insurance policies sold
Athanassopoulos (1997) [9]	Greece	68	Employees, ATMs, terminals, interest costs, non-interest costs, location	Non-interest income
Brockett et al. (1997) [16]	Texas (US)	21(300)	Interest expense, non- interest expense, provision for loan losses, total deposits	Interest income, total non-interest income, allowances for loan losses, total loans
Resti (1997) [58]	Italy	270	Employees, capital	Loans, deposits, non-interest income
Bhattacharya et al.	India	74	Interest expense, operating	Advances, deposits, investments

(1997) [13]			expense	
Schaffnit et al. (1997) [61]	Canada	291	Employees	Transactions, maintenance
Ayadi et al. (1998) [10]	Nigeria	10	Interest on deposits, expenses on personnel, total deposits	Total loans, interest income, non-interest income
Al-Shammari and Salimi (1998) [3]	Jordan	16	Selected financial ratios	Selected financial ratios
Chen and Yeh (1998) [20]	Taiwan	34	Employees, assets, number of branches, operating costs, interest expenses	Loans, investments interest income, non-interest income
Seiford and Zhu (1999) [63]	USA	55	Employees, assets, capital stock	Revenue, profits
Golany and Storbeck (1999) [34]	USA	182	Employees, space, marketing	Loans, deposits, accounts per customer, satisfaction
Drake and Howcroft (1999) [23]	UK	250	Number of loan accounts, number of mortgage accounts, number of cheque accounts	Personal loans, new cheque accounts, mortgage loans, insurance commission, change in 'marketed balances'
Zenios et al. (1999) [72]	Cyprus	144	Employees, terminals, space, current accounts, savings accounts, credit applications	Number of transactions
Mukherjee et al. (2002) [50]	India	68	Networth, borrowings, operating expenses, employees, number of branches	Deposits, net profit, advances, non-interest income, interest income
Ho and Zhu (2004) [37]	Taiwan	41	Capital stocks, assets, number of branches, employees	Sales, deposits
Sakar (2006) [60]	Turkey	11	Branch numbers, employees per branch, assets, loans, deposits	ROA, ROE, interest income/assets, interest income/operating income, non-interest income/assets
Wu et al. (2006) [70]	Canada	142	Employees, expenses	Deposits, revenues, loans
Howland and Rowse (2006) [38]	Canada	162	Non-sales FTE, sales FTE, size, city employment rate	Loans, deposits, average number of products/customer, customer loyalty
Pasiouras (2008) [56]	Greek	78	Fixed assets, employee expenses, customer deposits and short term funding, other non-interest expenses, number of employees, loan loss provisions	Loans, net interest income, other earning assets, net commission income, off-balance items, other operating income
Bergendahl and Lindblom (2008) [12]	Swedish	88	Credit losses, personnel expenses, non-interest expenses, interest-rate margins	Loan volume, deposit volume, other earning assets, number of bank branches
Mostafa (2009) [49]	Arab	85	Assets, equity	Net profit, rate on assets (ROA), rate on equity (ROE)
Liu (2010) [42]	Taiwan	25	Employees, assets, purchased funds	Demand deposits, short-term loan, long-term loan

Traditionally, the application of financial ratios helps the evaluation of bank performance. Accounting ratios may be used in order to interpret financial accounts or management accounting data. Two main reasons for using ratios as a tool of analysis are to allow comparison among banks of different size and to control for sector characteristics permitting the comparison of individual bank's ratios with some benchmark for the sector [36]. Furthermore, one of the fields in which formal or mathematical modeling of finance theory has found widespread application is risk measurement [24]. In the past, risk is usually evaluated by a function of expected profit and its standard deviation. The method is considered that the probability distribution depends on the parameter, such as Flannery (1981) [29], Gizycki (2001) [33], and Ennis and Malek (2005) [25]. However, a bank's financial information plays a vital role in decision making of credit risk-taking activities. Extensive literatures dedicated to the prediction of business failure as well as credit scoring concepts have emerged in recent years (e.g. [48] [17]). Financial ratios are among the most popular and widely used tools of financial analysis. They provide us with clues and symptoms of underlying conditions and have been found useful in predicting business failure (e.g. [39] [73] [71]). In general, financial ratio is an excellent tool in the evaluation of banks' credit risk and performance. Therefore, we employ financial ratios to assess and measure credit risk and profitability of a bank. In our DEA model, the ratios that assess credit risk are inputs, and the ratios that measure profitability are outputs.

Productivity growth is one of the major sources of economic development and a thorough understanding of the factors affecting productivity is very important. Current studies on productivity change have applied the Malmquist productivity index (MPI) approach, for example, Alam (2001) [1], Ataullah et al. (2004) [7], Guzmán and Reverte (2008) [35], and Liu (2010) [42], which is evaluated from efficiency scores based on DEA linear programming approach. Originally, Malmquist (1953) introduced a quantity index, defined as the amount by which one consumption bundle must be radially scaled in order to generate the same utility level provided by some base consumption bundle [44]. The MPI was first introduced in productivity literature by Caves et al. (1982) [18]. And Nischimizu and Page (1982) used a parametric programming approach to compute the index for the first time in the empirical context [51]. This index estimates the change in resource use over time that is attributable to efficiency change and due to technological change. And subsequently, Färe et al. (1989) decomposed productivity change into a part attributable to change of technical efficiency (TE) and technological change and used non-parametric mathematical programming models for its computation [26]. In this paper, we employ the MPI to investigate the TE and productivity change of Taiwanese commercial banks over the period 2005-08.

The remainder of the paper is organized as follows. Section II presents the methodology used in the study. Section III describes the data of this study. Section IV discusses the research findings. Section V presents the conclusions from the results obtained.

II. Methodology

Financial ratios measuring profitability, liquidity, and solvency prevailed as the most significant indicators. This study combines financial ratios with DEA model to evaluate the efficiency based on the changes in credit risk of Taiwanese commercial banks over the period 2005-08. In order to understand productivity change caused by the changes in credit risk due to the global financial crisis, we employ MPI which is evaluated from efficiency scores based on DEA linear programming approach. We describe the methodology as follows: DEA and MPI.

2.1 Data Envelopment Analysis (DEA)

To estimate efficiency scores for each DMU we use DEA estimator. We assume that there are n DMUs, $DMU_j, (j = 1,2,...,n)$, within a sample access to the same technology for transforming a vector of m inputs $x_{ij}, (i = 1,2,...,m)$, into a vector of s outputs $y_{rj}, (r = 1,2,...,s)$. Then the relative efficiency of DMU_j can be expressed as

$$E_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \tag{1}$$

where u_r and v_i represent output and input multipliers, respectively. In DEA, E_{j_k} is obtained by solving the following CCR model, which is built on the assumption of constant returns to scale (CRS) of activities and that it evaluates technical efficiency (TE).

$$\begin{aligned} max.\quad & E_{j_k} = \frac{\sum_{r=1}^{s} u_r y_{rj_k}}{\sum_{i=1}^{m} v_i x_{ij_k}} \\ s.t.\quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ \forall j \\ & u_r, v_i \ge 0 \end{aligned} \tag{2}$$

where j_k represents one of the DMUs, DMU_{j_k}. Model (2) is the input-oriented CCR-DEA model. In order to calculate more efficiently, we find the dual of model (2) to be

$$\begin{aligned} min.\quad & E'_{j_k} = \theta_{j_k} \\ s.t.\quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_{j_k} x_{ij_k},\ i = 1,2,\ldots,m \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rj_k},\ r = 1,2,\ldots,s \\ & \lambda_j \ge 0,\ j = 1,2,\ldots,n \end{aligned} \tag{3}$$

where θ_{j_k} is a real variable and λ_j is a non-negative vector.

If the relative efficiency is defined as $e_j = \sum_{i=1}^{m} v_i x_{ij} \big/ \sum_{r=1}^{s} u_r y_{rj}$, then the associated output-oriented CCR-DEA model is

$$\begin{aligned} min.\quad & e_{j_k} = \frac{\sum_{i=1}^{m} v_i x_{ij_k}}{\sum_{r=1}^{s} u_r y_{rj_k}} \\ s.t.\quad & \frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}} \ge 1,\ \forall j \\ & u_r, v_i \ge 0 \end{aligned} \tag{4}$$

The dual of model (4) is

$$\begin{aligned} max.\quad & e'_{j_k} = \varphi_{j_k} \\ s.t.\quad & \sum_{j=1}^{n} \delta_j x_{ij} \le x_{ij_k},\ i = 1,2,\ldots,m \\ & \sum_{j=1}^{n} \delta_j y_{rj} \ge \varphi_{j_k} y_{rj_k},\ r = 1,2,\ldots,s \\ & \delta_j \ge 0,\ j = 1,2,\ldots,n \end{aligned} \tag{5}$$

where φ_{j_k} is a real variable and δ_j is a non-negative vector.

In fact, since the very beginning of DEA studies, various extensions of the CCR model have been proposed, among which the BCC model is representative. The BCC model has its production frontiers spanned by the convex hull of the existing DMUs. The frontiers have piecewise linear and concave characteristics which leads to variable returns to scale (VRS) characterizations with (a) increasing returns-to-scale occurring in the first solid line segment followed by (b) decreasing returns-to-scale in the second segment and (c) constant returns to scale occurring at the point where the transition from the first to the second segment is made [64].

BCC model is used to evaluate the pure technical efficiency (PTE) and the scale efficiency (SE). The associated input-oriented BCC-DEA model is

$$\begin{aligned} max.\quad & E_{j_k} = \frac{\sum_{r=1}^{s} u_r y_{rj_k} - u_0}{\sum_{i=1}^{m} v_i x_{ij_k}} \\ s.t.\quad & \frac{\sum_{r=1}^{s} u_r y_{rj} - u_0}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ \forall j \\ & u_r, v_i \ge 0 \end{aligned} \tag{6}$$

In model (6), u_0 is an output weight.
The dual of model (6) is

$$\begin{aligned} min.\quad & E'_{j_k} = \theta_{j_k} \\ s.t.\quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_{j_k} x_{ij_k},\ i = 1,2,\dots,m \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rj_k},\ r = 1,2,\dots,s \\ & \sum_{j=1}^{n} \lambda_j = 1,\ j = 1,2,\dots,n \\ & \lambda_j \ge 0 \end{aligned} \tag{7}$$

The associated output-oriented BCC-DEA model is

$$\begin{aligned} min.\quad & e_{j_k} = \frac{\sum_{i=1}^{m} v_i x_{ij_k} + v_0}{\sum_{r=1}^{s} u_r y_{rj_k}} \\ s.t.\quad & \frac{\sum_{i=1}^{m} v_i x_{ij} + v_0}{\sum_{r=1}^{s} u_r y_{rj}} \ge 1,\ \forall j \\ & u_r, v_i \ge 0 \end{aligned} \tag{8}$$

The dual of model (8) is

$$\begin{aligned} max.\quad & e'_{j_k} = \varphi_{j_k} \\ s.t.\quad & \sum_{j=1}^{n} \delta_j x_{ij} \le x_{ij_k},\ i = 1,2,\dots,m \\ & \sum_{j=1}^{n} \delta_j y_{rj} \ge \varphi_{j_k} y_{rj_k},\ r = 1,2,\dots,s \\ & \sum_{j=1}^{n} \delta_j = 1,\ j = 1,2,\dots,n \\ & \delta_j \ge 0 \end{aligned} \tag{9}$$

In this paper, we employ model (5) (the output-oriented CCR-DEA model) to evaluate credit risk technical efficiency (CR-TE), and use model (9) (the output-oriented BCC-DEA model) to evaluate credit risk pure technical efficiency (CR-PTE) and credit risk scale efficiency (CR-SE).

2.2 Malmquist Productivity Index (MPI)

We define that $x \in R_+^m$ and $y \in R_+^s$ denote an input vector and an output vector of a decision making unit (DMU) in period t, $t = 1,2,\dots,T$. The production possibilities set (PPS) is defined as

$$PPS^t = \{(y,x) | x \text{ can produce } y \text{ at time } t\} \tag{10}$$

In reference [64], PPS^t is assumed to be closed, bounded, convex, and to satisfy strong disposability of inputs and outputs. The output distance function is

$$D_O(y,x) = min\left[u \middle| \left(\frac{y}{u}, x\right) \in PPS^t\right] \le 1 \tag{11}$$

In model (11), $D_O(y,x)$ satisfies the inequality $D_O(y,x) \le 1$, with $D_O(y,x) = 1$ if and only if,

$$PF_O(x) = \{y | (y,x) \in PPS^t, (\lambda y, x) \notin PPS^t, \lambda > 1\} \tag{12}$$

The PF_O is the output-oriented production frontier.

The distance function in model (11) is a within-period distance function, defined using period t data and period t technology. And (y_t, x_t) denote the output and input vectors of DMU at time t. The output distance function for DMU at time t, relative to the technology existing at time $t+1$, is defined as

$$D_O^{t+1}(y_t, x_t) = min\left[u \middle| \left(\frac{y_t}{u}, x_t\right) \in PPS^{t+1}\right] \tag{13}$$

Therefore, in constant returns to scale (CRS), the output-oriented MPI for DMU in period

$t+1$ is defined as

$$M_O^{t+1}\left(y_t, x_t, y_{t+1}, x_{t+1}\right) = \frac{D_{OC}^{t+1}\left(y_{t+1}, x_{t+1}\right)}{D_{OC}^{t+1}\left(y_t, x_t\right)} \tag{14}$$

And the output-oriented MPI for DMU in period t is defined as

$$M_O^{t}\left(y_t, x_t, y_{t+1}, x_{t+1}\right) = \frac{D_{OC}^{t}\left(y_{t+1}, x_{t+1}\right)}{D_{OC}^{t}\left(y_t, x_t\right)} \tag{15}$$

The geometric mean of adjacent-period output-oriented MPI is

$$M_O\left(y_t, x_t, y_{t+1}, x_{t+1}\right) = \left(\frac{D_{OC}^{t}\left(y_{t+1}, x_{t+1}\right)}{D_{OC}^{t}\left(y_t, x_t\right)} \times \frac{D_{OC}^{t+1}\left(y_{t+1}, x_{t+1}\right)}{D_{OC}^{t+1}\left(y_t, x_t\right)}\right)^{\frac{1}{2}} \tag{16}$$

In model (16), when $M_O\left(y_t, x_t, y_{t+1}, x_{t+1}\right)\begin{cases} > \\ = \\ < \end{cases}$ 1, it represents productivity $\begin{cases} \textit{improvement} \\ \textit{constant} \\ \textit{deterioration} \end{cases}$

Liu (2010) consider that comparing efficiency across years tells only part of the story, and the changes in distance function values from one year to the next year could be due either to: (a) movement of banks within the input/output space, or to (b) technological changes, i.e., to movement of the boundary of the production set over time [42]. In order to measure productivity change during the periods, we employ model (16) to calculate MPI. The method is output orientated DEA Malmquist. It is defined in model (16) measures distance from observed input/output vectors in one period to the technology in another period.

III. The Data

Financial institutions bridge the needs of lenders (savers) and those of borrowers. They provide the flow of resources from one party to the other. Among financial institutions, commercial banks play a major role. They have the largest share of intermediation and are at the very core of a financial system. This study used financial ratio and DEA to assess the financial performance of 34 Taiwanese commercial banks. We obtain the data from Taiwan Economic Journal (TEJ) database and annual report of our sample. This set should be as homogeneous as possible to be meaningful within the DEA relative efficiency measurement characteristic. The ratio of weighted outputs to weighted inputs constitutes the DEA performance index.

Furthermore, selection of proper variables to define and to measure financial performance is always an extremely important decision. Most of the studies in the literature apply DEA for measuring the comparative efficiency of banks. Several literatures evaluate scale efficiency, cost efficiency, and technical efficiency on bank operating performances, and that provide bank regulators with important information for decision-making. There are a few studies that measure bank performance by observing the change in earnings-based financial ratios including the value of return on equity (ROE), return on assets (ROA), return on tier 1 capital, average profit per employee and earnings per share (EPS). The five variables are used to determine if financial structure differences affect the relationship between the cash conversion cycle (CCC) and operating performance. Therefore, we specify five outputs that represent profitability of our sample:

1. Return on equity (Y_1) = Income after tax / Average shareholders' equity
2. Return on assets (Y_2) = Income after tax / Average assets
3. Return on tier 1 capital (Y_3) = Income before tax / Average tier 1 capital
4. Average profit per employee (Y_4) = Income after tax / Total employees
5. Earnings per share (Y_5) = (Income after tax - Dividends of preferred shares) / Weighted average outstanding shares

In addition, we select three financial ratios in credit risk; the input data consist of three main items:

1. Ratio of total loans to total assets (X_1) = Total loans / Total assets
2. Required reserve ratio (X_2) = Deposit reserve / Total deposits
3. Ratio of overdue loans (X_3) = Overdue loans / Total loans

IV. Empirical Analysis

Table 2 gives the descriptive statistics of the variables used in the empirical analysis. It includes mean and standard deviation. In inputs, the standard deviation tells us that there are considerable differences in ratio of deposit reserve to total deposits (X_2) intensity among the banks over the period 2005-08. In 2006, there are the higher means and standard deviation of the inputs (X_2) than the measurements of inputs in the other observed years. And in outputs, the standard deviation shows that there are considerable differences in average profit per employee (Y_4) intensity among the banks over the evaluated periods with year in 2006 being the most Y_4 intensive. In this analysis, we obtain a result that there are considerable differences in all inputs and outputs intensity among the banks in 2006. Furthermore, there are higher means of the outputs in 2005 than the measurements of outputs in the other observed years. We consider that banks had a higher profitability in 2005.

Table 2: Descriptive Statistics of Inputs and Outputs

	2005		2006		2007		2008	
Variable	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
X_1	62.535	10.090	62.958	10.607	64.509	10.540	63.619	9.590
X_2	22.326	24.859	27.209	44.407	20.912	17.866	20.609	11.844
X_3	2.137	0.851	2.206	1.248	2.007	1.033	1.856	0.924
Y_1	122.904	15.802	109.720	26.714	117.001	24.143	115.701	13.337
Y_2	6.281	1.254	5.676	1.816	5.975	1.545	5.623	1.171
Y_3	160.323	21.127	147.079	32.731	155.878	33.289	154.504	18.713
Y_4	12069.510	4023.458	11433.760	4761.517	11671.384	3735.533	10421.327	2182.938
Y_5	9.588	2.463	8.269	3.255	8.156	2.384	7.850	1.621

Table 3 presents the results of DEA. We apply the output-oriented DEA model to estimate contemporaneous credit risk technical efficiency (CR-TE), credit risk pure technical efficiency (CR-PTE), and credit risk scale efficiency (CR-SE) for the banks in our sample. The values of CR-TE, CR-PTE and CR-SE are required by the linear program in model (5) and model (9) solving for each bank over the study periods. In Table 3, we can find that Bank 7, 9, and 12 are efficient in all types of efficiencies over the periods 2005-08. It represents that the three banks have better performance than others, and there are no adverse effects in their credit risk management strategy. Nevertheless, there are thirteen banks never attaining the perfect efficiency score 1.000 during the 4 years, namely, Bank 3, 14, 17, 19, 20, 21, 22, 23, 25, 26, 27, 31, and 33. The result indicates that the thirteen banks have poorer performance than others over the study period.

Table 3: Technical Efficiency, Pure Technical Efficiency, and Scale Efficiency

Bank (DMU)	CR-TE					CR-PTE					CR-SE				
	2005	2006	2007	2008	Ave.	2005	2006	2007	2008	Ave.	2005	2006	2007	2008	Ave.
1	0.914	0.860	1.000	0.928	0.926	0.958	0.937	1.000	0.958	0.963	0.954	0.918	1.000	0.969	0.960
2	0.830	0.897	0.938	1.000	0.916	0.977	0.983	1.000	1.000	0.990	0.850	0.913	0.938	1.000	0.925
3	0.725	0.773	0.717	0.688	0.726	0.916	0.972	0.964	0.960	0.953	0.792	0.796	0.744	0.716	0.762
4	0.938	1.000	0.933	0.823	0.924	1.000	1.000	1.000	0.984	0.996	0.938	1.000	0.933	0.836	0.927
5	0.933	0.991	0.910	0.943	0.944	1.000	1.000	0.987	1.000	0.997	0.933	0.991	0.922	0.943	0.947
6	0.469	0.983	0.816	0.802	0.768	0.507	1.000	0.983	0.963	0.863	0.925	0.983	0.830	0.833	0.893
7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	0.879	0.775	0.828	1.000	0.871	0.929	0.891	0.926	1.000	0.937	0.946	0.869	0.895	1.000	0.928
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	0.960	1.000	1.000	0.635	0.899	0.968	1.000	1.000	0.837	0.951	0.991	1.000	1.000	0.759	0.938
11	1.000	1.000	0.970	0.809	0.945	1.000	1.000	0.989	0.933	0.981	1.000	1.000	0.981	0.867	0.962
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
13	1.000	1.000	1.000	0.950	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.988
14	0.578	0.854	0.737	0.731	0.725	0.654	0.943	0.941	0.924	0.866	0.884	0.906	0.783	0.791	0.841
15	1.000	0.761	0.815	0.942	0.880	1.000	0.790	0.887	1.000	0.919	1.000	0.963	0.918	0.942	0.956
16	0.667	0.513	0.756	0.672	0.652	0.854	0.607	1.000	0.916	0.844	0.781	0.846	0.756	0.734	0.779
17	0.646	0.693	0.658	0.680	0.669	0.860	0.896	0.916	0.910	0.896	0.751	0.773	0.718	0.748	0.748
18	1.000	0.900	0.801	0.854	0.889	1.000	0.987	0.910	0.931	0.957	1.000	0.912	0.881	0.917	0.928
19	0.691	0.712	0.681	0.608	0.673	0.913	0.849	0.920	0.857	0.885	0.757	0.839	0.740	0.709	0.761
20	0.783	0.628	0.771	0.699	0.720	0.879	0.678	0.955	0.914	0.857	0.891	0.927	0.808	0.765	0.848
21	0.880	0.900	0.866	0.574	0.805	0.942	0.960	0.877	0.767	0.887	0.934	0.937	0.987	0.748	0.902
22	0.680	0.664	0.708	0.603	0.664	0.906	0.824	0.941	0.836	0.877	0.751	0.805	0.752	0.721	0.757
23	0.680	0.739	0.837	0.581	0.709	0.925	0.900	0.941	0.819	0.896	0.736	0.821	0.889	0.709	0.789
24	0.819	0.966	0.744	0.880	0.852	1.000	0.967	0.753	1.000	0.930	0.819	0.999	0.987	0.880	0.921
25	0.908	0.715	0.683	0.688	0.749	0.960	0.829	0.861	0.816	0.867	0.946	0.862	0.792	0.843	0.861
26	0.702	0.617	0.658	0.641	0.655	0.891	0.684	0.809	0.790	0.794	0.787	0.902	0.813	0.811	0.828
27	0.828	0.918	0.741	0.719	0.802	0.940	0.928	0.887	0.873	0.907	0.881	0.989	0.836	0.823	0.882
28	1.000	1.000	1.000	0.936	0.984	1.000	1.000	1.000	0.955	0.989	1.000	1.000	1.000	0.979	0.995
29	1.000	0.550	0.485	0.553	0.647	1.000	0.550	0.574	0.626	0.688	1.000	0.999	0.846	0.883	0.932
30	1.000	0.604	0.769	0.721	0.774	1.000	0.633	0.940	0.840	0.853	1.000	0.956	0.818	0.858	0.908
31	0.771	0.640	0.497	0.686	0.649	0.933	0.696	0.652	0.909	0.798	0.826	0.920	0.762	0.754	0.816
32	1.000	0.336	0.581	0.570	0.622	1.000	0.372	0.744	0.701	0.704	1.000	0.904	0.781	0.813	0.875
33	0.739	0.595	0.050	0.568	0.488	0.893	0.665	0.060	0.727	0.586	0.828	0.894	0.836	0.781	0.835
34	1.000	0.901	1.000	1.000	0.975	1.000	1.000	1.000	1.000	1.000	1.000	0.901	1.000	1.000	0.975
Ave.	0.854	0.808	0.793	0.779	0.808	0.935	0.869	0.895	0.904	0.901	0.909	0.927	0.881	0.855	0.893

Note: CR-TE = credit risk technical efficiency; CR-PTE = credit risk pure technical efficiency; CR-SE = credit risk scale efficiency

In Table 4, there are seventeen banks with an efficiency change average value CR-MPI greater than 1.000. They are Bank 1, 2, 3, 5, 6, 8, 9, 14, 15, 16, 17, 20, 24, 28, 32, 33 and 34. This indicates that over the observation period, the productivity of the seventeen banks has been improving. And Bank 4, 7, 10, 11, 12, 13, 18, 19, 21, 22, 23, 25, 26, 27, 29, 30 and 31 have the efficiency change average value CR-MPI less than 1.000. This means that the productivity of the seventeen banks has been deteriorating.

In order to understand the relevance between the competitiveness and productivity change of the DMUs, we depict the credit risk technical efficiency and efficiency change of the Taiwanese commercial banks over the period 2005-08 in Figure 1. In Figure 1, we employ the horizontal axis to represent the individual mean of CR-TE at each DMU for measurement of the competitiveness and the vertical axis to display CR-MPI for measuring the productivity change of each bank. We utilize the total average values of CR-TE 0.808 and CR-MPI 1.000

to determine the threshold values. According to the threshold values 0.808 and 1.000, the 34 commercial banks can be classified into four categories as follows.

1. **Banks with high competitiveness on credit risk management and positive changes in productivity:** In total, there are nine banks, namely, DMU 1, 2, 5, 8, 9, 15, 24, 28, and 34. These banks have an average CR-TE above 0.808 and an average CR-MPI above 1.000. Among them, DMU 1, 2, 5, 8, 15, 24, 28, and 34 have not yet reached the efficient frontier on credit risk management. They must improve the policy or the strategy of credit risk management. However, compared to other banks, the nine banks are on the right track. The result shows that these banks should hold and gain the competitive advantage on credit risk management and improve their productivity over the evaluated periods. They should maintain and gain the greater competitive advantage and seek to find further improvements.

Table 4: Malmquist Productivity Index

Bank	CR-MPI			
(DMU)	2005/2006	2006/2007	2007/2008	Ave.
1	0.952	1.165	0.901	1.006
2	0.981	1.189	1.096	1.089
3	1.048	1.016	0.989	1.018
4	0.954	1.035	0.943	0.977
5	0.940	1.020	1.062	1.007
6	1.903	0.940	1.016	1.286
7	1.037	1.004	0.925	0.989
8	0.892	1.106	1.270	1.089
9	0.929	1.145	1.035	1.036
10	1.033	1.109	0.662	0.935
11	0.692	0.942	0.816	0.817
12	1.089	0.878	0.515	0.827
13	0.720	0.716	0.766	0.734
14	1.352	0.984	0.988	1.108
15	0.689	1.216	1.147	1.017
16	0.735	1.623	0.923	1.094
17	1.014	1.055	1.035	1.035
18	0.906	0.898	1.086	0.963
19	0.926	1.057	0.926	0.970
20	0.748	1.395	0.935	1.026
21	0.954	1.058	0.693	0.902
22	0.884	1.198	0.880	0.987
23	0.968	1.272	0.721	0.987
24	1.070	0.878	1.176	1.041
25	0.749	1.034	0.948	0.910
26	0.815	1.119	0.995	0.976
27	1.006	0.900	1.009	0.972
28	0.836	1.248	0.920	1.001
29	0.517	0.938	1.049	0.835
30	0.536	1.411	0.925	0.957
31	0.761	0.875	1.341	0.992
32	0.294	1.949	0.948	1.064
33	0.733	0.170	5.743	2.215
34	0.803	1.253	1.054	1.037
Ave.	0.896	1.082	1.101	1.026

2. **Banks with low competitiveness on credit risk management and positive changes in productivity:** They are DMU 3, 6, 14, 16, 17, 20, 32, and 33. They have an average CR-TE below 0.808, but an average CR-MPI above 1.000. The eight banks have not yet reached the efficient frontier on credit risk management and their average CR-TE have been even lower than the industry average. They must improve the policy or the strategy of credit risk management. And compared to other banks, although the eight banks do not have the competitive advantage on credit risk management, they have their substantial productivity for the four years. This indicates that the policy or the strategy of credit risk management of the eight banks is gradually improving.

3. **Banks with high competitiveness on credit risk management and negative changes in productivity:** DMU 4, 7, 10, 11, 12, 13, and 18 have an average CR-TE above 0.808, but an average CR-MPI below 1.000. And compared to other banks, these seven DMUs should hold the competitive advantage on credit risk management, but their average CR-MPI represent their productivity deterioration. And DMU 4, 10, 11, 13, and 18 have not yet reached the efficient frontier on credit risk management. The five banks must improve the policy or the strategy of credit risk management. We consider that the three banks must plan new strategies of credit risk management for new breakthroughs to be able to maintain a secure competitive advantage and gain high productivity.
4. **Banks with low competitiveness on credit risk management and negative changes in productivity:** In the case of DMU 19, 21, 22, 23, 25, 26, 27, 29, 30, and 31, these DMUs have an average CR-PTE below 0.808 and an average CR-MPI below 1.000. The result clearly implies that these banks have less competitiveness and productivity deterioration on credit risk management than other banks. We regard that these banks should reexamine their actions and activities in their credit risk management.

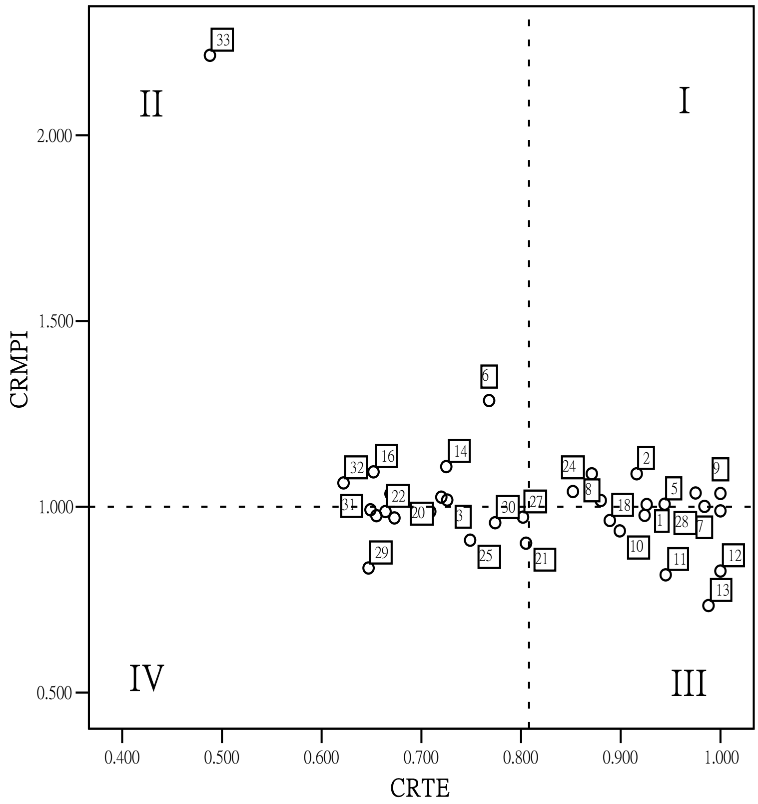

Figure 1: CR-TE and CR-MPI

V. Conclusion

In this paper, we emphasize that the consideration of the overall input space in performance evaluation is not a meaningful concept to the regulators. We should discuss with the characteristics of the influence on inputs and deal with the different aspects of the inputs separately, risk especially.

This study examines CR-TE, CR-PTE, CR-SE and measures the productivity of the 34 Taiwanese commercial banks over the period 2005-08. This paper uses output-oriented DEA model and financial ratios to measure CR-TE, CR-PTE and CR-SE.

The DEA result shows that, in 2005, 2006, 2007 and 2008, out of the sample of 34 banks, there are 35.29%, 23.52%, 23.52% and 17.65% of the banks that are found to be relatively efficient and there are 64.71%, 76.48%, 76.48% and 82.35% of the banks that are found to be relatively inefficient, respectively. Overall, the number of relatively inefficient banks is greater than the number of relatively efficient banks over the periods 2005-08.

According to the values of CR-TE and CR-MPI, we classify the 34 banks into four groups. The banks that had high competitiveness on credit risk management and positive changes in productivity should maintain and gain the greater competitive advantage and seek to find further improvements. The banks that had low competitiveness on credit risk management and positive changes in productivity should improve their credit risk management to maintain high productivity. The banks that had high competitiveness on credit risk management and negative changes in productivity must plan new strategies of credit risk management for new breakthroughs to be able to maintain a secure competitive advantage and gain high productivity. The banks that had low competitiveness on credit risk management and negative changes in productivity should reexamine their actions and activities in their credit risk management. Therefore, we regard that different groups of banks should have different strategies of credit risk management to survive in this changing environment.

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