



Measuring and categorizing technical efficiency and productivity change of commercial banks in Taiwan

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ABSTRACT

The banking industry plays a key role in the process of Taiwan's economic development, and the structure of the financial system in Taiwan has turned from a controlled system into a liberalized one. In this paper, we employ the Malmquist productivity index approach, which is calculated from efficiency scores based on DEA linear programming technique, to measure the technical efficiency and productivity change of the 25 commercial banks in Taiwan over the post Asian crisis period 1997–2001. We find that the technical efficiencies of 15 banks have been improving while 10 banks have been declining over the period. It is also found that the banking industry has a decrease in technical efficiency but owns upward shifts of technology since year 1998. Based on technical efficiency and the efficiency change of the banks, we classify the 25 banks in Taiwan into four categories to help realize the competitiveness and technical progress of the banks. Some of the commercial banks need to search for financial innovation activities and carry on production differentiation to be competitive in the market.

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1. Introduction

Over the past 30 years, Taiwan has achieved high economic development with mild inflation and low unemployment. The financial system plays a key role in the process of Taiwan's economic development. The banking industry in most economies has historically been much more regulated than other industry. Unlike other industries, the collapse of banks can have economy-wide repercussions as the payments system gets disrupted. Such regulation has been all the more stringent in the developing economies where controls on banking activities have been imposed to meet social and economic objectives of development. Thus, not only have there been strict controls on interest rate, there have also been stringent regulations related to branch licensing, directed credit programs, and mergers. Before liberalization, the banking sectors of Taiwan had these regulations as well.

In the 1990s, the central bank of Taiwan has initiated a number of liberalization measures to encourage commercial banks to gradually move toward a more market-driven. The rapid advances in computer and communications technology have led to the development of new bank services and financial instruments. More important, a large number of Taiwan economies undertook massive liberalization of banking sectors to make them more productive and efficient. The widespread relaxation of the financial

system has resulted in a more efficient financial market and enhanced financial technology. The structure of the financial system is then turning from a controlled system into a liberalized one. Especially, when the highest growth of region during the 1990s was hit by the Asian crisis in 1997, one realizes that an efficient financial system must have a sound regulatory system, not only to help financial institutions achieve expected development but also to prevent from relying on risk-taking.

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 of market risk, to evaluate the banks in Taiwan. This system relies on various financial ratios obtained from periodic reports of the entities under regulators' jurisdiction. The ratios are also aggregated into performance indices based on various weighting or scoring schemes. Although the aggregation of the ratios could follow a standard procedure, the complicated processes may involve subjective judgment. Furthermore, 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. The many technological and regulatory changes affecting banking in recent years have substantially altered the environment in which banks operate. Such changes may have significantly altered the technology of bank production, with possible consequences for long-run viability of the industry.

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Data envelopment analysis (DEA), developed by Charnes, Cooper, and Rhodes (1978), is a well established nonparametric approach used to evaluate the relative efficiency of a set of comparable entities called decision making units (DMUs) with multiple inputs and outputs. Numerous DEA theoretical and application studies have been reported, such as Färe, Grosskopf, and Lovell (1994), Seiford (1996), and Cooper, Seiford, and Tone (2000). The efficiency performance of the banking industry has been a critical research stream that draws considerable attention from both academicians and policy makers (Bauer, Berger, Ferrier, & Humphrey, 1998; Berger & DeYoung, 1997; Berger & Humphrey, 1997; Bhattacharyya, Lovell, & Sahay, 1997; Elyasiani & Mehdián, 1990; Kao & Liu, 2004; Lin, Lee, & Chiu, 2009; Liu, 2009; Miller & Noulas, 1996; Rezvanian & Mehdián, 2002; Mostafa, 2009; Sherman & Ladino, 1995; Yeh, 1996; Yue, 1992). Several authors have also utilized DEA efficiency measures as the evaluative information for the management component of CAMELS (Barr, Seiford, & Siems, 1993; Brockett, Charnes, Cooper, Huang, & Sun, 1997; Siems, 1992; Siems & Barr, 1998).

A number of recent studies have focused on investigating productivity change, mainly by employing Malmquist productivity index approach (e.g. Alam, 2001; Ataullah, Cockerill, & Le, 2004; Guzmán & Reverte, 2008; Hauner, 2005; Wheelock & Wilson, 1999), which is evaluated from efficiency scores based on DEA linear programming approach. This Malmquist productivity index technique enables separation of the catching-up or efficiency change effect, i.e., changes over time in the technical efficiency of each DMU with respect to best frontier, from technological change, i.e., the shift of best practice frontier over time due to technological progress. In this paper, we employ the Malmquist productivity index approach to investigate the technical efficiency and productivity change of commercial banks in Taiwan over the period 1997–2001, i.e., the period after the Asian crisis. Based on the measurement of technical efficiency and efficiency change, we classify the commercial banks in Taiwan into four categories to help realize the competitiveness and technical progress.

The rest of this paper is organized as follows: firstly, we introduce the approach of Malmquist productivity index, then we discuss the input and output factors used to measure the efficiency of commercial banks. Next, we utilize the case of Taiwan's commercial banks for illustration, and finally, the results are discussed and some conclusions drawn from the discussion.

2. Methodology

A firm whose combination of inputs and outputs lies in the interior of the feasible production set is technically inefficient, since it would be possible for the firm to expand its outputs while holding inputs constant (or alternatively, to reduce its inputs while holding outputs). Here, we estimate the Shephard (1970) output distance function, while measures how much a firm's outputs can be proportionally increased given the observed levels of its inputs. To estimate the distance functions, we use linear programming techniques that resemble other linear programming-based measures of technical efficiency known as data envelopment analysis (DEA). From the distance function estimates, we estimate Malmquist indices of productivity changes, which we then decompose into changes in technology and changes in efficiency.

In any realistic applied research setting, the true technology is unobserved and must be estimated. Since the true technology is unobserved, Shephard output distance functions are also unobserved and must be estimated, as do so the Malmquist indices of productivity change since they are typically composed of ratios of distance functions. When linear programming techniques are

used to evaluate efficiency, we are in effect using nonparametric estimators of the unobserved, true distance functions.

To formalize these concepts, and to allow for multiple input/multiple output setting, consider n banks which employ m inputs to produce s outputs over T time periods. Let \mathbf{x} and \mathbf{y} denote vectors of inputs and outputs, respectively. The production possibility set at time t is represented by

$$P^t = \{(\mathbf{x}, \mathbf{y}) | \mathbf{x} \text{ can produce } \mathbf{y} \text{ at time } t\}, \tag{1}$$

which may be described in terms of its sections, or output correspondence sets:

$$Q^t(\mathbf{x}) = \{\mathbf{y} | (\mathbf{x}, \mathbf{y}) \in P^t\}. \tag{2}$$

We make standard assumptions regarding $Q^t(\mathbf{x})$, namely: (i) P^t is convex, and $Q^t(\mathbf{x})$ is convex, bounded, and closed for all \mathbf{x} ; (ii) all production requires the use of some inputs, that is, $(\mathbf{x}, \mathbf{y}) \notin P^t$ if $\mathbf{y} \geq 0, \mathbf{x} = 0$; and (iii) both inputs and outputs are strongly disposal, that is, if $(\mathbf{x}, \mathbf{y}) \in P^t$ then $\tilde{\mathbf{x}} \geq \mathbf{x} \Rightarrow (\tilde{\mathbf{x}}, \mathbf{y}) \in P^t$ and $\tilde{\mathbf{y}} \leq \mathbf{y} \Rightarrow (\mathbf{x}, \tilde{\mathbf{y}}) \in P^t$ (see Shephard (1970)). We refer to the upper boundary of P^t as the technology at time t ; this technology may change over time due to innovation regulatory changes, or perhaps other factors.

Let $(\mathbf{x}_i^t, \mathbf{y}_i^t)$ denote the input and output vectors of bank i at time t . The Shephard (1970) output distance function for bank i at time t , relative to the technology existing at time $t + k$, is defined as

$$D^{t+k}(\mathbf{x}_i^t, \mathbf{y}_i^t) \equiv \inf \left\{ \theta > 0 | \mathbf{y}_i^t / \theta \in Q^{t+k}(\mathbf{x}_i^t) \right\}. \tag{3}$$

The distance function $D^{t+k}(\mathbf{x}_i^t, \mathbf{y}_i^t)$ gives a normalized measure of distance from the i th firm's position in the input/output space at time t to the boundary of the production set at time $t + k$ in the hyperplane where inputs remain constant.

The computation of productivity change and its decomposition to technical and efficiency changes is an important part of any empirical analysis related to productivity and efficiency measurement. Färe, Grosskopf, Lindgren, and Ross (1992) derived an input-oriented Malmquist index of productivity change: an analogous output-oriented Malmquist index of productivity change is given by:

$$MPI(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) = \left[\frac{D^t(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})}{D^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} \times \frac{D^{t+k}(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})}{D^{t+k}(\mathbf{x}_i^t, \mathbf{y}_i^t)} \right]^{1/2} \tag{4}$$

Given the definition in Eq. (5), the Malmquist productivity index may be interpreted as an index of total factor productivity. This index represents the productivity of $(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})$ relative to $(\mathbf{x}_i^t, \mathbf{y}_i^t)$. Values greater than 1 indicate increases in productivity, while values less than 1 indicate decreases in productivity over time; values equal to 1 indicate no change in productivity. Färe et al. (1992) decompose this Malmquist productivity index into sub-indices measuring change in efficiency and change in technology by rewriting (4) as:

$$\begin{aligned} MPI(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) &= \frac{D^{t+k}(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})}{D^t(\mathbf{x}_i^t, \mathbf{y}_i^t)} \times \left[\frac{D^t(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})}{D^{t+k}(\mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})} \times \frac{D^t(\mathbf{x}_i^t, \mathbf{y}_i^t)}{D^{t+k}(\mathbf{x}_i^t, \mathbf{y}_i^t)} \right]^{1/2} \\ &= CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) \times SIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) \end{aligned} \tag{5}$$

We obtain the first term on the right hand side of Eq. (5), $CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})$, in their decomposition and refer to this term as an index of pure efficiency change (also called catching-up efficiency). Both the numerator and the denominator of $CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k})$ measure the contemporaneous efficiency of firm i at times t and $t + k$. The value of $CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) > 1$ indicates an increase in output technical efficiency, while $CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) < 1$ indicates a decrease; $CIE(\mathbf{x}_i^t, \mathbf{y}_i^t, \mathbf{x}_i^{t+k}, \mathbf{y}_i^{t+k}) = 1$ would indicate no change in technical efficiency.

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