Chinese Banks' Efficiency and Productivity Change during the Financial Reform Era of 1998 to 2006

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Abstract

The problem of non-performing loans and the low efficiency of Chinese state banks led the Chinese government to undertake financial reform over the period of 1998 to 2006. Nevertheless, Chinese state banks' productivity declined during the early 2000's, raising concerns about a financial crisis in China. This paper analyzes fourteen Chinese banks' technical efficiency and productivity change during the period of financial reform. The efficiency analysis shows that the overall Chinese banking industry became more efficient, with a turning point in 2003. The productivity analysis finds a fall in Chinese state banks' productivity after 2003, indicating that their potential for productivity growth began to weaken from that point.

JEL Classification Number: G21, O16, R11

Key words: Efficiency, Productivity, DEA, Malmquist, China

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The author would like to thank Kyungsoo Kim, Yang Woo Kim, and Ouk-Heon Song at IMER, Bank of Korea, review panels (Jong-Ku Kang, Sang Kyu lee, Kyu In Lee, and Hyun Jung Kim) for all their support and many thanks to conference participants for theiruseful comments.

Paper written on Jan. 30, 2008, revised on Mar. 19, 2008, and publication confirmed on Jun. 03, 2008.

I. Introduction

In the Chinese financial industry, four state-owned commercial banks[1] have taken a dominant position. In the past, the four state-run commercial banks, which control most of the country's banking assets, were specifically instructed to lend to state-owned enterprises (SOEs)[2], this is rooted in the standard operating procedures of the Chinese financial institutions. However, even after the experience of having witnessed economic reform by embracing the market economy, state-owned enterprises continued to show increasingly poor performance. Accordingly, the state-owned commercial banks, which have invested heavily in these SOEs, became insolvent and there were growing concerns over a financial crisis in China[3]. Facing these challenges, China tried to resolve these problems through financial reform by 2006; it had completed the stock system reformation of state-owned commercial banks. In addition, the Chinese government began financial reform aimed at opening the financial market, after restructuring commercial banks into the stock market system.

If the Chinese banking industry, which supports the growth of the real economy, does not ensure its solvency, including a solution of the non-performing loans (NPLs) problem, the heavily bank-dominated financial industry in China is likely to become insolvent. If China undergoes a financial crisis, it will have a considerable effect on the many Asian countries that have entered the globalization era. Korea, whose economy is highly dependent on China, will be substantially hit. Because of this, it is necessary to research in depth the efficiency and productivity of the Chinese banking industry.

Despite the significance of the Chinese banking industry on Korean economy, there has been little research conducted on it. For research analyzing both the efficiency and the productivity of financial institutions, we have two types of approach including intermediation approaches regarding deposits as input, and production approaches, which consider deposits as output[4]. In recent years, the

1) These include Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, and China Construction Bank. Since 2005 when state-owned commercial banks' equity was opened to the stock market, Chinese bank structures of 100% state ownership have started to change. However, the fundamental structure of control, which implies that the government holds a major share in state-owned commercial banks, hasn't changed yet.

2) This policy is evidence of Chinese's centrally planned economic structures to promote development of heavy industries as a priority.

3) Refer to the articles from Economist (2001.8.23, 2003.1.17) and AWSJ (2002.8.7, 2003.1.20).

4) The intermediation approach regards financial institutions as making loans through labor, capital, and deposits, while the production approach regard deposits and loans as being made by labor and capital.

intermediation approach has been more widely used due to its reflection of the specialization of financial institutions (Chen · Skully · Brown 2005, p. 237)[5].

For an analysis of the intermediation approach, Chen · Skully · Brown(2005) compared the efficiency of banks before and after financial reform in 43 Chinese banks during the period of 1993 to 2000. Their results show that overall efficiency has improved since financial reform. The inefficiency of state-owned commercial banks is of a more serious degree than private commercial banks.

A study on the production approach includes Oh (2007). Oh (2007) showed that scale inefficiency is the major culprit for the decline of efficiency and argued that it is essential to have financial reform through restructuring.

While the researchers mentioned above mainly conduct cross-section analysis on efficiency, studies on changes in productivity have been rare. In this paper, we would like to evaluate the performance of financial reform by making a cross-section analysis on the efficiency of Chinese banking industry, in addition to a dynamic analysis on changes in productivity. Furthermore, we would like to analyze whether the inefficiency and low productivity of state-owned commercial banks, which the previous researchers demonstrated, were improved by financial reform from a perspective of growth and profitability.

The paper is constructed as follows. In Chapter II, we introduce details about China's financial reform. Chapter III presents a theoretical model to measure the efficiency and the productivity of the banking industry. Chapter IV describes the variables used in empirical analysis and the result of it, and Chapter V concludes the paper with thoughts on the implications for China's financial reform of China's embracing the market economy.

II. China's Financial Reform

Before moving from a socialist economy to a market-oriented economy in 1979, China was a typical centrally planned economy, with financial institutions intended to complement the government's economic programs. After witnessing

5) The variables selection of previous research was done by using those of efficiency analysis of the typical banking industry. Chen · Skully · Brown(2005) explained variables selection for analyzing banking efficiency, saying "it's a general form using inputs for the intermediation approach of capital (fixed assets investment), cost (price or number of labor, interest expenses or deposits) and loans (or interest payment) for outputs." (Chen · Skully · Brown 2005, p.237).

the low efficiency of Chinese commercial banks and rising levels of non-performing loans (NPLs), China decided to execute financial reform.[6] China's financial reform era can be divided into two periods: the early period of the reform era, which introduced a new financial system and legal system and the later period, which carried out enhancements to financial industry competitiveness following the first reform. (Mun 2001, p.1, Fu . Heffernan 2007, p.36).

The first financial reform period was roughly from 1979 to 1997. From 1979 to 1983, the framework of the modern financial system was established, creating four state-owned specialized banks and also non-bank financial institutions such as China International Trust & Investment Corp, the People's Insurance Company of China, and rural credit cooperatives. The established four specialized banks are Agricultural Bank of China for financial activities promoting reform in the agricultural sector; the Bank of China for dealing with foreign currency exchange activities; China Construction Bank Corporation, created to fund fixed assets investment; and China Investment Bank, whose loan portfolio primarily deal with small- and medium-sized businesses. During this period the government converted both fixed assets investment and operation funds, originally financed by the central government, into bank loans and imposed a duty of principal repayment and interest payment on firms. It also raised loan interest rates and imposed high default interest rates in order to bring about a more efficient allocation of funds and induce firms to manage efficiently.

During the period of 1984 to 1993, the two-tier banking system[7]was introduced and a broader financial system was created, consisting of the four state-owned specialized banks, ten stock-system commercial banks, municipal credit union, local banks, and securities for the purpose of fostering short-and long-term financial markets. The Industrial and Commercial Bank of China (ICBC) was founded in 1984 and the commercial banks took over business sector financing, which the People's Bank of China had previously been in charge of; this led to the separation of commercial banks from the central bank. Due to an increase in private savings and firms' increasing demand for funds, new resources for fund intermediation were called for. As a result, a money

6) Because of its mono-bank model typical of a centrally planned economy, after the reform, China suffered serious problems of resource misallocation, as evidenced by declining loan efficiency following the amalgamation of fiscal support, finance, and state-owned enterprises. Thus, restructuring of the financial system was necessary, in order to bring about the efficient allocation of funds (Chan Il Park 2005, Ki Bo ku 2006).

7) This means that the central bank is separated from the one-tier banking system which used to provide the commercial banking function.

market was set up during 1986 to 1989, including mechanisms such as a call market, commercial paper discount market, CD market, and CP market. In order to nurture the capital market, the Shanghai Stock Exchange was established in 1990. In addition to capitalizing the surplus income formed after the reform, the Shanghai Stock Exchange was promoted to lower the fiscal dependency of state-owned firms and to raise the efficiency of the system of managerial responsibility.

From 1994 to 1997, finance related laws, and a legal system to enforce those laws, were designed and created. Despite the adoption of the two-tier banking system, the four state-owned specialized banks operated as monopolies and fair competition was inhibited; this was a negative factor in the development of the Chinese financial industry and led to the finance and planning work of the four specialized banks being taken over by the newly-established China Development Bank and Agricultural Development Bank of China. The specialized banks were converted into state-owned commercial banks and began to take the responsibility for profits and losses generated by their operating activities. In order to improve abnormal loan practices undertaken between banks and their subsidiary firms and to advance the soundness of bank management, the Chinese government separated subsidiary firms from their banks and prohibited ancillary businesses. (Mun 2001, p.3).

The second financial reform was undertaken during the period of 1998 to 2006.[8] The restructuring was designed to solve the problem of non-performing loans through the injection of foreign exchange holdings, the issue of government bonds and establishment of asset management companies.[9]For the purpose of clearing up non-performing loans[10], which exceeded 25% of the total loans of the four state-owned commercial banks, the government expanded the

8) The second financial reform initially centered on banks, ahead of the opening of the yuan money market in 2007.

9) Problems involving non-performing loans arose mainly from funding of state-owned enterprises and for properties investment. Until 2000, up to 50% of banks credit extended to associated state-owned enterprises, and, in particular 86% of the banking assets of the four state-run commercial banks represented lending to SOEs. In the early '90s, there had been a dramatic increase in mortgage loans, but starting from 1993 with surging property prices, this declined, leading to increased levels of non-performing loans. The official estimate of non-performing loans in the four state banks was 1765.6 bilion yuan as of the end of 2001, which was 25.4% of total loan balances, making up the equivalent of 18.4% of GDP.

10) However, other financial institutions such as the International Financial Center or credit rating companies estimated the actual size of the non-performing loans to be 2.5 to 3 times higher than the official estimate. For example, the Bank of International Settlements estimated the size of non-performing loans as 47% of total loan balances, S&P calculated them at $540 billion, which was 50% of GDP, while estimates by McKinsey varied between 44 to 55% of GDP (Bank of Korea 2006).

equity capital of state-owned commercial banks[11]in 1998 and founded four asset management firms in 1999.

As we mentioned above, in order to resolve the problem of non-performing loans, as shown in Table 1, the Chinese government attempted to clear off non-performing loans by using fiscal funds and establishing asset management companies from 1998; unfortunately their performance was not effective. The Chinese government also increased the equity capital of state-owned commercial banks by the injection of 32 billion dollars in 1998 and took over the non-performing loans from state-owned commercial banks by setting up four asset management firms in 1999. The asset management firms took over non-performing loans with a face-value of 1400 billion yuan from state-owned commercial banks; these had arisen from loans extended before the implementation of the Chinese Commercial Bank Act[12]. Nevertheless, only 23.23 billion yuan of non-performing loans[13], 16.7% of the total, had been cleared off by September 2002.[14] Following this effort, other measures such as asset sales and securitization[15] debt for equity swaps[16], and establishment of limited partnerships with foreign financial institutions were used to dispose of non-performing loans. The government cleared off 62.2% of non-performing loans by the first quarter of 2006.

The Chinese government established China SAFE Investment (CHIL) in 2003 and used an estimated 60 billion dollars to resolve the problem of non-performing loans, giving 22.5 billion dollars to the China Construction Bank and

11) Issuing government bonds, only available for transactions in the interbank market, at a 30-year high interest rate of 7.2 % had benefited the four state-owned banks, which the entire amount onto their books.

12) In order to prevent the development of risky assets, it set out a lending schedule for state-owned enterprises made it obligatory to carry out credit screening and secure collateral before lending, establishing same party lending limits (within 10% of assets), and so on.

13) This includes debt for equity swaps and the sale of loans.

14) Refer to "Non-performing Loans in China's Banks and Their Resolution" in World Economic Review, volume 2002-44, Bank of Korea.

15) As a consequence of the entry into effect of the Trust Act from October 2001, an institutional foundation for securitization was established, which provided a solution for the problem of moral hazard that had arisen because of the overvaluation of non-performing loans and the disposal of state assets at knockdown prices, debt for equity swaps.

16) This implies the conversion of non-performing loans into the equity capital of the debt, meaning that the asset management firms share in the profits or sell off of their stake after securing assets through the conversion of the debts of state-owned enterprises into equity capital and the achievement of a management turnaround.

the Bank of China[17] and 15 billion dollars[18] to Industrial and Commercial Bank of China (ICBC). In line with the placement of foreign reserves, reform of the stock system was carried out at the same time by converting three of the state-owned commercial banks into joint stock companies. Additional financial reform was conducted by securing equity capital through the issuance of subordinated bonds, writing off non-performing loans and inducing foreign banks to take stakes as strategic investors. Faced with the full opening of the banking industry in 2007, the government carried out reform of the banking sector at a swift pace, inducing foreign capital (strategic investor abroad[19]), securing capital through initial public offerings (IPO), and the listing of banking stocks on local and foreign exchanges (see Tables 2 and 3).

Table 1 **Clearing off of non-performing loans by asset management firms**

unit: hundred million yuan

Asset management firms	Huarong (華融)	Xinda (信達)	Dongfang (東方)	Changcheng (長城)	Sum
(Banks with NPLs)	Industrial and Commercial Bank of China(ICBC)	China Construction Bank	Bank of China	Agricultural Bank of China	
Total take-over amount of NPLs (A)	4,077	3,730	2,674	3,458	13,939
Cleaning amount of NPLs (B)	443 (2,468)	702 (2,067.7)	340 (1,419.9)	838 (2,707.8)	2,323 (8,663)
Cash payback (C)	146 (546.6)	216(652.6)	86 (328.1)	77 (278.3)	525(1,805.6)
Progress rate of cleaning (B/A, %)	10.9 (60.5)	18.8 (55.4)	12.7 (53.1)	24.2 (78.3)	16.7 (62.2)
Cash payback rate (C/B, %)	33.0(22.15)	30.8 (31.56)	25.3 (23.11)	9.2 (10.28)	22.6 (20.84)

Source: People's Bank of China, Bank for International Settlements, China Banking Regulatory Commission (www.cbrc.gov.cn) as on Sep. 2002 (the figures in parenthesis are as on the end of March, 2006), and the World Economic Review 2006, Bank of Korea.

17) As of the end of 2003, foreign exchange from the foreign exchange reserves to the equivalent of about 373 billion yuan was provided to clear the non-performing loans.

18) In order to resolve the problem of non-performing loans, 15 billion dollars in foreign exchange from the reserves were provided to Industrial and Commercial Bank of China (ICBC).

19) Foreign financial institutions rushed to invest in the Chinese market in order to expand their business within China in future through the build-up of large organizations and in the expectation of an increase in the value of the stocks after the listing of the state -owned commercial banks.

Table 2 **Investment of foreign capital in China's state-owned commercial banks (2006)**

	Foreign investors	Amount	Equity stake
Industrial and Commercial Bank of China(ICBC)	Goldman Sachs(US), Allianz(GM) American Express(US)	$3.78 billion*	10%
Bank of China	RBS(ENG), Merrill Lynch(US), Lee Ga Sung Fund(HK)	$3.1 billion*	10%
	Temasek(SG)	$1.5 billion	5%
	UBS(SW)	$500 million	1.6%
	Asian Development Bank (ADB)	$75 million	0.24%
China Construction Bank	BoA(US)	$3 billion	9%
	Temasek(SG)	$1.4 billion	5.1%
Agricultural Bank of China	–	–	–

* Investors formed a consortium (World Economic Review 2006, Bank of Korea)

Table 3 **Commercial banks' listing on the stock market**

	Details	Amount raised
Bank of Communications	Listed shares on Hong Kong Exchange in June 2005	$2.2 billion
China Construction Bank	Listing on Hong Kong Exchange in Oct. 2005	$9.2 billion
Bank of China	Listing on Hong Kong Exchange in June 2006 Listing on Shanghai Stock Exchange in July 2006	$11.2 billion $2.5 billion
Industrial and Commercial Bank of China(ICBC)	Simultaneous listings on Hong Kong and Shanghai Stock Exchanges in Oct. 2006	$19.06 billion

Source: World Economic Review 2006, Bank of Korea

Through financial reform, Chinese banks have made considerable progress, showing healthy financial structures, improving operational capacity, and

changing their bureaucratic structure.[20] The China Banking Regulatory Commission announced that most banks had reached an 8% equity capital ratio as of the end of 2006. Despite these gains, risk factors such as intensified competition following the opening of the Chinese financial markets, the maintenance of past financial practices and moral hazard continue to exist. Indeed, many improvements still remain to be made, especially in areas such as profitability, financial soundness, banking system innovations, management autonomy and practices, and human resources.[21]

III. Analysis model

Before moving from a socialist economy to a market-oriented economy in 1979, China was a typical centrally planned economy, with financial institutions intended to complement the government's economic programs.

Most research on the efficiency of the global banking industry has centered on US financial institutions; this focus was used to help estimate economics of scale by using a method of estimating a cost function. Much of this research assumes that banks work efficiently and contains the implicit assumption that inefficiency results from problems of scope and scale. As banks produce at the points inside a production possibilities curve, technical inefficiencies may arise. A production possibilities curve is estimated from observed data, and should take into account the fact that technical inefficiency may occur. Research on these technical inefficiencies is used to create realistic production possibilities curve; this research generally takes one of two directions: Stochastic Frontier Analysis (SFA), a parametric method of assuming production function, or Data Envelopment Analysis (DEA), a non-parametric method of not assuming production function.

The method of measuring production efficiency by using the DEA approach, which this paper uses, was first proposed by Farrell (1957) and was later developed by others including Shephard (1970), and Banker et al. (1984). After

20) S&P revised China's sovereign credit rating upwards from A- to A in July 2006, reflecting the strengthening of the Chinese banking system and its astonishing prospects for economic growth. Moreover, UBS announced that the level of non-performing loans of state-owned commercial banks which had been as high as 50% had declined markedly and that it was positive as to the reduced occurrence of NPLs in future.

21) For greater detail, please refer to "China's Recent Banking Reform and Its Problems" in World Economic Review, volume 2006-87, Bank of Korea.

Shepherd (1970) introduced the efficiency measurement method of using production possibilities function, misspecification errors arising from the assumption of production function can be avoided by using the DEA method. In addition, this method is appropriate to deal with various outputs and inputs and has been widely used in estimating efficiency of financial industry. Since then, Färe et al. (1985, 1989, and 1994) have further developed it into an improved production measurement method by dividing productivity changes into efficiency changes and technology changes and conducting measurement using the Malmquist index.

1. Data Envelopment Analysis (DEA)

The paper uses data development analysis to gauge efficiency. This model measures and compares the relative efficiency between the most efficient bank generating the maximum output and other banks, utilizing the minimum input factor for the given amount or using a certain amount of input factor (s).[22)]

When there are banks that produce output of using input, linear programming for minimizing the use of input at the given production level is defined as follows (Färe 1985).[23)]

$$F_i(\mathrm{y},\mathrm{x}\,|\,C,S) = \min \theta : \theta \mathrm{x} \in L(\mathrm{y}|\,C,S) \qquad (1)$$

$$L(\mathrm{y}|\,C,S) = \{(\mathrm{x}_1 ... ,\mathrm{x}_N) \ : \ \sum_{k=1}^{K} z_k y_{km} \geqq y_m,\ m = 1,...,\ M,$$

22) DEA is a nonparametric method to compare the efficiency of multiple decision making units (DMUs) when the production process presents a structure of multiple inputs and outputs. Instead of measuring the efficiency of DMUs of enterprises or banks, where the weights structure is calculated by means of mathematical programming, it uses that of variable returns to scale (Banker, Charnes and Cooper 1984). According to Charnes, Cooper, and Rhodes (1978) for selecting DMU, it has to be an economic unit, enabling control of resources and produced output, which implies that DMU should control the resource distribution of inputs and outputs under any given circumstances. Also, a number of DMUs should be greater enough to allow degree of freedom in order to improve the reliability of efficiency results, indicating that the number of DMUs to be analyzed should be greater than that of inputs and outputs. DEA has a distinctive character in that it handles multiple inputs and outputs, without having to estimate either a cost function or production function.

23) According to Färe (1985), efficiency of banks is defined as a weighted sum of outputs to a weighted sum of inputs, which cannot be greater than 1, where constant returns to scale (CRS) are assumed (Charnes, Cooper, Rhodes 1978).

$$\sum_{k=1}^{K} z_k \, x_{kn} \leqq x_n, \; n = 1, \ldots, N,$$

$$z_k \geqq 0, \; k = 1, \ldots, K \; \}$$

where $F_i(y, x \mid C, S)$ refers to Farrell's input-oriented efficient function and its solution (θ^*) is the scale of technical efficiency of each bank. $L(y \mid C, S)$ denotes the input requirement set, which is all possible combinations of input vectors used for producing output from banks. C is constant returns to scale, S represents that the strong disposability assumption on output[24] holds, and is a weighted vector. y_{km} stands for the amount of mth output of kth bank, and x_{kn} denotes the amount of nth input of kth bank.

In the linear programming model in equation (1), constraint conditions are projected on banks inside the production possibilities curve. When the inefficient banks inside the production possibilities curve (x_n, y_m) decrease the input level proportionate to the output level, the constraint condition reaches, ($z_k \, x_{kn}$, $z_k \, y_{km}$) the point on the production possibilities curve at which the weighted vector, and efficiency value, θ^*, are determined.

The assumption of constant returns to scale (CRS) can be applied only to the case where all banks move in the optimal scale. However, there may be a case where banks cannot move in the optimal scale due to imperfect competition or budget constraints. Here technical efficiency is measured by applying the assumption of constant returns to scale and includes the effect of efficiency of scale. To solve these problems, we can assume variable returns to scale (VRS) and measure the efficiency. In this case, we can separate pure technical efficiency and measure the efficiency by controlling scale efficiency. The difference between equation (1) and equation (2) is that the sum of weighted vector, 1 is added as a constraint in equation (2) (Färe 1994).[25]

24) C, V, and S in parenthesis from equation (1) mean constant returns to scale (CRS), variable returns to scale (VRS), and strong disposability respectively. Here, strong disposability is termed free disposability, implying no restriction for inefficient DMUs to reduce the excessive inputs in order to induce efficiency (Färe 1985).

25) While CRS is needed to meet the condition of $z_k \geq 0$ from equation (1), having a straight production possibility curve without the existence of inefficiency, VRS has to meet the condition of $\sum_{k=1}^{K} z_k = 1$ like as in equation (2), showing a convex to production possibility curve of CRS since it has inefficiency (for more detail, refer to Färe 1994, page #73).

$$F_i(\mathrm{y},\mathrm{x}\,|\,V,S) = \min \theta : \theta\mathrm{x} \in L(\mathrm{y}|\,V,S) \qquad (2)$$

$$L(\mathrm{y}|\,V,S) = \{(\mathrm{x}_1,...,\mathrm{x}_N) \;:\; \sum_{k=1}^{K} z_k y_{km} \geq y_m,\ m=1,...,M,$$

$$\sum_{k=1}^{K} z_k \mathrm{x}_{kn} \leq \mathrm{x}_n,\ n=1,...,N,$$

$$\sum_{k=1}^{K} z_k = 1,\ z_k \geq 0,\ k=1,...,K$$

Scale efficiency denotes the extent of deviation from the most efficient frontier assuming CRS production technology. It is derived from the ratio of technical efficiency under constant returns to scale to pure technical efficiency under variables returns to scale.[26)]

$$S_i(\mathrm{y},\mathrm{x}|S) = F_i(\mathrm{y},\mathrm{x}\,|\,C,S) \,/\, F_i(\mathrm{y},\mathrm{x}\,|\,V,S) \qquad (3)$$

Input-oriented efficiency has the value of [0,1]. When the value of efficiency is 1, a bank is efficient. When the value is less than 1, a bank is inefficient. When the input-oriented scale efficiency is 1, the decision making unit is efficient in the aspect of scale. That is, the bank puts the most efficient input under a certain amount of outputs regardless of the fact that production technology is assumed to be either constant returns to scale or variable returns to scale. If the value is smaller than 1, the bank puts efficient input under the production technology of increasing (or decreasing) returns to scale. Under constant returns to scale, however, the bank is inefficient. In this case, the bank is inefficient in the aspect of scale (Färe 1985).

2. Malmquist Productivity Index

Using the Malmquist Productivity Index, we can conduct an analysis on how productivity of banking industry changes over time.

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26) Thus, $TE_{CRS} = PTE_{VRS} \cdot SE$ where technological efficiency (TE_{CRS}) is divided into pure technological efficiency (PTE_{prs}) and size efficiency (SE). That is $SE = TE_{CRS} / PTE_{VRS}$.

When we regard input and output of time t as (x^t, y^t), and input and output of time t+1 as (x^{t+1}, y^{t+1}), the growth rate index of total factor productivity can be expressed generally in equation (4) as follows.

$$\Delta TFP = \frac{y^{t+1}/x^{t+1}}{y^t/x^t} \tag{4}$$

We use a distance function to extend the index to a general case that considers various outputs. The distance function is a reciprocal of Farrell function measuring technical efficiency in the DEA analysis. In other words, the relationship between input-oriented distance function $D_i^t(x^t, y^t|C,S)$ and Farrell efficient function is represented as follows[27] (Shephard 1970, Färe 1988).

$$D_i^t(x^t, y^t \mid C,S) = 1/ (F_i(x_t, y_t \mid C,S) \tag{5}$$

In $D_i^t(x^t, y^t \mid C,S)$, suffix t denotes technology of time t (production possibilities curve), suffix i input-oriented, (x^t, y^t) input (x^t) and output (y^t) at time t, C in parenthesis constant returns to scale, and S means an assumption of strong disposability on output holds.

When the distance function equation (5) is applied to the definition of the rate of change in productivity, it becomes equation (6). As in Grosskopt (1993), we can define it as Malmquist productivity index (M_i^t) at time t in equation (7)[28].

$$\Delta TFP = \frac{y^{t+1}/x^{t+1}}{y^t/x^t} = \frac{D_i^t(x^{t+1}, y^{t+1} \mid C,S)}{D_i^t(x^t, y^t \mid C,S)} \tag{6}$$

$$M_i^t = \frac{D_i^t(x^{t+1}, y^{t+1} \mid C,S)}{D_i^t(x^t, y^t \mid C,S)} \tag{7}$$

27) Distance function (refer to D) assumes both CRS and strong disposability. Thus, efficiency here refers only to technological one, not separating the change in scale efficiency.

28) Refer to Grosskopt(1993) and Grifell-Tatje and Lovell(1995) for details of equation (6).

Equation (7) is the Malmquist productivity index (M_i^t) based on technology at time t. The Malmquist productivity index (M_i^{t+1}) based on technology at time t+1 can be expressed as equation (8).

$$M_i^{t+1} = \frac{D_i^{t+1}(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)}{D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S)} \quad (8)$$

In order to obtain the productivity index not obscured by technological factors on existing (or standard technologies), the Malmquist productivity index (M_i) is represented as a geometric mean of these two indexes in equation (9)[29] (Grosskopt 1993, Grifell-Tatje and Lovell 1995).

$$M_i(\mathrm{x}^{t+1}, \mathrm{y}^{t+1}, \mathrm{x}^t, \mathrm{y}^t) = \left(\frac{D_i^t(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)}{D_i^t(\mathrm{x}^t, y^t \mid C,S)} \; \frac{D_i^{t+1}(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)}{D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S)}\right)^{1/2} \quad (9)$$

When this equation is transformed, we can dissolve it into two indexes, an efficiency change index(EC) denoting changes in technical efficiency and a technological change index(TC), standing for the change in technology itself(production possibilities curve)[30](Fäe 1994).

$M_i(\mathrm{x}^{t+1}, \mathrm{y}^{t+1}, \mathrm{x}^t, \mathrm{y}^t)$

= EC: Efficiency Change (TC: Technological Change)

$$= \frac{D_i^{t+1}(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)}{D_i^t(\mathrm{x}^t, y^t \mid C,S)} \left(\frac{D_i^t(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)}{D_i^{t+1}(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)} \; \frac{D_i^t(\mathrm{x}^t, y^t \mid C,S)}{D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S)}\right)^{1/2} \quad (10)$$

29) Production index at a different point (t, t+1) has the awkward feature of having different production values depending more on standard points; thus this implies the calculation of the geometric average of values from two other points.

30) The first term in equation (10) shows a ratio of distance functions measured by two different technological levels, implying a change in technological efficiency. In other words, it measures efficiency changes of how as production levels of two different periods come near or far to/from a point on production possibility curve. The second term shows technological changes of two periods, indicating the geometric average of possible producing amounts, which is measured in between of t and t+1.

If each index is greater than 1, there is an improvement in productivity, efficiency, and technology. If it is smaller than 1, there is a decrease in these.

The input-oriented distance function at time t+1 based on technology at time t, $D_i^t(\mathrm{x}^{t+1}, \mathrm{y}^{t+1} \mid C,S)$ can be calculated from the relationship with the Farrell efficient function in equation (2) as follows.

$$D_i^t(\mathrm{x}^{t+1}, \mathrm{y}^{t+1} \mid C,S)^{-1} = \min \theta \tag{11}$$

$$s.t \quad \sum_{k=1}^{K} z_k \cdot \mathrm{y}_{km}^{t} \geq \mathrm{y}_{km}^{t+1}, m = 1,..., M$$

$$\sum_{k=1}^{K} z_k \cdot \mathrm{x}_{kn}^{t} \leq \theta \mathrm{x}_{kn}^{t+1}, n = 1,..., N$$

$$z_k \geq 0, \; k = 1,..., K$$

The input-oriented distance function at time t under technology at time t+1, $D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S)$ is calculated in the same way.

$$(D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S))^{-1} = \min \theta$$

$$s.t \quad \sum_{k=1}^{K} z_k \cdot \mathrm{y}_{km}^{t+1} \geq \mathrm{y}_{km}^{t}, m = 1,..., M \tag{12}$$

$$\sum_{k=1}^{K} z_k \cdot \mathrm{x}_{km}^{t+1} \leq \theta \mathrm{x}_{kn}^{t}, n = 1,..., N$$

$$z_k \geq 0, \; k = 1,..., K$$

Using the same method, we can derive four distance functions such as $D_i^t(\mathrm{x}^t, y^t \mid C,S)$, $D_i^{t+1}(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)$, $D_i^t(\mathrm{x}^{t+1}, y^{t+1} \mid C,S)$ and $D_i^{t+1}(\mathrm{x}^t, y^t \mid C,S)$. We can obtain the Malmquist productivity index (M), efficiency change index (EC), and technological index (TC) by substituting these functions with equation (10).

IV. Empirical analysis

1. Input output variables and data

A key characteristic of the banking industry is that it has a considerable effect on the national economy as a whole. As a result, governments typically impose significant regulation on it. In addition, banks have differences in input and output structures from general firms since a bank is a firm producing multi-item products and providing various financial services. In defining the input factor and output of the banking industry, there are two approaches namely the intermediation approach and the production approach, which depends on the role or function of banks.

In this chapter, we will conduct an analysis of efficiency using DEA centering on the intermediation approach commonly used in evaluating the efficiency of financial institutions, and an analysis on productivity change using the Malmquist productivity index. The model (A) uses stock variables both in input and output. Deposits, one of the stock variables used in this model, tend to increase irrespective of management performance since investment in stocks and bonds is not active owing to the underdevelopment of the financial markets. In the case of loans, there are limits in evaluating management performance through these indexes since government directed policy loans are included in the loans total. Taking these facts into account, we will also conduct an analysis on management performance through expense, interest cost and interest income in model (B). Owing to a lack of data on labor costs, we use the number of employees as a proxy variable for flow variables of labor.

Therefore, model (A) is for evaluation of growth and model (B) is for evaluation of profitability[31] inputs and outputs by model were used as variables in Table 4. Labor (the number of employees), capital (fixed asset investment), and deposits are used for inputs, and loans are used as outputs in model (A)[32]. In model (B), input factors are labor (the number of employees), expenses, interest cost, while interest income is used for output.[33]

The data used in the analysis are the panel data of 14 Chinese commercial

31) Variables for model A and B were selected in accordance with Chen · Skully · Brown(2005, p.237), being commonly used in efficiency analysis research, while research comparing analyses where stock and flow variables are employed make use of models by Leightner - Lovell(1998, pp.121-124) and Chung Hyungkwon(2007, p.14). This research uses the same variables as in the most of the previous research on the Chinese banking industry.

banks[34] from 1998 to 2006. The analysis period covers the second financial period. We carried out the analysis by dividing the period into three sub-periods, the beginning (1998-1999), the middle (2000-2003), and the end (2004-2006), while focusing especially on 1999,when the asset management firms were established to tackle the non-performing loans of state-owned firms, and also on 2003, the point of time when China SAFE Investments was set up, foreign exchange was provided to the commercial banks from the reserves, and the stock system reform began (2003). The Bank Scope Database of Bureau Van Dijk (1998-2006) is the main source of the input and output data of Chinese commercial banks, although China Financial Outlook and the CEIC Database are also used.

Table 4 **Definition of Inputs and Outputs**

Model	Input	Output
A growth evaluation	X1= labor X2= fixed asset investment X3= deposits	Y1= loans
B profitability evaluation	X1= labor X2= expense X3= interest cost	Y1= interest income

32) It is preferable to use normal loans excluding non-performing loans, but because China started to release information regarding amounts of non-performing loans of banks only after year 2000, efficiency analysis using normal loans is possible only for about 10 banks (annually) including four state-owned commercial banks and some private banks, while Malmquist productivity analysis cannot be done due to a lack of enough panel data. In order to compare the data for the period from 2000 to 2006, we add model A-1 of the productivity efficiency analysis using normal loans.

33) Each variable except the number of employees is cast to a constant price as on year of 2000, using the GDP deflator. A number of the previous research papers included securities investment and non-interest income as outputs, but we do not do so for this research because of inaccurate efficiency calculation due to the small number of DMUs while there are too many variables. Instead we consider only loans and interest income for outputs. Moreover, additional reasons for excluding securities investment and non-interest income as outputs are that interest income formed a greater part of net income (which was 89% in 2006) for the ten banks listed on the stock exchange, securities investment did not make up as big a of cash-flow as loans did due to the immaturity of the Chinese financial markets, and bonds or CDs other than savings (deposit) made up only a small part in terms of fundraising.

34) Banks covered by the research make up 70% of the entire banking industry in terms of their assets and they carry out lending and deposit business throughout the country, unlike other financial institutions; in a word, they form a similar reference set. Those banks are four state-owned commercial banks, namely the Industrial and Commercial Bank of China (ICBC), Agricultural Bank of China, Bank of China, and the China Construction Bank, and private bank like the Bank of Communication, China CITIC Bank, China Everbright Bank, Huaxia Bank, China Minsheng Banking Corporation, Guangdong Development Bank, Shenzen Development Bank, China Merchants Bank, Industrial Bank, and Shanghai Pudong Development Bank.

2. Analysis of estimation results

A. DEA analysis result

As seen in Model (A) in Table 5, the technical efficiency of the entire industry remains stationary (0.87→0.86) at the early and the middle period of financial reform, and slightly increased (0.86→0.90) in the late period of financial reform, which seems to reflect the fact that wide-ranging financial reform was pursued prior to the opening of banking markets. In the case of state-owned commercial banks, technical efficiency declines in the middle period relative to the early period of financial reform (0.86→0.76) and increases in the late period again (0.76→0.81). Technical efficiency of private commercial banks is higher than that of state-owned commercial banks and constantly increases during the period of financial reform (0.87→0.90→0.94)[35].

The loans of state-owned commercial banks contain a significant amount of policy loans to state-owned firms, due to governmental requests, in addition to the bank's own loan portfolio. Considering Chinese loan practices, the efficiency of state-owned commercial banks is likely to be overestimated. In model (A-1) in Table 5, we estimate efficiency by year, using the normal loans and excluding those classified as non-performing from the total value of loans as output and compare this result with model (A). During the period of 2000 to 2006, the efficiency of state-owned commercial banks in model (A-1) dropped by 0.085 (0.781→0.696), which supports the likelihood of overestimation of the efficiency of state-owned commercial banks. The efficiency of private commercial banks, in contrast, declined only slightly by 0.0021 (0.917→0.896), compared to model (A)[36].

Since the growth model using stock variables in model (A) contains government policy loans and non-performing loans, it has limits in its ability to evaluate management performance. Therefore, we carried out an analysis of profitability focusing on flow variables (model (B)). As seen in model (B) in

35) During the early part of the financial reform era, a number of banks tried to increase their efficiency to that of leading banks which have worked to restructure themselves over the reform era; some private commercial banks improved their efficiency substantially, while that of the state-owned commercial banks declined, trailing further behind those leading banks in terms of the efficiency. During the latter part of the reform, both state and private banks improved their efficiency to the level of that of leading banks, leaving only room of 21% for state banks and of 5% for private banks to improve efficiency in 2006.

36) Since data about non-performing loans of Agricultural Bank of China during 2000-2002 are unknown (posted), the analysis during this period is omitted; it is well known that levels of non-performing loans of Agricultural Bank of China are high, so that considering this, the levels of inefficiency of state-owned commercial banks may well be higher than estimated.

Table 5, technical efficiency in the banking industry as a whole rose throughout the entire period. The technical efficiency of state-owned commercial banks is lower than that of private commercial banks, but it increased in the middle and the late periods relative to the early one, indicating that financial reform was effective.

Table 6 compares the technical efficiency, divided into pure technical efficiency and scale efficiency, of different bank types. In model (A), there is little difference between the two efficiencies in private commercial banks, while scale efficiency is lower than pure technical efficiency in state-owned commercial banks. The low scale efficiency is consistent with the result of previous research on Chinese commercial banks. This seems to result from the fact that in the past the state-owned commercial banks were operated to support government objectives and not by market principles; because of this various inputs including labor, fixed asset investment, and deposits were out of proportion to loan outputs. In model (A-1), non-performing loans are eliminated from output and accordingly the scale efficiency of state-owned commercial

Table 5 **Efficiency Changes by Ownership Type**

		Year[1]									Annual average[1]				
		98	99	00	01	02	03	04	05	06	First period 98-99	Middle period 00-03	Later period 04-06	98-06	00-06
Model A	Total	0.899	0.840	0.836	0.866	0.859	0.865	0.901	0.898	0.892	0.869	0.856	0.897	0.872	0.873
		(0.109)	(0.100)	(0.095)	(0.104)	(0.128)	(0.115)	(0.080)	(0.096)	(0.107)	(0.089)	(0.089)	(0.088)	(0.068)	(0.103)
	State owned	0.946	0.789	0.750	0.756	0.775	0.757	0.841	0.798	0.791	0.864	0.759	0.810	0.798	0.781
		(0.057)	(0.082)	(0.072)	(0.061)	(0.124)	(0.081)	(0.096)	(0.067)	(0.094)	(0.055)	(0.083)	(0.085)	(0.067)	(0.083)
	Private	0.880	0.861	0.873	0.915	0.896	0.912	0.928	0.952	0.948	0.871	0.899	0.943	0.907	0.917
		(0.122)	(0.102)	(0.081)	(0.079)	(0.117)	(0.095)	(0.061)	(0.060)	(0.072)	(0.101)	(0.057)	(0.056)	(0.040)	(0.078)
Model A-1[2]	Total	n.a.	n.a.	0.757	0.828	0.800	0.866	0.843	0.856	0.867	n.a.	0.812	0.855	n.a.	0.830
				(0.162)	(0.124)	(0.155)	(0.109)	(0.121)	(0.119)	(0.119)		(0.136)	(0.119)		(0.129)
	State owned	n.a.	n.a.	0.624	0.694	0.637	0.746	0.726	0.721	0.735	n.a.	0.673	0.727	n.a.	0.696
				(0.075)	(0.075)	(0.079)	(0.059)	(0.091)	(0.054)	(0.031)		(0.072)	(0.053)		(0.063)
	Private	n.a.	n.a.	0.822	0.894	0.856	0.920	0.908	0.933	0.943	n.a.	0.872	0.928	n.a.	0.896
				(0.149)	(0.085)	(0.133)	(0.079)	(0.083)	(0.062)	(0.070)		(0.108)	(0.071)		(0.090)
Model B	Total	0.847	0.926	0.935	0.903	0.900	0.896	0.914	0.943	0.934	0.885	0.908	0.930	0.911	0.918
		(0.145)	(0.070)	(0.059)	(0.075)	(0.095)	(0.100)	(0.102)	(0.086)	(0.100)	(0.106)	(0.073)	(0.103)	(0.076)	(0.087)
	State owned	0.753	0.872	0.895	0.844	0.838	0.881	0.915	0.922	0.886	0.811	0.864	0.908	0.866	0.882
		(0.057)	(0.030)	(0.031)	(0.034)	(0.108)	(0.102)	(0.104)	(0.114)	(0.153)	(0.043)	(0.058)	(0.124)	(0.062)	(0.080)
	Private	0.887	0.949	0.951	0.928	0.927	0.902	0.914	0.953	0.959	0.917	0.927	0.942	0.930	0.933
		(0.150)	0.069)	(0.061)	(0.074)	(0.082)	(0.104)	(0.107)	(0.076)	(0.065)	(0.108)	(0.072)	(0.100)	(0.077)	(0.079)

Notes: 1) Results for each year are geometric averages of efficiencies of each bank and the annual average is the geometric average of those results (the figures in parenthesis represent standard deviations).
2) Figures used in model A-1 have been posted since 2000; thus efficiency calculation is possible only after year 2000.

banks turns out to be lower than they were in Model (A); however, this is not a significant difference in pure technical efficiency. In model (B), which uses the profitability approach method, there is no significant difference in either scale or technical efficiency between state-owned and private commercial banks in the later period of our analysis.

Table 6 **Changes in formation of efficiency by ownership type**

			Year									Annual			
			98	99	00	01	02	03	04	05	06	98-99	00-03	04-06	98-06
Model A	Total	TE	0.899	0.840	0.836	0.866	0.859	0.865	0.901	0.898	0.892	0.869	0.856	0.897	0.872
		PTE	0.956	0.930	0.945	0.961	0.951	0.959	0.977	0.991	0.994	0.943	0.954	0.987	0.962
		SE	0.940	0.903	0.884	0.901	0.904	0.901	0.922	0.906	0.898	0.921	0.897	0.909	0.906
	State	TE	0.946	0.789	0.750	0.756	0.775	0.757	0.841	0.798	0.791	0.864	0.759	0.810	0.798
		PTE	0.960	0.943	0.971	0.966	0.940	0.957	1.000	1.000	0.992	0.961	0.958	0.997	0.972
		SE	0.966	0.837	0.773	0.783	0.825	0.793	0.841	0.798	0.799	0.899	0.793	0.812	0.822
	Private	TE	0.880	0.861	0.873	0.915	0.896	0.912	0.928	0.952	0.948	0.871	0.899	0.943	0.907
		PTE	0.947	0.924	0.935	0.960	0.955	0.960	0.967	0.986	0.995	0.936	0.952	0.983	0.959
		SE	0.930	0.930	0.933	0.953	0.937	0.949	0.960	0.966	0.953	0.930	0.943	0.960	0.946
Model A-1	Total	TE	n.a.	n.a.	0.757	0.828	0.800	0.866	0.843	0.856	0.867	n.a.	0.812	0.855	n.a
		PTE	n.a.	n.a.	0.963	0.973	0.946	0.962	0.968	0.975	0.988	n.a.	0.961	0.977	n.a
		SE	n.a.	n.a.	0.786	0.851	0.844	0.901	0.869	0.879	0.879	n.a.	0.845	0.876	n.a
	State	TE	n.a.	n.a.	0.624	0.694	0.637	0.746	0.726	0.721	0.735	n.a.	0.673	0.727	n.a
		PTE	n.a.	n.a.	1.000	0.997	0.955	0.969	0.969	0.957	0.972	n.a.	0.980	0.966	n.a
		SE	n.a.	n.a.	0.624	0.694	0.667	0.768	0.747	0.754	0.757	n.a.	0.686	0.753	n.a
	Private	TE	n.a.	n.a.	0.822	0.894	0.856	0.920	0.908	0.933	0.943	n.a.	0.872	0.928	n.a
		PTE	n.a.	n.a.	0.947	0.963	0.943	2.959	0.968	0.983	0.996	n.a.	0.953	0.983	n.a
		SE	n.a.	n.a.	0.868	0.929	0.907	0.960	0.938	0.949	0.948	n.a.	0.915	0.945	n.a
Model B	Total	TE	0.847	0.926	0.935	0.903	0.900	0.896	0.914	0.943	0.934	0.885	0.908	0.930	0.911
		PTE	0.965	0.982	0.984	0.981	0.972	0.932	0.949	0.976	0.958	0.974	0.967	0.961	0.966
		SE	0.877	0.943	0.950	0.922	0.926	0.961	0.964	0.967	0.975	0.910	0.939	0.969	0.942
	State	TE	0.753	0.872	0.895	0.844	0.838	0.881	0.915	0.922	0.886	0.811	0.864	0.908	0.866
		PTE	0.992	0.992	0.982	1.000	0.997	0.940	0.937	0.934	0.905	0.992	0.980	0.925	0.964
		SE	0.759	0.880	0.910	0.847	0.840	0.937	0.977	0.987	0.980	0.817	0.883	0.981	0.899
	Private	TE	0.887	0.949	0.951	0.928	0.927	0.902	0.914	0.953	0.959	0.917	0.927	0.942	0.930
		PTE	0.954	0.978	0.984	0.974	0.962	0.929	0.954	0.997	0.986	0.966	0.962	0.979	0.969
		SE	0.930	0.970	0.967	0.954	0.962	0.970	0.958	0.956	0.973	0.950	0.963	0.962	0.960

Note: Results of each year are geometric average of efficiencies of each bank and annual average is geometric average of those results (TE: Technical Efficiency, PTE: Pure Technical Efficiency, SE: Scale Efficiency).

Comparing models (A) with (B), bank efficiency in model (B) is higher than that in model (A). This means that the revenue efficiency is greater than growth efficiency, and that there is no significant difference between private and state-owned banks in creating interest income.

The efficiency of state-owned commercial banks is compared in Figure 2[37]. In the case of state-owned commercial banks, the growth efficiency in model (A) is lower than the revenue efficiency in model (B). The efficiency in model (A-1) in which normal loans are covered is lower than that of model (A). Based on these figures, we can examine the effects of attempts to clear up the non-performing loans of state-owned enterprises through the use of government fiscal funding and foreign reserves. The efficiency in model (A) is lower than those years of a high level of non-performing loans (1998, 2002, & 2004), due to the decrease in loans (output) followed by clearing of non-performing loans. In model (A-1) utilizing normal loans excluding non-performing loans, the efficiency does no seem to decrease, while in model (B), which uses flow variables, the revenue efficiency in the years of 1999, 2003, and 2005 respectively increased as a result of the elimination of non-performing loans as interest income was applied.

The efficiency of individual banks was analyzed and the results are shown in Table 7. In order to compare the growth and revenue are efficiencies of each bank, we attempted to conduct a matrix analysis[38] in Figure 3 as used in Soteriou and Zenios (1999). As shown in Figure 3, a high-level group in terms of both growth and revenue efficiencies is included in the first quadrant. The group of high revenue efficiency and low growth efficiency is shown in the second quadrant and the fourth quadrant includes a group of high growth efficiency and low revenue efficiency. The group below the average level in terms of both revenue and growth efficiencies is shown in the third quadrant. All of four state-owned commercial banks are spread across the second, third, and fourth quadrant, but absent from first quadrant.

Seven private commercial banks among ten commercial banks, namely, China Minsheng Banking Corporation, Shanghai Pudong Development Bank, China Merchants Bank, China CITIC Bank, Industrial Bank, China Everbright Bank, and Shenzen Development Bank are located in the first quadrant, showing high growth and revenue efficiency. In contrast, four state-owned commercial banks are located in the second, third and fourth quadrant, demonstrating that their efficiency is lower than that of seven private commercial banks. The state-owned commercial banks, therefore, need to improve their efficiency by benchmarking these private commercial banks. Specifically, the China Construction Bank to do so to increase growth efficiency, Agricultural Bank of China for revenue

37) As shown in table 5, there is no big difference between models A, A-1, and B for private commercial banks so no analysis could be undertaken in graphic form.

38) Soteriou and Zenios (1999 p.1234) conducted a matrix analysis for DEA efficiency and profitability.

efficiency, and Bank of China and Industrial and Commercial Bank of China to boost both growth and revenue efficiencies.

Figure 1 **Comparison of Efficiency (by type of model)**

Note: Vertical scale is DEA index * 100

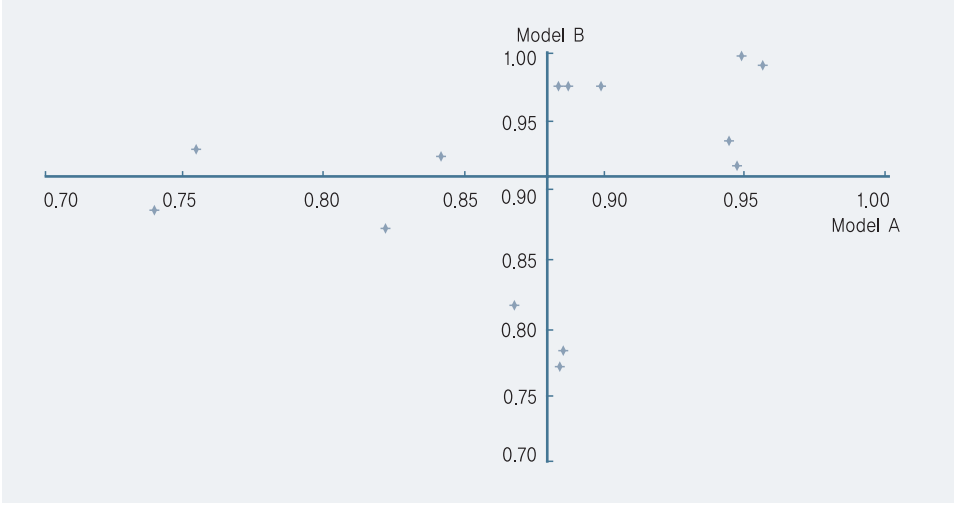
Figure 2 **Comparison of efficiency of State-owned commercial banks (by type of model)**

Note: Vertical scale is DEA index * 100

Table 7 **Efficiencies of Banks (1998-2006)**

		Model A			Model B		
		TE	PTE	SE	TE	PTE	SE
State owned	Industrial and Commercial Bank of China(ICBC)	0.82	1.00	0.82	0.87	1.00	0.87
	Agricultural Bank of China	0.89	1.00	0.89	0.78	0.86	0.91
	Bank of China	0.74	1.00	0.74	0.89	1.00	0.89
	China Construction Bank	0.75	0.90	0.84	0.93	1.00	0.93
Private	Bank of Communications	0.87	0.95	0.92	0.82	0.92	0.89
	China CITIC Bank	0.90	0.93	0.96	0.98	0.99	0.98
	China Everbright Bank	0.94	1.00	0.95	0.94	0.97	0.97
	Huaxia Bank	0.84	0.93	0.90	0.92	0.99	0.94
	China Minsheng Banking Corporation	0.95	1.00	0.95	1.00	1.00	1.00
	Guangdong Development Bank	0.88	0.90	0.98	0.77	0.81	0.95
	Shenzen Development Bank	0.95	1.00	0.95	0.92	0.99	0.92
	China Merchants Bank	0.89	0.94	0.94	0.98	1.00	0.98
	Industrial Bank	0.88	0.95	0.93	0.97	0.99	0.98
	Shanghai Pudong Development Bank	0.96	0.97	0.99	0.99	1.00	0.99

Figure 3 **Efficiency distribution matrix by model A & B**



Note: the point of intersection of the horizontal and vertical axes is the average of technological efficiency of model A& B, which is at (0.88, 0.91).

B. Analysis result of Malmquist productivity index

In examining the trend of productivity changes in the banking industry, the Malmquist productivity index is used. In model (A), which evaluates productivity based on growth, as seen in Table 8, the banking industry increases by an average of 2.9% during the entire period of the financial reform, and rises 5.0% during the middle period, displaying rapid growth: however, during that period the productivity of state-owned commercial banks declined by 2.3% while that of private commercial banks increased by 5.2%. The reason private commercial bank productivity increased may be attributable to their sound management structure and to the fact that they achieved stock market listings, which provides an incentive to increase productivity and profit.

We conducted an analysis by dividing the productivity index of the whole banking industry into efficiency change and technology change. The analysis reveals that the technology change index turns out to be higher than the efficiency change index in the early, mid and late periods, indicating that technology advance is a cause of the improvement in productivity. The efficiency change index increases only by 0.1% during the entire period of financial reform. This is because the inefficient banks inside the production frontier cannot catch up with the efficient banks on the production frontier. The

technology change index, in contrast, rises by 2.8%. This expands the production possibilities curve further.[39] Technological advancement, however, slows down in the mid (2.7%) and late (1.1%) period compared to the early period (4.6%), demonstrating that the influence of technological change driving productivity gains gradually decreases.

If the productivity index is divided by ownership structure, the productivity of state-owned commercial banks drops by 2.3% using model (A) over the entire period of financial reform. These results from falls in efficiency and technological change.[40] The productivity index of private commercial banks, however, increases by 5.2% throughout the whole period of financial reform, and technological advance (4.1%) is greater than the rise in efficiency (1%), which leads an increase in productivity.[41] During the first part of the financial reform, there was a decline in efficiency by 0.6%: while experiencing technological advance by 4.3%; overall, there was an increase in productivity by 3.8%. During the middle period, both an increase in efficiency and technological change of 1.8% and 5.1% respectively led to an increase in productivity by 7%. During the late part of the reform, there was an increase in efficiency of 1.2%, while benefiting from a modest 1.9% level of technological change.

39) Technological advance and efficiency change are both part of production change. Efficiency change can be explained as catching up with the production technology for loans (interest income) of efficient banks (so called catch-up effect), when technological advances interpreted as cutting down costs as applying the new production technology for loans (interest income).

40) During the first part of the financial reform, the efficiency of the state-owned commercial banks declined by 11%, leading to a reduction in the level of productivity by 6.2% technological advance of 5.5% notwithstanding. During the middle period, there was an increase in efficiency by 3% and a decline in technological change, which meant the movement of the production frontier, by 3%, having a slight change in productivity by 0.3%. Finally, during the late period of the reform, there was a decline in efficiency by 3.1% as well as in technological change by 0.5%; after all, a decline in productivity by 3.3%.

41) During the first part of the financial reform, there was a decline in efficiency by 0.6%: while experiencing technological advance by 4.3%; overall, there was an increase in productivity by 3.8%. During the middle period, both an increase in efficiency and technological change of 1.8% and 5.1% respectively led to an increase in productivity by 7%. During the late part of the reform, there was an increase in efficiency of 1.2%, while benefiting from a modest 1.9% level of technological change.

Table 8 **Malmquist productivity index and change in formation of commercial banks by ownership structure**

			Years in comparison								Annual average			
			98-99	99-00	00-01	01-02	02-03	03-04	04-05	05-06	98-00	00-04	04-06	98-06
A	Total	PC	0.956	1.063	1.068	1.050	1.101	0.984	1.003	1.016	1.008	1.050	1.009	1.029
			(0.101)	(0.159)	(0.106)	(0.160)	(0.095)	(0.092)	(0.072)	(0.046)	(0.075)	(0.049)	(0.009)	(0.048)
		EC	0.935	0.992	1.040	0.991	1.006	1.053	0.999	0.996	0.963	1.022	0.998	1.001
			(0.129)	(0.128)	(0.093)	(0.119)	(0.081)	(0.100)	(0.065)	(0.035)	(0.041)	(0.029)	(0.002)	(0.035)
		TC	1.022	1.071	1.029	1.060	1.094	0.934	1.001	1.020	1.046	1.027	1.011	1.028
			(0.104)	(0.075)	(0.049)	(0.092)	(0.041)	(0.077)	(0.034)	(0.031)	(0.035)	(0.069)	(0.014)	(0.049)
	State	PC	0.935	0.941	1.011	1.002	1.049	0.952	0.937	0.997	0.938	1.003	0.967	0.977
			(0.072)	(0.057)	(0.057)	(0.085)	(0.058)	(0.090)	(0.022)	(0.036)	(0.004)	(0.040)	(0.042)	(0.042)
		EC	0.836	0.948	1.014	1.025	0.976	1.112	0.942	0.997	0.890	1.031	0.969	0.978
			(0.095)	(0.103)	(0.044)	(0.081)	(0.059)	(0.095)	(0.024)	(0.036)	(0.079)	(0.057)	(0.039)	(0.079)
		TC	1.121	0.993	1.000	0.975	1.077	0.855	0.990	1.000	1.055	0.973	0.995	0.999
			(0.062)	(0.065)	(0.027)	(0.075)	(0.049)	(0.010)	(0.000)	(0.000)	(0.090)	(0.092)	(0.007)	(0.078)
	Private	PC	0.965	1.116	1.092	1.070	1.122	0.998	1.037	1.025	1.038	1.070	1.031	1.052
			(0.113)	(0.158)	(0.113)	(0.180)	(0.101)	(0.094)	(0.063)	(0.050)	(0.107)	(0.053)	(0.008)	(0.056)
		EC	0.977	1.010	1.050	0.977	1.018	1.027	1.029	0.996	0.994	1.018	1.012	1.010
			(0.121)	(0.137)	(0.107)	(0.133)	(0.088)	(0.096)	(0.059)	(0.037)	(0.023)	(0.031)	(0.023)	(0.026)
		TC	0.985	1.104	1.041	1.096	1.101	0.971	1.007	1.031	1.043	1.051	1.019	1.041
			(0.094)	(0.054)	(0.051)	(0.075)	(0.037)	(0.063)	(0.041)	(0.034)	(0.084)	(0.060)	(0.017)	(0.053)
B	Total	PC	0.913	0.997	0.980	1.087	1.063	1.002	0.985	1.004	0.954	1.032	0.995	1.003
			(0.123)	(0.062)	(0.061)	(0.105)	(0.129)	(0.123)	(0.082)	(0.054)	(0.059)	(0.050)	(0.014)	(0.053)
		EC	1.096	1.007	0.969	0.996	0.995	1.021	1.009	0.990	1.050	0.995	0.999	1.010
			(0.133)	(0.032)	(0.038)	(0.071)	(0.078)	(0.062)	(0.077)	(0.044)	(0.063)	(0.022)	(0.014)	(0.038)
		TC	0.834	0.989	1.016	1.092	1.068	0.981	0.975	1.06	0.908	1.038	0.996	0.994
			(0.059)	(0.058)	(0.040)	(0.052)	(0.107)	(0.107)	(0.035)	(0.027)	(0.110)	(0.050)	(0.029)	(0.078)
	State	PC	0.939	0.966	0.924	1.130	1.087	1.057	0.985	0.959	0.952	1.047	0.972	1.003
			(0.094)	(0.068)	(0.052)	(0.125)	(0.103)	(0.087)	(0.026)	(0.056)	(0.019)	(0.089)	(0.018)	(0.076)
		EC	1.161	1.022	0.946	0.989	1.052	1.041	1.007	0.958	1.089	1.006	0.983	1.020
			(0.062)	(0.032)	(0.053)	(0.092)	(0.125)	(0.104)	(0.015)	(0.064)	(0.098)	(0.049)	(0.035)	(0.067)
		TC	0.809	0.942	0.982	1.145	1.032	1.015	0.977	1.000	0.873	1.042	0.989	0.984
			(0.041)	(0.048)	(0.010)	(0.035)	(0.017)	(0.017)	(0.015)	(0.014)	(0.094)	(0.070)	(0.016)	(0.094)
	Private	PC	0.903	1.009	1.004	1.070	1.053	0.979	0.986	1.028	0.955	1.026	1.007	1.003
			(0.136)	(0.058)	(0.049)	(0.097)	(0.143)	(0.134)	(0.101)	(0.037)	(0.075)	(0.042)	(0.030)	(0.052)
		EC	1.070	1.001	0.978	0.999	0.972	1.013	1.010	1.006	1.035	0.990	1.008	1.006
			(0.148)	(0.031)	(0.030)	(0.067)	(0.037)	(0.037)	(0.096)	(0.023)	(0.049)	(0.019)	(0.003)	(0.030)
		TC	0.844	1.009	1.029	1.071	1.082	0.966	0.974	1.025	0.923	1.036	0.999	0.997
			(0.064)	(0.051)	(0.040)	(0.043)	(0.125)	(0.129)	(0.042)	(0.029)	(0.117)	(0.053)	(0.036)	(0.075)

Note: Figures of years in comparison is a geometric average of each bank's indexes and the annual average is a geometric average of those figures (standard deviations are in parentheses).

Since model (A) uses the total amount of loans as output in the analysis, productivity could be overestimated due to the non-performing loans. Therefore, we tried to conduct an analysis of productivity changes based on profitability in model (B).[42] The analysis results in model (B) show that the increase in productivity of the whole banking industry is only 0.3%. Observations show that

in model productivity fell in the early and late periods, and increased in the middle period. The productivity of state-owned commercial banks increased markedly relative to the productivity increase in model (A) during the middle period of financial reform (0.3→4.7%). This seems to be attributable to the fact that, during the middle period of financial reform, the disposal of non-performing loans and restructuring of the banking industry accelerated in conjunction with the establishment of asset management firms, which led to the improvement of profitability and therefore affected productivity.[43] In the late period of financial reform, the increase in productivity of private commercial banks, compared to model (A), decreased (3.1→0.7%). This shows that the improvement of productivity as based on profitability is insufficient relative to model (A) on the basis of external growth. As a result, the efficiency change index and technology change index of private commercial banks turn out to be lower in model (B) than in model (A) during the late period.

A matrix analysis is conducted as shown in Figure 4 in order to measure individual banks' productivity indexes and compare them in models (A) and (B) (see Table 9). Since the two models evaluate existing productivity indexes on the basis of growth and profitability, respectively, the first quadrant indicates that productivity based on growth and productivity based on profitability increase. The banks falling in the first quadrant are four private commercial banks i.e. China Minsheng Bank, Industrial Bank Co., Ltd., Shanghai Pudong Development Bank, and China Merchants Bank[44].

The four state-owned commercial banks (China Construction Bank, Industrial and Commercial Bank of China, Bank of China, and Agricultural Bank of China) are located in the second and third quadrants, indicating that they need to

42) For overestimated productivity, there are two approaches to resolve the problem; first, using model A with normal loans as outputs (instead of the total amount of loans) as with efficiency analysis, and the second makes use of the flow variables approach, in which interest costs are considered as inputs and interest income as outputs. In the case of normal loans as outputs in model A-1, some banks did not disclose data, nor was it is disclosed before 2000 about the scale of their non-performing loans, implying a lack of time-series data. The Malmquist productivity index analysis therefore used only model B.

43) During the middle part of the financial reform, state-owned commercial banks had a high level of technological advance, an increase of y 4.2% which led a rise in productivity even though there was only a slight change in efficiency by 0.6%. It was this period when there was the highest level of technological advance during financial reform.

44) Among those banks which were included in the first quadrant from efficiency matrix analysis (picture 3), China CITIC Bank, China Everbright Bank, and Shenzen Development Bank shifted to a low productivity group in terms of profitability due to a slowing of technological advance even though they had a high level of productivity (model A) and of efficiency (model B).

make efforts to improve productivity. The Bank of China and Agricultural Bank of China are located in the third quadrant and need to make a significant effort to increase productivity and efficiency. Agricultural Bank of China, which has not been listed yet, has the largest organizational scale among state-owned

Table 9 **Malmquist Productivity Index by Bank (1998-2006)**

		Model A			Model B		
		M	EC	TC	M	EC	TC
State owned	Industrial and Commercial Bank of China(ICBC)	0.96	0.96	1.00	1.01	1.03	0.98
	Agricultural Bank of China	0.98	1.00	0.98	0.98	0.99	0.99
	Bank of China	0.99	0.98	1.02	0.98	1.02	0.97
	China Construction Bank	0.97	0.98	0.99	1.04	1.04	0.99
Private	Bank of Communications	0.96	0.97	0.98	1.06	1.06	0.99
	China CITIC Bank	1.08	1.03	1.04	0.97	1.00	0.97
	China Everbright Bank	1.05	1.00	1.06	0.95	0.98	0.98
	Huaxia Bank	1.06	1.02	1.04	0.97	0.99	0.98
	China Minsheng Banking Corporation	1.12	1.04	1.08	1.03	1.00	1.04
	Guangdong Development Bank	1.06	1.01	1.05	0.99	1.01	0.98
	Shenzen Development Bank	1.04	1.00	1.04	0.99	0.99	1.00
	China Merchants Bank	1.03	0.99	1.04	1.01	1.00	1.01
	Industrial Bank	1.12	1.03	1.09	1.02	1.01	1.01
	Shanghai Pudong Development Bank	1.03	1.00	1.03	1.02	1.00	1.02

Note: Index by bank is the arithmetical mean of indexes and the standard deviations are in parentheses

commercial banks and is known to have enormous amounts of non-performing loans. Before listing, thus, it should put efforts into tackling the problem of non-performing loans in addition to the improvement of productivity.[45)]

After conducting a matrix analysis to develop the composition factors of productivity of each bank, it appears that the technological progress of those banks is slower in model (B) than in model (A), which can be attributed to the slowdown of productivity in model (B) (see Figure 5).

In model (A), the four state-owned commercial banks (Bank of China, Industrial and Commercial Bank of China, China Construction Bank, and Agricultural Bank of China) have efficiency change indexes lower than 1[46)]; their technological change indexes are also quite low, with both scores being lower than the results of those of private commercial banks, leading to a decrease in productivity. Other private commercial banks, except for Industrial Bank Co., Ltd., Shanghai Pudong Development Bank, and China Merchants Bank (which are located in the first quadrant), show sluggish efficiency growth and slow technological progress. If profitability is under consideration, there is little reason to increase productivity.

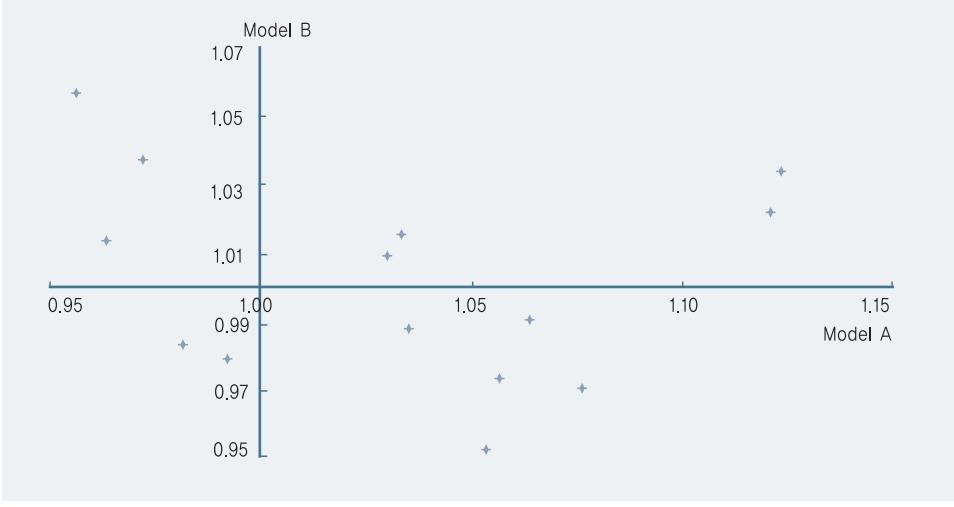
Both the efficiency and productivity of state-owned commercial banks turn out to be low according to the growth analysis, whereas their efficiency is relatively high from the profitability analysis. Also, productivity is shown to be comparatively high during the middle period of financial reform era. Considering that much of the profit of Chinese commercial banks comes from loan interest payments, the structure of the Chinese financial system and bank management factors should have a great impact on the profitability of state-owned commercial banks.

When we refer to the structure of the Chinese financial system, we are referring to the monopolistic status of the state-owned commercial banks and the Chinese government’s policy of securing the loan-deposit margin. The state-

45) Agricultural Bank of China, without any public funding, had a remarkably high level of non-performing loans (23.43% as of the end of 2006), compared to that of other state-owned commercial banks, which was less than 5%. Moreover, the Chinese government's policy to conduct the reform of the Agricultural Bank of China in liaison with that of rural areas (agricultural districts, agriculture, and peasantry) has slowed down attempts to resolve its non-performing loans problem (Refer to KIEP's "Briefing on the Chinese Economy’s Problems", vol 07-16, page 3. released on Sep. 2007, for the reform plan of Agricultural Bank of China).

46) Among the private commercial banks, technological change indexes for the Bank of Communications are the lowest. Although it is a private bank, the Chinese government holds a major stake and it is considered to be partially state-owned; in addition to the Bank of Communications, four state-owned commercial banks belong to a low technological change indexes group.

Figure 4 **Efficiency distribution matrix by model A & B**

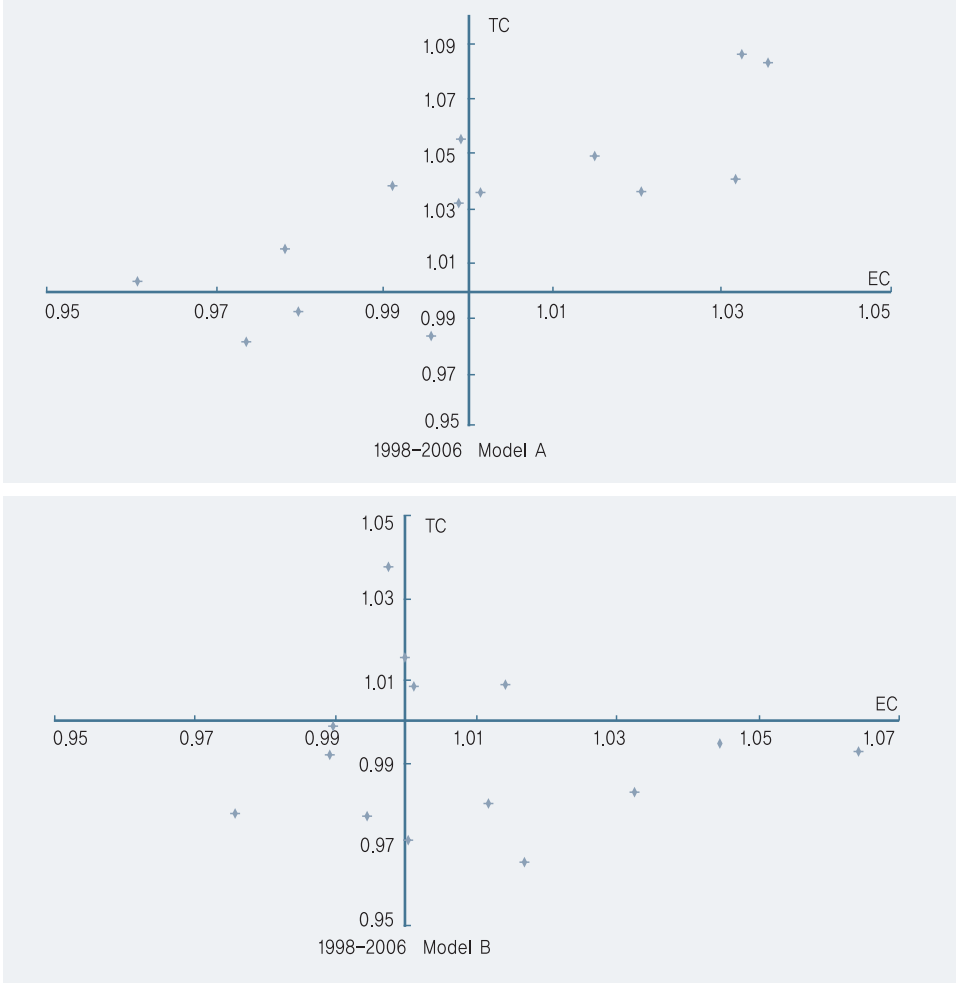


Note: Intersecting point of Matrix analysis is on (1,1)

owned commercial banks have improved their profitability by taking advantage of their monopolistic power in financial markets. This occurred as Chinese consumers saw their incomes increase rapidly following China's economic growth. With few developed alternative investment methods, Chinese consumers had few alternatives when it came to saving and investing their incomes. This was reinforced by the Chinese government's policy of securing the loan-deposit margin, which was held at 3.6% at the end of 2006.[47)]

47) In order to restrain the increase in loans and the expectation of inflation, People's Bank of China raised interest rates on one year maturity fixed deposits and loans several times throughout the year 2007 (shown as below), and still managed to ensure a loan-deposit margin within about 3.5% (Bank of Korea, Beijing Office, local reports Aug. 22, 2007). This is an example of the Chinese government's policy of guaranteeing the loan-deposit margin. Interest rate of loans: 6.12%→6.39%(Mar.18) →6.57%(May.19) →6.84%(Jul.21) →7.02%(Aug.22) →7.29%(Sep.15) Interest rate of fixed deposits: 2.52% →2.79%(Mar.18) →.06%(May.19) →3.33%(Jul.21) →3.60%(Aug.22) →3.87%(Sep.15)

Figure 5 **Technology Change and Efficiency Change Distribution Matrix by Bank**



Note: Intersecting point of Matrix analysis is at (1,1)

It appears that the various periods of financial reform have had great impacts on the profitability of the state-owned commercial banks. One significant factor for this increase in profitability was the formation of the asset management firms; this allowed the state-owned commercial banks to offload many of their non-performing loans and to expand their normal loan portfolio. The formation of the asset management firms had a relatively greater impact on the state-owned commercial banks than on private banks due to the fact that the state-owned banks had relatively higher numbers of non-performing loans. Table 10 shows

how the levels of non-performing loans of major commercial banks have declined substantially, especially in state-owned commercial banks.

Table 10 **Rate of Non-Performing Bonds of Major Commercial Banks(%)**

	2003	2004	2005	Mar.2006	Jun.2006
Four state-owned commercial bank	20.4	15.6	10.5	9.8	9.5
Stock-system banks	7.6	4.9	4.2	3.9	3.1
Total	17.8	13.2	8.9	8.3	7.8

Souce: China Banking Regulatory Commission(CBRC),CEIC

In addition to an improvement of management factors, including the strategic inducement of overseas investors, the state-owned commercial banks have improved their profitability and assets after being listed. The total asset value of commercial banks amounted to 40.9 trillion yuan as of end-June 2006. During the period of 2004 to 2006, their profitability improved markedly, increasing by 10 trillion yuan. As of end-2005, profits of the major commercial banks come to 1.1 trillion yuan, increasing by19.2% from the previous year. The Bank of China and China Construction Bank recorded profits after tax of 19.5 billion and 23.2 billion yuan, increasing 28.3% and 13.3% from the same period of the previous year.

Table 11 **Major Indexes of Listed State-Owned Commercial Banks(%)**

		China Construction Bank	Bank of China
BIS rate	2005 Jun. 2006	13.57 13.15	10.42 12.40
Roe (Return on Equity)	2005 Jun.2006	- 15.67	12.14 13.38
Ratio of Non-Performing Loans	2005 Jun.2006	3.84 3.51	4.90 4.40

Souce: Annual reports of China Construction Bank and the Bank of China

V. Conclusions

This paper conducts an analysis of the changes in the efficiency and productivity of 14 Chinese commercial banks through growth and profitability methods, using data during the period of 1998 to 2006. The results of the DEA analysis that measures efficiency are set out below.

The efficiency of the banking industry as a whole increased from the middle to the late period of financial reform both in the growth approach method of model (A) and in the profitability approach method of model (B). The efficiency of state-owned commercial banks is lower than that of private commercial banks. As the disparity in efficiency between the two groups narrows in model (B), there is very little difference between the state-owned and private commercial banks in terms of profitability. In model (A-1), which only considers normal loans as output (i.e. excluding non-performing loans), the efficiency of state-owned commercial banks is lower than that of private commercial banks; scale efficiency is especially low. This finding is consistent with the results of previous studies on Chinese commercial banks. A historical analysis of the Chinese banking system shows us that in the past the state-owned banks did not operated according to market principles but were instead guided by governmental planning; inputs (labor, fixed asset investments, and savings) were considerably larger than outputs (loans). This has changed with the onset of financial reform in China. The matrix analysis reveals that seven out of the ten private commercial banks have greater growth and profitability efficiency than the four state-owned commercial banks.

An analysis of the Malmquist productivity index shows that the productivity of the banking industry as a whole increased by 2.9% during the period of financial reform (shown in model (A)). This productivity increase (of 5%) was primarily led by private commercial banks. If we look at the composition factors of productivity changes, generally productivity improved because of technological progress as opposed to changes in efficiency. As technological progress slowed in the later period of financial reform, the rate of productivity increases declined. The result of the profitability approach method (model (B)) shows that the efficiency of the banking industry improves as a whole during financial reform. Due to sluggish technological progress, however, productivity only improves slightly (0.3%). During the middle period of financial reform, productivity based on profitability improves and productivity increases substantially (4.7%). Moreover, the Chinese government's policy of guaranteeing loan-deposit

margins was helpful to improving the profitability of the state-owned commercial banks.

In the matrix analysis, which takes into account both the growth approach method of model (A) and the profitability approach method of model (B), only four private commercial banks (China Minsheng Bank, Industrial Bank Co., Ltd., Shanghai Pudong Development Bank, and China Merchants Bank) show increases both in growth-based productivity and in profitability-based productivity. In contrast, the Bank of China and the Agricultural Bank of China display reductions in both growth-based productivity and profitability-based productivity.

There has been concern since the early 2000s over the likelihood of a global financial crisis stemming from the inefficiency of Chinese financial institutions and their high level of non-performing loans. According to this research, China's financial reform has increased the profit efficiency of state-owned commercial banks, but while the productivity of state-owned commercial banks increased markedly in the middle period of financial reform, it declined in the late period, indicating the weakening strength of productivity gain. It stands to reason that the development of a stable Chinese financial industry requires that productivity improvement be maintained through both increases in technology and efficiency.

The profitability of state-owned commercial banks, which is largely based on their monopolistic status in the market and the government's policy of guaranteeing loan-deposit margins, is expected to weaken gradually; this is largely due to the development of investment methods other than savings. It is imperative that the China's commercial banks increase their productivity by adopting advanced management methods, such as developing new profit models, diversifying their financial products, and developing risk appraisal methods.

This paper uses a non-parametric analysis in order to measure the efficiency and productivity of banks. Given that this study only uses the amount of input and output and technological conditions as factors, the analysis measures only efficiency and productivity indexes. It does not estimate production and cost functions. We need research that uses a parametric methodology such as a stochastic frontier analysis to complement the non-parametric analysis in the future.

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