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Research on the Efficiency of Chinese Commercial Banks Based on Undesirable Output and Super-SBM DEA Model

Lujun Zhou[1*], Shiyi Zhu[2]

[1]School of Economics, Hunan Agricultural University, Changsha, China
[2]School of Economics, Shenzhen University, Shenzhen, China
Email: *davi44049895@163.com, 1768020872@qq.com

Abstract

Based on Super-SBM DEA model, this paper investigates the efficiency of 12 Chinese commercial banks from 2005 to 2013 under the consideration of undesirable output, and verifies the truth that considering undesirable outputs (non-performing loans) can make research result more authentic by comparing with the consequence obtained without considering undesirable output. On this basis, this paper takes a further advantage of Malmquist index to analyze Chinese commercial bank efficiency. The results show that the efficiency of Chinese commercial Banks mainly depends on technological progress. Therefore, that technological progress is the factor influencing the efficiency of Chinese commercial Banks should not be ignored. Finally, this paper puts forward some relevant proposals for Chinese banking sector to improve operational efficiency and promote the technological progress.

Keywords

Super-SBM DEA Model, Malmquist Index, Chinese Bank Efficiency, Undesirable Outputs

1. Introduction

Since 1978 when Chinese reforming and opening-up policy was carried out, the speed of economic development has become very fast, in which the financial industry played a critical role through the commercial banks. The operating objective of commercial banks is to ensure the safety of funds and fight for maximum profitability on the basis of maintaining assets' liquidity. At the end of September 2014, the total asset of Chinese commercial banks reached RMB 126.82 trillion ($20.64 trillion, calculated by the exchange rate of USD against RMB in the

Table 1, the others below are the same) which accounted for 77.6% of banking financial institutions' total asset. The total asset of five state-owned commercial banks, including Agricultural Bank of China, China Construction Bank, Industrial and Commercial Bank of China, Bank of China and Bank of Communications, was RMB 66.88 trillion ($10.89 trillion) which accounted for 40.9% of banking financial institutions' total asset. In 2013, the net interest income of Chinese five commercial banks above was high to RMB 1.62 trillion ($0.26 trillion).

Non-performing loan (NPL) is taken as an important indicator in the evaluation of bank efficiency. At the end of 2012, non-performing loans of Chinese commercial banks amounted to RMB 492.9 billion ($ 77.98 billion), which is RMB 64.7 billion ($ 10.24 billion) more than that at the end of 2011. The amount of the balance of non-performing loans of Chinese commercial banks continued to rise to RMB 592.1 billion ($ 95.60 billion) in 2013, produced an increase of RMB 99.3 billion ($ 16.03 billion) when compared to that in 2012. This phenomenon indicates that Chinese commercial banks have constant pressure on slashing non-performing loans which could no doubt depress the operating efficiency of Chinese banks. First of all, non-performing loans could reduce lending capacity of banks, which means many good projects may not get the bank's financial support. In this situation, the whole market economy will be hit. Secondly, loans are the main means for banks to gain revenue. A large number of non-performing loans will drop the liquidity of bank funds, thus affecting the bank's profitability. What's more, the high rate of non-performing loans may cause panic among investors in the financial industry, making a large amount of money transferred out of the financial sector and ultimately may even lead to bank failures. In this paper, we regard non-performing loans as an undesirable output which is added to the output indicators to analyze the economic efficiency of Chinese commercial banks.

2. Literature Review

A number of scholars have begun to study the efficiency of commercial banks since 1950s while the earliest methods used is financial indicator method [1]. Now commonly used method is efficient frontier analysis which can be divided into parametric frontier analysis and non-parametric frontier analysis according to whether you want to estimate the difference of parameters or not. Data envelopment analysis (DEA) is a kind of linear programming method, was proposed by Charnes *et al.* based on a relevant viewpoint of Farrell, and is a technique that has been used in many different sectors (e.g., González E *et al.*,; LaPlante AE *et*

Table 1. Rate of exchange of USD against RMB.

Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ROE	8.1917	7.9718	7.604	6.9451	6.8310	6.7695	6.4588	6.3210	6.1932	6.1428

PS: Data from the People's Bank of China website.

al.,; Liu W *et al.*,; Hong Li *et al.*,; Hong Li *et al.*,) [2]-[8]. Many scholars have studied bank efficiency with a variety of DEA methods and have made some achievements already while Sherman and Gold are the first [9]. In addition, Maudos and Pastor have compared Spanish banks' cost efficiency and profit efficiency trends from 1985 to 1996 [10]. Fotios Pasiouras has used DEA method to analyze the data of Greek commercial banks from 2000 to 2004 [11]. George Assaf, A. *et al.* used the two-stage DEA model to measure the efficiency of Arab Banks, and finally made relevant suggestions. Based on DEA super-efficiency model, Noura, A.A. *et al.* made samples ranked better by considering the efficiency of each sample instead of cross-comparisons among samples [12] [13]. Barros *et al.* added the non-performing loans into the efficiency evaluation of banking system, and measured the changes in technical efficiency and productivity of Japanese banks [14]. Emília Zimková analyzed the technical efficiency and the super-efficiency of a representative sample of the commercial banking institutions in Slovakia with the aid of well-known radial and non-radial DEA models [15]. Iveta Řepková applied the Data Envelopment Analysis (DEA) window analysis on the data of the Czech commercial banks and to examine the efficiency of the Czech banking sector from 2003 to 2012 [16].

In recent decades, DEA method gradually has been applied to survey efficiency of commercial banks in China. Some literatures are showed in Table 2. The research objects of these papers are not exactly the same, and the research methods are also inconsistent. The efficiency of China's commercial banks has been studied from the aspects of cost efficiency, technical efficiency, scale efficiency and profit efficiency and so on. All of these Chinese scholars have gotten some valuable conclusions. However, these papers also have some limitations: Primarily, China's research on the efficiency of commercial banks is still at a relatively low level, the theoretical research is quite weak while the depth of study is not enough. Secondly, the existed literatures are mostly empirical analyses which have certain timeliness. According to the selection of samples and the impact of different factors, the conclusions of papers are also different. Thirdly, there are little literatures have considered the effect of undesirable output on bank efficiency, so the available information could not reflect the real situation of commercial bank's efficiency comprehensively.

Traditional DEA models require getting outputs as much as possible while under the minimal input resources, however, undesirable outputs such as waste water, exhausted gas and the non-performing loans of banking business in this paper are unavoidable for production and living. It is necessary to take account the undesirable outputs into efficiency evaluation model. The papers in Table 2 only QingJun Cui *et al.* and Jinming Zhang *et al.* studied the impact of undesirable output on banks [24] [25]. According to the current landscape of Chinese banking sector, the high non-performing loans of commercial banks will seriously restrict the efficiency and threaten the safety of operations.

To make it evaluate economic efficiency perfectly under the constraint of un-

Table 2. Chinese researches on efficiency of commercial banks.

Author	Title	The main contents or conclusions
Yu Wei Li Wang (1997)	Research on efficiency of Chinese commercial banks: a non-parametric analysis	The paper considered Chinese commercial banks' technical efficiency, scale efficiency and returns to scale, and proposed measures to improve the efficiency of the bank [17]
Jianhua Zhang (2003)	The DEA methods and an empirical analysis on efficiency of Chinese commercial banks from 1997 to 2001	The paper measured the efficiency of all types' commercial banks and pointed out the overall resource utilization level of Chinese banking sector. [18]
Nan Zhu etc. (2004)	An empirical research and reform strategies on the efficiency of Chinese state-owned commercial banks	This paper showed that the utilizations of human resource were not high in Chinese state-owned commercial banks and the overall efficiency of commercial banks was in a lower level. [19]
Yong Luo Lili Cao (2005)	The evaluation on efficiency of Chinese commercial banks based on super-efficiency model	This paper pointed out that the efficiency of joint-stock commercial banks were generally higher than that of state-owned commercial banks [20].
Daqiang Yang Aiwu Zhang (2007)	The evaluation on efficiency of Chinese commercial banks from 1996 to 2005	The paper showed that Chinese commercial banks had significant cost efficiency and profit efficiency, what's more, the cost efficiency and profit efficiency of the state-owned commercial banks were higher than that of joint-stock commercial banks, but efficiency growth rate of the latter slower than the former significantly [21].
Jinlan Yao Dingxiang Mao (2009)	The evaluation and analysis on efficiency of joint-stock commercial banks based on DEA-Tobit two-step method	This paper showed that there was a significant positive correlation between profitability of assets and bank efficiency while savings and loan ratio correlated to bank efficiency negatively [22].
Min Feng Daojun Fang (2011)	The analysis on operating efficiency of listed commercial banks based on DEA method (2003-2010)	This paper analyzed the technical efficiency, pure technical efficiency and scale efficiency of 13 Chinese listed commercial banks from 2003 to 2010 and pointed out measures for Chinese commercial banks to improve operational efficiency [23]
QingJun Cui Zengyao Zhao Qunwei Wang (2012)	The research on operating efficiency of Chinese commercial banks considering undesirable output	This paper showed that the operating efficiency of 14 Chinese commercial banks have been improved to some extent from 2005 to 2010 [24].
Jinming Zhang Peng Liao Juanjuan Xie (2012)	The analysis on efficiency of Chinese commercial banks under the constraint of non-performing loans	To measure the efficiency of 11 Chinese listed commercial banks under the constraint of non-performing loans by using directional distance function and DEA super-efficiency model [25].
Qian He Xingyu Chen (2013)	An empirical analysis on efficiency of Chinese commercial banks based on DEA method	The paper showed that most of the commercial banks have not reached economies of scale and were at the stage of increasing returns to scale while four state-owned commercial banks, except Bank of China, were at the stage of decreasing returns to scale [26]

desirable outputs, scholars have been making efforts for improving the DEA model. The common solution is to regard undesirable outputs as input indicators (e.g., Qingjun Cui *et al*.; A.V. Hailu *et al*.,) [24] [27]. However, in spite of existing rationality to cater to the evaluation idea of traditional DEA models, this approach violates the actual production process, and produced much deviation between measure results and the actual situation (e.g., W.B. Liu. *et al*, [28]). H. Scheel used a form of the data transfer function methods to do a certain conversion on undesirable output and then regard the undesirable output as desirable output [29]. The data transfer function methods consist of linear data conver-

sion method, nonlinear data conversion method and negative output method [30]. These forms all have certain limitations so that they can't accurately reflect the true results of the evaluation. For instance, Jinming Zhang *et al.* used the directional distance function and DEA super-efficiency to measure the efficiency of 11 listed commercial banks under both situations that considering non-performing loans and ignoring non-performing loans [25]. Although being used to evaluate bank efficiency under the constraint of undesirable outputs, the radial and output-oriented directional distance function cannot explain the slack variables. Therefore, Tone use the non-radial and non-oriented SBM model with the slacks indicating the input excess and output shortfall, and this model can overcome the shortcomings as stated above [31]. However, the scheduling problem under the condition that the efficiency values of some Decision-Making Units (DMU) are 100% still can't be solved. On the basis of the SBM model, Tone proposed the Super-SBM model solving the scheduling problem and dealing with the undesirable outputs consequently [32] [33]. This paper uses Super-SBM model, which is considered as the most effective and realistic model at present, to examine efficiency of Chinese commercial banks under the constraint of undesirable output model. What's more, the paper combines with Malmquist Index to understand the root causes of changes in bank efficiency and makes some recommendations as accurately as possible to remedy the efficiency of commercial banks.

3. Select the Model and the Variables

3.1. Model Selection: Super-SBM Model

Compared to traditional CCR and BCC model, SBM model [31] directly put the slack variables into the objective function to settle the problem of the input and output slacks. As a non-radial and non-oriented DEA model, SBM model can not only avoid the radial and oriented deviation, but also reflect the essence of the efficiency evaluation better than other models. We know that the best performers have the full efficient status denoted by unity (or 100%) in most models of Data Envelopment Analysis (DEA), however, there are often more than one DMU have this "efficient status" in practical applications of DEA models so that the relative efficiency of these efficient DMUs are indistinguishable. A natural idea is to do DEA evaluation on these efficient DMUs repeatedly for the satisfactory result, but this approach is quite cumbersome. Tone proposed the Super-SBM model solving the "super-efficiency" issue [32]. In addition, modern banking operation is often accompanied by undesirable outputs like non-performing loans. The bank that producing more desirable outputs and less undesirable outputs with less input resources should be recognized as efficient. This paper adopts Super-SBM model to measure efficiency of Chinese commercial banks with undesirable outputs based on the research of Tone [33].

This paper selects 12 Chinese commercial banks as the DMUs. Each unit contains three factors which are input, desirable outputs and undesirable outputs (non-performing loans in this paper), as represented by three vectors:

$x \in R^m$, $y^g \in R^{s_2}$, $y^b \in R^{s_2}$. The matrices X, Y^g, Y^b are defined as follows

$$X = [x_1, x_2, \cdots, x_n] \in R^{m \times n},$$
$$Y^g = [y_1^g, y_2^g, \cdots y_n^g] \in R^{s_1 \times n},$$
$$Y^b = [y_1^b, y_2^b, \cdots y_n^b] \in R^{s_2 \times n},$$

Assume that, $X > 0$, $Y^g > 0$, $Y^b > 0$. Then the production possibility set P is defined by $P = \left\{ (x, y^g, y^b) \middle| x \geq X\lambda, y^g \leq y^g\lambda, y^b \geq y^b\lambda, \lambda \geq 0 \right\}$

A certain DMU (x_0, y_0^g, y_0^b) is expressed as

$$x_0 = X\lambda + S^-$$
$$y_0^g = Y^g\lambda - S^g$$
$$y_0^b = Y^b\lambda + S^b$$
$$S^- > 0, \ S^g > 0, \ S^b > 0$$

The vectors $S^- \in R^m$, $S^g \in R^{s_1}$ and $S^b \in R^{s_2}$ represent slacks in inputs, desirable outputs and undesirable outputs respectively. m, s_1 and s_2 stand for the number of factors for inputs, desirable outputs and undesirable outputs. "S^-" indicates that the actual input resource is more than frontier investment. "S^g" points that the desirable output produced in the realistic operation is less than frontier desirable output. "S^b" means that actual undesirable output level is greater than the leading edge of the undesirable output level. λ is the intensity vector.

The DMU (x_0, y_0^g, y_0^b) is SBM-efficient in the presence of undesirable outputs if and only if there are no superfluous input, no insufficient desirable output and no redundant undesirable outputs, *i.e.*, $S^- = 0$, $S^g = 0$, $S^b = 0$. On the contrary, it means the DMU is inefficient and the inputs, undesirable outputs and undesirable outputs need to be improved. In this paper, we discuss the super-efficiency issues under the assumption that the DMU (x_0, y_0^g, y_0^b) is SBM-efficient.

The production possibility set P' is defined by excluding (x_0, y_0^g, y_0^b) from (X, Y^g, Y^b), as follows

$$P' = \left\{ (\bar{x}, \bar{y}^g, \bar{y}^b) \middle| \sum_{j=1, j \neq 0}^n x_j\lambda_j \leq \bar{x}, \ \sum_{j=1, j \neq 0}^n y_j^g\lambda_j \geq \bar{y}^g, \ \sum_{j=1, j \neq 0}^n y_j^b\lambda_j \leq \bar{y}^b, \bar{y}^g \geq 0, \lambda \geq 0 \right\}$$

The subset $\bar{P}$ of P' is defined as

$$\bar{P} = P' \cap \left\{ \bar{x} \geq x_0, \bar{y}^g \leq y_0^g, \bar{y}^b \geq y_0^b \right\}$$

According to the research of Tone (2001, 2004) [31] [33], the Super-SBM model dealing with undesirable outputs is shown in the following expression.

[Un-Outputs Super-SBM]

$$\delta^* = \min \frac{\frac{1}{m} \sum_{i=1}^m \frac{x_i^-}{x_{i0}}}{\frac{1}{s_1 + s_2} \left(\sum_{r=1}^{s_1} \frac{\bar{y}_r^g}{y_{r0}^g} + \sum_{r=1}^{s_2} \frac{\bar{y}_r^b}{y_{r0}^b} \right)}$$

Subject to

$$\sum_{j=1, j \neq 0}^{n} x_j \lambda_j \leq \overline{x}$$

$$\sum_{j=1, j \neq 0}^{n} y_j^g \lambda_j \geq \overline{y}^g$$

$$\sum_{j=1, j \neq 0}^{n} y_j^b \lambda_j \leq \overline{y}^b \qquad (1)$$

$$\overline{x} \geq x_0, \; \overline{y}^g \leq y_0^g, \; \overline{y}^b \geq y_0^b, \; \overline{y}^g \geq 0, \; \lambda \geq 0$$

In this paper, the Super-SBM model dealing with undesirable outputs is under the assumption of constant returns to scale. The Super-SBM model can also be extended to a more expanded data set and to the variable returns to scale environment. What's more, the Super-SBM model dealing with undesirable outputs can be modified into input orientation and output orientation. Please see Tone [31] [33] for more details.

3.2. Data Sources and Indicator Selection

This paper selected 12 Chinese commercial banks as the DMUs, which contains Agricultural Bank of China (ABC), China Construction Bank (CCB), Industrial and Commercial Bank of China (ICBC), Bank of China (BOC), Bank of Communications (BOCOM), Shanghai Pudong Development Bank (SPDB), Industrial Bank Co., Ltd. (CIB), Huaxia Bank (HXB), China Everbright Bank (CEB), China Minsheng Bank Corp., Ltd. (CMBC), China Merchants Bank (CMB) and China CITIC Bank (CITIC). China's five large state-owned commercial banks (ABC, CCB, ICBC, BOC and BOCOM) make their business cover a wide range, representing China's the most abundant capital and financial strength. In addition, the rest are representative commercial banks which have developed rapidly. The remaining seven commercial banks have set up more service points in China's major cities quickly while their market share and net profit have increased year by year. Increasing popularity and credibility make them the learning objects of many joint-stock commercial banks in China. All of the 12 commercial banks are prominent and typical and their operating efficiency level could reflect the overall situation of China's commercial banks competitiveness to a certain extent. Data of 12 Chinese commercial banks are gained from the 2005-2013 "Financial Statistics Yearbook" and the listed banks' annual group reports.

To select the input and output indicators is difficult and critical since inputs and outputs should maintain a strong linear relationship to reflect the actual situation of DMUs. Currently, the methods that experts and scholars at home and abroad often used are production approach (PA), intermediation approach (IA) and assets approach (AA). The production approach is to treat bank as a special production business that uses capital and labor to produce financial products, so labor and capital can be chosen as input variables while the number of deposit accounts and loan items can be selected as output variables. Banks are seen as intermediation between savings and investors according to intermediation approach. Banks usually obtain funds from residents who possessing surplus money and then provide it to residents in need of capital. Assets approach,

the characteristics of which is that input and output variable is determined by the balance sheet items, is improved on the basis of intermediation approach. Input indicators contain factors such as deposits, labor and capital while output indicators consist of the amount of investment, the number of loans, interest income, non-interest income, and so on.

It is unreasonable to adopt any one of three ways directly to define the input and output of commercial banks. The actual situation of the Chinese banking industry must be considered in the selection of input and output indicators. In view of the availability and the representative of indicators, this paper chooses labor force, fixed assets and interest expense as input indicators while treats the loan balance, deposits, net profit and non-performing loans as output indicators. The collected data of labor force is a head count, which contains managers, business people and other staffs of headquarter and all levels of branches. Labor force can reflect the bank's investment in human capital. As the bank's investment in physical capital, fixed asset, which displays the actual operating scale of the banks to some extent, is the material basis to stabilize efficiency. Interest expense is a vital part of the bank's input costs and means a lot to the efficiency. Among the output indicators, the deposit is the largest source of bank funds which manifests the ability of banks to absorb capital and largely determines the bank's cash flow and operational capital. Lending is the main way for banks to get profit so that loan balance to some extent stands for the scale of the bank's operations. Net profit shows the actual profitability of banks in a year and keeps a close relationship with the efficiency level. Non-performing loan, deemed to be a kind of undesirable output, directly represents the health degree of bank's operation. Besides, considering both quantity and quality of loans can make the results much more complete and convincing.

4. Empirical Test: Results and Analysis

4.1. Descriptive Analysis of Indicators

Compare Figure 1 with Figure 2, we can discover non-performing loans of Chinese five state-owned commercial banks (ABC, CCB, ICBC, BOC, BOCOM) were significantly higher than other commercial banks from 2005 to 2013. There is a clear decline of CEB's NPL during 2005 to 2008 in Figure 2. Moreover, the non-performing loans of the seven commercial banks present a gentle trend during 2008 to 2011 while showing a rising tendency between 2011 and 2013. Except ABC, the 4 state-owned commercial banks' non-performing loans are kept in a relatively stable range from 2005 to 2013 in Figure 1. The non-performing loan of ABC was up to RMB 740.425 billion, and then a sharp decline in 2008, the non-performing loan was down to RMB 103.247 billion at the end of the year, and got back into a normal fluctuation range. This phenomenon is due to the stripping of non-performing loans, which is approved by Ministry of Finance on November 21, 2008, taking December 31, 2007 as the base date, ABC disposed non-performing assets of RMB 815.695 billion according to book value, including doubtful loan of RMB 217.323 billion, loss loan of RMB 549.445 billion and
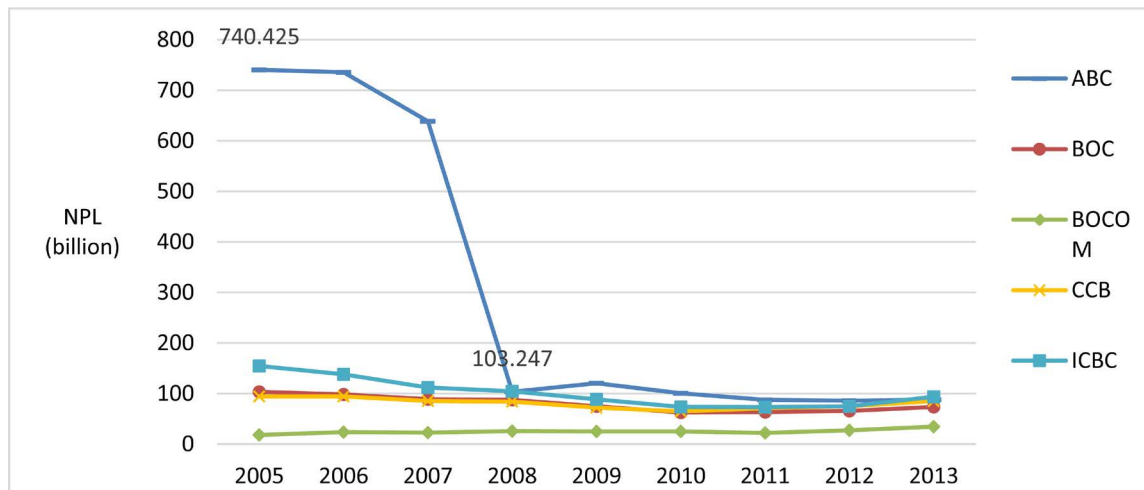
Figure 1. The NPL of 5 Chinese lager state-owned commercial banks (2005-2013).
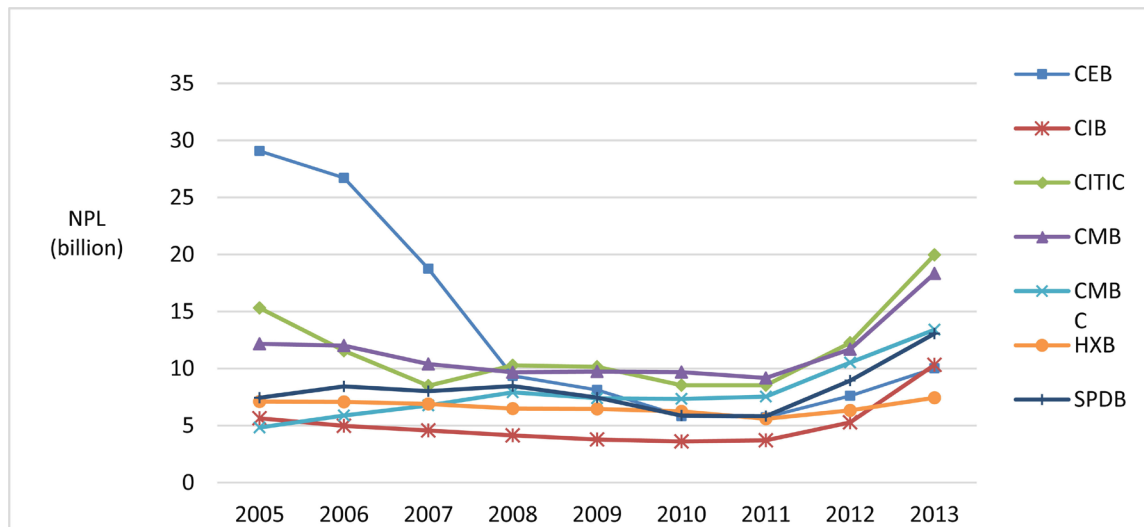

Figure 2. The NPL of other 7 Chinese commercial banks (2005-2013).

non-credit assets of RMB 48.927 billion. Furthermore, RMB 150.602 billion was reloaned by People's Bank of China to ABC free of interest to replace a part of non-performing assets mentioned above while the remaining RMB 665.093 billion was formed as the receivables of Ministry of Finance, meanwhile, the interests of which should be calculated at an annual rate of 3.3% since January 1, 2008.

As can be seen from Figure 3, the net profits of four state-owned banks (ABC, BOC, CCB, ICBC) from 2005 to 2013 were generally higher than that of other commercial banks. Each bank's net profit kept increasing every year. Owing to the fact that much bad loans were accumulated during the year of 2005 to 2007, ABC's net profit was much lower compared with the other three state-owned banks. In addition to the four state-owned commercial banks, the development of BOCOM is the fastest and prominent in general commercial banks. According to the collected data, the trends of loan balance, deposits, interest expense and other indicators are similar, moreover, the commercial banks' data except
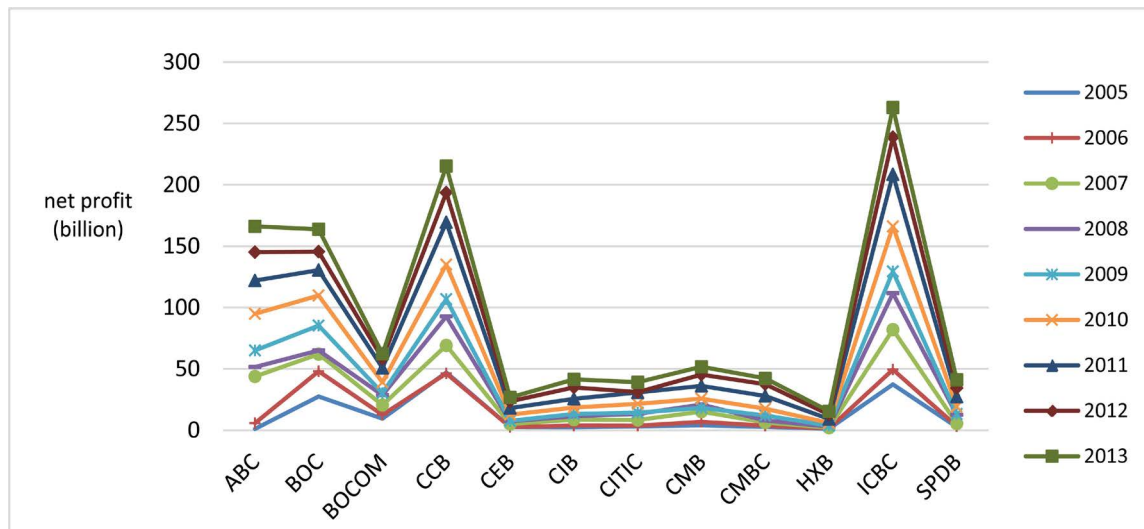
Figure 3. Net profits of 12 Chinese commercial banks (2005-2013).

non-performing loans are showing an increasing trend every year from the longitudinal angle, whereas from the horizontal angle, the four state-owned banks own the larger scale of operation and market share, therefore, the values of the indicators are often bigger than the other general commercial banks, but it does not mean that the operating efficiency of state-owned banks must be higher than the general commercial banks.

4.2. The Analysis on the Results of Super-SBM Model

This paper establishes a non-radial and non-oriented Super-SBM model with the assumption of constant returns to scale and uses software MaxDEA6.3 to analyze the data of 12 commercial banks from 2005 to 2013. Banks' annual efficiency values are shown in Table 3, what's more, the banks are ranked in accordance with their mean efficiency of 9 years.

Table 3 presents the mean efficiency of every bank of 9 years, from which we can discover that CCB, CMBC, SPDB, CIB, CMB and CITIC have been operated effectively while the mean efficiency of other banks of 9 years are less than 1. The mean efficiency of five state-owned commercial banks is scored 0.810 while that of the rest seven joint-stock commercial banks is 0.962, illustrating that operation efficiency of state-owned commercial banks less than that of joint-stock commercial banks. The mean efficiency of all the 12 commercial banks is scored 0.892, indicating that Chinese banking efficiency still need to be improved vigorously.

In order to verify that it is essential to evaluate the efficiency of commercial banks under the constraint of undesirable outputs and analyze the impact made by undesirable outputs, this paper gets the mean efficiency of 12 Chinese commercial banks without considering the undesirable output in the same way, then compares the results under the two situations. The mean efficiency values without considering the undesirable output are shown in Table 4.

Compared to the total mean efficiency value shown in Table 3, the total mean

efficiency value of 12 banks without considering undesirable output is even smaller, the reason is that non-performing loans and non-performing loan ratio of almost Chinese commercial banks have been decreased in recent years so as to make the banks' overall efficiency raised.

Table 3. Efficiency of 12 commercial banks considering undesirable output.

DMU	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean	Ranking
ICBC	0.598	0.589	1.001	1.031	1.029	1.026	1.039	1.115	1.120	0.950	7
CCB	1.125	1.031	1.018	1.000	1.012	1.010	1.014	1.008	1.025	1.027	5
BOCOM	1.002	0.671	0.581	0.596	0.580	0.567	0.585	0.696	0.741	0.669	10
ABC	0.064	0.218	1.035	1.007	0.463	1.017	1.008	1.018	1.017	0.761	8
BOC	0.525	0.548	0.503	0.532	1.024	0.603	0.549	0.629	0.866	0.642	12
Mean	0.663	0.611	0.828	0.833	0.822	0.845	0.839	0.893	0.954	**0.810**	
CEB	1.035	0.669	0.705	0.602	0.606	0.559	0.618	0.724	0.831	0.705	9
HXB	0.718	0.704	0.619	0.558	0.568	0.574	0.538	0.673	0.895	0.650	11
CMBC	1.300	1.191	1.112	1.068	1.054	0.816	0.762	1.013	0.918	1.026	6
SPDB	1.001	1.044	1.016	1.083	1.052	1.098	1.113	1.098	1.086	1.066	3
CIB	0.755	1.076	1.168	1.276	1.259	1.217	1.140	1.214	1.151	1.140	1
CMB	1.106	1.134	1.105	1.176	1.048	1.015	1.041	1.118	1.061	1.089	2
CITIC	0.753	1.002	1.067	1.014	1.150	1.160	1.252	1.054	1.098	1.061	4
Mean	0.953	0.974	0.970	0.968	0.962	0.920	0.923	0.985	1.006	**0.962**	
Total mean	0.819	0.807	0.904	0.906	0.897	0.885	0.884	0.943	0.982	**0.892**	

Table 4. Efficiency of 12 commercial banks ignoring undesirable output.

DMU	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean	Ranking
ICBC	0.638	0.634	1.001	1.042	1.039	1.035	1.044	1.151	1.134	0.969	7
CCB	1.174	1.042	1.009	1.000	1.011	1.011	1.014	1.008	1.026	1.033	4
BOCOM	0.735	0.662	0.608	0.633	0.580	0.613	0.621	0.730	0.739	0.658	9
ABC	0.050	0.200	1.035	1.010	0.492	1.022	1.011	1.024	1.023	0.763	12
BOC	0.550	0.523	0.543	0.581	1.024	0.635	0.598	0.674	0.855	0.665	10
Mean	0.629	0.612	0.839	0.853	0.829	0.863	0.858	0.917	0.955	**0.817**	
CEB	1.041	0.761	0.805	0.650	0.634	0.570	0.626	0.754	0.729	0.730	8
HXB	0.764	0.727	0.597	0.554	0.577	0.604	0.551	0.703	0.783	0.651	11
CMBC	1.267	1.197	1.123	1.080	1.054	0.819	0.738	1.017	0.881	1.020	6
SPDB	0.828	1.048	1.021	1.051	1.022	1.041	1.040	1.102	1.085	1.026	5
CIB	0.757	1.093	1.170	1.151	1.090	1.093	1.005	1.071	1.095	1.058	2
CMB	1.101	1.159	1.117	1.123	0.780	1.011	1.021	1.091	1.044	1.050	3
CITIC	0.848	1.002	1.076	1.016	1.161	1.168	1.294	1.068	1.135	1.085	1
Mean	0.944	0.998	0.987	0.946	0.903	0.901	0.896	0.972	0.965	**0.946**	
Total mean	0.799	0.820	0.919	0.903	0.869	0.883	0.879	0.947	0.960	**0.887**	

Without considering the undesirable output will underestimate bank efficiency and cause deviation between the efficiency values obtained and the actual situation consequently. Supposing that undesirable outputs are ignored, CITIC's ranking will jump to No. 1 from No. 4, CCB's ranking will jump to No. 4 from No. 5, BOCOM's ranking will jump to No. 9 from No. 10, BOC's ranking will jump to No. 10 from No. 12 and CEB's ranking will jump to No. 8 from No. 9 while ABC, SPDB, CIB and CMB ranked down. This phenomenon reveals that non-performing loans should be mainly responsible for the operating efficiency decline of CITIC, CCB, BOCOM, BOC and CEB, so the managers of these banks should try best to revitalize the bad loans and improve the quality of loan in the next.

Whether considered undesirable output or not, the mean efficiency of five state-owned commercial banks are less than that of the rest seven joint-stock commercial banks. What we can learn from the result is that large-scale funds and high market share haven't made the state-owned commercial banks greater operating performance. On the contrary, the efficiency values of the state-owned commercial banks are much lower than other joint-stock commercial banks because of decreasing returns to scale. Doubtlessly, large-scale commercial banks should do better in the terms of improving scale efficiency in the future.

So as to understand the fluctuations of 12 Chinese commercial banks' mean efficiency from 2005 to 2013 intuitively, this paper makes the following line chart (Figure 4).

As can be seen from Figure 4, non-performing loans even has no impact on the fluctuation of the mean efficiency of commercial banks, and the mean efficiency shown in a slow rising process whether considered the undesirable outputs or not. Fluctuation in 2007 appeared the first turning point shown in the chart, which is consistent with the actual situation that global economy had been hit hardly because of the financial crisis triggered by American subprime mortgage crisis. The financial crisis dramatically spread to the whole world in a short period of time, of course, Chinese economy didn't escaped from this disaster, however, and the impact of financial crisis on Chinese banking sector was rela-
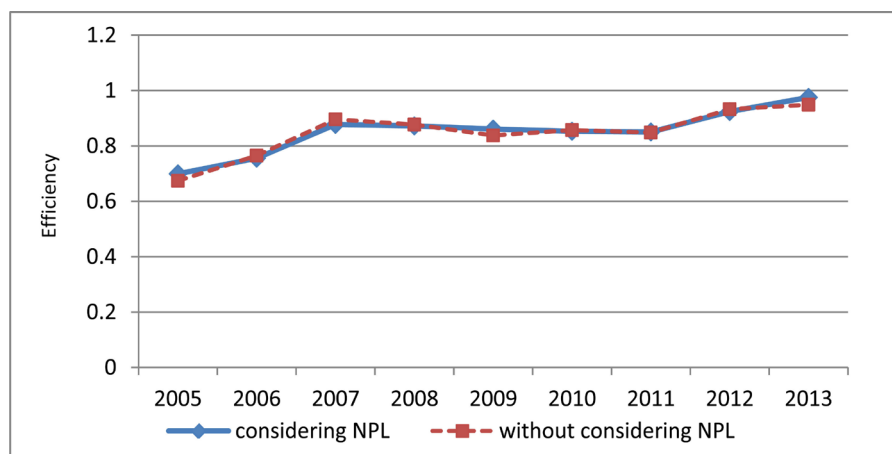

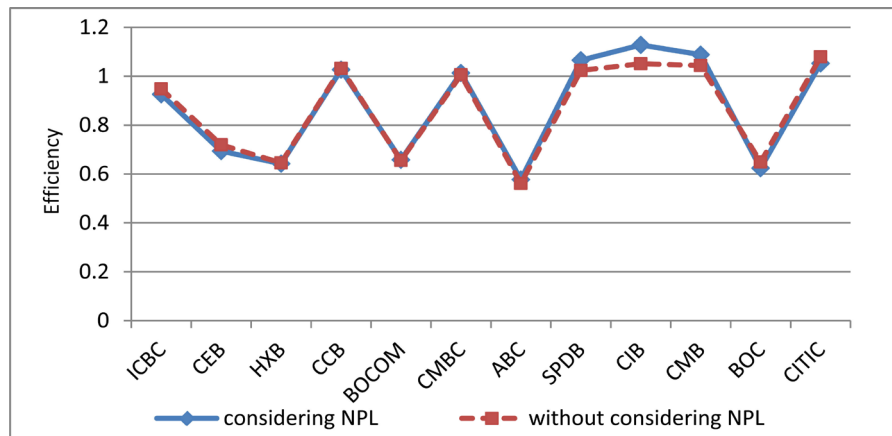Figure 4. The mean efficiency of 12 Chinese commercial banks (2005-2013).

Figure 5. The mean efficiency of single Chinese commercial bank (2005-2013).

tively small. The recession of the real economy led to a credit crisis, making the bank's loan quality greatly deteriorated, as a result, operating efficiency of banks suffered a serious blow. Although the fluctuation in **Figure 4** doesn't show a significant decline, we can see the change obviously. Under the situation of considering undesirable output, efficiency value is slightly higher than that without considering undesirable output, therefore, Super-SBM model could make the research results more credible and more in line with actual business processes.

To analyze how the undesirable output influence the efficiency of single Chinese commercial bank, this paper calculates the mean efficiency values of nine years of every bank under both two situations that considered undesirable output and ignored undesirable output (**Figure 5**).

As show in **Figure 5**, two polylines couldn't overlap completely, which means there are differences among the efficiency of commercial banks under the two cases, so it is necessary to add the non-performing Loans into output indicators as the results are more authentic when considering the impact of undesirable output.

4.3. The Reasons for Efficiency Changes of Chinese Commercial Banks by Malmquist Index Decomposition

The Malmquist productivity index, introduced by Caves *et al.* using input and output distance functions and further extended by Färe *et al.*, was used to measure the productivity changes originally [34] [35]. And then Färe *et al.* combined Malmquist with data envelopment analysis (DEA) theory [36]. With the continuous improvement of data envelopment analysis theory and extensive application of the method, the index has been widely used in various fields.

The Malmquist Index with undesirable outputs between period t and $t + 1$ is given as

$$M\left(x^{t+1}, y^{t+1}, b^{t+1}, x^t, y^t, b^t\right) = \left[\frac{D^t\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D^t\left(x^t, y^t, b^t\right)} \times \frac{D^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D^{t+1}\left(x^t, y^t, b^t\right)}\right]^{\frac{1}{2}}$$

where x^{t+1}, y^{t+1}, b^{t+1} represent input, desirable outputs and undesirable out-

puts at period $t + 1$ respectively and x^t, y^t, b^t correspond to input, desirable outputs and undesirable outputs at period t respectively.

Following Färe *et al.*, the Malmquist Index can be decomposed into changes in technical efficiency and changes in frontier technology under the assumption of constant returns to scale as follows[36]:

$$M\left(x^{t+1}, y^{t+1}, b^{t+1}, x^t, y^t, b^t\right)$$

$$= \frac{D^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D^t\left(x^t, y^t, b^t\right)} \times \left[\frac{D^t\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)} \times \frac{D^t\left(x^t, y^t, b^t\right)}{D^{t+1}\left(x^t, y^t, b^t\right)}\right]^{\frac{1}{2}}$$

$$= \text{EC} \times \text{TC}$$

Under the hypothesis of variable returns to scale, efficiency change (EC) can be further disentangled into pure efficiency change (PEC) and scale efficiency change (SEC) for the different efficiencies obtained in VRS Malmquist and CRS Malmquist. The decomposition is shown in the following formula.

$$\text{EC} = \frac{D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^t\left(x^t, y^t, b^t\right)} \times \left[\frac{D_C^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)}{D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)} \times \frac{D_V^t\left(x^t, y^t, b^t\right)}{D_C^t\left(x^t, y^t, b^t\right)}\right] = \text{PEC} \times \text{SEC}$$

where $D_V^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)$ denotes the distance function for variable returns to scale (VRS) at period $t + 1$ and $D_C^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}\right)$ represents the distance function for constant returns to scale (CRS) at period $t + 1$. PEC represents pure technical efficiency change, SEC shows scale efficiency change and TC reflects technical progress.

According to data of 12 Chinese commercial banks from 2005 to 2013, this paper calculates banks' TFP index, and other indices including TC, PEC and SEC, as shown in Table 5:

Table 5. Malmquist index values of 12 banks based on undesirable output.

DMU	TFP	TC	SEC	PEC	Ranking
ICBC	1.116	1.032	1.063	1.017	3
CCB	1.005	1.017	1.016	0.973	10
BOCOM	1.056	1.096	0.967	0.996	4
ABC	1.027	0.726	1.416	0.999	8
BOC	1.191	1.119	1.065	1.000	1
Mean	1.079	0.998	1.105	0.997	
CEB	0.993	1.020	0.980	0.993	12
HXB	1.053	1.024	0.987	1.042	5
CMBC	1.013	1.058	1.000	0.958	9
SPDB	1.002	0.992	1.000	1.010	11
CIB	1.131	1.073	1.035	1.019	2
CMB	1.030	1.036	1.000	0.995	7
CITIC	1.053	1.005	1.000	1.048	5
Mean	1.039	1.030	1.000	1.009	
Total mean	1.056	1.016	1.044	1.004	

Table 5 shows the total mean TFP index of 12 commercial banks is 1.056, total mean TC is 1.016, total mean SEC is 1.044 and total mean PEC is 1.004. This decomposition result shows that changes in technology, changes in the scale efficiency and the changes in pure efficiency are all the causes of TFP change. However, the relatively bigger reason for mean TFP change of 12 Chinese commercial banks is changes in scale efficiency. The total mean TFP index of five state-owned commercial banks is 1.079, total mean TC is 0.988, total mean SEC is 1.105 and total mean PEC is 0.997, which means that change in scale efficiency is primarily responsible for mean TFP change of five state-owned commercial banks.

From the analysis of 12 commercial banks, only CEB's TFP index is less than 1, just 0.993, this explains that change in pure efficiency is the biggest reason that resulted in the TFP change of CEB.

The TFP index of other commercial banks are all bigger than 1, but influenced by different factors. For example, TFP index of BOC is 1.191, TC, SEC and PEC are shown as 1.119, 1.065 and 1.000 respectively, the result means that TFP change of BOC is determined by TC and SEC, what's more, SEC makes greater impact on TFP change than TC. TFP index of CMB is 1.030, and TC, SEC and PEC are shown as 1.036, 1.000 and 0.995 severally, from the above, technological change is the main reason for TFP change of CMB. The situations of other banks above could be analyzed in the similar way.

Generally speaking, although PEC is the main factor for the mean TFP change of 12 commercial banks, for single bank concerned above, the main reasons for TFP change are not the same absolutely. The trends of four indices are shown in Figure 6.

As can be seen from Figure 6, the trend of TC is consistent with that of TFP mostly, even a large part of two lines in the middle are matched completely. This phenomenon means that TC is the core element to determine the efficiency of the commercial banks. Technological change also provides driving force for commercial banks to improve their operating efficiency. With the development of social science and technology, especially the rapid development and wide ap-
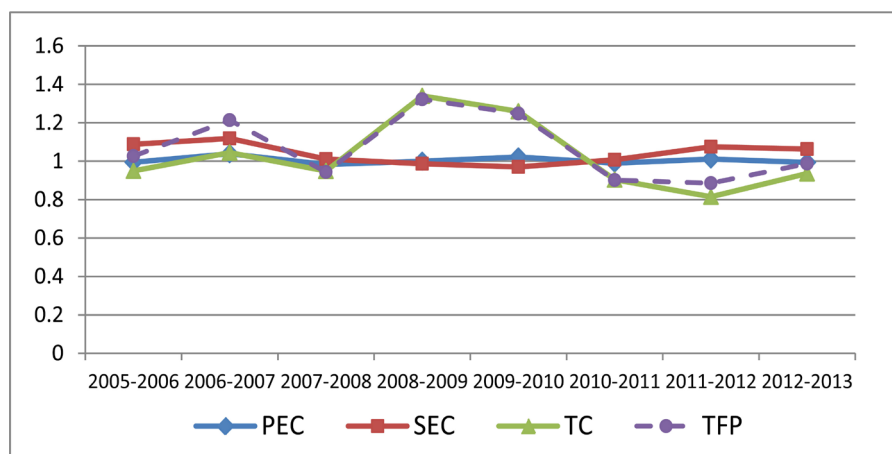

Figure 6. The trends of four Malmquist indices from 2005 to 2013.

plication of the internet economy, the economy has got a full range of promotion. Technological innovation and progress not only have reduced the cost of commercial banks, but also greatly increased the average earnings of banks. In contrast to western commercial banks, Chinese commercial banks still have a lot to be reformed currently. The non-asset profit incomes of western banks are much more than that of Chinese commercial banks, such as trust business incomes, leasing business incomes, cash management incomes, information service incomes, other non-interest incomes and so on. China should actively learn advanced management technology from foreign banks, make network technology integrated into the financial services flexibly, and promote the computer technology, automation and information management into Chinese banking sector. Since science and technology are primary productive forces, advances of technology can optimize the efficiency of the banking business and increase operating incomes. However, the most important thing is that it can help commercial banks to seek new opportunities, open up new markets, and create new funding sources and business opportunities in the increasingly competitive environment. To sum up, science and technology is the key to the sustainable development of commercial banks.

5. Conclusion

The innovative content of this thesis is to treat non-performing loans as output indicator together with loan remaining, considering the quality and quantity of loans simultaneously. Using the most effective Super-SBM Model to measure the data of 12 commercial banks from 2005 to 2013 in both cases that considering undesirable output and without considering undesirable output, the comparison indicates that it is necessary to consider undesirable output when measuring efficiency of banks, and the evaluation result would be more authentic and more in line with the actual bank operations. TFP index, TC index, PEC index and SEC index of 12 Chinese commercial banks from 2005 to 2013 are shown in the line charts (Figure 6), which presents that technological change determines total factor productivity principally. Technological progress can not only reduces the operating costs but also increases the banking business income.

Acknowledgements

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