Measuring Changes in Chinese Banking Productivity and Profitability

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Abstract

This paper adopts the Hicks-Moorsteen (HM) TFP index and Data Envelopment Analysis (DEA) to explore efficiency and its relation to changes in profitability and productivity in Chinese commercial banks (CBs). We decompose the HM TFP index into changes in technology, pure technical efficiency, scale efficiency, and output mix and then test for distribution differences when comparing the Malmquist and Hicks-Moorstein productivity indices for a given type of data. The study results reveal that the CBs experience primarily an increment of mix-efficiency rather than an improvement in pure technical efficiency (improvement in management practices) and that Chinese CBs pursue technological progress to meet the requirements for financial innovation and internet banking. This paper highlights the importance of analyzing performance from multiple perspectives and provides alternative explanations for improving productivity and profitability based on technical efficiency in general. Our results indicate that including non-performing loans as the input increases the efficiency score, but off-balance sheet items do not have a significant impact.

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1. Introduction

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The banking sector is the backbone of the Chinese economy, accompanied by the new normal of Chinese financial development. Developments in communication and company technologies have expanded, leading them to modernize distribution networks through internet banking and traditional activities. The Chinese banking sector was opened to foreign competition at the end of 2006 with entry to the World Trade Organization (WTO). China's State Council is expected to improve efficiency and productivity in the banking sector based on total factor productivity (TFP). Chinese former Premier Li has stressed that they must adequately resolve the challenges of financial risk based on overall judgment (Li et al., 2014) to prevent the emergence of systematic risk (Fu & Heffernan, 2009; Maredza & Ikhide, 2013). The entry of new foreign banks into the Chinese market has injected a reasonable degree of competition (Lambson, 1983; Ray & Das, 2010) b. However, banks face different constraints derived from governmental policies &y and Das, 2010). The growth of productivity and profitability is strongly dependent on the proper function of the banking system.

Compared to developed countries, there have been far fewer studies on changes in productivity and profitability in commercial banks (CBs) due to improved systems in developing countries. Deregulation following entry into the WTO in 2006 has significantly hastened the pace of the opening-up of the banking sector in China. Given the increased competition from local and foreign banks, CBs have had to become more innovative, provide better quality services, and optimize their business structures and processes. Banking reform has established the foundation of a competitive, modern banking system where financial efficiency is based on technical efficiency. Studies on increasing the productivity of CBs include the evaluation of efficiency, depending on the choice of input and output variables (Wang, 2014; Fu & Heffernan, 2007; Bassem, 2014), and the offering of services such as the utilizing of physical resources from the capital, labor, and funds to produce loans, income-based interest, and non-interest activities (Rogers & Sinkey, 1999; Ben Soltane, 2008; Hag et al., 2010; Gutierrez-Nieto et al., 2007).

To achieve these multiple objectives, profitability, and productivity changes in the banking sector are essential for well-functioning CBs in the long run. In this framework, studies aimed at decomposing the efficiency and productivity of CBs have become more appealing in an efftoormance on asset liquidity (Zhobased on; Bassem, 2014). Over the last decade, Chinese CBs have seen a significant increase in the use of fee-based services as an element of financial innovation. It is necessary to pursue broader growth (Wang and Lu, 2015; Boyd, Kwak & Smith, 1998; Barth, Caprio & Levine, 2004), Banks have conglomerate affiliations assured with diversification to reduce risk (Berger, Hasan and Zhou, 2010). The current environment of Chinese CBs is transitioning from one with little flexibility to diversification and a more extraordinary significant ovation This change derives from choices made under the WTO accession agreement. The results imply that CBs with higher levels of diversification tend to be larger, have smaller net interest margins, have relatively more off-balance sheet activities

(OBS), and experience fewer non-performing loans. In fact, there has been a dramatic change in weather performance which has implications for profitability and productivity. It is necessary to explore the expansion that has occurred after opening the local market to the entry of foreign banks and the efficiency found in both State own estate-own private banks (Ray and Das, 2010).

This study is an empirical exercise to measure the productivity and profitability change of CBs in China from 2006-2015. There have been several stuseveralnese bank efficiency that has considered non-traditional activities (Lozano-Vivas and Pasiouras, 2010; Berger and Humphrey, 1997; Wang and Lin, 2014), the operation of a diversity of businesses to add value or cost complementarities (Cummins et al. 2010; Wang and Liu, 2015), the profitability and productivity of Chinese banks (Chen et al. 2005), competition efficiency (Bolt and Humphrey, 2010; Hughes et al., 2001; Lieu, Yeh, Chiu, 2005; Banker et al., 2010; Chiu, Chen and Bai, 2011), cost efficiency (Berge and DeYoung, 1997; Huang and Huang, 2002; Peng and Wang, 2004; Hauner, 2005; Chiu and Chen, 2009), bank branch efficiency (Paradi & Zhu, 2013; Soteriou and Zenios, 1999; Stanton, 2002), neural networks (Wu et al. 2006), as well as financial innovation (Wang and Liu, 2015).

The contribution of this paper is, first, to model NPL consistently, using the Hicks-Moorsteen (HM) index of TFP and DEA to survey the efficiency of CBs in China (Diewert, 1992; Paradi and Paradise201), and to decompose productivity growth into technology change, which captures the movement towards a new frontier. To date, there have been few studies on this issue.

Productivity growth is measured using the HM TFP index, which is estimated by taking the traditional Solow residual and can be decomposed into the TFP and an index measuring relative price changes (Kerstens and Woestyne, 2014; O'Donnell, 2010). The Hicks-Moorsteen TFP index is a theoretical identification method that can be described as multiplicatively complete under any return-to-scaleassumption. Technical regress can be conceptualized as ca ontraction of the production possibilities set, representing technological shifts from output growth (Hulten, 2001; Van Beveren, 2010). Imeasuresof the change in the external environment in which production takes place based on the amount of output that can be used given a set of inputs. The Hicks-Moorstein index is specific to a particular case of banking performance (O'Donnell, 2010, 2012a; Bjurek, 1996; Kerstens and Woestyne, 2014). The HM TFP index can be decomposed into measures of technical change, technical efficiency change, scale efficiency change and mix efficiency change components. Its main disadvantage is the necessity to compute the distance functions, but the data envelopment analysis (DEA) technique can be used to solve this problem.

The Malmquist TFP index, first proposed by Färe et al. (1994), uses linear programming methods to construct a series of non-parametric production frontiers, to capture a shift in the production frontier from efficiency improvement. The Hicks-Moorsteen index has a TFP interpretation in general (O'Donnell, 2010, 2012a; Kerstens and Woestyne, 2014). Technical efficiency, scale efficiency and return to scale have been discussed about the overall efficiency with various findings (Yu et al. 1997, Zhang, 2003; Zhu, 2004; Yong et al. 2005; Yang and Zhang, 2007; Yao and Mao, 2005; Feng and Fang, 2011; Cui et al. 2012; Zhang et al. 2012; Zhang et al. 2012; He and Chen, 2013). From the viewpoint of both cost efficiency and profit, Yang and Zhang (2007) found a positive relation between profitability and efficiency. The degree of similarity between the Malmquist and the Hicks-Moorsteen productivity indices has been formally tested using NPL input vectors (Yao and Mao, 2011; Cui et al., 2012; Kerstens and Woestyne, 2014; Zhou and Zhu, 2017). Our contribution is computation of these primal productivity indices using a balanced panel under a variety of technology specifications, to test whether both productivity indices coincide. We also use DEA to examine the efficiency of Chinese CBs and, with the HM TFP index, to understand the differences between productivity indices (Ataullah et al., 2004).

The rest of the paper is organized as follows: In Section 2 we describe the productivity and profitability change and outline the nonparametric DEA methodology. In Section 3 we discuss the data sources along with identification of the inputs and output as reported in Section 4. Section 5 summarizes the empirical findings, while some concluding remarks are made in the final section.

2. Definitions of technology and productivity index

We consider industry productivity to be defined as m outputs from n inputs. To introduce productivity we first describe how a vector of inputs $X = (x_1.....x_n) \in \Re_+^n$ is transformed into a vector of outputs $Y = (y_1.....y_p) \in \Re_+^p$. An input-output bundle (x, y) is considered attainable when the output bundle can be produced from the input bundle x (Ray and Das, 2010). For each time period t, the production possibility set T^t summarizes the set of all attainable vectors of input and output. Following past findings by Bjurek (1996), the HM productivity index, with a base period t, is defined as the ratio of the Malmquist output quantity index (Kerstens and Woestyne, 2014) in base period t:

$$HM_t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{O_t(x^t, y^t, y^{t+1})}{I_t(x^t, x^{t+1}, y^t)}, \tag{1}$$

whereby the output quantity index is defined as

$$O_t(x^t, y^t, y^{t+1}) = \frac{D_t^0(x^t, y^{t+1})}{D_t^0(x^t, y^t)} \quad , \tag{2}$$

and the input quantity is defined as

$$I_t\left(x^t, x^{t+1}, y^t\right) = \frac{D_t^i\left(x^{t+1}, y^t\right)}{D_t^i\left(x^t, y^t\right)}. \tag{3}$$

The productivity in the banking industry can be defined as the ratio of output quantity produced in a specific time period to the sum of one or all input factors required to produce the output quantity. The measured HM TFP index indicates a gain (loss) if it larger (smaller) than unity, when it highlights productivity improvement. Similarity, a base period t+1 HM TFP index is defined as follows:

$$HM_{t+1}\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{O_{t+1}\left(x^{t+1}, y^{t+1}, y^t\right)}{I_{t+1}\left(x^t, x^{t+1}, y^{t+1}\right)}. \tag{4}$$

Färe et al. (2004) proposed using the distance function formulated by Shephard (1970) to define a desirable and an undesirable output-oriented measure of technical efficiency. The output distance is the output-oriented measure of technical efficiency, while the output distance function measures the largest radial construction of the input vector that is attainable while taking the output vector to the production frontier (O'Donnell, 2010; Abad, 2015):

$$D_t^O\left(x_t, y_t\right) = \begin{Bmatrix} \inf_{\lambda}\left\{\lambda > 0 : \left(x_t, \frac{y_t}{\lambda}\right) \in T_{Et}\right\} if \left(x_t, \frac{y_t}{\lambda}\right) \in T_{Et} \; for \quad some\, \lambda > 0 \\ +\infty \qquad\qquad otherwise \end{Bmatrix}. \tag{5}$$

In the input-oriented case, this measure indicates the maximum radial contraction of an input that remains in the technology:

$$D_t^I\left(x_t, y_t\right) = \begin{Bmatrix} \sup_{\lambda}\left\{\lambda > 0 : \left(\frac{x_t}{\lambda}, y_t\right) \in T_{Et}\right\} if \left(\frac{x_t}{\lambda}, y_t\right) \in T_{Et} \; for \quad some\, \lambda > 0 \\ 0 \qquad\qquad otherwise \end{Bmatrix}. \tag{6}$$

The monotonicity and homogeneity properties of the output distance function ensure that this index satisfies the determinateness axiom as being multiplicatively-complete. The non-parametric method developed by O'Donnell (2011) in response to the inadequacy of the popular Malmquist TFP index will be utilized (Kerstens and Woestyne, 2014). The HM TFP index can be formulated as:

$$TFP = HM_t\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left(\frac{D_t^O\left(x_t, y_{t+1}\right)}{D_t^O\left(x^t, y^t\right)}\right) \times \left(\frac{D_t^I\left(x_{t+1}, y_t\right)}{D_t^I\left(x_t, y_t\right)}\right), \tag{7}$$

where y and x are vectors of quantities; and $D^O(.)$ and $D^I(.)$ are output and input distance functions. A geometric mean of these two HM TFP indices is:

$$TFP_{t,t+1} = \left(\frac{D_t^O\left(x_t, y_{t+1}\right)}{D_t^O\left(x_t, y_t\right)} \frac{D_t^I\left(x_{t+1}, y_t\right)}{D_t^I\left(x_t, y_t\right)} \frac{D_{t+1}^O\left(x_{t+1}, y_{t+1}\right)}{D_{t+1}^O\left(x_{t+1}, y_t\right)} \frac{D_{t+1}^I\left(x_{t+1}, y_{t+1}0\right)}{D_{t+1}^I\left(x_t, y_{t+1}\right)}\right)^{1/2}. \tag{8}$$

More specifically, consider the productivity change indices as the TFP as a measure of the outward shift in technology from period t to period t+1. The production function is linearly homogeneous with constant returns to scale (Diewert, 1992; Hicks, 1961; Miirsteen, 1961), and the TFP index with a base period t is defined as the ratio of the Malmquist output quantity index in base t over a Malmquist input quantity index in the same period t as in Eq. (5) to Eq. (6) (Kerstens and Woestyne, 2014).

2.1 Productivity change and its components

Technical progress primarily refers to expansion of the production possibility set (O'Donnell, 2010). The HM TFP index can be exhaustively decomposed into measures of technical change through increased knowledge, while technical efficiency improvement refers to increases in output-input ratios made possible by eliminating mistakes in the production process.

Output orientation measures the expansion of output that is necessary for efficiency improvement while holding inputs constant. Pure Technical Efficiency (PTE) is illustrated in Figure 1 as the measure of the horizontal distance from point A to point C on the restricted frontier:

$$PTE = \frac{O_{nt}}{\overline{O}_{nt}} = \frac{slope \quad 0A}{slope \quad 0B}. \tag{9}$$

To illustrate the relation between the measures of productivity and efficiency, the curve passing through point E is an unrestricted production frontier, basically, it is the boundary of the production possibilities set that is available to firms when all mixing restrictions are relaxed. The measure of residual output-oriented scale efficiency is defined as follows:

$$RSE_{nt} = \frac{\hat{O}_{nt} / I_{nt}}{O_{nt}^{*} / I_{t}^{*}} = \frac{slope \quad 0C}{slope \quad 0E} = \frac{slope \quad 0C}{slope \quad 0D} \tag{10}$$

The output oriented mixed efficiency (OME) is a measure the increase in TFP as the firm moves from B to C on the unrestricted frontier, which is a movement from one mix-efficient point to another, and may contain a residual mixing effect (O'Donell, 2010):

$$OME_{nt} = \frac{\overline{O}_{nt}}{\hat{O}_{nt}} = \frac{slope \quad 0D}{slope \quad 0E}, \tag{11}$$

where $\overline{O}_{nt}$ is the maximum aggregate output that is technically attainable when I_{nt} is used to produce a scalar multiple of O_{nt}; $\hat{O}_{nt}$ is the maximum aggregate output possible when using i_{nt} to produce any output vector; $\hat{I}_{nt}$ is the maximum aggregate input possible when using any input vector to produce $q_{i,t}$; and $\overline{O}_{nt}$ and $\bar{I}_{nt}$ are the aggregate output and input obtained when TFP is maximized, subject to the limitation that the output vectors are scalar multiples of O_{nt} as well as the input vectors of I_{nt}. The OME is a measure of the increase in TFP that takes place by keeping inputs fixed and can be achieved the potential gains through economies of scale.

O'Donnell (2010) refers to point C as a point on the mix-invariant optimal scale. The measures of efficiency are defined as the multiplicatively complete TFP index that remains after accounting for the effects of pure technical efficiency and pure scale efficiency, in terms of aggregate quantities,

$$TFPE_{nt} = \frac{O_{nt} / I_{nt}}{O_{nt}^{*} / I_{nt}^{*}} = \frac{TFP_{nt}}{TFP_{t}^{*}} = \left(PTE_{nt} \times OME_{nt} \times RSE_{nt}\right). \tag{12}$$

A similar equation holds to firm n in period t. The comparison of the TFP of firm n in period t with the TFP of firm m in period t+1 can be written as follows:

$$TFP\_I = \frac{TFP_{n,t}}{TFP_{m,t+1}} = \frac{TFP_{t}^{*}}{TFP_{t+1}^{*}} \times \left(\frac{PTE_{n,t}}{PTE_{m,t+1}} \times \frac{OME_{n,t}}{OME_{m,t+1}} \times \frac{RSE_{n,t}}{RSE_{m,t+1}}\right) = TC \times \left(PTEC \times OMEC \times RSEC\right) \tag{13}$$

The first term in parentheses on the right-hand side of Eq. (13) is a measure of technical change. It measures the difference between the maximum TFP possible using the period-t technology and the maximum TFP possible using the period-t+1 technology. The economy experiences technical progress or regress when $TFP_{t}^{*} / TFP_{t+1}^{*}$ is greater than or less than one. The other ratios on the right-hand side of Eq. (12) are obvious measures of pure technical efficiency change, residual mixing and scale efficiency change. Thus, the HM TFP index measuring the efficiency of banking sectors of the inequalities and represents the decomposition given by the new Eq. (13).

2.2 Profitability change

In period t, suppose that the firm utilizes x_{n}^{t} units of each n=1……N inputs to produce y_{m}^{t} units of each m=1….M outputs. The price of input n in period t is I_{n}^{t}, and the price of output m is O_{m}^{t}. Thus the profitability ratio for period t is given by Eq. (9) as follows:

$$\pi^{*} = \frac{\sum_{m=1}^{M} O_{m}^{t} y_{m}^{t}}{\sum_{n=1}^{N} I_{n}^{t} x_{n}^{t}}, \tag{14}$$

and the profitability change ratio is (Banker et al. 1996):

$$PROC = \frac{\sum_{m}^{M} O_m^{t+1} y_m^{t+1} \Big/ \sum_{n}^{N} I_n^{t+1} x_n^{t+1}}{\sum_{m}^{M} O_m^{t} y_m^{t} \Big/ \sum_{N=1}^{N} I_n^{t} x_n^{t}} . \tag{15}$$

Profitability change can be written as the product of the multiplicatively complete TFP index (O'Donnell, 2010). Eq. (10) can be used decompose this into its productivity and price recovery condition (Banker et al. 1996; Alsyouf, 2007). It is defined as the ratio of the value of t+1 level outputs to t level outputs, divided by the ratio of the value of t+1 inputs to t level inputs, suggesting that it measures the technical efficiency of firms. The price recovery ratio can help to measure the ability of the firm to become price or allocation efficient (Banker et al. 1996). Eq. (10) also presents the product of the terms of trade with the TFP. Our empirically implementable term of trade is an index of the output prices divided by an index of the input prices. PROC means the multiplicatively complete to measure the combined effects of technical progress and improvement in the terms of trade. Using our framework, we capture the effects of a change in the balance of terms of trade. For example, if the deficit increases, there will be a decrease in scale in the firm that, in some respects, is similar to a short run increase in the TFP, when it exists on a decrease of the return to scale. Thus, we define the following profitability change indices which incorporate the reverse relation between the terms of trade and TFP under the condition of lack of technical changed and complete product efficiency. However, the reverse relations fail with changes in technical progress and efficiency in the market-oriented economy.

2.3 The DEA approach

The DEA can be used to compute and decompose the Hicks-Moorsteen index that has been selected from the class of multiplicatively complete indices, essentially because it is relatively straightforward to estimate the distance function. The production possibility set is convex and both inputs and outputs can be freely discarded. In this case, the production possibility set is constructed as a function of the production technology from an observed data set as follows:

$$\omega' y = \beta + \lambda' x_{nt} , \tag{16}$$

where $y_{n,t}$ represents local linearity of the output vectors in the condition of variable returns to scale as well as β; η is non-negative, if $\beta < 0$, and the technology exhibits a local increase in returns to scale, and $\beta > 0$ meaning a local decrease in returns to scale. If $\beta = 0$, it means locally constant returns to scale. In this paper, we use the output-oriented DEA model and maximize the value of the distance function at in Eq. (5), so the distance function will be written as Eq. (17):

$$D_t^0(x_{nt}, y_{nt}) = \frac{y_{nt}}{\beta + \lambda' x_{nt}} \leq 1. \tag{17}$$

The initial problem involves selecting the values of ω, ϕ and β to maximize $D_t^O(x_{nt}, y_{nt})$. In this case, technical regress is prohibited. The unknown parameters are constrained so that $D_t^O(x_{nt}, y_{nt}) \leq 1$ for i=1,…,n and r=1,…,t. A restricted solution can be identified using the normalization of $\omega' y_{nt}$=1, in which case the linear programming is as follows:

$$\begin{aligned} D_t^O(x_{nt}, y_{nt})^{-1} &= \min_{\beta,\lambda,\omega} \beta + \lambda' x_{ir} \\ & s.t. \quad -\omega' y_{nt} + \lambda' x_{ir} + \beta \geq 0 \\ & for\, i = 1,\ldots,N \quad and \quad r = 1,\ldots,t, \\ & \omega' y_{nt} = 1 \\ & \omega, \lambda \geq 0 \end{aligned} \tag{18}$$

Eq. (18) can be solved using a standard linear programming software package to obtain solutions in an alternative and dual form.

Efficient frontier analysis can be divided into parametric and non-parametric methods according to optimization of the meanings of parameters. DEA is kind of linear programming method, which allows management to objectively identify an efficient frontier, which consists of the most efficient decision making units (DMUs), in this case banks. For the best DMUs it is assumed that the production possibility set is convex and the areas in need of improvement within the bank's complex operating situations can be identified.

3. Methodology

Currently, the two main approaches are the production approach and the intermediation approach (Berger and Humphrey, 1997). CBs usually obtain funds for purchase from residents who possess surplus units, and use labor and capital to transform these funds into loans and other assets (Berger and Humphrey, 1991; Siems, 1992; Yue, 1992; Berger, 1992; Hughes & Mester, 1993; Kaparakes et al., 1994; Yeh, 1996; Leong & Dollery, 2004; Maredza and Ikhide, 2013). It is pointed out in past studies that the intermediation approach may be more appropriate for evaluating entire financial institutions, better reflecting the actual situation of DMUs.

Off-balance sheet activity (OBS) items and non-interest income can be considered as additional outputs. The inclusion of OBS has a statistically significant impact on profit efficiency which includes loan commitments, future and forward contracts, standby L/C, options arrangements, SWAPs as well as securitization (Clark and Siems, 2002; Ray and Das, 2010; Lozano-Vivas and Pasiouras, 2010; Kummar, 2011). In recent years, CBs have been diversifying in the banking sector, seeing the generation of income from OBS business and fee-based income (Sufian and Chong, 2008). We use OBS as a proxy variable for estimation of profit efficiency in analysis of how non-interest income from fees, commissions, brokerage fees has become part of a standardized pricing mechanism (Ray and Das, 2010).

Deposits, non-performing loans and fixed assets, together with real resources (labor and capital) are treated as inputs, whereas outputs include only bank assets that generate revenue such as loans, investments (Sealy and Lindley, 1977) and OBS (Ray & Das, 2010). We consider four inputs: (borrowed) funds (deposit and borrowing items), number of employees, fixed assets and non-performing loans. The non-performing loan is a key indicator of risk-taking for commercial banks. The large number of NPLs became a signal of the financial crisis triggered by the US subprime mortgage crisis. The myriad of NPLs concentrated in the banking sector is directly representative of the degree of health of the bank's operations (Barseghyan, 2010) and has an impact on operational efficiency, especially in the profitability stage (Zhu, Wang, Wu, 2015). In addition, consideration of the quality of loans can make the results more complete and convincing. The amount of staff can reflect the bank's investment in human capital so data should include the number of managers, business people, and staff members from headquarter and all branch levels.

The costs of the three inputs are measured by taking the average interest paid per RMB of borrowed funds as a cost of borrowed funds, average staff salary cost and the cost of fixed assets measured by non-labor operational costs per RMB amount of fixed assets. The three outputs include investments, performing loan assets and OBS. The associated price indicator for investment, total amount of that interest income, other interest revenue and gain-bill trade, gains on long-term equity investment to be settled, is then divided by the real amount of total investment. Consideration of performing loans as an output measure, similar to the system used in the US, is a new concept in China's banking system. In today's banking industry, the focus has shifted away from traditional income to the generation of non-interest fee-based income as a distinct output (Rogers, 1998; Tortosa-Ausina, 2003).

4. Empirical findings

4.1 Data and Descriptive statistics

Our study covers an eleven-year period beginning with from the financial year 2006 to 2015. Data used in this study cover only commercial banks with no fewer than five branches during the period. We exclude regional rural banks because their domain of operations is restricted to local famers and small to medium sized enterprises. We also excluded foreign banks because their operational services extend to the clients of their parent banks abroad and thus their considerations in terms of input and output are very different from other banks with a significant presence in China. The financial statements of CBs operating in the Chinese banking sector were collected from the China Stock Market and Accounting Research (CSMAR) database maintained by Shenzhen GTA Education Tech Ltd. This financial database is commonly deemed as valid and reliable and it is available to Chinese research institutions. Summary statistics of the measures of year-wise distribution of output and input vector efficiency are presented in Table 2. NPL is taken as an important indicator in the evaluation of CB efficiency, providing an indication of the extent to which different banks exhibit the quality and degree of management efficiency. At the end of 2014, the total NPL of CBs amounted to RMB 577 billion, RMB 454.2 billion more than at the end of 2011. The amount of NPLs held by Chinese CBs continued to rise to RMB 949 billion in 2014, an increase of RMB 372 billion compares to the total in 2014. This result suggests that NPLs have depressed the operating efficiency and reduced the lending capacity of CBs (Zhou & Zhu, 2017). The amount of NPLs has led to a drop in the liquidity of funds and had an effect on the profitability of the financial industry.

The mean of OBS ranges from RMB 20.09 to RMB 65.91, the standard deviate is 64.75 and the mean of the value of capital ranges from 165.1 billion RMB to 358.2 billion RMB. This fact can be interpreted as being representative of the heterogeneity of the CB’s characteristics which have evolved differently depending on their size and scale. The mean of the number of employees is 59,053 over all periods and shows a gradual decrease from 2012 in the sample. The mean of funds is about 295.6 million, as expected for large banks. In addition, the amount of performing loans is about RMB159.6 million. Investment has a mean value of about RMB 431.5 million with a standard deviation of about 1,043.5 million. The data show non-performing loans, calculated according to the underlying collateral or where interest has not been overdue for more than 3 months. Considerable variation exists in the balance derived from loans. For example, the average NPL was almost 5 million before 2008, but with a standard deviation of 10.71% (2008), indicative of the existence of considerable variation. The total amount of funds has increased steadily, rising from 250 million (RMB) for the smallest contribution in 2006 to 540 million, with a shrinkage of the variation in 2014.

4.2 Profitability, terms of trade and productivity

An indication of the decline is the shrinking portion of the TFP index held by CBs, which has fallen from 11% in 2008-2009, to 29% in 2009-2010, and 27% in 2010-2011. This reduction in CB efficiency suggests that the global financial crisis has also hurt the level of profitability, productivity and growth in non-traditional activities, such as commercial paper, funds and corporate bonds to yield commission. Table 3 shows the results of analysis of the index of efficiency. It can be seen that profitability has decreased from 2007-2015 even through all Chinese CBs have shown positive TFP growth, with the exception of the year 2009-2013, where there was a rise in the revenue of 25.3% per year due to policies of openness and non-interest income activities.

There are three indices of bank profitability efficiency considered for CBs, namely the revenue index, cost index and profitability index. Thus, CBs with higher diversification of operations of non-interest income have higher profitability. It is suggested that competition is costly when CBs need to deal with more complex activities which may involve significant transaction costs and system risk. Several state-owned CBs with good governance were more efficient than city-run CBs with poor governance, such that private information about the quality of the borrower can be extracted for information about firm-specific risk (Von Thadden, 1994).

Although most previous CB efficiency studies have utilized inputs and outputs as reflecting terms of trade, this study found that the real problem is the decline in the price of output (average of 15.75 %), whereas the price of inputs first dropped and then rose during this period. The estimated changes in productivity and its evolution are summarized in Table 4. Overall, the HM productivity change experienced by CBs averaged 14.3% per year and suggested an improvement in performance from 2012 to 2015. Similarly, as shown by the results over the sample period, the average annual rate of change in technical efficiency was -2.1%, while the rate of technological change was -5.5%.

The aftermath of the global financial crisis from 2010 to 2012 made a special contribution. There were two periods when CBs experienced a significant recovery of TFPEC of above 100%, the period from 2009-2010 (23.5%), and from 2010-2011 (17.3%). We find that the funds of input play a negative role in the efficiency meaning that median deposits are more efficient than the others. It can be concluded that the key to success for CBs is their use of technology, and due to non-interest based income, to establish a relationship of trust with their potential customers, resulting in lower transaction costs for internet banking and e-commerce. However, TFPEC indicates slow recovery after entry to the WTO. Assets and land values were identified as being actively traded at the beginning of the release of the Property Laws in 2007. The PTEC is 0.6% and TC is -5.5%, indicating that most of the CB's productivity showed little improvement when environmental risk stemming from technical regression was incorporated. We find that most of the OMEC values are greater than 1 and the TFPEC values indicate positive change during the period from 2010 to 2012. The results are indicative that the beginning of the enforcement of the Property Law and the gradual progress of Financial Technology (Fin Tech). The CBs encounter a very challenging and competitive environment with the inclusion of foreign banks and Fin Tech, having a determinant impact on their performance.

4.3 Changes in productivity and profitability of individual banks

Using data for 35 Chinese CBs from 2006 to 2015, this paper calculates HM profitability and productivity indices which can be decomposed into PROC, TT, technological change (TC), total factor productivity efficiency change (TFPEC), PTEC, OMEC and residual scale efficiency change (RSEC), as shown in Table 5. The table shows that the total mean TT index of the 35 DMUs is 1.059, the total mean TFPI is 0.984, the total mean RSEC is 1.008, the total mean PTEC is 0.976, and the total mean OMEC is 1.011. The decomposition results show that changes in technology, changes in the scale of efficiency and changes in pure efficiency are all causes of changes in the.

For the larger banks, namely contain ABC, CCB, ICBC, BOC and BOCOM (see Appendix for the names of the banks), the ratio is made higher than for other smaller banks, which is representative of them having the most abundant capital and greater financial stability. A mixed efficiency value larger than one represents rapid development and increased service content in major channels leading to a rapid increase in market share and profit throughout mainland China year by year. Sixteen of the CBs in the sample (BOD, GZCB, XMCCB, HXB, CMBC, HXB, CMBC, HKB, JSH, BSB, CIB, BOB, ABC, HSB, CQCB, LZB, CCB, BOG) had subsidiaries and numerous branches throughout the entire period of our analysis. Larger scale CCBs developed a competitive advantage based on the transfer intangible assets such as technology and reputation for OBS activity.

In Table 5, it can be seen that GZCB, JSH, JSB, BOG, CITIC, CEB, HSB and LZB have a higher OME efficiency that is reflective of competitiveness and expansion of diversification. Analysis of the DMUs shows that the OMEC index of 21 CBs is less than 1. This can be explained by a weak mixed-efficiency and diversification strategy for the development of the OBS, derivatives, and Fin Tech. Only JSB 2.313 showed that strong productivity but weak profitability, with the terms of trade also being larger than 1, specifically 1.028. They showed dominant technology efficiency, representative of trading efficiency from diversification but this caused higher risk-taking decisions.

Comparison of both the HM and Malmquist indices shows clear deterioration in the efficiency and productivity measures clearly following the global financial crisis. Nevertheless, with limited exposure to foreign assets and adequate level of capital level productivity could be maintained. OBS activities may indirectly lead CBs to higher profit margins through interest and fee income which promote more diversified margin-generating assets (Angbazo, 1997). The TC even grew more from 2010 to 2012, but has declined to -30.4% since 2012. This indicates that credit risk, including higher probability of default and risk of loss, may affect technical efficiency. There could be increased risk to capital or default risk due to a decline in technical efficiency and the simultaneous increase in mixed-efficiency from 2012 to 2015. To examine whether there is a statistically significant differences between the groups' TFP index, we perform the Kruskal-Wallis (K-W) non-parametric test. The results of the K-W test indicate that under the VRS (Table 7) and CRS (Table 8) compared with Malmquist TFP index, the χ^2 -value in 4.296, the p-value is 0.023. A marginal effect at a significance level of 5% is shown (see Table 7). It is proven that the contribution of the HM TFP index by the primal productivity indices is always feasible. Once more, the differences between the Malmquist and Hicks-Moorsteen productivity indices are significantly different with varying significance levels for the different CRS specifications, as shown in Table 8.

We reconcile these seemingly contradictory findings by exploring the effect of both a change in the TFP index over the long run on Chinese CB development. The contradiction means that the indices of both TFP measurements are not likely to be identified by their relative scores. Therefore, the results display a discrepancy between the TFP indices. Table 9 shows a number of the contradictions, and a comparison of the VRS and CRS. It can be seen that the VRS has more contradictions than the CRS, a total of 32 as opposed to 13 for CRS. It is worthwhile noting that there is identifiable shock which explains changes in the TFP and their decomposition into HM and Malmquist measurements. The results are consistent with Table 7 and Table 8.

4.4 Robustness

Table 6 indicates that the robustness measure was on average 97.9% which means that for the period from 2006-2015, CBs fell 2.1% short of implementation of the maximum possible productivity using the available technology. This is lower overall than in Table 4. CBs compete in imperfect markets that are not as well developed as their traditional activities (Bassem, 2014). They are always restrictions placed upon spending due to intervention by the government although CBs can generate money from foreign investors. As stated earlier, Matthews and Zhang (2010) found efficiency scores of 94.4%, 96.8% and 99.6% for three groups in China. It appears that best practices have shifted the frontier outwards leaving the average CB to seek moderate growth to catch-up.

Credit risk arises because loans are subject to non-performance (Wong, 1997). We examine the impact when we remove this input item. CBs do not know “ex ante” which loans will perform and the effect on efficiency (Drake et al., 2006 and Pasiouras, 2008). However, Mester (1999) remarks differently on the inclusion of credit risk, arguing that excessively risky loans might be labeled as inefficient in comparison to spending resources to ensure that loans are of higher quality. Table 10 presents the results from decomposition of the HM TFP index. It can be seen that the REV index ranges between 0.796 (2009-2010) and 1.718 (2012-2013), with an overall mean over the entire period equal to 1.686, while the corresponding figures for cost index are 0.898 (2012-2013), 1.353 (2013-2014) and 1.543 (overall mean), respectively. Hence, during the period from 2009-2014, CBs could improve their revenue index.

By comparison, without NPL as an input vector, the TFPEC is shown in Table 11. The TFPI is lower compared to with the NPL (Table 4), suggesting that the DMU is more productive with the inclusion of credit risk and less productive when we conserve loan inputs.

5. Conclusion

We suggested that Chinese CBs should expand physical channels and would benefit by the introduction of Fin Tech, network banking and e-banking to improve their productivity and profitability. Towards this end, recruiting more expertise and the organization of professional teams for financial innovation design is necessary to generate higher efficiency. There could be a decline in environmental risk and reduction of NPL to absorb the fluctuation brought about by OME in terms of diversification to create more profit. It is necessary to consider non-interest income when measuring the efficiency of CBs, which suggests that technological change, determines the total factor productivity and that actual bank operations are dependent on technological progress together with Fin Tech and the network. This can not only control operating costs but also enlarge income resources.

There are several possible explanations for these findings. First, these CBs may transfer resources with increased skills gained OBS activity and Fin Tech to increase their technical efficiency. They can retain their customers by increasing diversification, financial innovation and risk management to reduce NPL. This along with improvement in reputation by the gain in experience can lead to sustainable development in terms of profitability and productivity.

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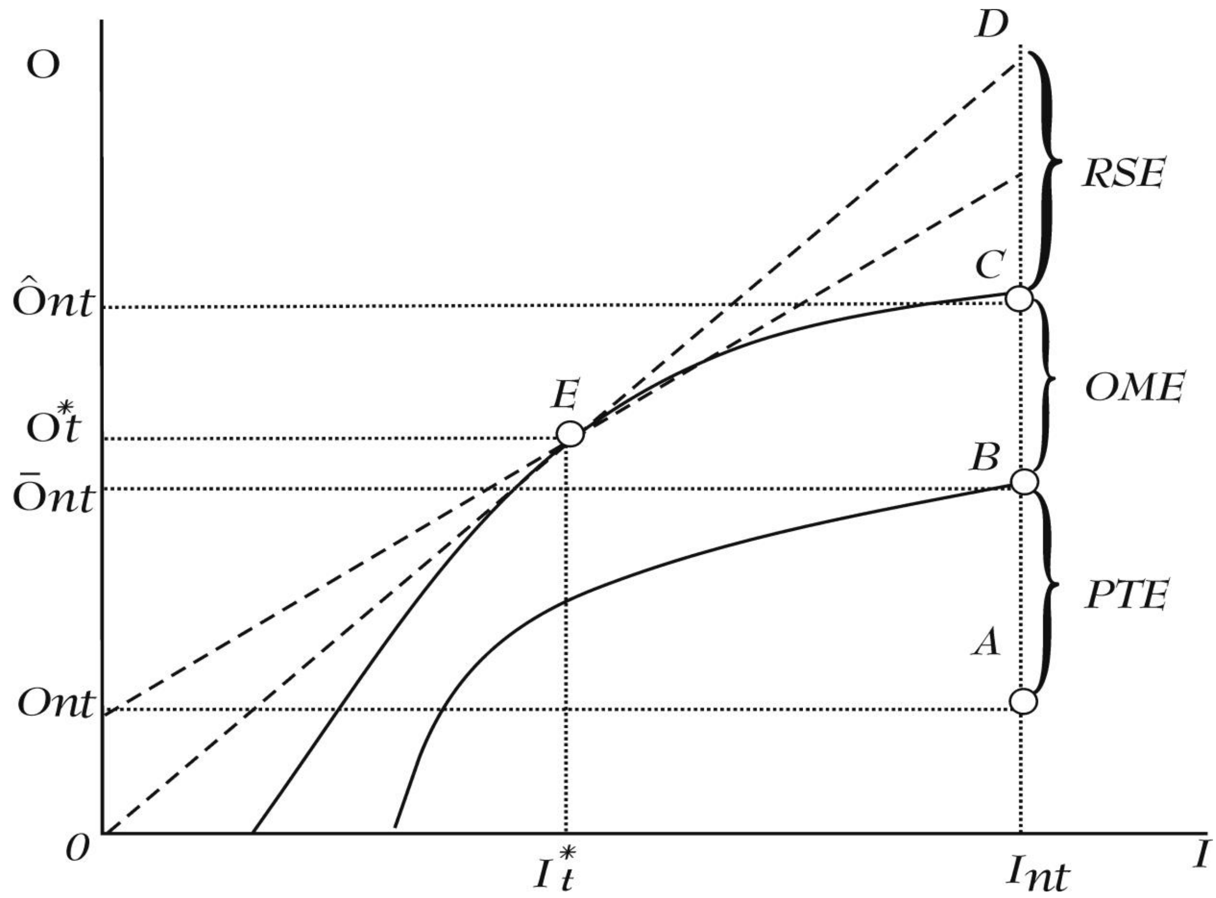

Figure 1. Output-oriented measures of efficiency for a multiple-input multiple-output firm
Data source: O’Donnell, C. J. (2012).

Table 1 Operating definitions of output-input variables

Year/ variables	Variable name	Variable definition
X_F	Funds	Central bank and interbank deposit plus borrowing items
X_L	Labor	Number of full-time employees
X_C	Capital	Assets minus accumulated depreciation
X_N	Non-performing loans	Non-performing loans refer to loans where repayment of the principal or interest have been overdue for more than 3 months, as well as any loan whose principal debtors and surety have been sued for non-payment or the underlying collateral has been disposed of, although the repayment of the principal or interest have not been overdue for more than 3 months.
w_F	Price of Funds	(interest accrued from deposits, borrowed items and expenditure) divided by funds
w_L	Price of Labor	(payment and provisions for employees) divided by labor
w_C	Price of Capital	(rent, taxes, lighting, insurance and other administrative costs) divided by fixed assets
w_N	Price of non-performing loans	Price of loans (reversal of loan loss/real NPL)
Y_I	Investment	(Net financial assets measured as fair value profit loss abstract) plus (held-to-maturity financial assets (net)) plus (stock investments measured by the equity method abstract) plus (other financial assets abstract) plus (available-for-sale financial assets (net).
Y_P	Performing loans	Cash due from bank-debits plus discounts and loans abstract plus interest income (resell)
Y_O	Off-balance sheet assets	Reserves for guarantees plus reserves for loan commitments plus LC for guarantees and IPO
P_I	Price of investment	(interest income + other interest revenue + gain-bills trade + gain on trade investment + gains on long-term equity investment to be settled) ÷ real amount of total investment
P_P	Price of PL	Interest on discounts and loans plus interest income (due from banks and reselling) / real amount of PL
P_O	Price of OBS	(Service fees and commissions) / real OBS

Table 2 Efficiency of Chinese commercial banks: 2006-2015

Variable name	Total		2006		2008		2010		2012		2014	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Funds (billions of RMB)	2,956	716.2	2,491	2,635	2,331	465.5	3,546	706.9	4,931	102.9	5,369	11,412
Labor (person)	59,053	117,401	78,335	134,333	78,904	134,139	78,765.	134,215	72,914	136,192	72,864	136,219
Capital (billions of RMB)	203.3	58.11	345.2	128.9	165.1	33.76	208.8	42.89	253	54.63	358.2	775.3
Non-performing loans (billions of RMB)	52	128	238	614	507	107.1	454.2	967	577	124.8	949	184.8
Price of Funds	1.15	8.04	0.42	1.43	0.12	0.00	3.42	12.5	0.16	0.39	0.82	2.92
Price of Labor	1,370.4	1,268.9	861.2	846.6	1,017	158	1,073.7	798.7	1,304.1	1,166.9	1,856.3	1,169.8
Prices of Capital	66.87	322.4	54.1	148.7	4.02	0.50	50.9	86.6	9.77	2.22	58.8	132
Price of non-performing	157.8	517.6	34.3	789.2	0	160.8	371.9	758.4	0	0	6.77	39.9

loans (thousands of RMB)												
Investment (billions of RMB)	431.5	1,043.5	630.09	2,255.5	370.6	755.0	469.6	915.4	395.3	13.35	760.9	1,181.5
Performing loans (billions of RMB)	159.6	451.5	341.4	1,364	861.6	131.45	116.7	182.7	148.0	41.51	261.9	442.8
Off-balance sheet assets	31.7	64.75	31.5	117.05	20.09	47.53	32.22	84.71	22.35	0.29	65.91	144.84
(thousands of RMB)	0.41	4.05	0.23	0.15	2.88	15.0	0.19	0.12	0.24	0.20	0.17	0.07
Price of investment	1.17	1.53	0.82	1.22	1.58	1.89	1.83	2.18	2.31	0.00	1.18	1.18
Price of PL	9.03	21.62	4.79	9.78	6.05	11.1	13.7	30.5	0.54	16.7	4.56	8.25

Table 3 Profitability, productivity, term of trade in Chinese commercial bank

Period	Profitability			Term of Trade			Productivity		
	REV index	COST index	PROC index	P index	W index	TT index	Q index	I index	TFP index
2006-2007	0.922	0.669	1.378	1.596	1.606	1.006	1.021	1.816	1.373
2007-2008	1.306	0.951	1.373	1.019	1.239	1.216	1.022	1.371	1.129
2008-2009	1.308	1.426	0.917	1.008	0.759	0.753	1.079	1.409	1.217
2009-2010	1.404	1.603	0.876	1.036	0.836	0.807	1.080	1.445	1.086
2010-2011	1.272	1.455	0.874	0.995	0.998	0.997	1.078	1.502	0.876
2011-2012	1.267	1.473	0.860	0.938	1.036	0.905	1.080	1.692	0.950
2012-2013	1.267	1.485	0.853	0.941	1.111	0.847	1.079	1.496	1.007
2013-2014	1.268	1.487	0.853	0.967	1.336	0.724	1.079	1.385	1.179
2014-2015	1.268	1.487	0.853	0.925	1.051	0.880	1.080	1.303	1.470
Average	1.253	1.337	0.982	1.047	1.108	0.903	1.066	1.491	1.143

Table 4 Decomposed HM TFP index of Chinese commercial banks

Period	TFPI	TC	TEC	PTEC	OMEC	RSEC
2006-2007	1.373	0.788	0.820	1.013	1.000	1.027
2007-2008	1.129	0.958	0.996	1.046	0.992	0.994
2008-2009	1.217	0.870	0.900	1.033	1.005	0.996
2009-2010	1.086	0.921	0.921	1.000	1.000	1.000
2010-2011	0.876	1.084	1.235	1.074	1.062	0.998
2011-2012	0.950	1.130	1.173	1.021	1.002	1.015
2012-2013	1.007	0.925	0.898	1.075	1.017	0.990
2013-2014	1.179	0.863	0.893	1.009	1.005	1.020
2014-2015	1.470	0.965	0.971	1.000	0.854	1.178
Average	1.143	0.945	0.979	1.006	0.982	1.024

TFPI=Total Factor productivity index; TC=Technological change; TEC=Technical efficiency change

PTE=Pure technical efficiency change; OMEC=Output oriented mixed efficiency change; RSEC=Residual scale efficiency change

Table 5 Decomposed profitability and productivity change in Chinese commercial banks

CBs	PROC	TT	TFPI	TC	TFPEC	PTEC	OMEC	RSEC
PAB	1.000	0.912	1.000	1.097	1.000	1.000	0.831	1.097
BOD	1.000	1.011	1.000	0.989	0.989	1.000	1.022	1.000
GZCB	1.000	0.968	1.000	0.721	0.721	1.000	1.924	1.000
XMCCB	1.000	1.003	1.000	0.997	0.997	1.000	1.006	1.000
CGB	0.980	1.937	0.98	0.937	0.956	0.981	1.140	0.999
HFB	0.945	0.958	0.945	0.986	1.044	1.003	1.091	0.942
NBCB	1.057	1.384	1.057	1.044	0.988	1.111	0.965	0.951
SPDM	1.017	0.807	1.017	1.26	1.239	1.000	0.619	1.017
HXB	1.000	0.808	1.000	1.238	1.238	1.000	0.652	1.000
CMBC	1.000	0.682	1.000	1.141	1.141	1.000	0.768	1.000
CZB	1.267	1.014	1.267	1.25	0.987	1.032	0.521	1.227
CMB	1.116	0.904	1.116	1.234	1.105	1.012	0.596	1.103
HKB	1.000	0.885	1.000	1.212	1.212	1.000	0.681	1.000
JSH	1.000	0.926	1.000	0.828	0.828	1.000	1.459	1.000
NCB	1.026	1.532	1.026	1.052	1.024	0.920	0.811	1.116
JSB	0.705	1.028	0.705	0.771	1.094	0.970	2.313	0.727
HZ	0.783	0.769	0.783	1.018	1.301	0.734	0.905	1.066
CBHB	1.592	2.503	1.592	1.644	1.033	1.000	0.232	1.592
NJCB	0.971	0.901	0.971	1.106	1.14	0.989	0.833	0.981
BSB	1.000	0.780	1.000	1.282	1.282	1.000	0.608	1.000
CIB	1.069	0.915	1.069	1.245	1.282	1.000	0.586	1.000
BOB	1.000	0.770	1.000	1.298	1.298	1.000	0.594	1.000
BOS	0.904	0.823	0.904	1.099	1.216	0.916	0.839	0.987
ABC	1.000	0.935	1.000	1.07	1.07	1.000	0.873	1.000
HSB	1.000	1.094	1.000	0.914	0.914	1.000	1.197	1.000
BOCOM	0.969	0.884	0.969	1.044	1.077	0.957	0.906	1.013
ICBC	1.022	0.893	1.022	1.145	1.12	1.000	0.747	1.022
CQCB	1.000	0.880	1.000	1.137	1.137	1.000	0.774	1.000
LZB	0.863	0.977	0.863	0.883	1.022	0.863	1.284	1.000
JLB	0.949	1.468	0.949	0.997	1.051	0.983	1.041	0.966
CEB	0.655	1.152	0.655	0.82	1.252	0.841	1.909	0.779
CCB	1.000	0.945	1.000	1.063	1.063	1.000	0.885	1.000
BOC	0.939	0.983	0.939	0.955	1.017	1.000	1.168	0.939
BOG	0.856	1.808	0.856	0.71	0.829	0.856	1.985	1.000
CITIC	0.745	0.826	0.745	0.902	1.211	0.98	1.617	0.760
Average	0.984	1.059	0.984	1.060	1.082	0.976	1.011	1.008

Table 6. Decomposed Malmquist TFP index of Chinese commercial banks

Periods	TFPEC	TC	PTEC	SEC	TFPI
2006-2007	1.040	0.894	1.013	1.027	0.930
2007-2008	1.040	1.006	1.046	0.994	1.046
2008-2009	1.029	0.852	1.033	0.996	0.877
2009-2010	0.973	1.073	0.974	0.998	1.043
2010-2011	0.955	0.944	0.979	0.975	0.901
2011-2012	0.805	0.987	0.982	0.819	0.795
2012-2013	1.025	0.891	1.004	1.029	0.922
2013-2014	1.061	0.709	0.988	1.074	0.752
2014-2015	0.879	0.898	0.951	0.925	0.790
Average	0.979	0.917	0.997	0.982	0.895

Table 7. The difference between Hicks-Moorsteen TFP index by VRS and Malmquist TFP index

Null Hypothesis		$TFPEC^{HM}$ vs $TFPEC^{MALM}$	TC^{HM} vs TC^{MALM}	$PTEC^{HM}$ vs $PTEC^{MALM}$	SEC^{HM} vs SEC^{MALM}	$TFPI^{HM}$ vs $TFPI^{MALM}$
Kruskal-Wallis Rank test	χ^2	4.296	3.829	2.474	3.889	2.261
	P-value	0.035^{**}	0.026^{**}	0.071	0.027^{**}	0.005^{***}

Table 8. Difference between the Hicks-Moorsteen TFP index calculated by the CRS and Malmquist TFP index

Null Hypothesis		$TFPEC^{HM}$ vs $TFPEC^{MALM}$	TC^{HM} vs TC^{MALM}	$PTEC^{HM}$ vs $PTEC^{MALM}$	SEC^{HM} vs SEC^{MALM}	$TFPI^{HM}$ vs $TFPI^{MALM}$
Kruskal-Wallis Rank test	χ^2	2.67	1.07	3.851	3.851	0.42
	P-value	0.052^{*}	0.174	0.027^{**}	0.027^{**}	0.997

Table 9 Contradiction between the HM TFP and MALM index

Periods	HM contradiction with MALM (VRS)	HM contradiction with MALM (CRS)
2006-2007	3	2
2007-2008	8	1
2008-2009	3	2
2009-2010	5	0
2010-2011	2	5
2011-2012	4	1
2012-2013	8	3
2013-2014	1	3
2014-2015	1	0

Total	35	16

Table 10. Decompose profitability and productivity index When remove the NPL

Period	Profitability			Term of Trade			Productivity		
	REV index	COST index	PROC index	P index	W index	TT index	Q index	I index	TFP index
2006-2007	0.986	1.037	1.000	0.953	1.223	1.166	0.953	1.223	0.970
2007-2008	0.885	0.710	0.955	0.589	0.782	0.461	0.942	1.101	0.944
2008-2009	0.873	0.883	1.204	0.730	1.109	0.810	1.042	0.721	1.003
2009-2010	0.796	1.091	1.929	1.841	1.292	2.379	1.076	0.938	0.971
2010-2011	0.841	0.784	0.944	0.937	0.723	0.677	1.044	0.891	0.935
2011-2012	1.473	1.002	1.099	1.066	1.383	1.474	1.235	0.822	0.788
2012-2013	1.718	0.898	1.279	1.003	1.112	1.115	0.908	1.115	1.055
2013-2014	1.657	1.353	1.551	0.777	1.039	0.807	0.729	0.427	1.192
2014-2015	0.960	1.483	1.668	0.809	1.256	1.016	0.807	1.018	1.019
Average	1.686	1.547	1.084	1.069	1.531	1.637	1.764	1.031	0.986

Table 11 Decomposed for HM TFP index with the removal of NPL

Period	TFPI	TC	TFPEC	PTEC	OMEC	RSEC
2006-2007	0.970	0.977	0.948	0.959	1.148	1.011
2007-2008	0.944	1.026	0.968	1.015	1.131	0.930
2008-2009	1.003	0.973	0.982	1.029	1.040	0.975
2009-2010	0.971	0.997	0.897	0.997	1.099	1.051
2010-2011	0.935	0.969	1.160	0.951	1.117	0.896
2011-2012	0.788	1.408	1.135	0.824	1.029	0.936
2012-2013	1.055	1.153	1.031	1.131	0.640	1.101
2013-2014	1.192	0.888	1.052	1.067	0.900	0.935
2014-2015	1.019	0.696	0.890	0.977	1.864	0.777
Average	0.986	1.040	1.007	0.994	1.108	0.957