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Dong, Yizhe; Firth, Michael ; Hou, Wenxuan ; Yang, Weiwei

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Evaluating the performance of Chinese commercial banks: A comparative analysis of different types of banks

Yizhe Dong
The School of Management and Business, Aberystwyth University
Aberystwyth, Wales
yid1@aber.ac.uk

Michael Firth*
Department of Finance and Insurance, Lingnan University
Tuen Mun, NT, Hong Kong
mafirth@Ln.edu.hk

Wenxuan Hou
The Business School, University of Edinburgh
Edinburgh, Scotland
wenxuanhou@gmail.com

Weiwei Yang
Derby Business School, University of Derby
Derbyshire, England
w.yang@derby.ac.uk

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*Corresponding author. Tel.: +852 26168950; fax: +852 24621073. We thank the editor and two anonymous reviewers for helpful comments on a previous version of the paper. Firth acknowledges the support of a grant from the HKSAR Government (GRFLU340412).

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Abstract

This paper examines the cost and profit efficiency of four types of Chinese commercial banks over the period from 2002 to 2013. We find that the cost and profit efficiencies improved across all types of Chinese domestic banks in general and the banks are more profit-efficient than cost efficient. Foreign banks are the most cost efficient but the least profit efficient. The profit efficiency gap between foreign banks and domestic banks has widened after the World Trade Organization transition period (2007-2013). Ownership structure, market competition, bank size, and listing status are the main determinants of the efficiency of Chinese banks. We also find a causal relationship between efficiency and SROE by using the panel auto regression method. The evidence from the shadow return on equity (SROE) suggests that policy makers should be cautious of the adjustment costs imposed by the recapitalization process, which offsets the efficiency gains.

Keywords: Finance; Efficiency; Stochastic frontier analysis; Shadow return on equity; Chinese banking

JEL Code: G21, G28, P34

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1. Introduction

China's banking sector has grabbed the attention of international investors and the financial media in recent years thanks to the opening up of the banking market after China joined the World Trade Organization (WTO) in 2001 and the enormous strides made in banking reform and deregulation in the past 15 years. In many regards, Chinese banks seem to have been immune to the recent global banking epidemic due to their "closed" capital accounts and insulated banking sector that primarily relies on traditional banking business that is not exposed to risky and complex financial instruments. However, there are lingering concerns about the fragility of the Chinese banking system. The close link between stated-owned commercial banks (SOCBs) and state-owned enterprises (SOEs) increases the number of non-performing loans for these banks and raises concerns about the safety and soundness of the Chinese banking sector. In light of this, the Chinese government has implemented a series of reforms to transform state-owned banks from state-dominated bureaucracies into modern market-oriented banking institutions. The reforms include removing the credit ceiling on deposits and loans, disposing of SOCBs' non-performing loans, recapitalizing the SOCBs, encouraging banks to seek a listing on the stock exchange, introducing management incentives based on efficiency measures, and introducing foreign strategic investors. While these reforms have had a positive impact on the SOCBs, many of the problems with state-owned banks are not yet fully resolved. The banks remain relatively undercapitalized, have high bad-loan ratios, weak corporate governance, and fail to allocate resources efficiently (Allen et al., 2005; Lin and Zhang, 2009; Jiang et al., 2009).

Many medium and small-sized commercial banks, most notably city commercial banks (CCBs), have emerged and developed rapidly in the past decade. Unlike the SOCBs, these newly established banks typically have a lower level of state ownership and their shareholders include local government, SOEs, private enterprises, foreign strategic investors, and wealthy individuals. This diversified ownership structure means that CCBs can raise funds from various channels outside of the state system and they are fully responsible for their own lending policies. Consequently, their loan portfolios tend to be much stronger than those of the big state-owned banks. In addition, the medium and small-sized commercial banks have played a very important role in the development of financial markets and the economy in China. In particular, they are heavily involved in the financing of small and medium-sized enterprises (SMEs), an area that will be a key driver of China's economic growth in the future (Allen et al., 2005) but one where the state-owned banks have traditionally been weak. Current economic downturns in Europe, the

U.S., and elsewhere have resulted in significant declines in China's export growth rates and, as a result of this, a large number of Chinese SMEs have had to cease operations or have gone bankrupt due to financing difficulties or breaks in the funding chain. To help mitigate or prevent this from happening in the future, the smaller banks can provide prompt and effective financing to SMEs, and this will help China to continue its economic development and help improve social stability. The Chinese government recently released a policy memorandum that emphasizes the importance of the CCBs to the financial market and which encourages them to seek listings on domestic and/or international stock exchanges and expand their business operations to other regions or cities. Thus, the CCBs are seen as a vital facilitator of economic growth in China and it is therefore of interest to assess their performance efficiencies over the last twelve years, a period that has seen the most significant developments in banking.

A number of studies have investigated bank efficiency (or performance) in China (e.g., Chen et al., 2005; Fu and Heffernan, 2007; Ariff and Can, 2008; Berger et al., 2009; Du and Girma, 2011; Asmild and Matthews, 2012; Dong et al., 2014; Matthews, 2013). However, most of these studies only focus on analysing the SOCBs and joint stock commercial banks (JSCBs), which are relatively large and have nationwide business operations[1]. These studies typically do not consider the role or importance of small banks (such as CCBs) in the Chinese banking sector. In addition, the above mentioned studies all employ relatively small samples, which weaken the generalizability of the research findings.

China has introduced aggressive bank recapitalization programmes over the last twelve years, with the aim of reducing financial risks and ensuring bank viability. For example, the government injected 514.8 billion yuan in equity from its foreign exchange reserves into four big SOCBs during the period 2003-2005. As a more recent example, the Agricultural Bank of China (a SOCB) received a 130 billion yuan capital injection from a unit of the country's Sovereign Wealth Fund at the end of 2008. In 2004, the China Banking Regulatory Commission (CBRC) promulgated new capital rules, mainly based on the Basel II rules, to require Chinese commercial banks to replenish their capital base to meet a minimum capital adequacy ratio (CAR) of 8% on or before 2007[2]. In addition, the government has encouraged foreign financial institutions to invest in Chinese domestic banks by taking up to a 25% ownership stake in them. Within the five-year period between 2004 and 2008, 24 domestic banks acquired fresh capital from 36 foreign partners. The Chinese authorities also encouraged banks to raise new capital by listing

[1] A study by Zhang et al. (2012) is one of the few exceptions. This article investigates the relations between law enforcement and technical efficiency using a sample that only includes Chinese CCBs.

[2] According to a CBRC spokesman, under the new stricter rules, the CAR of banks decreased by an average of 2% compared to what they would have been under the previous set of rules formulated in 1995.

on stock exchanges via an initial public offering (IPO) in last decade[3]. All these measures were designed to boost banks' capital bases and improve the health of the banking sector. However, recapitalization imposes resource costs on both the economy as a whole and on the banking system in particular. The impact of the massive recapitalization programme on bank performance is therefore of interest to bank managers and policy makers alike. Boucinha et al. (2012) and Duygun et al. (2012) examine the cost of recapitalization by estimating the shadow (or true) return on equity using an econometric model of banking industry costs, using samples of Portuguese and Turkish banks, respectively[4]. However, to the best of our knowledge, no studies have examined this important issue in the context of the Chinese banking sector. Economies of scale have important implications for regulators and bank managers in terms of merger and acquisition issues, but, to date, there is very limited empirical evidence on scale economies in the Chinese banking sector.

The main purpose of our paper is to provide new evidence on the state of the banking industry in China. First, we assess both the cost and profit efficiency levels of Chinese banks during the period following WTO accession, using a comprehensive dataset. By estimating the efficiency levels of Chinese banks using stochastic frontier analysis (SFA), we examine the impact of the Chinese banking reforms and compare the performance of CCBs with those of SOCBs, JSCBs, and foreign banks. Furthermore, we compare the efficiency of CCBs in different regions to investigate whether inequalities in regional economic development affect performance. The results provide us with a comprehensive understanding of the different segments of the Chinese (commercial) banking sector and the impacts of the recent reforms on bank performance. Second, in order to explore the impact of recapitalization on the Chinese banking sector, we estimate the shadow return on equity by developing a specification of the frontier cost function subject to a capitalization constraint. We also explore the relation between the efficiency level and the shadow return on equity by using a panel vector auto regression (PVAR) framework, The results are broadly consistent with those from the one stage stochastic frontier approach. Finally, we investigate scale economies in the Chinese banking sector, the results of which could provide very useful information for regulatory analysis and for decision makers.

The rest of the paper is organized as follows. Section 2 provides some background information relating to the Chinese banking sector. Section 3 reviews the recent literature on Chinese banking efficiency. Section 4 presents the methodology and data employed in our empirical analysis. Section 5 discusses the empirical results and Section 6 concludes.

[3] By the end of 2014, there are 21 Chinese banks listed on domestic stock exchanges and/or the Hong Kong Stock Exchange. Among them, 16 Chinese banks launched IPOs during our sample period 2002-2013.

[4] The accounting value, return on equity (ROE), can be used to measure the cost of equity. However, ROE may not be a good measure because it is volatile and incorporates subjective provisions that are expedient to the bank's top management at any particular time.

2. Institutional background of the Chinese banking sector

Over the last thirty years, China has been one of the world's fastest-growing emerging economies and it became the world's second largest economy in terms of nominal GDP in 2010. China's banking sector has played a key role in its economic growth. In order to create a sound and effective banking system, the Chinese authorities implemented a comprehensive programme of banking reforms designed to address the institutional, political, and organizational problems faced by the banking industry. The gradual reforms have created a banking sector in China with multiple categories of banking institutions, operating in separate market segments with (generally) clearly delineated functions. According to the banks' ownership structures and functions, the CBRC classifies banks as wholly state-owned policy banks, large-scale (state-owned) commercial banks, JSCBs, CCBs, rural commercial banks (RCBs), locally incorporated foreign banks, and other banking institutions.

A major feature of the Chinese banking sector is that it is dominated by the five largest SOCBs: the Agricultural Bank of China (ABC), the Bank of China (BOC), the China Construction Bank, the Industrial and Commercial Bank of China (ICBC), and the Bank of Communications (BOCOM)[5]. Starting in 2005, the CBRC began to transform these wholly state-owned banks into joint-stock corporations by introducing foreign strategic investors and seeking listings on stock exchanges. Through this recapitalization process, the banks have diversified their ownership and are now supposedly operating as profit-making commercial banks with less government intervention than before[6]. The market share of the five largest SOCBs has fallen over the last decade (from 59.31% of the total assets in the banking sector in 2002 to 43.34% at the end of 2013), while the market share of the other types of commercial banks, such as the JSCBs and CCBs, have steadily increased. There are currently twelve JSCBs with national operating licences, representing the second tier of Chinese banks. Because the JSCBs were established more recently than the SOCBs, they are not burdened with any historical policy lending (and therefore have fewer non-performing loans) and tend to be more agile and responsive to market conditions. JSCBs are allowed to offer a wide variety of banking services, including accepting deposits, extending loans, and providing foreign exchange and international transaction services. They also regularly finance SMEs, an area in which the state-owned banks have traditionally been weak.

[5] BOCOM used to be classed as a JSCB. However, it is much larger than the other JSCBs, and its shares are owned by a number of different state-owned entities. Therefore, in 2006, the CBRC redefined it as a SOCB. Thus, it joined the other four big state-owned banks (previously known as "the Big Four") to form "the Big Five". For consistency, we treat BOCOM as a SOCB rather than a JSCB throughout the entire sample period.

[6] However, these banks are still majority owned by the central government and thus subject to government policies and influence.

China's CCBs have only a short history in China's banking sector. They were originally wholly owned or controlled by local government. However, since the turn of the century, they have gradually been transformed into (private) joint-equity corporations with a more diversified set of shareholders. CCBs are subject to less state intervention and may have relatively better corporate governance than the big state-owned banks (Ferri, 2009). By the end of 2013, there were 144 CCBs in China, valued at RMB 15.18 trillion, with an average annual growth rate of 23.84% over the period from 2002 to 2013, and accounting for 10.03% of the total banking assets in China. However, CCBs are unevenly distributed across China, having more branches in the better-developed eastern provinces (such as Zhejiang) than in the less developed western provinces (such as Ganshu).

Because of their smaller size, the CCBs have struggled to compete with the Big Five and the JSCBs. However, in recent years, they have made significant progress in upgrading their operational and managerial capacities, as well as promoting innovative products and technologies. They have gradually nurtured their own brands and corporate cultures, and have begun to play a pivotal role in financing the development of small and micro-enterprises and the consumer finance business. They have identified a clear market niche and developed a strategy of "staying focused on localities of incorporation, serving small and micro enterprises, [and] tailoring products and services to seek differentiated competition with large commercial banks" (CBRC, 2011 p26). Competition with larger banks has resulted in some CCBs being among the most innovative financial institutions in China. CCBs tend to be concentrated in the cities where they were founded. Unlike the JSCBs, CCBs were not originally allowed to operate at the national level, which impeded their potential for expansion. However, since 2006, the supervisory authorities have gradually relaxed this geographical restriction for those CCBs that are well managed and have good performance, and over time it is expected that CCBs will develop beyond their traditional regional role.

One of the milestones in China's financial liberalization process was its accession to the WTO in late 2001. Since December 2001, the Chinese government has progressively removed regulatory constraints and implemented many reforms to open up its banking sector to foreign banks. By December 2006, under the terms of the accession agreement, China had removed all geographic and customer-related restrictions on foreign banks. Foreign banks are no longer treated differently from domestic banks and at the end of 2013 there were 42 locally incorporated foreign banks licensed to engage in both local and foreign currency business with all types of customers. Foreign banks have a distinct advantage over Chinese banks when it comes to consortium loans, foreign trade financing, retail business, fund management, and financial derivatives because of their broader international trading connections that allow them to spread

risk and secure different types of customers (Tong, 2005). However, the global financial crisis harmed foreign banks' reputations in China and their profitability has deteriorated in the last few years (the Economist, 2014). Despite this, foreign banks are expected to play a more important role in the future, by attracting foreign capital, intensifying competition in the Chinese banking sector, introducing advanced management techniques and expertise, and promoting efficiency improvements and corporate governance in Chinese banks (Luo et al., 2015).

3. Literature on Chinese banking efficiency

Since the late 1980s, there have been many studies measuring the efficiency of banks, using either parametric (e.g., Stochastic Frontier Analysis) or non-parametric (e.g., data envelopment analysis) approaches[7]. The estimation of bank efficiency is important because it allows practitioners and policy makers to examine the impact of ownership structure on banking efficiency (Bonin et al., 2005; Fries and Taci, 2005; Staub et al., 2010; Tzeremes, 2015), to assess the effects of deregulation on banking efficiency (Bhattacharya et al., 1997; Jaffry et al., 2013), to investigate the impact of (a changing) market structure on banking efficiency (Berger, 1995; Berger and Hannan, 1997; Fu and Heffernan, 2007), to explore the relations between bank size and efficiency (Berger and Humphrey, 1997; Chen, 2002), and to evaluate the effect of governance changes (Berger et al., 2005).

Over the last thirty years, the Chinese banking sector has experienced significant institutional and structural changes, which have attracted a number of scholars to study Chinese bank efficiency. Chen et al. (2005) used data envelopment analysis (DEA) to estimate the cost, technical, and allocative efficiency of 43 Chinese banks over the period 1993 - 2000. Their results show that the Big Four state-owned banks had higher technical efficiency and allocative efficiency than the national JSCBs. They also found that the financial deregulation policies implemented in 1995 improved both the technical and allocative efficiency of the Chinese banking sector. Ariff and Can (2008) also used DEA to investigate the cost and profit efficiency of 28 Chinese commercial banks over the period from 1995 to 2004. Their results show that over the entire study period, cost efficiency is greater than profit efficiency although the latter has been growing at a faster pace. JSCBs and CCBs, on average, appear to be more efficient than the SOCBs. Furthermore, they show that medium-sized Chinese banks are significantly more efficient than both their smaller or larger counterparts.

Fu and Heffernan (2007) employ SFA to investigate the X-efficiency of the Chinese banking sector over the period 1985 to 2002. Their results show that the JSCBs were relatively more X-

[7] See Duygun and Pasiouras (2010) for a survey of research in this area. They review recent studies that use operational research and artificial intelligence techniques to assess bank efficiency and performance.

efficient than the SOCBs. Similarly, Kumbhakar and Wang (2007), using an input stochastic distance function approach, found that the four largest SOCBs were less technically efficient than the JSCBs over the period 1993-2002. They also found that small banks tend to be more efficient than large banks and that there was no evidence that deregulation had significantly improved Chinese banking efficiency.

Berger et al. (2009) used SFA to analyse alternative profit and cost efficiency measures for Chinese banks over the period from 1994 to 2003. They found that foreign banks and non-Big-Four state-owned banks were the most cost-efficient Chinese banks, followed by the Big Four, with private domestic banks being the least cost-efficient. They also find that foreign banks were the most profit-efficient, followed by private domestic banks and non-Big-Four state-owned banks, with Big Four state-owned banks found to be the least profit-efficient. The main focus of Berger et al.'s (2009) study, however, was on the effects of minority foreign ownership. They reported that minority foreign ownership has a positive effect on both cost and profit efficiency.

Jiang et al. (2009) used stochastic distance function models to examine the technical efficiency of major Chinese commercial banks over the period from 1995 to 2005. They found that joint stock banks and the Big Four state-owned banks were the most efficient Chinese banks with foreign banks the least efficient. More recently, Asmild and Matthews (2012) applied multi-directional efficiency analysis (a non-parametric approach) to investigate the efficiency levels of Chinese commercial banks over the period 1997-2008. Their results show that joint equity banks are more efficient than the Big Four state-owned banks. However, they also found that since 2003, the efficiency of the state-owned banks has improved.

In summary, our brief review of the Chinese banking efficiency literature shows some mixed and contradictory results and identifies some research gaps[8]. To help address these gaps in the literature, we use a one-stage stochastic frontier model (Battese and Coelli, 1995) to assess the efficiencies of Chinese banks over the period 2002-2013 in order to provide additional empirical evidence in this area.

4. Methodology and variables

4.1. Empirical method

In this study, we use SFA, as developed by Aigner et al. (1977), to estimate both cost and profit efficiencies, which measure how far away a bank's cost or profit is from that of the hypothetical "best practice" bank if both banks were producing the same output configuration

[8] Appendix A summarizes the results from the major efficiency studies on the Chinese banking sector. Differences in findings across studies may be due to different methodologies, model specifications, and the sample periods being analysed.

under the same environmental conditions[9,10] (see Berger and Mester, 1997; Isik and Hassan, 2002). The efficiency scores are estimated using the one-stage stochastic frontier model (Battese and Coelli, 1995), where the effects of the environmental variables on inefficiency are modelled jointly with the cost (or profit) frontier, in order to account for variables (such as ownership structure, market structure, etc.) that may have a significant influence on bank efficiency levels. The cost and profit frontier models are expressed as follows:

$$TC_{it} = f(Y_{it}, W_{it}, Z_{it}; \beta) + v_{it} + u_{it} \ \ and \ \ u_{it} = \delta E_{it} + w_{it}$$

and

$$\pi_{it} = f(Y_{it}, W_{it}, Z_{it}; \beta) + v_{it} - u_{it} \ \ and \ \ u_{it} = \delta E_{it} + w_{it}$$

where t denotes the time dimension; TC and π are respectively the observed total costs and profits of a bank before tax; Y_i and W_i are vectors of output and input prices for the ith bank; Z_i is a vector of control variables; β is a vector of technology parameters; v_{it} is a two-sided normal disturbance term with zero mean and variance σ_v^2 and represents the effects of statistical noise; the inefficiency term u_{it} is independently but not identically distributed and takes the form $u_{it} \sim N^{+}(dE_{it}, s_u)$; the truncation point is dE_{it}.; E_{it} captures the observed factors that are assumed to determine efficiency; δ is a vector of estimated parameters, and the random error term w_{it} captures the effect of the "unobserved" factors and follows a truncated normal distribution with zero mean and constant variance.

4.2. Variable definitions

There are two main approaches in the banking literature to measure the flow of services that banks provide; these are the production approach and the intermediation approach. Under the production approach, banks are thought of as production units that utilize physical inputs such as capital and labour to produce transactions and document-processing services for their customers, such as taking customer deposits and issuing loans. The intermediation approach (IA), suggested by Sealey and Lindley (1977), treats a bank as an intermediary that collects funds from savers and transforms those funds into profitable projects (loans and other earning assets). These two approaches differ in their views of the role of banks but neither fully captures the dual roles of

[9] Each bank is benchmarked against the fitted stochastic frontier (sometimes called the best-practice frontier), which indicates the cost or profit of a bank that uses the best practices under ideal conditions (Hughes and Mester, 2012)

[10] There are two different versions of the profit efficiency concept, namely, standard profit efficiency (SPE) and alternative profit efficiency (APE). SPE shows how close a bank is to generating the maximum profits, given specified input prices and output prices. It assumes that output markets are perfectly competitive. In contrast, APE assumes that imperfect competition exists, so that banks have some market power over what they charge. APE measures how close a bank is to earning maximum profits, by adjusting the price of outputs and the quantity of inputs given a particular level of output, and particular input prices. Therefore, this approach allows us to estimate profit efficiency without having any information on output prices. Because there are no reliable data available on banks' output prices, and there is imperfect competition in the Chinese banking sector, we use APE in our analysis. See Berger and Mester (1997) for a more detailed discussion of this issue.

financial institutions. Our study follows the intermediation approach as it has certain conceptual advantages and the data needed to implement it are readily available.[11] Total costs (*TC*) include interest expenses, salaries and employee benefits and other operating costs. For profit efficiency estimation, we use profits before tax (*PBT*) to replace total costs. The outputs consist of total loans (y_1), other earning assets (y_2), and non-interest income (y_3).[12,13] Note that the input variables are not incorporated explicitly into the efficiency frontier models summarized in equation (1) but are represented by the impact of their input prices. There are three input prices: the price of total borrowed funds (w_1) (the ratio of total interest expenses to total borrowed funds), the price of physical capital (w_2), also known as the flow factor price for capital (measured by the ratio of other operating expenses to fixed assets)[14], and the price of labour (w_3) (using the ratio of personnel expenses to the number of employees as a proxy). In addition to the above input prices and output variables, we also include the total equity capital of the individual banks (z) as a quasi-fixed input[15]. This is used to control for insolvency risk as it provides a cushion against portfolio losses and financial distress and influences the probability of a bank's failure. In addition, because banks lever their equity capital with demandable debt to reflect their attitudes toward risk, it can control for the different risk preferences of banks (see Mester, 1996). The time trend variable (T) is also included in the stochastic cost function in order to control for the effects of technical progress.

We also incorporate environmental variables into our efficiency model in order to account for heterogeneity and to investigate the determinants of bank efficiency. Bank size is considered an important factor that may affect efficiency and it can be used to control for potential scale biases

[11] The intermediation approach treats deposits as an input, which is more convincing than the production approach (which treats deposits as an output) since they are paid for in part by interest payments and the funds raised provide the bank with its basic "raw material", namely, investable funds. Furthermore, the intermediation approach emphasizes the overall costs of banks, and is thus appropriate for addressing questions related to cost minimization (Ferrier and Lovell, 1990). Moreover, the intermediation approach uses money values as measures of output (for loans, other earning assets, and non-interest income, etc.) and the necessary information to construct the measures is generally available from a bank's financial statements or from other sources (e.g., the Almanac of China's Finance and Banking). Against this, the production approach requires information such as the number of accounts, the number of loans, etc., which is generally not publicly available. Finally, the intermediation approach is also the most widely used approach in the empirical bank efficiency literature and, as Berger and Humphrey (1997) suggest, the intermediation approach is better for measuring the efficiency of banks as a whole.

[12] Although off balance sheet (OBS) items are technically non-earning assets, they increase the bank's income and are an important component of the banking business. Therefore, they should be included when modelling a bank's cost characteristics, otherwise total output will be understated (Jagtiani and Khanthavit, 1996). Thus, following Fu and Heffernan (2007), Lozano-Vivas and Pasiouras (2010), and Liadaki and Gaganis (2010), we use the non-interest income as a proxy for non-traditional activities, that is, OBS items.

[13] The non-interest income is not the best proxy for banking output because it is an earning rather than a financial output. However, data on aggregated OBS items are not available for all banks in the sample. A common feature of non-traditional activities is that they generate non-interest income for a bank. Hence, the non-interest income can serve as proxy for non-traditional activities. Moreover, Lozano-Vivas and Pasiouras (2010) show that using either aggregated OBS items or non-interest income as an indicator of non-traditional activities have similar impacts on the estimation of efficiency.

[14] Other operation expenses is equal to general operating expenses (overhead costs) less personnel expenses. It consists of depreciation expenses and other expenditure on fixed assets (e.g., maintenance and material costs).

[15] Using the level of equity as a quasi-fixed input rather than the equity to asset ratio in the cost function is standard in the literature (e.g., Berger and Mester, 1997; Duygun et al., 2013). The reason is well explained by Mester and Hughes (1993) and Mester (1996). The banks may not hold the optimal level of equity capital if that level implies a degree of risk, which is unacceptable (a bank exhibits some risk aversion) and/or the regulations set minimum capital requirements.

in the estimation process (Kumbhakar and Wang, 2007). Bank size is an important determinant of net interest margins and spreads if there are economies of scale in the Chinese banking sector. In other words, one bank may be more efficient than another as a result of the economies of scale that arise from size rather than because of better management. Casu and Girardone (2006) find that larger banks might reap efficiency benefits from economies of scale and/or scope. Furthermore, larger banks may have better qualified and experienced management teams, that are more effective in cost control, thereby resulting in higher profits (Evanoff and Israilevich, 1991). Instead of introducing arbitrary size dummies into the modelling procedure (e.g., Kumbhakar and Wang, 2007), we use the logarithm of total assets as a proxy for bank size (ln(TA)). The competitive conditions of the market in which a bank operates may influence its efficiency level (see Fries and Taci, 2005; Casu and Girardone, 2009; Koetter et al., 2012). Banks in highly concentrated (less competitive) markets exercise market power by charging higher spreads than is the case in less concentrated markets. Managers will have less pressure to control their costs as a consequence of this and may be able to enjoy the "quiet life" hypothesized by Hicks (Berger and Mester, 1997). In contrast, a competitive market forces banks to minimize costs and increase profits (e.g., through shifts in outputs) and thus they become more cost and profit efficient (Schaeck and Čihák, 2010).

We include both the Lerner index (Lerner, 1934) and the Herfindahl-Hirschman index (HHI) in our model in order to measure the impact of market structure on bank efficiency. We use the Lerner index, which represents the mark-up of price over marginal costs, as a proxy for the degree of market power[16]. HHI is a proxy for market concentration and is defined as the sum of the squared asset market shares of all banks. We also include a dummy variable (*Listed*) that indicates whether or not a bank's shares are publicly traded on a stock exchange. This institutional variable is included in order to capture the fact that listing status may improve a bank's efficiency because of the market discipline mechanism and the requirement for better corporate governance that is imposed when listing on a stock exchange (see Ray and Das, 2010; Jiang et al., 2009). A bank with high government ownership could enjoy the advantage of either implicit or explicit financial and regulatory support from the government (Faccio et al., 2006). Hence, banks with more government ownership will have lower default and bankruptcy risk and will be more likely to attract funds by paying lower rates of interest on borrowing and take on more risky loans (but with higher return) than other banks. These in turn can possibly reduce a bank's borrowing cost and increase revenue, and influence their cost and profit efficiency as a

[16] The Lerner index (Lerner, 1934) represents the mark-up of price over marginal costs. Following Carbo et al. (2009), the index is empirically calculated as $(P_{TAit} - MC_{TAit})/P_{TAit}$. P_{TA} is the bank's average price, measured by the ratio of its total revenues to total assets and MC_{TA} is the bank's estimated marginal cost, using a fixed effects model, from a translog cost function with a single output (total assets), three input prices (i.e., the price of funds, labour and physical capital), a fixed net-put (equity capital), and technical changes (using a time trend as a proxy).

consequence. Therefore, we use the proportion of government ownership to control for the implicit or explicit impact of government guarantee. A bank with high government ownership is often perceived as enjoying the advantage of either implicit or explicit financial and regulatory support from the government (Faccio et al., 2006). Hence, banks with more government ownership will have low default and bankruptcy risk and would be likely to attract funds by paying lower rates of interest on borrowing and take more risky loans (but with higher return) than other banks. These in turn can reduce the banks' borrowing cost and increase revenue, and influence their cost and profit efficiency as a consequence. Finally, we include bank-type dummy variables in our analysis, in order to capture possible ownership and market segmentation differences between the Big Five (SOCBs), the JSCBs, the CCBs, and foreign banks (see Berger et al., 2009; Ferri, 2009; Asmild and Matthews, 2012).

4.3. Model specification

We use the transcendental logarithmic (translog) form, which is the most commonly used functional form in the bank efficiency literature, to specify the frontier. Our empirical cost frontier model is as follows:

$$\ln(TC_{it}) = \alpha + \sum_{m=1}^{3}\beta_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3}\beta_{mn} \ln y_{mit} \ln y_{nit} + \sum_{j=1}^{3}\gamma_j \ln w_{jit} + \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3}\gamma_{jk} \ln w_{jit} \ln w_{kit}$$
$$+ \frac{1}{2}\sum_{m=1}^{3}\sum_{j=1}^{3}\psi_{mj} \ln y_{mit} \ln w_{jit} + \varphi_1 \ln E_{it} + \frac{1}{2}\varphi_2 \ln E_{it}^2 + \sum_{m=1}^{3} \ln y_{mit} \ln E_{it} + \sum_{j=1}^{3}\xi_j \ln w_{jit} \ln E_{it}$$
$$+ \theta_1 T + \frac{1}{2}\theta_2 T^2 + \sum_{m=1}^{3}\kappa_m \ln y_{mit} T + \sum_{j=1}^{3}\rho_j \ln w_{jit} T + \eta \ln E_{it} T + v_{it} + u_{it}$$

and

$$u_{it} = \delta_0 + \delta_1 \ln(TA_{it}) + \delta_2 Lerner_{it} + \delta_3 HHI_t + \delta_4 listed_{it} + \delta_5 Gov_{it} + \delta_6 SOCB_i + \delta_7 JSCB_i + \delta_8 CCB_i + \omega_{it}$$

where ln(*TC*) is the logarithm of total costs, ln y_{mit} is the logarithm of the *m*th output of bank *i* at time *t*, ln w_{jit} is the logarithm of the *j*th input price of bank *i* at time *t*, ln z_{it} is the logarithm of the total equity of bank *i* at time *t*, and *T* is a time trend used to capture technology changes. In addition, the inefficiency term u_{it} is an explicit function of a number of environmental variables that are assumed to influence the distance of each bank from best practice; $\alpha, \beta, \gamma, \psi, \varphi, \lambda, \xi, \theta, \kappa, \rho, \eta$, and δ are the parameters to be estimated, and the standard symmetry restrictions, $\beta_{nm} = \beta_{mn}$ and $\gamma_{jk} = \gamma_{kj}$, are applied. Finally, the total cost and input price terms are normalized by one of the input prices, w_3, in order to impose a linear homogeneity of degree one on the input prices. The cost efficiency of a bank is defined as CE_{it} = 1 / exp (u) and takes a value between 0 and 1. Alternative profit efficiency (APE) is estimated similarly. We use profit before tax as the

dependent variable, and the same independent variables as we used in the cost function[17,18]. The profit efficiency is given as $APE_{it} = \exp(-u)$ and also takes a value between 0 and 1.

Besides cost and profit efficiency, we also calculate scale economies using the estimated cost frontier. The identification of scale economies has many implications. For example, their existence is usually considered powerful evidence in favour of the benefits of conducting mergers and acquisitions. According to Panzar and Willig (1977), the overall scale economies (SE) can be measured as $SE_{it} = 1/\sum_{j=1}^{3} \frac{\partial \ln TC_{it}}{\partial \ln y_{jit}}$. If SE > 1, a proportionate rise in all outputs leads to a less than proportionate rise in total costs, implying the existence of economies of scale. If SE<1, total costs increase more than proportionately with the increase in outputs, implying diseconomies of scale. Hence, when a bank is operating under decreasing (increasing) returns to scale, there is scale inefficiency (efficiency). If SE = 1, then the bank is operating at the optimal production level in the sense that it exhibits constant returns to scale.

Typically, the equity capital is held for both prudential and regulatory reasons, as equity capital is helpful for absorbing financial losses and maintaining the soundness of banks. Holding either an excessive or an inadequate level of equity could impose extra costs on banks. Hence, defining the appropriate level of equity capital is extremely important. Chinese banks have experienced massive recapitalization in the last ten years. Therefore, it is of interest to examine the impact of this recapitalization on the Chinese banking industry's performance by estimating the shadow return on equity (SROE)[19]. SROE, developed by Hughes et al. (2001), is computed from the negative of the elasticity of a bank's total costs with respect to the level of equity capital, that is $\mathrm{SROE} = -\frac{\partial \mathrm{TC}_{it}}{\partial \mathrm{z}_{it}}$. For a given set of output prices, changes in total costs are the negative of the change in economic profit. Therefore, in the short-run cost function, the negative of the derivative of costs with respect to the fixed level of capital should be considered as the true implicit return on equity (Kenjegalieva et al., 2009). In other words, it is a measure of how much banks are willing to pay for their equity capital[20, 21].

Generally, banks that are over-leveraged or reliant on debt and thus underutilize equity capital can be expected to show a relatively high SROE, while banks that are leveraged to a lesser degree are likely to show a lower value. Banks whose current equity capital levels are well above

[17] There are 13 bank observations in the sample that exhibit negative profits. We delete these observations from the sample in order to ensure that all dependent variables are positive so that the natural log of profit can be taken.
[18] As the profit function does not require the linear homogeneity of degree one in prices, we do not normalise the profit before tax and input price terms by one of the input prices.
[19] The shadow return on equity is also known as the shadow price of equity capital.
[20] The advantage of using the SROE is that it is estimated from a bank's cost function and is thus more reliable and closer to the true cost of equity, while the accounting return on equity, which is widely used in other studies, is calculated from the accounting figures in financial reports, which are easily manipulated.
[21] The SROE will equal the market price when the level of equity minimizes costs or maximizes profits (Hughes et al., 2001).

the long-run equilibrium, or that are overcapitalized, such as those under a major recapitalization, may be expected to show a very low or possibly negative SROE (Duygun et al., 2012). Negative SROE is an indication that the short-run adjustment from one highly leveraged equilibrium position to another with lower leverage can impose significant short-run adjustment costs. The critical question for policy makers and banking regulators is whether these short-run adjustment costs are outweighed by the efficiency benefits.

4.4. Data

Our sample is an unbalanced panel that covers 142 Chinese banks over the period from 2002 to 2013, with a total of 1,163 observations. The sample comprises the five SOCBs, twelve national and regional JSCBs, 93 CCBs, and 32 foreign banks. At the end of 2013, these banks owned almost 95.3% of the total assets of Chinese commercial banking institutions. Thus, we believe that our sample offers a good representation of the overall Chinese banking market. The data are mainly drawn from BankScope – Fitch's international bank database – and individual banks' annual financial reports. These data are double-checked against other data sources such as the CBRC's database, the China Economic Information Network (www.cei.gov.cn), and the China Statistical Yearbook. All financial variables are measured in the Chinese domestic currency, Renminbi (RMB), and denoted in millions. The monetary variables have been deflated to the year 2002 using the Chinese GDP deflator. Appendix B shows the means, standard deviations, and other statistics of the variables across the 142 banks over the entire sample period from 2002 to 2013.

5. Empirical results

5.1. Overall cost and profit efficiency

The stochastic cost (profit) frontier models are estimated using maximum likelihood techniques and the estimated results are reported in Appendix C. Since the main focus of this study is to analyse efficiency and its determinants, we do not discuss the estimated coefficients of the frontiers in great detail. However, we do note that the estimated cost function fulfils the theoretical requirements for a valid cost function in the sense that it turns out to be a monotonic non-decreasing function of the input prices and outputs and also is concave in the input prices.[22] Moreover, the high value of the estimated γ parameter (0.893) indicates that the vast majority of the residual variation is due to cost inefficiency effects and strongly supports the use of the stochastic frontier model rather than the standard Ordinary Least Squares (OLS) model.

[22] Tests for monotonicity of the cost function are satisfied by every bank in the sample, because point estimates of $\partial\ln(TC)/\partial\ln(Q_i)$ and $\partial\ln(TC)/\partial\ln(W_i)$ are all positive. In addition, the Hessian of the estimated cost function with respect to input prices is negative semi-definite and so the concavity of the cost function in input prices is also satisfied.

Table 1 shows the estimation results for the cost and profit efficiency levels for the full sample period as well as for the three sub periods. The overall cost efficiency level of 0.697 suggests that, on average, the sampled banks could potentially reduce their input costs by about 30% by using their inputs more efficiently, without changing their output levels. Similarly, the overall profit efficiency level of 0.685 suggests that, on average, banks could improve their profits by 31.5% to match the performance of the "best practice" bank[23].

[Insert Table 1 about Here]

To investigate the impact of the banking sector openness policy that began after China's accession to the WTO and the recent global financial crisis on the performance of Chinese banks, we divide our full sample period into three sub periods, WTO transition (2002-2006), post-WTO transition (2007-2009),[24] and post-financial crisis (2010-2013). The results presented in Table 1 show that both the cost and profit efficiency scores, on average, improved over the sample period. We also use the non-parametric Wilcoxon-Mann-Whitney[25] tests to examine the efficiency differences across the transition, post-transition, and post-financial crisis periods. The results of the tests confirm that the both cost and profit efficiency levels for Chinese banks during the post-transition period are statistically significantly higher than during the transition period and the cost and profit efficiency levels in the post-financial crisis period are statistically significantly higher than during the pre-financial crisis period, at the 5% level of significance. The results imply that the full opening up of the banking sector has had a positive effect on Chinese banks' performance and the 2008 financial crisis did not have a significant impact on the Chinese banking sector. These improvements in efficiency may be due to the measures taken in the recent banking reforms, such as the writing off of a large number of toxic assets, recapitalization, corporate governance improvements, risk management improvement[26], and the introduction of foreign strategic investors.

[23] In order to check the robustness of our results, we also use an SFA model with an alternative specification of outputs (the value-added approach) to estimate both cost and profit efficiencies. The value-added approach focuses on the intermediation activities of banks but suggests that deposits should also be considered as an output since they constitute elements on which customers bear opportunity costs and are involved in the creation of added value (see Berger and Humphrey (1997) for a more detailed discussion). The mean cost efficiency and profit efficiency obtained from the value-added approach are 4.6% and 13% lower than the intermediation approach. But the trends of efficiency levels obtained from the two approaches are broadly similar over time. The Spearman rank correlations between them are 74.12% for cost efficiency and 81.47% for profit efficiency, respectively.

[24] China joined the WTO in 2001, but the opening up of the financial market has been gradual and cautious. According to her WTO commitments, China was required to gradually open up its banking sector by removing regulatory obstacles over a five-year transition period (2002-2006). Since the end of this transition period, the Chinese banking sector has been fully open to foreign competitors.

[25] The Wilcoxon-Mann-Whitney test is based on comparisons of the ranks rather than the averages.

[26] The quality of loans is significantly improved over the sample periods. According to the CBRC, the non-performing loan ratio of commercial banks decreased dramatically from 17.6% in 2003 to 6.7% in 2007 and further decreased to 1.5% in 2013.

5.2. Efficiency based on ownership differences

The Chinese banking sector can be divided into four major categories, namely SOCBs, JSCBs, CCBs, and foreign banks (FBs). Although these banks all operate in the same market, each group has distinct ownership structures and market segmentation, and faces a different set of regulations. In the light of this uneven and varying regulatory environment, we expect to find performance variations both across the groups of banks and over time. We explain these variations below.

The mean values of the cost and profit efficiency scores, according to bank type, are reported in Table 1 for both the full period and the sub periods. Table 1 shows that the FBs, on average, are the most cost-efficient, with scores of 79.9%, followed by the CCBs (67.9%), JSCBs (66.5%), and the SOCBs (63.1%). In contrast, the results for profit efficiency show that the SOCBs (76.8%) and JSCBs (76.2%) are the most profit-efficient, followed by the CCBs (74.3%), and FBs (38.5%), which are the least profit-efficient. The results of the Wilcoxon-Mann-Whitney tests show that most of the differences are significant, and this is further confirmed by our one-stage estimation results that are shown later, in Appendix C (Panel B).

The sub period results for the different categories of banks are revealing. Both the cost and profit efficiency results suggest that the SOCBs are the least efficient during the pre-transition period but become the most efficient after the transition. The cost efficiency of the SOCBs increases by 7.8% and the profit efficiency by 24.4% between the two periods. These increases in efficiency indicate that banks took advantage of the recent reforms, which include partial privatization, the introduction of foreign strategic investors, the listing of banks' share capital on foreign and Chinese exchanges, and the establishment of a system for boards of directors. These reforms improve the banks' governance mechanisms and lead them to engage in more market-oriented business. In contrast, however, both cost and profit efficiencies of foreign banks have deteriorated significantly in the financial crisis period, implying that adverse circumstances arising out of foreign banks' home operations had spill over effects on their Chinese operations.

We analyze the efficiency levels in more detail, by bank type. Figure 1 and Figure 2 show the average values of cost and profit efficiency over the sample period, based on bank type. As we can see from Figure 1, foreign banks exhibit very good performance in cost efficiency relative to the other types of banks, implying that they may have better managerial expertise, experience, technology, and governance. The trend or patterns of cost efficiency levels for the other types of banks are broadly similar over time. The cost efficiency of domestic banks has gradually improved over the sample period. This is due to the Chinese government encouraging domestic banks to introduce foreign strategic investors, improve their corporate governance, and become listed on stock exchanges. These measures appear to have enhanced banks' performances.

[Insert Figure 1 and Figure 2 about Here]

We observe that foreign banks exhibit much lower profit efficiency than other types of banks (Figure 2). This implies that foreign banks may lack local knowledge of the market and are hampered by (implicit) restrictions on the extent of their business activities, which constrain their earnings and profitability. It is also difficult for foreign banks, especially the new entrants, to attract customers who have long-term relationship with domestic banks. Moreover, given limited bank networks and customer base, many loan products and fee-based services such as mortgage loans and paying utility bills on behalf of bank clients may not be very profitable.

Figure 2 also shows a decline in profit efficiency in the FBs during 2008-2009. This significant decline may reflect the costs for FBs of setting up their businesses and carrying out branch expansion programmes and/or a difficulty in expanding FB presence in China during that period. The results also suggest that the recent global crisis has had a negative impact on the foreign banks in China. However, profit efficiency has begun to improve from 2009 onwards and the improvement may be due to the removal of business restrictions, the strong demand for corporate credit from multinationals expanding within China, and an increasing number of local enterprise customers. The profit efficiency of Chinese domestic banks has improved over the sample period, implying that they have benefited from the strong national economic growth in last ten years. However, there was a decline between 2007 and 2009, which may be due to the global financial crisis that curtailed growth. More specifically, the SOCBs have shown a considerable improvement in average profit efficiency from 2004 to 2013, climbing from 54.1% in 2004 to 89.16% in 2013. This finding implies that the continuing banking reforms have helped to improve the SOCBs' profitability and profit efficiency. The improvement may also be due to strong government connections and priority roles in implementing government policies, such as infrastructure spending, which have boosted their earnings and profitability. The CCBs also exhibit an increase in profit efficiency over the sample period. There are several possible explanations for this result. First, in the past, the CCBs were often controlled directly by local governments and experienced significant pressure to lend for policy purposes. However, during the last decade, the local government's ownership in CCBs has decreased significantly and this may have correspondingly reduced political inference in the banks' operating decisions, leading to improved corporate governance and profit performance. In addition, the CCBs often focus on the usury market, where borrowers such as small and medium-sized businesses are charged relatively high interest rates. As a result, these banks could be reaping very high profits that improve their profit efficiency.

CCBs play an increasingly important role in the funding of SMEs. Overall, China's growth has been impressive but there are considerable imbalances in the economic development across different regions of the country. The municipalities and the eastern and coastal areas have generally developed more quickly and have more mature private economies than the northern and western areas. Therefore, we now investigate whether the performance of a CCB depends on the economic development of the geographical area in which it conducts its business. We divide China into six economic regions plus an extra category made up of four municipalities[27]. As shown in Table 2, the CCBs in the (eastern) coastal and (central) south areas exhibit good overall performance in terms of both cost and profit efficiency. The CCBs located in four municipalities show high profit efficiency but low cost efficiency. However, the CCBs in the north, northwest, and northeast show relatively low levels of cost and profit efficiency. These results suggest that a CCB's performance is positively related to the level of economic development in the region in which it is located. The sub period results show that banks from all regions have improved both their cost and profit efficiencies since the transition period, which suggests that strong economic growth can lead to significant efficiency gains for banks in all regions.

[Insert Table 2 about Here]

Banks in provincial capitals generally come under stricter regulatory scrutiny and pay higher subsidies than those in cities that are not the capitals of provinces. Thus, we also investigate whether the administrative status of the city in which the bank is located plays a role in determining its efficiency. We compare both the cost and profit efficiency of CCBs in provincial cities and cities that are not provincial capitals. Banks from non-provincial capital cities show more cost and profit efficiency than the banks from provincial capital cities. Meanwhile, the sub period results show that, although both subcategories of banks have enjoyed improvements in both cost and profit efficiency, the CCBs in cities that are not provincial capitals have benefitted more since the transition period.

5.3. Economies of scale

Industry economies of scale have important implications for regulators and bank managers in terms of growth and merger and acquisition issues. In this section we use the cost frontier model outlined earlier, to analyse the economies of scale in the Chinese banking sector over the period 2002-2013 for the same four categories of banks as above.

[27] The six regions are the centre and south (Henan, Hubei, Hunan, An'hui and Jiangxi), the east coast (Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan), the north (Inner Mongolia, Hebei and Shanxi), the northeast (Jilin, Liaoning and Heilongjiang), the southwest (Sichuan, Guizhou, Yunnan, Guangxi and Tibet), and the northwest (Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang), and the four municipalities are Beijing, Shanghai,Tianjin, and Chongqing.

[Insert Table 3 about Here]

Table 3 reports the annual estimates of scale economies calculated using the SFA model. We find that the economies of scale for non-SOCB banks over the period 2002-2013 are significantly greater than one, suggesting the existence of economies of scale in the Chinese banking sector. We also note that the estimates exhibit a decreasing trend over time and this pattern indicates that Chinese banks have made efforts to achieve optimal operating efficiency over time (constant returns to scale). Based on the estimates for each type of bank, the table shows that significant scale economies exist in the CCBs and FBs. This, in turn, implies that small banks can potentially save on operating costs by extending their production scale or through mergers. For the SOCBs, the scale economies are significantly less than one, with a slightly decreasing trend. This result suggests that the big banks are experiencing diseconomies of scale and, therefore, could reduce their average costs and achieve efficiency gains by decreasing their scale of operations. However, the big SOCBs will face major challenges if they try to cut their costs, for example, by reducing the number of branches and employees across the country and reducing the large amount of lending for social and political purposes. Moreover, as the SOCBs are generally in a monopoly position, they have less incentive to reduce their costs by downsizing. Note, also, that the scale economies for JSCBs for the later sample period (2006-2013) are very close to unity (that is, these banks exhibit almost constant returns to scale), indicating that the JSCBs generally have optimal asset size and are the most scale-efficient banks. In summary, the results suggest that the average cost curve for the Chinese banking sector is U-shaped, with medium-sized banks being more scale-efficient than either very large or very small banks.

5.4. Shadow return on equity

As most Chinese banks were undercapitalized before the country joined the WTO in 2001, one of the most important aspects of the recent banking reforms was the recapitalization of the domestic banks in order that they would fulfil the minimum capital adequacy ratio (8%) requirement. Therefore, one of the key objectives of this paper is to examine the effect of recapitalization on the Chinese banking industry by examining the SROE.

[Insert Figure 3 about Here]

As shown in Figure 3, there is a decreasing trend in the SROE for different types of banks over the full sample period. However, the SROE of Foreign banks and JSCBs show an increase during the global financial crisis period, implying that these banks seem willing to pay more to increase their equity capital during that period. These results suggest that recapitalization leads to a decrease in the SROE; the decline may also reflect the relatively low funding costs and the

increased competition in the Chinese banking sector. The increase in SROE in 2008-2009 may be due to a rise in the central bank's interest rate and funding costs during those years, thus implying that these banks are willing to pay more to raise their equity capital during the financial crisis period. It is interesting to note that the sign on the SROE is positive initially, but becomes negative by the end of the period. This may be because, during or after a severe recapitalization period, banks tend to deviate from their long-run equilibrium, which can cause the SROE to become negative. This finding is consistent with Duygun et al. (2012), who find that, during a recapitalization period, the SROEs of Turkish banks also become negative. In addition, we find that the mean SROE is consistently higher for FBs than for domestic commercial banks. This implies that FBs are still underutilizing equity capital or have funding costs that are higher than those of their counterparts.

Overall, our results suggest that the short-run adjustment from one highly leveraged equilibrium position to another with lower leverage can impose significant short-run adjustment costs. Policy makers should be cautious of the fact that the increased efficiency may be offset by the adjustment costs imposed by the recapitalization process. This is a critical question for both policy makers and banking regulators.

5.5. Efficiency and shadow return on equity

The relation between the SROE and banks' cost and profit efficiency is also of interest. Table 4 reports the mean of the SROE for the most and least efficient quartiles of banks. We find that the most efficient banks have significantly smaller SROEs. This indicates that the least efficient banks appear to be over-leveraged and appear to underutilize equity relative to the most efficient banks, and they may be able to improve their efficiency by holding extra capital.

[Insert Table 4 about Here]

Given the absence of a priori theory regarding the relation between efficiency and SROE, we also use the PVAR method for our analysis. The PVAR framework explicitly addresses the endogeneity problem by treating all variables as potentially endogenous and modelling the feedback loops between the variables[28]. Table 4 reports the correlations between the (cost and profit) efficiency scores and the SROE. We find a negative relationship between the efficiency scores and the estimated SROE. Table 5 presents the parameter estimates of the system of equations for cost and profit efficiency and SROE. The SROE impact on cost efficiency is negative but not significant; however its impact on profit efficiency is significant and negative, suggesting that, generally, decreasing the SROE by raising equity capital could lead to increased

[28] See Love and Zicchino (2006), Koutsomanoli-Filippaki and Mamatzakis (2009), and Love and Ariss (2014) for a more detailed discussion on the PVAR method.

profit efficiency levels for banks[29]. On the other hand, the impact of SROE on both profit and cost efficiencies is significant and negative. This result implies that a causal relationship from SROE to efficiency may exist.

Next we focus our discussion on the impulse-response results presented in Figure 4 which show the response of each variable of the VAR analysis (cost or profit efficiency and SROE) to its own innovation and to the innovation of the other variable. From the first row of Figure 4 the effect of a one standard deviation shock of SROE on cost and profit efficiency is negative but is relative small in magnitude. The response of efficiency to a shock in SROE takes place after 2 years, while it converges towards the zero line thereafter. These results weakly confirm our previous finding that reduced SROE could lead to increased efficiency. On the other hand, we observe that SROE decreases in response to a positive shock in efficiency, suggesting that reverse causality in regard to efficiency and SROE also exists and indicating that improvement in efficiency could reduce the true implicit return on equity (i.e. SROE). To further support our analysis, we present variance decompositions (VDCs), which indicate the percentage of the variation in one variable that is explained by the shock in another. We report the total effect accumulated over 10 and 20 years in Table 6. We observe that cost and profit efficiencies explain about 30% and 24% of the variation in SROE after 20 years, respectively, while SROE explains about 7% and 7.6% of the variance in cost and profit efficiencies, respectively. The results provide more evidence reaffirming the significance of efficiency in explaining the variation in SROE.

[Insert Table 5 and Table 6 about Here]

[Insert Figure 4 about Here]

5.6. Determinants of cost and profit efficiency

The main benefit of using Battese and Coelli's (1995) model is that it enables us to not only examine the level of efficiency but also investigate the potential determinants of efficiency in Chinese banks[30]. The impact of environmental factors on Chinese banks' cost and profit efficiencies are reported in panel B of Appendix C. The coefficients on the logarithm of total assets are statistically significant and positive for the profit efficiency scores, indicating that larger banks seem to be relatively more profit-efficient than smaller banks. Our findings here are

[29] One must bear in mind, as we showed in the previous section, that massive recapitalization can push the SROE into a negative region. The adjustment costs imposed by a recapitalization process could offset the efficiency gains.

[30] We also use PVAR to examine the relations between the efficiency scores and their determinant factors as a robustness test. In a PVAR system all variables are endogenously determined. Therefore, we only include the variables (i.e. bank size, HHI, Lerner Index, and government ownership) which might be considered to be endogenous for the PVAR analysis. The results are generally consistent with the findings by using the one stage stochastic frontier approach (SFA). The results are available on request.

in line with many previous efficiency studies (e.g., Srairi, 2010). This effect could be due to larger banks' wider penetration of the market and their ability to increase revenue at a relatively lower cost (Perera et al., 2007). They may also have more professional or specialized management teams that are better able to control costs and increase revenue.

Positive and statistically significant coefficients for the Lerner index in the cost model, suggest that banks with greater market power (a larger Lerner value) are better at minimizing costs. However, we also find a significantly negative relationship between the Lerner index and profit efficiency. This result seems to support that the "quiet life" hypothesis, which asserts that banks with market power forego revenues or incur higher costs. However, we do not find any significant relationship between efficiency and the concentration indicator (HHI)[31]. Concerning the effect of a stock exchange listing on bank efficiency, we find that the coefficient associated with the listed bank dummy variable is statistically significant, with a positive impact on cost efficiency. This result suggests that the intense public scrutiny that accompanies a stock listing exerts market discipline over bank management and listed banks are thus more cost-efficient than banks that are not listed. However, this relationship is not significant in the profit efficiency model, suggesting that the listing effect does not contribute to the level of profit efficiency. In addition, the coefficients show that FBs exhibit higher cost efficiencies than JSCBs, SOCBs, and CCBs but significantly underperform other types of banks in terms of profit efficiency. The magnitudes of the coefficients indicate that JSCBs are the most cost efficient among Chinese domestic banks and SOCBs are the most profit-efficient. These results generally confirm the findings discussed earlier. Finally, we find that banks with higher government ownership tend to be more profit efficient, implying that the higher level of government guarantee can help banks to reduce some borrowing costs and increase revenue, which in turn improves banks' profit efficiency.

6. Conclusion

This paper examines the cost and profit efficiencies of 142 commercial banks in China, over the period 2002-2013. It compares the performance of Chinese banks across different ownership types before and after the completion of the WTO transition period (including post global financial crisis period). Our findings show that the cost and profit efficiency levels are, on average, around 70%. To improve efficiency levels, banks need to pay more attention to both the cost-minimizing and revenue-generating processes. We further compare the efficiency based on

[31] Many studies use the market concentration measure as a proxy for the degree of market power but this broad measure fails to assess individual firms' abilities to charge marked-up prices (Boone, 2008).

different types of banks. The CCBs and JSCBs show more cost efficiency than the SOCBs over the sample period. However, the CCBs are less profit-efficient, while the FBs have the lowest profit efficiency scores. We find that both the cost and profit efficiency have increased across all types of domestic banks since the WTO transition period was completed. This improvement suggests that opening up the banking sector has had a positive effect on the performance of China's banks, and there is no doubt that the recent banking reform in China has been fruitful. However, the profit advantage of domestic banks over foreign banks is widening after the WTO transition period because of institutional arrangements and cultural and social networks.

Given the increasing importance of CCBs to the Chinese banking sector, we also compare CCBs based on geographical differences. Our findings show that CCBs in the four municipalities and in more developed areas of China enjoy the highest performance levels in terms of profit efficiency, suggesting that the level of economic development in the region in which a CCB is located plays an important role in determining the CCB's performance. The sub period results show that banks from all regions improve both their cost and profit efficiency scores after the WTO transition period. We next do a comparison of whether CCBs in cities that are not provincial capitals exhibit higher efficiency levels than those in provincial cities. Our empirical results show that economies of scale are prevalent across the Chinese banking sector. This is mainly the result of widespread scale economies in small-sized CCBs, suggesting that this group could obtain cost savings by increasing the scale of their operations. In contrast, the SOCBs suffer from diseconomies of scale.

The SROE results illustrate an overall decreasing trend over the sample period but with a slightly increase during the period 2008-2009. It is interesting to note that the sign on average SROE becomes negative after the financial crisis. The change in sign can be explained by the increase in the capital ratio due to the recent capital injection given to domestic banks. This suggests that policy makers and regulators should be cautious about such strategies, as the increased efficiency may be offset by adjustment costs imposed by the recapitalization process. Regulators should be alert to the fact that when banks are reducing positions of previous over-leveraging, the disequilibrium true implicit ROE could turn negative for a substantial period. Moreover, by using the PVAR method, we find negative relationships between the efficiency scores and the SROE. On the other hand, we also find a strong reverse causal relationship between them, suggesting that an increase in efficiency leads to a decrease in SROE. Last, but not least, we investigate the factors that influence the efficiency of Chinese banks. We find that market power and ownership type significantly influence both the cost and profit efficiency of Chinese banks. Moreover, larger banks and banks with a high level of government guarantee are more profit efficient that other banks.

Our results have important policy implications. First, the evidence from our study shows that the recent Chinese banking reform has been successful in enhancing the performance of Chinese banks, on both the cost and the profit side. However, there is still much room for improvement, given the current levels of efficiency. The main source of inefficiency comes from both the cost and revenue side, implying a need for more fundamental changes in management and operational decision-making processes, from policy orientation to market orientation. Second, as CCBs are playing an increasingly important role in local economic development and the funding of SMEs, the central authorities should encourage and give more support to the development of CCBs, especially those in less developed regions such as the north and northwest. Third, the findings regarding economies of scale suggest that small banks such as CCBs could improve their efficiency by increasing their size, perhaps through mergers and acquisitions. In addition, the government should completely remove the restriction on CCBs that forces them to operate within their own cities' boundaries. This geographical constraint is likely to damage performance levels by preventing the CCBs from exploring more business opportunities, effectively spreading risk, and achieving economies of scale. Moreover, small banks in China are generally not able to offer a full range of services because either they are too expensive to provide or are subject to regulatory constraints. Therefore, the small banks could adopt the operational model of small U.S. banks by purchasing (standardized and infrequent) services and products from larger banks that are either able to offer a broader range of service such as check-clearing, mortgage and credit card processing, investment banking services, and international transactions[32]. To accomplish this, small banks could reduce operating expenses and increase revenues by providing cheaper and broader services to their customers, which in turn improve the banks' cost and profit efficiency. Fourth, the SROE analysis should remind policy makers to be cautious about the fact that, although an increase in equity capital may help banks to absorb financial losses, it also imposes short-run adjustment costs that may offset the gains in efficiency. Finally, as public listing is shown to have a positive effect on cost efficiency, the Chinese government should encourage domestic banks to seek an IPO. This will help banks to widen their funding sources, reduce their reliance on the government, and achieve better corporate governance and transparency.

[32] We thank the reviewer for pointing this issue out.

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Figure 1. Average cost efficiency by bank type

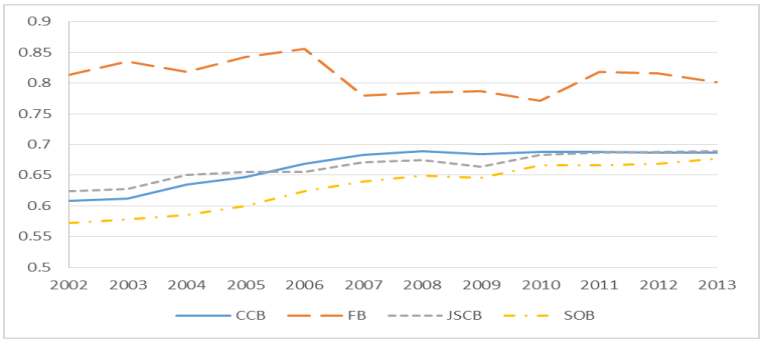

Figure 2. Average profit efficiency by bank type

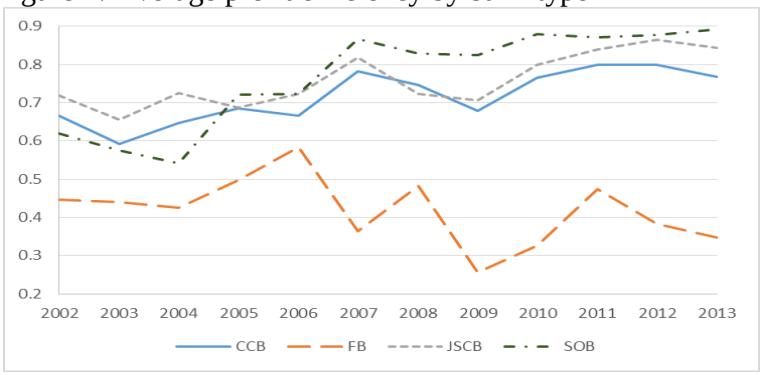

Figure 3. Shadow return on equity for Chinese banks (2002-2013)

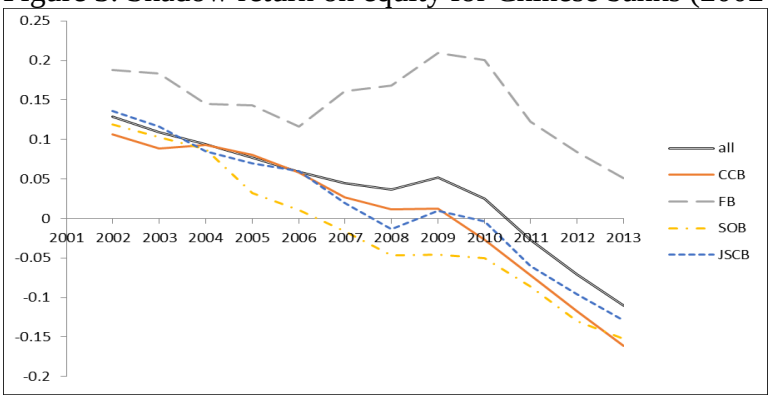

Figure 4 Impulse response functions to shocks

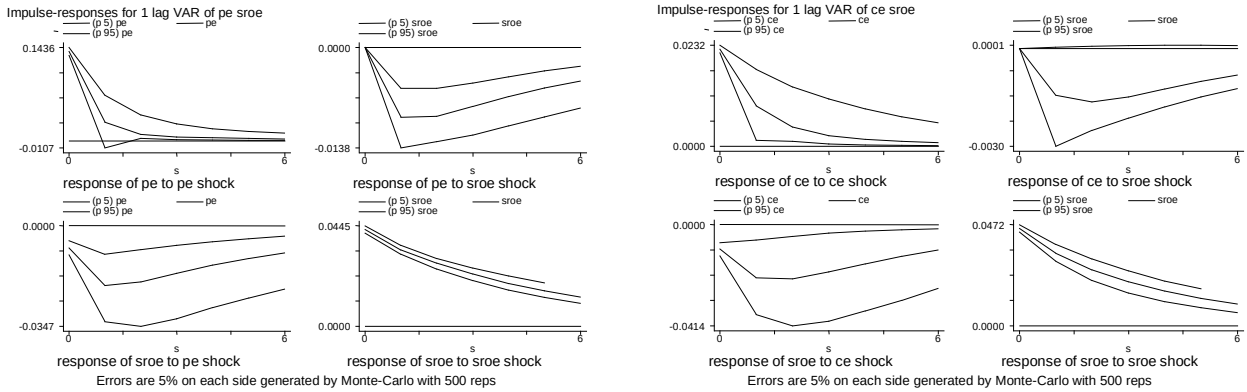

Table 1. Average efficiency scores and significance of tests for different bank groups

	Cost efficiency				Profit efficiency			
	full sample	2002-2006	2007-2009	2010-2013	full sample	2002-2006	2007-2010	2010-2013
Overall	0.697	0.655	0.701	0.712	0.685	0.656	0.674	0.705
FBs	0.799	0.836	0.784	0.802	0.385	0.491	0.357	0.385
CCBs	0.679	0.650	0.686	0.687	0.743	0.662	0.734	0.783
JSCBs	0.665	0.643	0.670	0.687	0.762	0.702	0.749	0.837
SOCBs	0.631	0.592	0.645	0.670	0.768	0.636	0.840	0.880
Wilcoxon-Mann-Whitney test*								
SOCBs vs JSCBs	Sig.	Sig.	Sig.	Sig.	Insig.	Sig.	Sig.	Sig.
SOCBs vs CCBs	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SOCBs vs FBs	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
JSCBs vs CCBs	Sig.	Insig.	sig.	Insig.	Sig.	Sig.	Insig.	Sig.
JSCBs vs FBs	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CCBs vs FBs	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Transition vs Post transition period			Sig.			Sig		
Pre- vs Post financial crisis			Sig.			Sig.		

*We use the non-parametric Wilcoxon-Mann-Whitney test to check for differences between bank types. This is a non-parametric analogue to the independent samples t-test and can be used when there is no assumption that the dependent variable is a normally distributed interval variable. The significance level is at the 5% level.

Table 2. Average efficiency of CCBs by region and administrative status

	Cost efficiency				Profit efficiency			
	full sample	2002-2006	2007-2009	2009-2013	full sample	2002-2006	2007-2009	2010-2013
Central and South	0.698	0.665	0.696	0.707	0.772	0.627	0.742	0.827
East coast	0.685	0.660	0.686	0.687	0.763	0.677	0.698	0.821
North	0.680	0.657	0.687	0.686	0.675	0.638	0.621	0.716
Northeast	0.678	0.652	0.678	0.685	0.750	0.669	0.743	0.783
Northwest	0.679	0.633	0.680	0.695	0.734	0.673	0.754	0.748
Southwest	0.683	0.660	0.692	0.688	0.734	0.571	0.710	0.832
Municipalities	0.645	0.615	0.658	0.659	0.784	0.717	0.800	0.817
Non-provincial capital cities	0.689	0.662	0.695	0.696	0.741	0.654	0.747	0.772
Provincial capital cities	0.670	0.641	0.673	0.677	0.735	0.650	0.690	0.792

Table 3. Economies of scale estimations for Chinese banks (2002-2013)

	All	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
FB	1.178*	1.307*	1.275*	1.208*	1.182*	1.174*	1.164*	1.171*	1.166*	1.160*	1.105*	1.085*	1.076*
CCB	1.116*	1.237*	1.198*	1.169*	1.163*	1.157*	1.142*	1.118*	1.091*	1.087*	1.081*	1.075*	1.071*
JSCB	1.016	1.091*	1.075*	1.052*	1.035*	1.024	1.020	1.018	1.015	1.009	0.995	0.993	0.987
SOCB	0.869*	0.902*	0.881*	0.887*	0.879*	0.875*	0.870*	0.869*	0.871*	0.868*	0.861*	0.855*	0.849*
All	1.078*	1.183*	1.175*	1.162*	1.094*	1.089*	1.065*	1.056*	1.058*	1.049*	1.044*	1.041*	1.036*

Notes: 1. Scale economies estimates are evaluated at the mean of the data rather than the mean estimate of scale economies calculated at each observation.
2. * indicates that scale economies estimates are statistically different from 1 at the 5% level, for a two-tailed test.

Table 4. Average SROE in different subsamples and test for group differences

		CE	SROE		PE	SROE
Most efficient quartile	291	0.785	0.016	288	0.895	-0.003
Least efficient quartile	291	0.629	0.073	288	0.329	0.094
Test of SROE difference [a]		-4.833**			-11.349***	

Notes: [a] Z-value from the Wilcoxon-Mann-Whitney U test of differences in medians.
** and *** indicate that the difference between the most efficient quartile of banks and the least efficient quartile of banks is significant at the 5% or 1% level, respectively.

Table 5. Panel VAR of a two variable model

Dependent variable	CE_{-1}	$SROE_{-1}$	Obs
CE	0.402(0.219)*	-0.032(0.018)*	878
SROE	-0.644(0.435)	0.744(0.048)***	878

	PE_{-1}	$SROE_{-1}$	Obs
PE	0.196 (0.181)	-0.224(0.053)***	866
SROE	-0.116(0.055)**	0.790(0.020)***	866

Notes: The PVAR models are estimated using system GMM. Reported numbers show the coefficients of regressing the dependent variables on lags of the independent variables.
***, ** and * indicate the 1%, 5% and 10% significance levels respectively.

Table 6 Estimates of variance decomposition

	S	CE	SROE		PE	SROE
CE	10	0.982	0.017	PE	0.982	0.018
SROE	10	0.298	0.699	SROE	0.238	0.760
CE	20	0.982	0.018	PE	0.981	0.019
SROE	20	0.301	0.702	SROE	0.240	0.762

Note: S: time periods ahead (years ahead); CE: cost efficiency; PE: profit efficiency.

Appendix A

Author / Year	Banks (obs.)	Period	Method	Variables	Main Results
Chen et al. (2005)	43 (NA)	1993-2000	DEA	Outputs: loans, deposits and non-interest income Inputs: labour, deposit and physical capital	Big Four state-owned banks had higher technical efficiency and allocative efficiency than the national JSCBs Overall average cost efficiency is higher than the overall average profit efficiency
Ariff and Can (2008)	28 (230)	1995-2004	DEA	Outputs: loans and investments. Inputs: loanable funds, number of employees and physical capital.	Profit efficiency remarkably increased while cost efficiency remained almost unimproved over the study period. JSCBs and CCBs, on average, appear to be more efficient than the SOCBs. Medium-sized Chinese banks are significantly more efficient than both their smaller or larger counterparts.
Fu and Heffernan (2007)	14 (187)	1985-2002	SFA	Outputs: total loans, total deposits total investments and non-interest income Inputs: funds, labour and fixed assets	JSCBs were relatively more X-efficient than the SOCBs
Kumbhakar and Wang (2007)	14 (132)	1993-2002	SFA	Outputs: total loans net, other earning assets Inputs: labour, fixed assets, total deposit and total borrowed funds	Four largest SOCBs are less technically efficient than the JSCBs small banks tend to be more efficient than large banks
Berger et al. (2009)	38 (266)	1994-2003	SFA	Outputs: total loans, total deposits, liquid assets, other earning assets Inputs: interest expenses and non-interest expenses	Foreign banks and non-Big-Four state-owned banks are the most cost-efficient Chinese banks, with private domestic banks being the least cost-efficient. Foreign banks are the most profit-efficient and Big Four state-owned banks are the least profit-efficient. Minority foreign ownership has a positive effect on both cost and profit efficiency.
Jiang et al. (2009)	N/A (310)	1995-2005	SFA	*Model 1:* Outputs: net interest income and non-interest income*;* Inputs: total interest expense and non-interest expense. *Model 2:* Outputs: total loans, total deposits and non-interest income; Inputs: total interest expense, labour costs and physical capital. *Model 3:* Outputs: total loans, total deposit and other earning assets*;* Inputs: total interest expense, physical capital, and labour costs.	Joint stock banks and the Big Four state-owned banks are the most efficient Chinese banks, with foreign banks the least efficient.
Asmild and Matthews (2012)	14 (168)	1997-2008	DEA	Outputs: net interest earnings and non-interest earnings Inputs: number of employees, fixed assets, total deposits	Joint equity banks are more efficient than the Big Four state-owned banks. Since 2003, the efficiency of the state-owned banks has improved.
Hou et al. (2014)	44 (N/A)	2007-2011	DEA	Outputs: total net loan, other earning assets Inputs: total deposits, fixed assets and no. of employees	Intense market competition helps improve technical efficiency and technical efficiency is positive associated with risk taking
Wang et al (2014)	16 (114)	2003-2011	DEA	Outputs: noninterest income and interest income Inputs: fixed assets and labour	The Chinese banking reform improves its overall efficiency over the study period. Efficiency differences between the state-owned and joint-stock commercial banks are reduced over the study period

Notes: N/A: not available; DEA: data envelopment analysis; SFA: stochastic frontier analysis.

Appendix B. Descriptive Statistics of Variables

Description	Obs.	Mean	Std. Dev.	Min.	Max.
Full sample					
Total cost[a]	1163	9881.474	31874.85	21.699	281002
Profit before tax[a]	1150	5394.766	20706.68	0.475	221342.1
Total loans[a]	1163	194198.7	647149.2	58.871	5536780
Total other earning assets[a]	1163	89983.76	322630.7	0.589	2834485
Non-interest income[a]	1163	2072.933	7757.766	0.353	79329.89
Price of funds	1163	0.0205	0.0091	0.004	0.081
Price of physical capital	1163	1.2897	2.2010	0.087	22.125
Price of labour[a]	1163	0.1373	0.0723	0.019	0.560958
Equity[a]	1163	20846.27	75182.19	1.213	745433.8
Time trend	1163	7.988822	2.9157	1	12
Total assets[a]	1163	372112	1237182	609.601	10600000
Government ownership	1163	0.1437	0.2018	0	1
Herfindahl index	1163	0.1030	0.0178	0.077	0.153
Lerner index	1163	0.4048	0.1783	-1.651	0.764
Listed banks	1163	0.1263	0.3324	0	1
SOCBs	1163	0.0515	0.221294	0	1
JSCBs	1163	0.1169	0.321486	0	1
CCBs	1163	0.6509	0.47689	0	1
Foreign banks	1163	0.1805	0.384825	0	1
Big banks (SOCBs)					
Total cost[a]	60	124909.1	65934.39	18955	281002
Profit before tax[a]	60	72422.49	56124.25	1579.107	221463.2
Total loans[a]	60	2614144	1246107	426763	5536780
Total other earning assets[a]	60	1275640	702515.1	159301	2834485
Non-interest income[a]	60	27383.33	21255.59	1863	79329.89
Price of funds	60	0.01626	0.003274	0.011494	0.025698
Price of physical capital	60	0.43569	0.090474	0.231227	0.592833
Price of labour[a]	60	0.094306	0.031635	0.038762	0.140135
Equity[a]	60	278064.2	188127.5	1.308942	745433.8
Total assets[a]	60	4943842	2487303	732003	10600000
Government ownership	60	0.724161	0.218669	0.3095	1
Lerner Index	60	0.1812	0.1236	-0.1512	0.3321
Listed banks	60	0.633333	0.485961	0	1
Medium banks (JSCBs)					
Total cost[a]	136	19377.3	18099.23	458.0666	80699.81
Profit before tax[a]	136	9114.726	10295.95	253.6	45454.09
Total loans[a]	136	346777.7	284570.2	7276	1293452
Total other earning assets[a]	136	114123.5	96673.73	3189.501	503300.8
Non-interest income[a]	136	2893.293	3774.171	107.8652	20066.19
Price of funds	136	0.021113	0.006884	0.010444	0.044811
Price of physical capital	136	0.803062	0.336569	0.26595	2.83595
Price of labour[a]	136	0.18368	0.056272	0.022108	0.318255
Equity[a]	136	32538.38	35862.93	1.213689	156571
Total assets[a]	136	6.727941	3.415578	1	12
Government ownership	136	0.061981	0.143594	0	0.7088
Lerner Index	136	0.2202	0.0973	-0.2526	0.3876
Listed banks	136	0.558824	0.498363	0	1
Small banks (CCBs & FBs)					
Total cost[a]	967	1408.788	2114.895	21.69921	23217.14
Profit before tax[a]	954	680.525	1059.756	0.475	11209.4
Total loans[a]	967	22588.12	33573.69	58.87103	344314.2
Total other earning assets[a]	967	13021.63	20843.47	0.58871	188705.2
Non-interest income[a]	967	387.1074	281.7002	0.353226	2690.583
Price of funds	967	0.020713	0.009597	0.003838	0.080087
Price of physical capital	967	1.41122	2.391229	0.087403	22.125
Price of labour[a]	967	0.133457	0.073245	0.018988	0.560958
Equity[a]	967	3242.133	4358.811	30.53464	46099.61
Total assets[a]	967	8.258532	2.724281	1	12
Government ownership	967	0.11926	0.144002	0	0.9264
Lerner Index	967	0.2659	0.1865	-1.6509	0.7647
Listed banks	967	0.034126	0.181647	0	1

[a] Unit: RMB one million

Appendix C. Parameter estimates of the cost and profit frontier

Panel A

Cost frontier			Profit frontier		
Variables	Coefficient	t-Ratio	Variables	Coefficient	t-Ratio
lny_1	0.564***	35.93	lny_1	0.232***	7.41
lny_2	0.138***	14.39	lny_2	0.067***	4.24
lny_3	0.135***	7.77	lny_3	0.151***	5.2
$ln(w_1/w_3)$	0.730***	56.03	lnw_1	0.092***	3.02
$ln(w_2/w_3)$	0.055**	5.65	lnw_2	0.179***	8.00
			lnw_3	0.164***	5.17
$0.5* lny_1^{\wedge 2}$	-0.004***	-0.15	$0.5* lny_1^{\wedge 2}$	0.122***	3.01
lny_1*lny_2	-0.033***	9.84	lny_1*lny_2	0.038*	1.68
lny_1*lny_3	-0.034**	-2.22	lny_1*lny_3	-0.11326	-3.87
$0.5*lny_2^{\wedge 2}$	0.024***	7.94	$0.5*lny_2^{\wedge 2}$	0.015*	1.83
lny_2*lny_3	-0.024**	-2.34	lny_2*lny_3	-0.002	-0.09
$0.5*lny_3^{\wedge 2}$	0.072***	5.24	$0.5*lny_3^{\wedge 2}$	0.099***	4.04
$0.5*ln(w_1/w_3)^{\wedge 2}$	0.066***	2.77	$0.5*lnw_1^{\wedge 2}$	-0.236**	-2.48
$ln(w_1/w_3)*ln(w_2/w_3)$	-0.017	-1.18	lnw_1*lnw_2	-0.128***	-3.18
			lnw_1*lnw_3	0.063	0.82
$0.5*ln(w_2/w_3)^{\wedge 2}$	0.003	0.23	$0.5*lnw_2^{\wedge 2}$	0.021	1.21
			Lnw_2*lnw_3	0.003	0.06
$lny_1*ln(w_1/w_3)$	-0.055***	-3.47	lny_1*lnw_1	-0.152***	-2.71
$lny_1*ln(w_2/w_3)$	0.102***	7.68	lny_1*lnw_2	0.110***	2.76
			lny_1*lnw_3	-0.103**	-2.42
$lny_2*ln(w_1/w_3)$	0.015**	2.19	lny_2*lnw_1	0.061**	2.04
$lny_2*ln(w_2/w_3)$	-0.011*	-1.93	lny_2*lnw_2	-0.060***	-4.48
			lny_2*lnw_3	0.021	0.72
$lny_3*ln(w_1/w_3)$	-0.036*	-1.93	lny_3*lnw_1	0.110***	2.76
$lny_3*ln(w_2/w_3)$	0.037**	2.55	lny_3*lnw_2	0.787***	3.30
			lny_3*lnw_3	0.117***	2.85
lnz	0.131***	7.48	lnz	0.344***	11.26
$0.5*lnz^{\wedge 2}$	0.000	0.04	$0.5*lnz^{\wedge 2}$	0.061***	6.64
$lnz*lny_1$	-0.021**	-2.08	$lnz*lny_1$	0.001	0.03
$lnz*lny_2$	0.032***	3.99	$lnz*lny_2$	-0.048*	-2.26
$lnz*lny_3$	-0.011	-0.93	$lnz*lny_3$	0.014	0.86
$lnz_1*ln(w_1/w_3)$	0.080***	4.36	$lnz*lnw_1$	0.132**	2.11
$lnz_1*ln(w_2/w_3)$	-0.104***	-6.58	$lnz*lnw_2$	0.042**	1.96
			$lnz*lnw_3$	-0.049	-1.61
T	0.015	1.1	T	-0.014	-1.27
$0.5*T^{\wedge 2}$	-0.003	-1.61	$0.5*T^{\wedge 2}$	-0.001	-0.4
T lny1	-0.058***	-7.02	T lny1	0.020***	2.69
$Tlny_2$	-0.021***	-5.21	$Tlny_2$	0.005278	1.02
$Tlny_3$	0.004	1.12	$Tlny_3$	-0.028***	-4.47
$T*ln(w_1/w_3)$	-0.009**	-2.13	$T*lnw_1$	0.008	0.51
$T*ln(w_2/w_3)$	0.002	0.6	$T*lnw_2$	-0.023***	-2.93
			$T*lnw_3$	-0.018	-1.5
Tlnz	0.024***	6.1	Tlnz	0.005	0.62
Constant	-0.619	-0.05	Constant	0.638***	16.46

Panel B

Inefficiency term			**Efficiency term**		
Intercept	-0.542	-0.05	Intercept	13.110***	20.44
lnTA	0.825	0.68	lnTA	0.787**	2.16
Lerner	0.555***	9.99	Lerner	-5.095***	-20.15
HHI	0.063	0.03	HHI	-3.999	-1.36
Listed	0.070**	2.55	Listed	0.280	1.45
SOCB	-0.302***	-3.37	SOCB	1.487***	4.72
JSCB	-0.210***	-5.56	JSCB	0.605***	6.38
CCB	-0.303***	-11.63	CCB	0.485***	3.55
GOVOWN	0.065	1.5	GOVOWN	0.374**	1.99
sigma-squared	1.280		sigma-squared	0.2873	
gamma	0.893		gamma	0.941	

Notes: Because the original results from the Battese and Coelli's (1995) model provide the relation between the determinant factors and cost *inefficiency* scores, we therefore reverse all signs of the estimates parameters with the determinant variables to identify effects of these variables on cost *efficiency*; ***, ** and * indicate the 1%, 5% and 10% significance levels, respectively.