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Persistent and transient inefficiency: Explaining the low efficiency of Chinese big banks[1]

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ABSTRACT

A vast literature shows that China's five largest state-owned banks (the Big Five) suffer from low cost efficiency. We offer a new explanation of this situation, by decomposing overall efficiency of Chinese banks into two parts: persistent and transient efficiency. Using the model of Kumbhakar, Lien, and Hardaker (2014) based on the stochastic frontier approach, we measure persistent and transient efficiency for a large sample of 166 Chinese banks over the period 2008–2015. We show that the lower efficiency of China's Big Five banks is almost entirely due to low persistent cost efficiency, indicating structural problems. On the contrary, the Big Five banks transient efficiency is similar to other Chinese banks, reflecting a good aptitude to minimize their costs in the short-term. Our findings support the view that major structural reforms are needed to enhance the efficiency of China's Big Five banks.

1. Introduction

The Chinese financial system is primarily based on banks, so the efficiency of its banks has substantial implications for the overall efficiency of the financial system. The cost efficiency of banks is a measure of the ability of banks to produce a certain level of output at a minimal cost. The lower the cost, the greater the efficiency. Higher efficiency, in turn, is associated with better managerial performance and allows banks to compete through lower loan rates. Greater cost efficiency of banks also enhances financial stability (Berger & DeYoung, 1997; Podpiera & Weill, 2008) and promotes economic growth (Hasan, Koetter, & Wedow, 2009; Lucchetti, Papi, & Zazzaro, 2001).

The consensus of the widely-studied topic of cost efficiency of Chinese banks is that the overall efficiency of the banking sector is

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still low compared to international standards (Allen, Gu, & Qian, 2017) and especially the five largest state-owned banks (the Big Five[2]) suffer from low efficiency (Berger, Hasan, & Zhou, 2009: Fungáčová, Pessarossi, & Weill, 2013). Given that the Big Five account for about 40% of Chinese banking system assets, their low efficiency potentially threatens the country's financial development and financial stability. Specific policy measures that might help raise efficiency include reducing the market share of the Big Five banks and making significant changes in governance practices.

However, the literature falls short of identifying the factors that explain this low efficiency. This gap is essentially due to a methodological limitation. Former studies are only considering the overall efficiency of Chinese banks and do not decompose it into persistent and transient component (long-term and short-term inefficiency). This distinction seems to be instrumental for understanding the Chinese banking sector. Persistent inefficiency accounts for the presence of structural problems in the bank, which include poor organization, weak management or political incentives preventing cost minimization. Transient inefficiency is related to time-varying issues such as the adaptation to changes in the economic environment.

This distinction does reflect a common hypothesis concerning the explanation of the low efficiency of China's Big Five banks compared to other types of banks, such as foreign banks and joint-stock banks. Big Five banks would be *structurally* inefficient compared to other types of banks. Such an assumption entails critical policy measures, such as reducing state ownership, shrinking banks' size, reorganizing their structure, and creating profit-oriented incentives for management. If low Big Five banks' efficiency does *not* stem from structural reasons, different policy measures would be required to ensure that these banks are efficient in the short-run. Short-term adjustments such as changes in the inputs prices or temporary policy support would then be more adequate than structural transformations.

Identifying the sources of Big Five banks' inefficiency is vital for selecting the appropriate policy measures. Recent progress in efficiency methodology allows identifying the relative proportion of long-term and short-term inefficiency within the overall efficiency of banks. The objective of this study is to draw upon this novel technique to provide a new perspective on explaining the different level of efficiencies among Chinese banks. We test the hypothesis of different long-term and short-term efficiency of Chinese banks by providing a decomposition of their efficiency into its transient and persistent components. Making this distinction is instrumental for understanding the Chinese banking sector and designing appropriate policy measures.

We measure the persistent inefficiency and transient inefficiency of Chinese banks by applying the model of Kumbhakar, Lien, and Hardaker (2014) and thus contribute to the burgeoning literature accounting for this distinction. Their approach takes advantage of the nature of panel data to decompose overall efficiency into persistent and transient components. It relies on a three-step procedure that estimates a cost function with panel data and applies the stochastic frontier approach to isolate persistent and transient inefficiency components. The model provides a major improvement to traditional stochastic frontier models in the literature on bank efficiency. Former models based on the stochastic frontier approach view inefficiency either as time-invariant (Berger, 1993; Schmidt & Sickles, 1984), time-invariant mixed with firm variables (Battese & Coelli, 1992, 1995) or transient only (Greene, 2005). The model of Kumbhakar et al. (2014) allows us to estimate and disentangle persistent efficiency and transient efficiency.[3]

Filippini and Greene (2016) find that this approach provides new and more precise estimates. The persistent efficiency estimate provides a new measure of efficiency which is not related to the estimate provided by the approach of Battese and Coelli (1995). The estimate of the transient inefficiency, while more closely related to the one obtained using the approach of Greene (2005), provides useful additional information on short-term inefficiency.

We consider a large and unique dataset of 166 banks for the period 2008–2015, including the Big Five banks, joint-stock commercial banks, city commercial banks, rural banks and foreign banks. We hand-collect data from banks annual reports to extend the coverage of our dataset. We rely on the panel nature of our dataset to examine the roots of Chinese banks inefficiency and assess whether lower efficiency for the Big Five banks is observed for both persistent and transient components.

Our paper contributes to the analysis of the efficiency of Chinese banks. Our results help better understand the gap in efficiency of the Big Five banks and demonstrate the application of the stochastic frontier model in separating persistent bank efficiency from transient bank efficiency. In terms of methodology, this paper also complements the recent work of Badunenko and Kumbakhar (2017) on disentangling persistent and transient efficiency in the Indian banking industry.

The rest of the article is structured as follows. Section 2 provides the overview of the Chinese banking sector and reviews the related literature. Section 3 presents the data and methodology. Section 4 displays the main estimations. Section 5 provides robustness checks and Section 6 concludes.

2. Related literature

This section provides a description of the Chinese banking industry and reviews the main literature on the efficiency of Chinese banks.

[2] The Big Five banks are the following banks: Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, China Construction Bank and Bank of Communications. Under the China Banking Regulatory Commission (CBRC) classification these banks constitute a separate group entitled large commercial banks.

[3] Two recent papers provide alternative ways to estimate the model. Tsionas and Kumbhakar (2014) use a Bayesian approach. Filippini and Greene (2016) utilize a maximum simulated likelihood approach.

2.1. Chinese banking industry

The Chinese government has gradually reformed the banking sector over recent decades, a transformation that reflects trends for the Chinese economy as a whole. Prior to the launch of reforms in 1978, the People's Bank of China (PBC) was the sole bank in China performing both central bank and commercial bank functions. Major Chinese banks today are publicly listed and rank among the world's largest banks. Banking sector assets more than tripled between 2008 and 2016. They account for over 310% of GDP,[4] making the Chinese banking system one of the world's largest (IMF, 2017). Bank loans still serve as the main source of external financing for Chinese firms. According to the World Bank data, domestic credit to private sector by banks represents 157% of Chinese GDP in 2016, compared with 97% in France, 77% in Germany and 53% in the United States.

Several reforms profoundly reshaped the banking industry. The first reform of consequence was the creation of a two-tier banking system. The PBC retained its central bank functions and transferred its commercial operations to four specialized state-owned banks: Agricultural Bank of China (ABC), the Bank of China (BoC), the People's Construction Bank of China (which changed its name in 1996 to China Construction Bank, or CCB), and the Industrial and Commercial Bank of China (ICBC). They were allowed to accept deposits and grant loans and started to function as financial intermediaries in the mid-1980s. Together with the Bank of Communications (BOCOM), these banks today constitute the Big Five.

The second phase of reforms started in 1994. In response to the accelerating asset quality deterioration of large state-owned banks and separate policy lending from commercial lending, the government created three policy banks. In 1998, the first round of state-bank recapitalization was implemented to deal with non-performing loans. Transfer of non-performing loans to asset management companies commenced within a year, and the government put in place reforms to stimulate competition among banks. This led to the creation of new bank formats such as national-level joint-stock commercial banks, city credit cooperatives and city cooperative banks. China acceded to the WTO in 2001, committing to opening its banking system to foreign banks over the next five years.

The third stage of reform focused on developing governing structures and strengthening the balance sheets of the mammoth state-owned banks. Four largest banks were gradually transferred into joint-stock companies to prepare them for a series of initial public offerings. The first IPO took place in 2006, the fourth and final one (ABC) was completed in 2010.

The revamping of the banking sector was accompanied by a gradual liberalization of the financial system. Interest rate deregulation began with liberalization of lending rates in 2013. China removed the interest rate ceiling on deposits of less than one year in October 2015. These changes seem to have improved credit pricing and increased the share of loans well above or below the benchmark rate (OECD, 2017).[5] China also rolled out a deposit insurance scheme in May 2015. In a pull-back from the trend to market-based mechanisms, the PBC introduced selective liquidity support and reined in the scope of measures to liberalize the financial system (OECD, 2017).

Despite general success at reforms and the entry of foreign investors, China's banking sector remains largely in the hands of the state. The state authorities involved depend on the type of bank. The China Banking Regulatory Commission (CBRC) classifies banks into several groups based on ownership structure. The first group is the Big Five banks. These are the largest state-owned banks that have been transferred into joint-stock companies and publicly listed in the last decade. In addition to having the state as majority owner, they all have private and foreign minority owners. These banks provide nationwide wholesale and retail services and have a strong focus on funding state-owned enterprises. According to the CBRC, the big state-owned banks held 39% of all commercial banking system assets in 2015. Despite the continuous growth in their assets, their share in the banking sector is gradually decreasing, spiking at 57% in 2004. The decrease is mainly due to other banks and non-bank institutions that have entered lending and credit market (Allen, Qian, & Qian, 2018).

The second group of banks consists of joint-stock commercial banks. These also operate nationwide, and are usually mid-sized banks with mixed ownership. The central government or a municipal government rarely act as direct owners of such banks. These are relatively new banks, with the first ones established in the early 2000s. Joint stock banks largely operate typical commercial banking business and target an SME customer base. These banks accounted for 19% of Chinese banking sector assets at the end of 2015, an increase of 7% from 2004.

The third group, “small-size” banks operating regionally or locally, includes city commercial banks, rural commercial banks and small local banks (e.g. rural cooperative banks, rural credit cooperatives, and village and township banks). City commercial banks are a product of shareholding reform of former urban credit cooperatives. Before 2006, a city commercial bank could only operate in the city where it was headquartered. Originally created to carry out local government lending operations, some of these banks are still owned by local governments. These banks are instrumental in funding small and medium-sized enterprises. Their share in the banking sector has doubled within ten years, reaching 11% at the end of 2015. Rural banks mainly target the rural population and usually operate within a small township or village.

The fourth group, foreign banks, does not account for a significant part of the banking sector assets. Their share has not changed significantly during the last decade and it stood at about 1% in 2015.

2.2. Efficiency in Chinese banking

Several studies investigate the efficiency of Chinese banks. Chen, Skully, and Brown (2005) investigate the impact of the 1995

[4] The corresponding number for advanced economies is about 283% and emerging ones 95%.

[5] Pricing below the benchmark rate could just indicate favorable bank lending to SOEs.

bank deregulation on the cost efficiency of Chinese banks. Estimating the cost efficiency of 43 Chinese banks over the period 1993–2000 with nonparametric data envelopment analysis (DEA), they find that large state-owned banks and small joint-stock commercial banks are more efficient than medium-sized joint-stock commercial banks. The mean yearly cost efficiency scores for the whole sample range from 42.6% to 58.2%.

Fu and Heffernan (2007) estimate the cost efficiency of Chinese banks over the period 1985–2002, employing the stochastic frontier analysis (SFA). Their sample contains 14 banks (four state-owned banks and ten joint-stock commercial banks). They show that joint-stock commercial banks are more efficient than state-owned banks. The mean efficiency scores range between 40% and 52%, depending on the distributional assumptions.

Ariff and Can (2008) extend the analysis of the efficiency of Chinese banks to profit efficiency. They measure cost efficiency and profit efficiency of 28 Chinese commercial banks over the period 1995–2004 with DEA. They estimate the mean cost efficiency of Chinese banks at 79.8%, significantly higher than mean profit efficiency which ranges between 43.9% and 50.5%, depending on the profit frontier specification. They also find a better cost and profit efficiency for joint-stock commercial banks than for state-owned banks.

Berger et al. (2009) study how ownership influences bank efficiency in China. Employing the stochastic frontier approach, they estimate cost and profit efficiency on a sample of 38 banks over the period 1994–2003. Their key conclusions are that the Big Four state-owned banks are the least efficient banks in China and foreign banks the most efficient. Their result stands for both cost efficiency and profit efficiency. The mean efficiency scores for the whole sample are 89.7% for cost efficiency and 47.6% for profit efficiency.

Asmild and Matthews (2012) apply non-parametric multi-directional envelopment analysis to compare the efficiency of four state-owned banks and ten joint-stock banks over the period 1997–2008. Their methodology reveals “efficiency patterns” that suggest joint-stock banks are more efficient than state-owned banks. The two types of banks do not appear to convergence over time.

Fungáčová et al. (2013) investigate the relationship between bank competition and cost efficiency on a sample of 76 Chinese banks (including the Big Five banks, joint-stock commercial banks, city commercial banks, foreign banks and a few other banks) over the period 2002–2011. They utilize the stochastic frontier approach to measure cost efficiency scores. While observing an average efficiency score of 74.6% over the period for all Chinese banks, they find the Big Five banks to be the least efficient and foreign banks most efficient. In addition, they find no significant relation between bank competition and cost efficiency in China.

Dong, Firth, Hou, and Yang (2016) study cost and profit efficiency of Chinese banks between 2002 and 2013. They use the stochastic frontier model of Battese and Coelli (1995) and gather a sample of 142 banks including the Big Five banks, joint-stock commercial banks, city commercial banks, and foreign banks. They extend the analysis of Berger et al. (2009) to a greater sample and employ more recent data. They obtain mean efficiency scores of 69.7% for cost efficiency and 68.5% for profit efficiency. They also find that the Big Five banks are the least cost efficient banks and foreign banks most efficient. While the cost efficiency of the Big Five banks is significantly and persistently lower than the efficiency of all other groups, the highest profit efficiency is registered by the Big Five banks and joint-stock commercial banks. The authors point out an improvement in the profit and the cost efficiency for Chinese banks over the study period.

To sum up, the literature on bank efficiency in China shows that ownership exerts an impact on bank efficiency, with a consensual view that the Big Five banks are less cost efficient than the other banks. We extend this literature by disentangling persistent efficiency and transient efficiency for our sample of Chinese banks, a sample larger than any dataset employed in earlier studies.

3. Methodology and data

This section lays out the methodology used to calculate the cost efficiency of banks and distinguish persistent inefficiency from transient inefficiency. A data description is included.

3.1. Methodology

The proposed methodology seeks to determine efficiency scores of Chinese banks with a view to disentangling persistent inefficiency from transient inefficiency. While persistent inefficiency is stable over time, transient inefficiency varies over time. Distinguishing persistent from transient inefficiency, sometimes referred to as the *Greene problem*, was long considered out of reach (Greene, 1980). Recent methodological innovations by Kumbhakar et al. (2014), however, provide a solution.

Taking advantage of the nature of panel data, they first construct a mechanism to separate persistent and transient inefficiency, starting with a standard cost function for panel data:

$$\log c_{it} = h(\boldsymbol{y}_{it}, \boldsymbol{w}_{it}; \theta) + a_i + \epsilon_{it}, \tag{1}$$

where $i = 1, \ldots, n$ denotes the i^{th} bank and $t = 1, \ldots, T_i$ denotes the time period in which bank i is observed, c_{it} measures the total cost of the bank i at time t, $\boldsymbol{y}_{it}$ denotes the vector of outputs, $\boldsymbol{w}_{it}$ the vector of input prices and $h(.)$ is the cost function. a_i is the error-term for the bank i over all time periods and ϵ_{it} is the error term for bank i at time t.

Kumbhakar et al. (2014) employ the two error terms of the panel data to distinguish between persistent and transient inefficiency. Using the SFA approach, they divide the time-invariant error-term a_i into two parts: *a random part* that accounts for exogenous events affecting bank's costs (v_{0i}) and *an inefficient part* that reflects the bank's cost inefficiencies (u_{0i}):

$$a_i = v_{0i} + u_{0i} \tag{2}$$

Table 1
Descriptive statistics.
This table provides descriptive statistics of the variables used in the frontier estimation. Total Costs (*tc*) is the sum of personal expenses, interest expenses and other expenses. All variables are in CNY millions.

	All	Mean	Median	Std. Dev.	Min.	Max.
Total costs (*tc*)	974	17,920	2309	59,481	4	476,525
Gross loans (*y1*)	974	389,076	41,082	1,349,610	98	11,900,000
Other earning assets (*y2*)	974	329,216	41,060	1,041,124	163	8,638,760
Personal expenses/assets (*w1*)	974	0.0060	0.0055	0.0027	0.0004	0.0271
Operating expenses/assets (*w2*)	974	1.7158	0.7653	2.7836	0.0007	24.8596
Interests/Total Funding (*w3*)	974	0.0131	0.0130	0.0053	0.0001	0.0514

By definition, u_{0i} is fixed over time and represents the persistent inefficiency of bank *i*. They reproduce this approach and divide the variable error-term ϵ_{it} into a random part, which accounts for exogenous events affecting bank's costs (v_{it}), and an inefficient part (u_{it}):

$$\varepsilon_{it} = v_{it} + u_{it} \tag{3}$$

As u_{it} changes over time, it represents the transient inefficiency, of bank *i*. Overall, the cost function becomes:

$$\log c_{it} = h(\boldsymbol{y}_{it}, \boldsymbol{w}_{it}; \theta) + v_{0i} + u_{0i} + v_{it} + u_{it} \tag{4}$$

The error term now has four components. The first component v_{0i} captures the latent heterogeneity across banks. The second component, u_{0i}, captures the persistent inefficiency of the bank *i*. The third component v_{it} captures the random shocks affecting the bank *i* at each period *t*. The fourth component u_{it} captures the transient inefficiency.

To estimate the cost function (4), we employ the methodological approach developed by Kumbhakar, Wang and Horncastle (2015, p. 275–276).

In this three-step approach, a standard cost function for the panel data is first estimated as in (1). It has a fixed error-term a_i and a variable error-term ϵ_{it}. We employ a translog cost frontier with fixed-effects at the bank level. In line with Fungáčová et al. (2013), we use the intermediation approach for the specification of input prices and outputs. This approach assumes that banks collect deposits and transform them into loans using labor and capital. We consider two outputs, loans (*y1*) and other earning assets *(y2)*. We incorporate three input prices. The first input price is the price of labor (*w1*), which is the ratio of personnel expenses to total assets (*w1*). The second input price is the price of physical capital (*w2*), computed as the ratio of other non-interest expenses to fixed assets. The last input price is the price of borrowed funds (*w3*), defined as the ratio of interest paid to total funding. Homogeneity conditions are achieved by scaling the price of labor and the price of physical capital by the price of borrowed funds. The explained variable is Total Cost (*TC*), which is the sum of personnel expenses, other non-interest expenses, and interest paid. We include dummy variables for the years. We end up with the following translog cost-function:

$$\ln\left(\frac{TC}{w_3}\right) = \beta_0 + \sum_m (\theta_m \ln y_m) + \sum_n \left(\beta_n \ln \frac{w_n}{w_3}\right) + \frac{1}{2}\sum_m \sum_j (\theta_{mj} \ln y_m \ln y_j) + \frac{1}{2}\sum_n \sum_k \left(\beta_{nk} \ln \frac{w_n}{w_3} \ln \frac{w_k}{w_3}\right) + \sum_n \sum_m \left(\gamma_{nm} \ln \frac{w_n}{w_3} \ln y_m\right) + \sum_{i=2008}^{2015} \vartheta_i year_i + a_i + \varepsilon_{it} \tag{5}$$

where $m = 1, 2$ and $j = 1, 2$ denote the outputs and $n = 1, 2, 3$ and $k = 1, 2, 3$ denote the inputs prices. In this specification, a_i captures the bank's fixed effect and ϵ_{it} is the classical random noise. This first step gives the predicted value of a_i and ϵ_{it}, respectively α_i and ε_{it}.

The second step uses the predicted value ε_{it} obtained in (5) to estimate the time-varying inefficiency u_{it}. We assume that v_{it} is a random noise i.i.d with a distribution $N(0, \sigma_v^2)$ and u_{it} follows a distribution $N^+(0, \sigma_u^2)$. We estimate u_{it} in (3) with a standard stochastic-frontier technique. We obtain a prediction of the bank's time-varying inefficiency $\hat{u}_{it}$ using the Jondrow, Lovell, Materov, and Schmidt (1982) procedure. Transient cost efficiency (TCE) is calculated as in Battese and Coelli (1992): $TCE = \exp(\hat{u}_{it} \mid \varepsilon_{it})$.

In the third step, we retrieve the bank's persistent inefficiency. We split the bank's fixed-effect α_i predicted in (5) into two components: the bank's latent heterogeneity v_{0i} and the bank's persistent inefficiency u_{0i}. Again, we assume that v_{0i} is a random noise i.i.d. following a $N(0, \sigma_{v_0}^2)$ distribution and that u_{0i} follows a $N^+(0, \sigma_{u_0}^2)$ distribution. We estimate u_{0i} in (2) using a standard stochastic-frontier technique. We obtain a prediction of the bank's persistent inefficiency $\hat{u}_{0i}$ using the Jondrow et al. (1982) procedure. Persistent cost efficiency (PCE) is calculated as in Battese and Coelli (1992), $PCE = \exp(\hat{u}_{0i})$.

Finally, the overall cost efficiency (OCE) is obtained as the product of the persistent and transient cost efficiency: $OCE = PCE \times TCE$.

We further refine this approach by parametrizing the variance of the inefficiency terms, in steps 2 and 3. We parametrize the variance of the transient and persistent efficiency using dummy variables for each bank type, employing Big Five as the benchmark group. We also employ a set of variables that is likely to affect banks' efficiency in China: *Equity Ratio*, defined as the ratio of equity to assets; *RRR*, defined as the reserve requirement ratio, set by the PBC; *Listed*, which is a dummy variable taking one if the bank is listed; and *HK Listed,* which takes the value of one if the bank is listed in Hong-Kong and zero otherwise.

Table 2
Descriptive statistics by bank type.
This table provides descriptive statistics of the variables depending on the bank type. Total Costs (*tc*) is the sum of personal expenses, interest expenses and other expenses. All variables are in CNY millions.

	N	Mean	Median
The big five banks			
No. of banks	5		
Total costs (*tc*)	40	270,608	255,797
Gross loans (*y1*)	40	6,138,315	6,035,720
Other earning assets (*y2*)	40	4,743,255	5,051,629
Personnel expenses/assets (*w1*)	40	0.0053	0.0054
Operating expenses/assets (*w2*)	40	0.4750	0.4435
Interests/total funding (*w3*)	40	0.0130	0.0134
Joint-stock commercial banks			
No. of banks	12		
Total costs (*tc*)	92	43,420	36,807
Gross loans (*y1*)	92	918,876	784,837
Other earning assets (*y2*)	92	839,852	631,380
Personnel expenses/assets (*w1*)	92	0.0049	0.0049
Operating expenses/assets (*w2*)	92	0.9502	0.8469
Interests/total funding (*w3*)	92	0.0136	0.0129
City commercial banks			
No. of banks	83		
Total costs (*tc*)	502	3480	2114
Gross loans (*y1*)	502	65,194	35,992
Other earning assets (*y2*)	502	75,668	40,473
Personnel expenses/assets (*w1*)	502	0.0052	0.0050
Operating expenses/assets (*w2*)	502	0.9196	0.6224
Interests/total funding (*w3*)	502	0.0134	0.0130
Rural commercial banks			
No. of banks	26		
Total costs (*tc*)	123	4409	2486
Gross loans (*y1*)	123	82,166	55,781
Other earning assets (*y2*)	123	79,825	39,267
Personnel expenses/assets (*w1*)	123	0.0061	0.0059
Operating expenses/assets (*w2*)	123	0.7199	0.5068
Interests/total funding (*w3*)	123	0.0145	0.0140
Foreign banks			
No. of banks	40		
Total costs (*tc*)	217	1594	882
Gross loans (*y1*)	217	27,913	13,526
Other earning assets (*y2*)	217	26,986	13,445
Personnel expenses/assets (*w1*)	217	0.0083	0.0073
Operating expenses/assets (*w2*)	217	4.6753	3.4375
Interests/total funding (*w3*)	217	0.0115	0.0110

3.2. Data

Our analysis employs a unique dataset containing a total of 974 observations of 166 banks, covering the period 2008–2015. We use hand-collected data from the annual reports of the relevant bank websites to supplement yearly bank-level financial statement data of Chinese banks from BankScope database. Our sample encompasses the majority of the Chinese banking sector's assets. We omit earlier time periods as data are only available for a limited number of banks. To put our dataset into perspective; Berger et al. (2009) use a 38-bank sample in their efficiency analysis, and Dong et al. (2016) a 142-bank sample in their investigation of cost and profit efficiency.

The banks in our sample are divided into five categories based on ownership structure: the Big Five banks, joint-stock commercial banks (JSCB), city commercial banks (CCB), rural commercial banks (RCB) and foreign banks. This division follows the CBRC classifications. The descriptive statistics of the main variables used in the analysis are provided in Tables 1 and 2.

We observe that the price of physical capital is much higher for foreign banks than for the other banks. This can be explained by the fact that the foreign banks have a small market share all around the country and their customers are mainly foreign companies. As such they do not have a large network of branches and therefore have lower fixed assets on average than the other banks. In addition they are mainly located in very large cities associated with higher operating costs for the offices. Our finding of higher price of physical capital accords with Dong et al. (2016) who report the mean price of physical capital for big banks, medium banks, and small banks, the latter category combining foreign banks and city commercial banks, and observe a much higher mean price for the latter category of banks.

Table 3
Cost frontier.

Panel translog cost frontier with fixed-effects at the bank-level. Definition of the variables is provided in the methodological section. We follow the approach of Kumbhakar et al. (2014) and divide the efficiency into persistent and transient parts. Time dummy variables are included but not reported. *, ** and *** denote an estimate significantly different from 0 at the 10%, 5% and 1% level, respectively.

	log(tc/w3)
log(y1)	0.554***
	(3.63)
$\log(y1)^2$	0.189***
	(11.08)
log(y2)	0.316***
	(3.47)
$\log(y2)^2$	0.154***
	(9.35)
log(y1) × log(y2)	−0.167***
	(−9.97)
log(w1/w3)	0.306
	(1.41)
$0.5 \times \log(w1/w3)^2$	0.246***
	(8.98)
log(w2/w3)	−0.026
	(−0.22)
$0.5 \times \log(w2/w3)^2$	0.022**
	(2.59)
0.5 × log(w1/w3) × log(w2/w3)	−0.002
	(−0.04)
log(y1) × log(w1/w3)	0.046***
	(2.66)
log(y1) × log(w2/w3)	−0.016
	(−0.89)
log(y2) × log(w1/w3)	−0.026
	(−1.60)
log(y2) × log(w2/w3)	0.021*
	(1.72)
Constant	2.328**
	(2.57)
Transient error component	
usigmas	
Constant	−4.723***
	(−22.34)
Persistent error component	
usigmas	
Constant	−4.755***
	(−6.31)
N	974
No. of groups	166
F	439.39***
R^2 within	0.95
Residuals skewness	0.43***

4. Results

This section presents our results. We start with our main estimation of the cost function and present the transient and persistent efficiency across for different types of banks over time. We then move to the marginal effects analysis of the parametrized cost function.

4.1. Main results

This section presents our main results. Table 3 provides the estimated coefficients for the cost frontier. We display the mean efficiency scores per year and per type of banks in Table 4. We report overall, transient and persistent efficiency scores.

Regarding the efficiency of the full sample, the average overall efficiency score is 86.49%. This score is higher than what has been found in most of the previous studies. Fungáčová et al. (2013) obtain an average score of 74.6% and Dong et al. (2016) find an average score of 69.7%. Notably, it is lower than the mean efficiency score of 89.7% reported by Berger et al. (2009).

Delving into the different components of the overall efficiency, we observe that the transient efficiency and the persistent

Table 4
Efficiency measures.

This table provides the efficiency scores of the banks over the years and depending on the bank type. We follow Kumbhakar et al. (2014) and divide efficiency into persistent and transient parts.

Years	All			Big 5		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	86.44%	92.82%	93.13%	84.09%	91.05%	92.36%
2009	86.66%	93.08%	93.09%	85.87%	92.97%	92.36%
2010	86.61%	93.09%	93.04%	86.94%	94.13%	92.36%
2011	86.58%	93.08%	93.02%	84.95%	91.97%	92.36%
2012	86.36%	92.88%	92.94%	86.50%	93.66%	92.36%
2013	86.32%	92.85%	92.94%	87.25%	94.47%	92.36%
2014	86.53%	93.06%	92.99%	86.89%	94.08%	92.36%
2015	86.49%	93.00%	93.01%	86.60%	93.76%	92.36%
Total	86.49%	92.98%	93.01%	86.14%	93.26%	92.36%
	Joint-Stock			Foreign		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	87.00%	93.45%	93.11%	88.20%	92.96%	94.87%
2009	87.42%	93.89%	93.11%	88.83%	93.47%	95.03%
2010	87.69%	94.18%	93.11%	88.06%	92.87%	94.81%
2011	87.11%	93.70%	92.97%	87.84%	92.75%	94.71%
2012	86.48%	93.02%	92.97%	87.94%	92.83%	94.72%
2013	86.94%	93.52%	92.96%	87.69%	92.53%	94.78%
2014	86.23%	92.75%	92.97%	88.07%	92.87%	94.83%
2015	85.60%	92.08%	92.97%	88.89%	93.70%	94.87%
Total	**86.79%**	**93.30%**	**93.02%**	**88.17%**	**92.99%**	**94.82%**
	CCB			RCB		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	86.12%	93.15%	92.47%	84.33%	90.48%	93.20%
2009	86.01%	93.02%	92.45%	85.19%	91.42%	93.17%
2010	85.73%	92.85%	92.33%	86.77%	93.21%	93.09%
2011	85.87%	93.10%	92.24%	87.28%	93.71%	93.14%
2012	85.87%	93.10%	92.22%	85.13%	91.86%	92.44%
2013	85.61%	92.74%	92.30%	86.26%	92.93%	92.71%
2014	85.85%	92.97%	92.34%	86.74%	93.54%	92.76%
2015	85.53%	92.64%	92.33%	86.64%	93.46%	92.74%
Total	**85.81%**	**92.93%**	**92.33%**	**86.21%**	**92.84%**	**92.82%**

Table 5
Differences in overall efficiency.

This table provides the difference in the overall efficiency scores of the Big 5 banks over the years. Student's test is used to determine significance. *, **, and *** denote significant difference at the 10%, 5%, and 1% level, respectively.

	Big5 – Joint-stock	Big5 – CCB	Big5 – RCB	Big5 – Foreign	Big5 – All	JSCB – (Big5, CCB and RCB)
2008	−0.0291***	−0.0203	−0.0024	−0.0411**	−0.0247	0.0126
	(−5.51)	(−1.24)	(−0.15)	(−2.48)	(−1.55)	(1.17)
2009	−0.0155**	−0.0014	0.0068	−0.0296**	−0.0083	0.0151*
	(−2.82)	(−0.12)	(0.54)	(−2.37)	(−0.67)	(1.99)
2010	−0.0076	0.0121	0.0016	−0.0112	0.0034	0.0172**
	(−1.35)	(1.14)	(0.14)	(−0.76)	(0.29)	(2.4)
2011	−0.0216*	−0.0092	−0.0233*	−0.0289**	−0.017	0.011
	(−1.98)	(−0.71)	(−2.11)	(−2.79)	(−1.48)	(1.38)
2012	0.0002	0.0063	0.0137	−0.0144	0.0015	0.0072
	(0.03)	(0.36)	(0.32)	(−1.24)	(0.07)	(0.47)
2013	0.0032	0.0165	0.0099	−0.0044	0.0097	0.011
	(0.46)	(0.95)	(0.35)	(−0.25)	(0.51)	(0.83)
2014	0.0066	0.0105	0.0016	−0.0118	0.0037	0.0013
	(0.68)	(0.94)	(0.16)	(−0.96)	(0.32)	(0.18)
2015	0.01	0.0108	−0.0004	−0.0229**	0.0012	−0.0025
	(1.24)	(0.96)	(−0.04)	(−2.24)	(0.1)	(−0.35)
Total	**−0.0065****	**0.0033**	**−0.0007**	**−0.0203*****	**−0.0037**	**0.0089****
	(−2.22)	**(0.67)**	**(−0.1)**	**(−4.35)**	**(−0.71)**	**(2.52)**

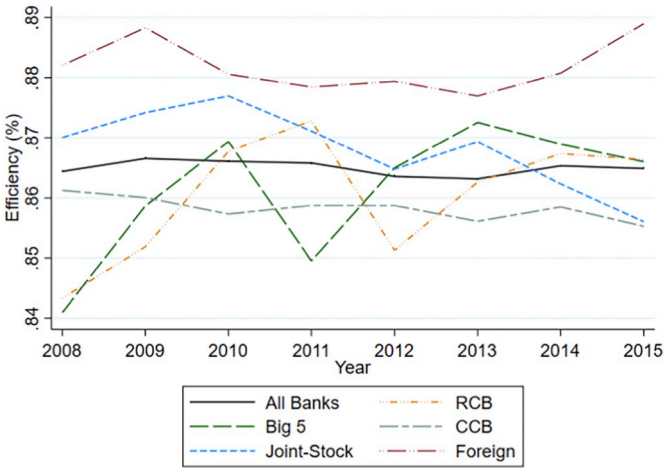

Figure 1. Mean overall efficiency scores of Chinese banks by ownership type.

efficiency reach very similar levels, with means over the period of 92.98% and 93.01%, respectively. The overall conclusion for Chinese banks must be that on average they suffer as much from persistent inefficiency as from transient inefficiency.

Third, the evolution of transient efficiency over time does not show high volatility. Yearly mean scores for transient efficiency range between 92.82% and 93.09%. In addition, there is no clear trend for transient efficiency since there is no gradual rise or fall over the period. The same holds true when looking at the persistent efficiency of all banks, for which changes only stem from changes in the sample of banks. As a result, the overall efficiency of Chinese banks turns out to be quite stable over the period.

Table 4 also reports the efficiency of banks depending on ownership type. We can draw several conclusions on the efficiency of the Big Five banks. The Big Five banks have lower overall efficiency than most other types of banks. While the Big Five banks have an average overall efficiency of 86.14%, average overall efficiency is 86.21% for the rural commercial banks, 86.79% for the joint-stock commercial banks and 88.17% for foreign banks.

We calculate the differences in the overall efficiency scores between the Big Five banks and the other types of banks and test their significance in Table 5. Fig. 1 draws the mean overall efficiency per group and over years. The overall efficiency is significantly lower for the Big Five banks in comparison with that for joint-stock commercial banks and foreign banks. Only city commercial banks, with an average overall efficiency of 85.81%, are less efficient than the Big Five banks (although the difference is not statistically significant). We also test to see if the efficiency of the joint-stock commercial banks differs from the other domestic banks (the Big Five banks, CCB and RCB). Joint-stock commercial banks exhibit a higher efficiency than the other domestic banks. This may suggest that direct state ownership in China in these other banks might hamper bank efficiency.

The comparison of the overall efficiency across the different types of banks confirms the general conclusion that the Big Five banks exhibit a lower cost efficiency than other types of banks. In line with the previous studies of Berger et al. (2009), Fungáčová et al. (2013) and Dong et al. (2016), we find that the Big Five banks are less efficient than the joint-stock commercial banks and the foreign banks.[6] Our results differ slightly from the previous literature when comparing the efficiency of the Big Five banks and city commercial banks; we conclude higher efficiency for the Big Five banks, while Fungáčová et al. (2013) and Dong et al. (2016) find the opposite. However, time periods and bank samples of these studies differ from the present study. They use a lower number of observations for city commercial banks, which may explain differences in conclusions. Overall, since we use more recent and comprehensive data than the former studies, our findings tend to confirm the persistence of low efficiency for the Big Five banks.

We now turn to our key question: Does the low efficiency of the Big Five banks mainly stem from persistent inefficiency or from transient inefficiency? We find that persistent inefficiency slightly dominates transient inefficiency for the Big Five banks. Mean persistent efficiency is 92.36% and mean transient efficiency 93.26%. The low overall efficiency of the Big Five banks results more from persistent than from transient inefficiency.

This result is supported by the analysis of the differences in transient efficiency and in persistent efficiency between the Big Five banks and the other types of banks. We report the differences in transient and persistent inefficiency and test their significance in Tables 6 and 7, respectively. Figs. 2 and 3 draw the mean transient and persistent efficiency respectively, per group and over years. Over the period, the Big Five banks do not have significantly lower transient efficiency than any other type of banks. However, they have significantly lower persistent efficiency than the joint-stock commercial banks and the foreign banks. Hence, the weak performance of the Big Five banks in cost efficiency relative to the other types of banks comes from a lower persistent efficiency. Low persistent efficiency indicates the presence of structural problems in these banks. Our results support the view that major changes should be implemented to enhance the efficiency of the large state-owned banks. On the opposite, the Big Five banks are as efficient as the other banks in term of transient efficiency. This indicates that they are able to efficiently adjust their costs to the market

[6] Berger et al. (2009) consider a group of Big Four banks.

Table 6
Differences in transient efficiency.
This table provides the difference in the transient efficiency scores of the Big 5 banks over the years. Student's test is used to determine significance. *, ** and *** denote significant difference at the 10%, 5% and 1% level, respectively.

	Big5 – Joint-Stock	Big5 – CCB	Big5 – RCB	Big5 – Foreign	Big5 – All	JSCB – (Big5, CCB and RCB)
2008	−0.024***	−0.021	0.0057	−0.0191	−0.0186	0.0079
	(−3.46)	(−1.22)	(0.34)	(−1.2)	(−1.17)	(0.69)
2009	−0.0091*	−0.0005	0.0155	−0.005	−0.0011	0.0104
	(−1.9)	(−0.05)	(1.34)	(−0.42)	(−0.11)	(1.54)
2010	−0.0005	0.0128	0.0092	0.0126	0.0109	0.0119*
	(−0.16)	(1.43)	(0.97)	(0.88)	(1.09)	(2)
2011	−0.0173*	−0.0113	−0.0174	−0.0078	−0.0116	0.0058
	(−1.83)	(−1)	(−1.64)	(−0.73)	(−1.18)	(0.86)
2012	0.0064*	0.0055	0.0179	0.0082	0.0081	0.0014
	(2.14)	(0.34)	(0.48)	(0.74)	(0.44)	(0.1)
2013	0.0095**	0.0174	0.0154	0.0194	0.0168	0.0065
	(3.11)	(1.1)	(0.77)	(1.02)	(1.03)	(0.59)
2014	0.0133*	0.0112	0.0055	0.0121	0.0106	−0.004
	(1.83)	(1.24)	(0.6)	(0.98)	(1.1)	(−0.68)
2015	0.0168**	0.0113	0.0031	0.0006	0.008	−0.0081
	(2.21)	(1.04)	(0.38)	(0.06)	(0.79)	(−1.22)
Total	**−0.0004**	**0.0033**	**0.0043**	**0.0027**	**0.0029**	**0.0037**
	(−0.17)	**(0.73)**	**(0.66)**	**(0.58)**	**(0.64)**	**(1.17)**

Table 7
Differences in persistent efficiency.
This table provides the evolving differences in the persistent efficiency scores of the Big 5 banks over the years. Student's test is used to determine significance. *, ** and *** denote significant difference at the 10%, 5% and 1% level, respectively.

	Big5 – Joint-Stock	Big5 – CCB	Big5 – RCB	Big5 – Foreign	Big5 – All	JSCB – (Big5, CCB and RCB)
2008	−0.0075	−0.0011	−0.0084*	−0.0251***	−0.0081	0.0056
	(−1.44)	(−0.14)	(−1.85)	(−6.69)	(−1.07)	(1.16)
2009	−0.0075	−0.0009	−0.0081	−0.0267***	−0.0077	0.0059
	(−1.44)	(−0.13)	(−1.73)	(−6.54)	(−1.01)	(1.26)
2010	−0.0075	0.0003	−0.0073	−0.0245***	−0.0071	0.0067
	(−1.44)	(0.04)	(−1.45)	(−5.6)	(−0.95)	(1.45)
2011	−0.0061	0.0012	−0.0078	−0.0235***	−0.0068	0.0059
	(−1.11)	(0.15)	(−1.59)	(−5.1)	(−0.84)	(1.18)
2012	−0.0061	0.0014	−0.0008	−0.0236***	−0.006	0.0069
	(−1.11)	(0.17)	(−0.05)	(−5.07)	(−0.65)	(1.14)
2013	−0.006	0.0006	−0.0035	−0.0242***	−0.0061	0.0056
	(−1.04)	(0.08)	(−0.28)	(−5.22)	(−0.68)	(0.95)
2014	−0.0061	0.0002	−0.004	−0.0247***	−0.0065	0.0053
	(−1.11)	(0.02)	(−0.33)	(−6.18)	(−0.74)	(0.94)
2015	−0.0061	0.0003	−0.0038	−0.0251***	−0.0067	0.0054
	(−1.11)	(0.04)	(−0.31)	(−6.44)	(−0.77)	(0.97)
Total	**−0.0066*****	**0.0003**	**−0.0046**	**−0.0246*****	**−0.0068****	**0.0059*****
	(−3.63)	**(0.11)**	**(−1.24)**	**(−16.62)**	**(−2.3)**	**(3.14)**

conditions. Hence, our results support the need of structural reforms of the Big Five banks but do not highlight the need for specific short-term reforms.

The analysis of the yearly transient efficiency scores uncovers that the time series of the transient efficiency is particularly volatile for the Big Five banks. The mean transient efficiency score evolves between 91.05% and 94.47%. It is much more volatile than for the other types of banks.[7] This volatility of short-term inefficiency also results in more volatile overall efficiency. This result suggests that the Big Five banks are particularly reactive to short-term events related to e.g. window guidance.

The only group of banks with higher persistent than transient efficiency are the foreign banks. All other bank types are more hampered by persistent inefficiency than by transient inefficiency, following the same pattern as the Big Five banks. In line with the results for the overall efficiency, the persistent efficiency of the joint-stock commercial banks is significantly higher than that of the other domestic banks. This supports the view that the influence of the state on the other domestic banks may exert a negative impact on the persistent efficiency.

In a nutshell, we find that the Big Five banks are less efficient than joint-stock commercial banks and foreign banks. This lower

[7] The time-series standard deviation of the transient mean efficiency of the Big Five banks is 1.13%, while it is 0.11% for the mean of the whole sample.

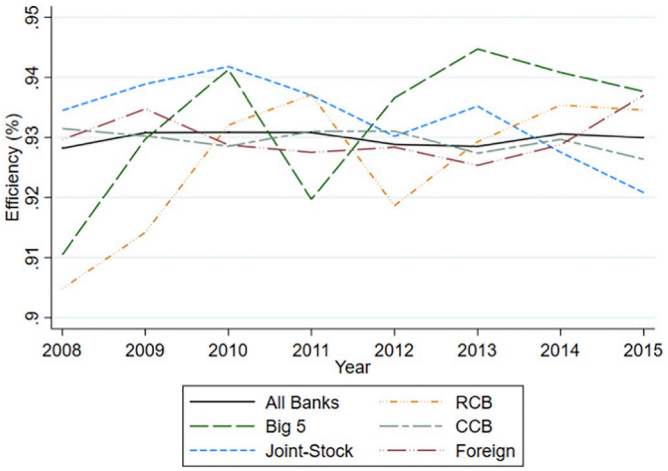

Figure 2. Mean transient efficiency scores of Chinese banks by ownership type.

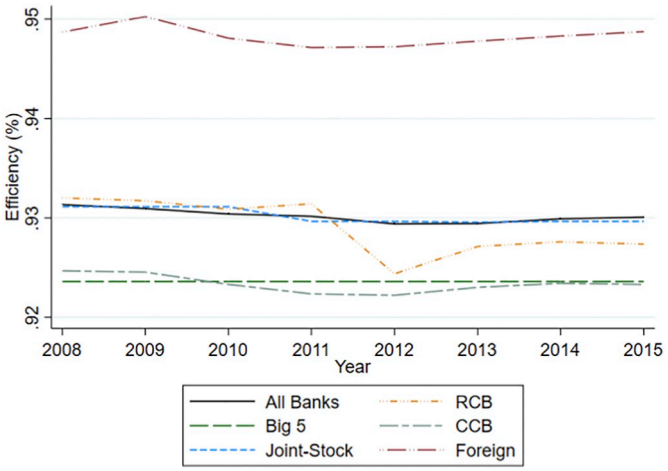

Figure 3. Mean persistent efficiency scores of Chinese banks by ownership type.

efficiency mainly stems from low persistent efficiency, suggesting that structural changes have to be implemented to improve the efficiency of the Big Five banks. In addition, transient efficiency is particularly volatile for the Big Five banks, which tend to react more to short-term shocks.

4.2. Marginal effects

We now turn to the parametrization of the cost function and the associated marginal effects on banks' efficiency. Table 8 presents the estimations of the parametrized error terms, with Big Five as the omitted group. As these estimates are not readily interpretable, we compute the marginal effects of each variable on the unconditional transient and persistent efficiency, following the approach laid out in Kumbhakar et al. (2014). Table 9 presents the results. We report the marginal effect of parameters on both the mean and the variance of the inefficiency components. A negative sign of the margin indicates a reduction in cost inefficiency. We obtain estimates of the standard errors using a bootstrapping approach: we calculate 1000 iterations of the parametrized cost function and derive the corresponding distribution of the marginal effect.

We first turn to the marginal effect of the parameters concerning the transient inefficiency. Following our main results, we do not observe any difference in the effect of the different bank types on transient efficiency, compared with Big Five banks. This is the case for both the mean and the variance of the transient inefficiency term. This confirms the view that Big Five banks do not suffer from a higher transient inefficiency. We also do not observe any significant effect of the equity ratio, the reserve requirement ratio, listing in general, or listing in Hong-Kong. This supports the view that short-term inefficiency essentially stems from the ability of banks to adapt to their environment in the short-term. Regulatory requirements as well as structural changes that can originate from the listing of the company in the domestic or foreign markets do not seem to exert any significant impact.

We now consider the marginal effects of the parameters on the persistent inefficiency of Chinese banks. Confirming our main results, we observe that there is a negative marginal impact on persistent inefficiency for foreign and joint-stock banks. Compared

Table 8
Parametrization of the inefficiency terms.

Panel translog cost frontier with fixed-effects at the bank-level. We only report the parametrization parameters and use the same specification of the cost function as in Table 3. In the parametrization of the variance, *Big Five* is the omitted group. Definitions of the variables are provided in the methodological section. *, ** and *** denote an estimate significantly different from 0 at the 10%, 5% and 1% level, respectively.

	Transient error variance	*Persistent error variance*
Foreign	0.533	−50.934
	(0.78)	(−0.00)
Joint-stock	−0.035	−0.993**
	(−0.05)	(−2.28)
RCB	1.103	−0.448
	(1.59)	(−0.94)
CCB	0.546	−0.299
	(0.84)	(−0.67)
Equity ratio	−0.615	−11.008***
	(−0.39)	(−2.93)
RRR	0.063	0.058
	(1.16)	(1.35)
Listed	−0.471	−0.124
	(−1.15)	(−0.43)
HK listed	0.270	−0.637*
	(0.66)	(−1.66)
Constant	−6.275***	−3.096***
	(−5.00)	(−3.43)
N	969	969
No. of groups	165	165
Log-likelihood	772.79	578.44
Chi^2	87.96***	346.04***

Table 9
Marginal effects.

This table displays the marginal effects of the parametrized cost function. We report both the marginal effect of the variable on the mean and the variance of the unconditional persistent and transient inefficiency. A negative sign indicates a reduction of inefficiency. Margins are expressed in percent. We use bootstrapping approach to calculate standard errors and report the corresponding *Z*-test. Definitions of the variables are provided in the methodological section. *, ** and *** denote significant difference at the 10%, 5% and 1% level, respectively.

Marginal effects on unconditional transient inefficiency

	Effect on the mean			Effect on the variance		
	Margin	Z	*p*-value	Mean	Z	p-value
Foreign	0.02	0.78	0.43	0.002	0.81	0.42
Joint-stock	−0.001	−0.06	0.95	0	−0.07	0.94
RCB	0.041	0.77	0.44	0.004	1.04	0.30
CCB	0.02	1.07	0.28	0.002	1.04	0.30
Equity ratio	−0.023	−0.06	0.95	−0.002	−0.08	0.94
RRR	0.002	0.97	0.33	0	0.91	0.36
Listed	−0.018	−1.38	0.17	−0.002	−1.39	0.17
HK listed	0.01	0.61	0.54	0.001	0.70	0.49

Marginal effects on unconditional persistent inefficiency

	Effect on the mean			Effect on the variance		
	Margin	Z	p-value	Mean	Z	p-value
Foreign	−2.98***	−17.66	0.00	−0.527***	−9.41	0.00
Joint-stock	−0.058***	−5.18	0.00	−0.01***	−4.88	0.00
RCB	−0.026	−1.22	0.22	−0.005	−1.25	0.21
CCB	−0.018	−1.17	0.24	−0.003	−1.17	0.24
Equity ratio	−0.644***	−3.59	0.00	−0.114***	−3.41	0.00
RRR	0.003*	1.81	0.07	0.001*	1.77	0.08
Listed	−0.007	−1.08	0.28	−0.001	−1.07	0.29
HK listed	−0.037***	−3.15	0.00	−0.007***	−3.09	0.00
Observations	969					

Table 10
Mean inputs – Efficiency measures.

This table provides the efficiency scores of the banks over the years and depending on the bank type. We follow Jiang et al. (2013) and use mean inputs to calculate the cost frontier and efficiency estimates. We follow Kumbhakar et al. (2014) and divide efficiency into persistent and transient parts.

Years	All			Big 5		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	59.88%	89.13%	67.10%	20.83%	88.50%	23.52%
2009	60.50%	89.34%	67.75%	21.16%	89.85%	23.52%
2010	60.58%	89.46%	67.66%	21.22%	90.18%	23.52%
2011	61.57%	89.30%	68.86%	21.08%	89.68%	23.52%
2012	62.92%	89.30%	70.43%	20.78%	88.30%	23.52%
2013	63.24%	89.34%	70.86%	21.08%	89.68%	23.52%
2014	63.21%	89.22%	70.80%	21.27%	90.51%	23.52%
2015	62.47%	89.27%	70.21%	21.31%	90.76%	23.52%
Total	**61.95%**	**89.29%**	**69.39%**	**21.09%**	**89.68%**	**23.52%**
	Joint-stock			Foreign		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	38.85%	89.69%	43.33%	70.09%	90.47%	77.21%
2009	39.45%	91.09%	43.33%	69.99%	89.55%	77.96%
2010	38.82%	89.50%	43.33%	70.09%	89.62%	78.16%
2011	40.16%	89.20%	44.86%	68.32%	89.06%	76.77%
2012	40.44%	88.91%	45.47%	67.26%	86.84%	77.47%
2013	40.81%	89.51%	45.58%	68.25%	88.13%	77.69%
2014	40.71%	89.63%	45.47%	70.90%	90.10%	78.81%
2015	40.57%	89.45%	45.47%	70.25%	89.46%	78.60%
Total	**40.00%**	**89.61%**	**44.64%**	**69.34%**	**89.09%**	**77.85%**
	CCB			RCB		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	63.58%	88.60%	71.79%	59.75%	88.44%	67.53%
2009	64.77%	89.25%	72.58%	56.48%	86.67%	65.28%
2010	63.95%	89.26%	71.56%	60.86%	89.81%	67.67%
2011	65.46%	89.26%	73.15%	62.08%	90.15%	68.84%
2012	67.37%	90.31%	74.62%	67.53%	91.01%	74.04%
2013	66.04%	89.52%	73.81%	68.62%	90.21%	75.96%
2014	65.52%	88.96%	73.37%	65.42%	88.35%	74.26%
2015	64.78%	89.40%	72.69%	65.50%	88.19%	74.66%
Total	**65.23%**	**89.32%**	**73.00%**	**64.62%**	**89.19%**	**72.50%**

with Big Five banks, being a foreign bank marginally reduces the persistent inefficiency by 2.98%. The effect is also negative for joint-stock commercial banks (−0.058%). We further observe a negative marginal effect on the variance of the persistent inefficiency. On the contrary, we do not observe any significant effect concerning RCB or CCB for neither the mean nor the variance of the persistent inefficiency. Hence, the parametrization of the inefficiency terms of the cost function supports our main findings.

Regarding the effect of the other parameters on the persistent inefficiency, we document three findings. First, increasing the equity ratio of banks exerts a positive marginal impact on persistent inefficiency. A one-point increase of the equity ratio is associated with a reduction of 0.644% of the persistent inefficiency, as well as a reduction of 0.114% of its variance. This finding indicates that by increasing the equity requirements the authorities could contribute to reduction of banks' persistent inefficiency. This means that higher capital ratio is associated with a better cost efficiency. Banks with stronger financial positions have to pay a financing premium, reducing their costs. This is in line with the findings confirming the positive impact of higher capital ratios on banking activities (e.g. Bayoumi & Melander, 2008; Noss & Toffano, 2016).

Second, we document a negative marginal effect of an increase in the reserve requirement ratio on persistent inefficiency. Increasing this rate by one-point reduces Chinese banks' efficiency by 0.003%. Increasing the mandatory reserves at the PBC turns out to be costly for banks in that it also contributes to the reduction of their efficiency in the long-run. This result entails important consequences for the central bank, as a tightening of the monetary policy also produces a negative impact on the cost efficiency. It complements the findings of Fungáčová, Nuutilainen, and Weill (2016), who show that while the use of reserve requirements is an effective monetary policy tool, it does not foster bank lending. A decrease in banks' cost efficiency can explain this finding.

Last, while listing in general does not significantly impact banks' persistent efficiency, being listed in Hong-Kong contributes to a marginal reduction in banks' persistent inefficiency. This is the case for both the mean and the variance of persistent inefficiency. This result shows the crucial role of international listing in fostering efficiency in the long-run. It also emphasizes the role of foreign ownership in providing the appropriate incentives for Chinese banks to curb their cost inefficiencies. Our results are thus in line with the literature that finds the positive effect of Hong-Kong listing on tampering management's misconduct (e.g. Peng, Wei, & Yang, 2011).

Overall, both our main results and our marginal effects' analyses support the view that Big Five banks' inefficiency stems from

Table 11
Battese and Coelli efficiency measures.
This table provides the efficiency scores of the banks over the years and depending on the bank type following Battese and Coelli (1995).

	Full sample	Big5	Joint-stock	CCB	RCB	Foreign
2008	89.04%	90.97%	94.06%	87.33%	86.32%	91.14%
2009	88.42%	91.93%	93.23%	86.38%	88.70%	90.67%
2010	88.37%	91.90%	93.26%	86.17%	91.25%	89.30%
2011	88.66%	85.41%	91.75%	86.23%	91.81%	91.84%
2012	90.55%	92.60%	92.62%	89.32%	88.35%	93.02%
2013	88.39%	92.59%	91.67%	85.71%	87.89%	93.35%
2014	87.08%	88.66%	88.88%	84.74%	89.08%	90.17%
2015	88.81%	89.08%	89.74%	86.61%	90.94%	91.72%
Total	**88.62%**	**90.39%**	**91.85%**	**86.48%**	**89.36%**	**91.48%**

long-term inefficiency. We document the role of equity ratio and foreign listing in improving persistent efficiency, while increasing reserve requirements are associated with a decline in persistent efficiency.

5. Robustness checks

We provide three robustness tests to confirm the validity of our results. First, we estimate the cost function using average market input prices. Second, we compute efficiency scores based on Battese and Coelli's (1992) approach and compare them with our results. Third, we perform estimations by subperiods.

5.1. Average market input prices

The use of a cost function makes the underlying assumption that markets are competitive. The large (even if decreasing) share of Big Five banks in the Chinese banking industry may cast some doubt on the reliability of this hypothesis. Big Five banks are likely to be able to set the price of their inputs, distorting the competition in the banking industry to their advantage. This could affect our results by overestimating the efficiency of the Big Five.

To consider this possibility, we follow the approach of Jiang, Yao, and Feng (2013) and use market average input prices for each year in the estimation of the cost function. Market average prices are likely to be more exogenous to Big Five banks, better reflecting their ability to minimize their cost without taking advantage of the leading position in the banking sector. We then recalculate the cost frontier and the efficiency estimates. Table 10 reports the overall, transient, and persistent efficiency scores, using market average input prices.

Considering the competition in the input side of the market strongly reduces the overall efficiency of the Chinese banking sector. The overall efficiency drops to 61.95%. This is largely due to a drop in persistent efficiency that falls to 63.69%. Transient efficiency is closer to our main estimates, at 89.29%. Most of the decline is due to a collapse of Big Five's persistent efficiency. It reaches 23.52% over the period, compared to 92.36% in our main specification of the cost function. Their overall efficiency reaches 21.09%, which is substantially lower than our main estimates. While the other banks also experience a decline in their efficiency scores when using the average market input prices, this reduction is much less substantial than for Big Five. Overall, taking into account the ability of Big Five banks to distort input prices in the banking sector confirm our results. Big Five are substantially less efficient than the other types of banks, primarily because of their very poor long-run efficiency.

5.2. Alternative efficiency estimation

While the approach of Kumbhakar et al. (2014) has now been largely implemented in the efficiency literature, it remains relatively new in the banking literature. To put our results in perspective with previous studies and ensure that they do not stem from an extended sample, we calculate Battese and Coelli's (1992) measure of cost efficiency, commonly used in the banking literature. Table 11 reports the efficiency scores.

Overall, we obtain similar estimates of efficiency as in our main estimations. Using Battese and Coelli's (1992) approach, the overall efficiency reaches 88.62% for the whole sample, compared with 86.49% using Kumbhakar et al.'s (2014) methodology. The estimates for the different groups of banks are also in line with our main results in that Big Five banks are less efficient than joint-stock commercial banks and foreign banks. Our approach shows that this result essentially stems from the long-term inefficiency of Big Five banks, a result that cannot be derived using the previous methodology, while being essential to capture the characteristics of the Chinese banking sector.

5.3. Estimations by subperiods

We check whether our results stand unchanged when we divide the full sample into subsamples. The period of study has been characterized by several reforms which were gradually implemented over time. We therefore divide the full sample into two

Table 12
Efficiency measures estimated by sub-periods.

This table provides the efficiency scores of the banks over the years and depending on the bank type. We perform estimations on two sub-samples: 2008–2011, and 2012–2015. We follow Kumbhakar et al. (2014) and divide efficiency into persistent and transient parts.

Years	All			Big 5		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	95.46%	95.58%	99.87%	95.13%	95.25%	99.87%
2009	95.70%	95.82%	99.87%	96.06%	96.18%	99.87%
2010	95.64%	95.76%	99.87%	96.21%	96.33%	99.87%
2011	95.56%	95.68%	99.87%	95.79%	95.91%	99.87%
2012	94.10%	94.24%	99.86%	94.37%	94.50%	99.86%
2013	94.05%	94.18%	99.86%	95.35%	95.48%	99.86%
2014	94.29%	94.42%	99.86%	93.75%	93.88%	99.86%
2015	94.13%	94.26%	99.86%	94.36%	94.49%	99.86%
	Joint-stock			Foreign		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	95.94%	96.06%	99.87%	95.64%	95.76%	99.87%
2009	95.96%	96.08%	99.87%	95.59%	95.71%	99.87%
2010	95.87%	96.00%	99.87%	95.46%	95.58%	99.87%
2011	95.27%	95.39%	99.87%	95.64%	95.76%	99.87%
2012	94.11%	94.25%	99.86%	94.09%	94.22%	99.86%
2013	94.98%	95.11%	99.86%	93.19%	93.32%	99.86%
2014	94.31%	94.44%	99.86%	94.21%	94.34%	99.86%
2015	94.36%	94.50%	99.86%	94.80%	94.94%	99.86%
	CCB			RCB		
	Overall	Transient	Persistent	Overall	Transient	Persistent
2008	95.46%	95.58%	99.87%	94.58%	94.70%	99.87%
2009	95.73%	95.85%	99.87%	95.15%	95.27%	99.87%
2010	95.53%	95.65%	99.87%	96.09%	96.21%	99.87%
2011	95.45%	95.57%	99.87%	96.14%	96.26%	99.87%
2012	94.07%	94.21%	99.86%	94.14%	94.27%	99.86%
2013	94.14%	94.28%	99.86%	94.12%	94.25%	99.86%
2014	94.37%	94.50%	99.86%	94.26%	94.39%	99.86%
2015	93.82%	93.95%	99.86%	93.98%	94.11%	99.86%

subperiods of equal size: 2008–2011, 2012–2015. We redo the estimations separately for each subperiod. The estimations are reported in Table 12.

We need to point out that with estimations on short periods, we obtain very similar levels of persistent efficiency for all types of banks. This is the consequence of the implemented methodology: we use a fixed effects model on a very short period over a large number of banks and a stochastic frontier model on the residuals. By construction, this provides us with estimations which are very similar across banks. Therefore the estimations by subperiods are more interesting for the comparison of transient efficiency across banks.

We observe that transient efficiency has decreased between the first and the second subperiod. While mean transient efficiency scores are between 95.58% and 95.82% for 2008–2011, they range from 94.18% to 94.26%. Thus the analysis by subperiods indicates an improvement in transient efficiency which was not observed with estimations over the whole period as in that case we found transient efficiency quite stable over time. Since persistent efficiency is very stable over time with this methodology on short periods, the overall efficiency has improved between two subperiods.We still find that there are differences in efficiency for different types of banks. The overall efficiency and the transient efficiency are lower for the Big Five banks in comparison with joint-stock commercial banks and foreign banks.

6. Conclusion

This analysis of Chinese bank efficiency builds on a common claim in the literature that China's Big Five banks suffer from low cost efficiency. Given that these banks control a large market share of the Chinese banking industry, weak cost efficiency could put drag on the Chinese economy by slowing economic growth or destabilizing the financial system.

Decomposition of the overall inefficiency of Chinese banks into persistent inefficiency and transient inefficiency components is helpful in determining whether the low efficiency of the Big Five banks comes mainly from structural problems or short-term adaptations to economic conditions.

Our first observation is that transient and persistent efficiency are roughly of the same order of magnitude for all Chinese banks, i.e. overall efficiency is equally decomposed between both components. Second, the Big Five banks have on average lower overall efficiency than other Chinese banks. This weakness of the Big Five banks stems from their lower persistent efficiency. Indeed, the Big Five banks have greater transient efficiency than persistent efficiency, and their persistent efficiency is lower than for the other types of banks. No difference among types of banks is observed for transient efficiency. Third, the Big Five's transient efficiency is more

volatile than for the other banks, suggesting the Big Five banks are more sensitive to short-term events. Finally, we document a positive marginal effect of the capital ratio and Hong-Kong listing on persistent efficiency, and a negative effect of an increase in reserve requirements. This result indicates how the regulator might be able to contribute to the lowering of Chinese banks' persistent inefficiency.

Our main conclusion is that the much-discussed efficiency problem of the Big Five banks in China may be largely attributed to persistent inefficiency; the short-term inefficiency of the Big Five banks is no different from the other types of banks. As higher volatility of the Big Five transient inefficiency could also blur interpretations of overall efficiency score, the clarity provided here by differentiating two inefficiency components is welcome. Low persistent efficiency of the Big Five banks supports the view that China needs to move ahead with major structural reforms of the banking industry. Such reforms will likely include further privatization, and higher capital ratio requirements, in order to obtain changes in the governance structures and reductions in state support. Future research could include assessment of the efficiency impact of such measures.

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