A Study on the Impacts of Risk Taking on Chinese Commercial Bank Profit Efficiency

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Abstract:

Using an unbalanced panel dataset of 38 commercial banks in China, stochastic frontier models and a one-stage analysis approach, we investigate the impacts of bank risk taking, market structure and governance structure on profit efficiency. Our empirical results show that large commercial banks' profit efficiency is higher and stable, while the small and medium banks' profit efficiency shows an increasing and converging trend, but decline in the late two years. Ignoring risk factors leads to significant underestimation of the efficiency score. The inefficiency effects of risk-taking are significantly positive, indicating that higher the risk is associated with greater inefficiency.

Keywords:

Risk Taking, Commercial Banks, Profit Efficiency, Stochastic Frontier Analysis

1. Introduction

Against a background of rapid economic growth, China's banking industry has experienced "golden ten years" when assets expanded quickly, profit continued to rise, and the level of non-performing loans (NPLs) kept declining. According to the 2016 list of top 1000 banks compiled by The Banker magazine, four of the world's top five banks are Chinese. Industrial & Commercial Bank of China (ICBC) became the world's largest bank in 2013, and its growth has continued unabated since.

However, behind the surface prosperity, China's commercial banks have faced numerous challenges in their attempt to realize stable development. Especially in the last few years, reflecting multiple shocks caused by increasing competition in both the domestic and global banking sectors, government-driven industrial restructuring and slowing economic growth, China's banking industry has faced unprecedented "difficult times". According to 2013 China Financial Stability Report, the NPLs of Chinese banks began to increase for the first time in eight years. In particular, there are potential risks in the off balance sheet business. By the end of March 2016, the China Banking Regulatory Commission (CBRC) reported that NPLs had risen to an 11-year-high of 1.4 trillion yuan, or 1.75 percent of total bank lending. Many bank analysts believe the real NPL situation in China's banking sector is far worse than official data suggests.

Nevertheless, as the principal part of China's financial system, commercial banks play a pivotal role in Chinese economy. In recent years, although China's stock market has achieved tremendous development driven by China's economic reforms, the role of direct financing has increased, but the dominant status of the banking sector has not changed substantially. Bank lending is still the main financing channel, and savings deposits remain the most common investment channel. China's economy and society cannot afford a bank systemic risk outbreak. Banks' ability at risk control and maintaining performance plays a crucial role to China's economic development and social stability.

With China's economy entering the 'new normal' of slowing economic growth, the banking system will face a more challenging period. The steady decline in the economic growth rate will lead to a weakening in asset quality. Banks with significant loans to troubled industrial firms and property developers will therefore be exposed to higher default risk, compelling financial institutions and regulatory authorities to be more concerned at the balance of risk and performance.

The Global Financial Crisis has generated renewed interest into how the institutional and regulatory environment influence bank risk taking and performance (Houston et al., 2010). This begs the question about the potential interrelationships between bank risks and efficiency, something which is going to be important in China if bad debts increase.

This paper aims to fill the gap in the literature, estimate the profit efficiencies of Chinese commercial banks, and investigate the impacts of risk taking and other variables on the efficiency estimation. Following Battese and Coelli (1995), Berger and Mester (1997), Altunbas and Chakravarty (2001) and Jiang et al. (2009), we employ a one-stage SFA model taking into consideration both risk taking and other variables. The empirical results show that the average profit efficiency of China's commercial banks has increased over most of the period studied (2002 – 2015), apart from the final two years. This is prior to the anticipated increase in non-performing loans, but a thorough study of how the banking system has responded to risk in the past will allow us to more realistically assess future developments.

Our main empirical focus is to approve the impacts of bank risk taking through a comparative analysis of risk constraints and risk free models. The results suggest that ignoring impacts of risk would result in significant underestimation of bank efficiency. In addition, the inefficiency effect of the risk taking variable is significantly positive. That is the higher the risk, the lower the bank profit efficiency.

This paper is organized as follows. Section 2 presents the literature review. Section 3 outlines research methodologies and specifies empirical model. Section 4 shows the data on Chinese commercial banks. Section 5 discusses the empirical results. Section 6 describes the Robustness tests. Section 7 concludes.

2. Literature review

Over the past few decades, bank efficiency has been a hotspot in the academic research. Numerous studies have focused on measuring the efficiency of commercial banks, adopting different methods, and analyzing the determinants of bank efficiency from different angles. Berger and Humphrey (1997) document 130 studies on financial institutions' efficiency, using data from 21 countries, from various types of institutions including banks, bank branches, savings and loan institutions, credit unions and insurance companies. More recent publications include

Lozano-Vivas and Pasiouras (2010), Fang et al. (2011), Holod and Lewis (2011), Garza-García (2012) and Chortareas et al. (2013).

A number of studies have looked at the efficiency of Chinese commercial banks, with many of the key contributions summarised by Huang et al (2017). These have generally found that the state-owned commercial banks were less efficient than the joint-stock commercial banks, although of the 26 studies that they reviewed, only 3 considered any data for the period since 2010. Huang et al (2017) examined the technical efficiency of banks up to 2015, using network SFA and found superior performance for the joint-stock commercial banks. Our study differs from theirs by focusing on profit efficiency

Some early studies use a two-stage method to examine the potential relationship between bank risks and efficiency. The first stage employs data envelopment analysis (DEA) (Elyasiani et al., 1994; Barr et al., 1994), or stochastic frontier analysis (SFA) (Mester, 1996; Berger and DeYoung, 1997; Kwan and Eisenbeis, 1997) to investigate the efficiency of banks. In the second stage, a logistic regression model (Mester, 1996) or Granger-causality techniques (Berger and DeYoung, 1997) may be used to examine the interaction between bank risks and efficiency.

The outbreak of the 2007 US subprime crisis compelled institutions and researchers to pay more attention to bank risks, and there are more and more studies of bank performance taking risk variables into account. Including a risk factor as a non-discretionary input variable, Sufian (2010) explored the impacts of risk on the technical and scale efficiency estimates of Chinese commercial banks using DEA.

Employing Granger-causality methods in a panel data framework, Fiordelisi et al. (2011) assess the inter-temporal relationships between bank efficiency, capital and risk for the European commercial banking industry.The results suggest that there seems to be a bi-directional causal link between capital and non-performing loans as a measure of risk. Sun and Chang (2011) evaluate the role of risk in the cost efficiency of international banks in eight emerging Asian countries. Using a heteroscedastic and non-monotonic stochastic frontier approach, they find that each risk measure presents a different effect on banks' efficiency. Applying a similar approach to Barros et al. (2012), Gunay (2012) measures the efficiency of deposit banks operating in Turkey by incorporating credit risk as an undesirable by-product. Empirical results indicate that efficiency scores are much lower when NPLS are incorporated in the model. Saeed and Izzeldin (2014) examine the relationship between efficiency and default risk in Gulf Cooperation Countries (GCC) and three non-GCC countries over the period 2002–2010. Using both the ratio of equity to assets and distance to default as risk measures, they find that increased risk is associated with increased cost efficiency but reduced profit efficiency. Employing a two-stage semi-parametric DEA model, Hou et al. (2014) investigate the impacts of market structure and bank risk taking on the efficiency of Chinese commercial banks. Their empirical results show that technical efficiency is positively associated with the risk taking, with more risk taking implying credit expansion by banks.

In contrast to the previous two-stage methods, there have been in recent years some innovative methodological approaches taking risk factors into consideration in estimating bank efficiency. For example, Glass et al. (2014) investigate the relative performance of Japanese cooperative banks between 1998 and 2009, explicitly modelling non-performing loans as an undesirable output. The analysis highlighted that regulatory pressure to reduce non-performing loans can have an adverse impact on both output and performance. Epure and Lafuente (2015) suggest that incorporating risk in efficiency analyses is increasingly important against the background of the financial crisis. They propose a managerial control tool that integrates risk in efficiency measures of Costa Rican banks during 1998–2012. To capture credit risk, NPLs are defined as an undesirable output.

Following Glass et al. (2014) and Epure and Lafuente (2015), using a hybrid DEA model, Chen et al. (2015) evaluate the impact of NPLs on the efficiency of Taiwan's banking sector from 2006 to 2010, treating risk as an important factor and taking both radial and non-radial factors into consideration. They find that most of the inefficient banks have higher levels of NPLs (risk). When banks pursue efficiency, they need to take account of potential risk.

There is no clear consensus on the efficiency of China's banking sector in academic circles. In particular, the recent financial crisis suggests that it is important to incorporate risk in efficiency analyses, and compels related institutions to throw more concern on the balance of risk and performance. There are more research papers on the topic than ever, but most previous studies can only show the interrelationships between risks and performance. They could calculate neither the inefficiency effects nor specific impacts of bank risk.

In addition, the conventional two-stage procedure suffers from serious econometric problems, due to its contradictory assumptions on the independence of the inefficiency effect in the two stages (Battese and Coelli, 1995; Kumbhakar and Lovell, 2003). Fries and Taci (2005) and Jiang et al. (2009) argue that one-stage SFA model is more appropriate in efficiency studies in transition economies where problems of measurement errors and uncertain economic environments are more likely to prevail. Given these knowledge gaps, this paper seeks to estimate the profit efficiency of Chinese commercial banks, and investigate the impacts of risk taking and other variables on the efficiency estimates.

3. Methodology

Stochastic frontier analysis (SFA) is a frequently used method for banking efficiency studies. It pre-specifies a functional form for the best practice frontier and decomposes the error term into random error and inefficiency. There are two different forms of the profit function (Berger and Mester, 1997). The standard profit function expresses profit as a function of input and output prices. The alternative profit function examines profit as a function of input prices and output quantities. We use an alternative profit function to establish the empirical model. As the two-stage procedure can lead to estimation bias (Fries and Taci, 2005), this study uses the one-stage approach proposed by Battese and Coelli (1995).

The original formulation of this model is as follows:

$$Y_{it} = X_{it}\beta + (V_{it} - U_{it}),\, U_{it} = z_{it}\delta + \varepsilon_{it} \quad (1)$$

where Y_{it} is the production in period t for the i-th firm; X_{it} is the input in period t for the i-th firm; β is the coefficient vector to be estimated; V_{it} is the random disturbance term, which is assumed independent from U_{it} and subject to the normal distribution $N(0, \sigma_v^2)$; U_{it} is the inefficiency term comprised of two parts, where ε_{it} is defined by the truncated normal distribution $N(u_{it}, \sigma_u^2)$; $z_{it}\delta$ is the mean of inefficiencies modelled as a linear function of a vector of firm characteristics.

We use the stochastic frontier profit function to estimate profit efficiency score for each bank. Following Mester (1996), Berger and Mester (1997), Altunbas and Chakravarty (2001), we formulate the profit function as follows:

$$\prod(y_{it}, w_{it}) = \pi(y_{it}, w_{it})e^{v_{it} - u_{it}}, \; U_{it} = \delta_0 + \delta z_{it} + \varepsilon_{it} \quad (2)$$

where $\prod$ is the profit at each observation point; Y_{it} is the production in period t for the i-th firm; w_{it} is the relevant price of input factor; other parameters have the same meaning and properties as in equation(1).

When u_{it} is defined by the truncated normal distribution $N(u_{it},\sigma_u^2)$, profit efficiency is as follows:

$$Eff_{it}=\frac{E(\pi_{it}\left|u_{it},g_{it}\right.)}{E(\pi_{it}\left|u_{it}=0,g_{it}\right.)}=e^{-u_{it}} \quad (3)$$

Where Eff_{it} is the profit efficiency score in period t for the i-th firm; g is the model's parameter estimates. Then we can specify a Fourier function formula of stochastic profit frontier model as equation (4) (Yao et al., 2008; Jiang et al., 2009).

$$\begin{aligned}\ln\left(\frac{\Pi_{it}}{W_{1,it}}\right) &= \alpha_0+\sum_{m=1}^{2}\alpha_m \ln Y_{m,it}+\sum_{n=2}^{3}\beta_n \ln\left(\frac{W_{n,it}}{W_{1,it}}\right)+\frac{1}{2}\sum_{m=1}^{2}\sum_{j=1}^{2}\alpha_{mj}\ln Y_{m,it}\ln Y_{j,it}\\ &+\frac{1}{2}\sum_{n=2}^{3}\sum_{k=2}^{3}\beta_{nk}\ln\left(\frac{W_{n,it}}{W_{1,it}}\right)\ln\left(\frac{W_{k,it}}{W_{1,it}}\right)+\sum_{m=1}^{2}\sum_{n=2}^{3}\rho_{mn}\ln(Y_{m,it})\ln\left(\frac{W_{n,it}}{W_{1,it}}\right)\\ &+\theta_1 t+\frac{1}{2}\theta_2 t^2+\phi_1\ln(R_{it})+\frac{1}{2}\phi_2\ln(R_{it})\ln(R_{it})+\phi_{1m}\sum_{m=1}^{2}\ln(R_{it})\ln(Y_{m,it})\\ &+\phi_{2n}\sum_{n=2}^{3}\ln(R_{it})\ln\left(\frac{W_{n,it}}{W_{1,it}}\right)+V_{it}-U_{it}\end{aligned} \quad (4)$$

The prices of input factors W_{it} are assumed to be homogeneous. That is $\sum_{n=2}^{3}\beta_n=1$, $\sum_{n=2}^{3}\beta_{nk}=0$, $\sum_{k=2}^{3}\beta_{nk}=0$. On the other hand, to ensure symmetry of the cross terms, we also need to constrain the function, $\alpha_{mj}=\alpha_{jm}$, $\beta_{mk}=\beta_{km}$ ($m,j=1,2$, $n,k=2,3$).

The corresponding inefficiency effect model is as follows:

$$u_{it}=\delta_0+\delta_1 R_{it}+\delta Z_{it}+\varepsilon_{it} \quad (5)$$

Where R is the risk taking variable, it is used to estimate the impacts of risk taking on bank profit efficiency. Z is a group of inefficiency effect variables. The specific variable definitions and meaning will be further described below.

4. Variable and data

4.1 Variable Selection

Firstly we need to identify the inputs used by banks, and the resulting output(s) produced. We adopt the intermediation approach (Sealey and Lindley, 1977), where a bank is regarded as a financial intermediary. Capital, labor and funds are specified as inputs and gross loans and other earning assets as the outputs.

The z-score is commonly used as a measure of bank risk taking in previous research (Yeyati and Micco, 2007; Lepetit and Strobel, 2013). Mathematically, it is expressed in the following equation:

$$Z - score = \frac{ROA + (Equity / Asset)}{\sigma(ROA)} \tag{6}$$

We compute moving mean and standard deviation of ROA over previous 4 years, and combine these with current period value of equity-to-asset ratio. For this study that is limited to annual data, we use the range between the maximum and minimum of ROA as an alternative volatility measure. In recent years, through reforms to property rights, the opening of the market for foreign investment and other reform measures, the internal governance structure and external market environment of China's bank industry have undergone fundamental changes. Previous studies suggest that market share significantly affects banking efficiency (Altunbas and Chakravarty, 2001). State ownership has a negative impact on bank efficiency (Bonin et al., 2005; Yao et al., 2008; Jiang et al., 2009). There is also a close relationship between the macroeconomic environment, asset size and bank efficiency (Berger et al., 2009). Based on the above considerations, we select a set of control variables including market structure, governance structure and the macroeconomic environment.

Variables and their definitions for the SFA and inefficiency models are shown in Table 1.

Table 1. Variable selection and definition of the SFA model

Variable Symbol	Variable Definition
$\prod_{it}$	Profit before Tax
$Y_{1,it}$	Gross Loans
$Y_{2,it}$	Other Earning Assets
X_{1it}	Deposits & Short term Funding
X_{2it}	Number of Employees
X_{3it}	Net Value of Fixed Assets
$W_{1,it}$	Total Interest Expense /(Deposits & Short term Funding)
$W_{2,it}$	Personnel Expenses / Number of Employees
$W_{3,it}$	Other Operating Expenses / Net Value of Fixed Assets
R_{it}	z-score that we calculated
Market Share	Total assets of sample bank / banking total assets
Ownership	1 represents a non-state-owned bank, 0 represents a state-owned bank
Listed	1 indicates a listed bank, 0 indicates non-listed
GDP	the natural logarithm of per capita GDP
Asset	the natural logarithm of total assets

4.2 Data Sample and Sources

In this paper, we use financial data for 38 Chinese commercial banks', including big-5 banks, 10 joint-stock banks (JSCBs), 18 large-scale city commercial banks (CCBs) and 5 rural and cooperative commercial banks (RCCS, with these two latter categories jointly referred to as C&RBs). The banks are listed in Appendix 1, with their abbreviations. The data mainly come from Bankscope, except for number of employees and other missing data which come from bank annual reports and GDP which comes from the China National Statistics Office.

We start the study in 2002 as the first full financial year of China's accession to WTO. This was the time for full openness to foreign investment and thus an important landmark for the development of China’s financial system, especially for commercial banks.

This study covers several major changes in China's banking sector. For example, from 2003 to the end of 2009, four state-owned banks have completed shareholding reform. Since December 2006, China began to implement new regulations for foreign banks. The dataset covers all types of commercial banks except foreign banks.

The descriptive statistics are shown in Table 2.

Table 2. Descriptive statistics

Variables	Mean	Maximum	Minimum	Std. Dev.	Probability
Profit	20407	285398	7	46708	0.000
Gross Loans	689200	8209951	2243	1395567	0.000
Other Earning Assets	494958	4944532	240	933341	0.000
Fixed Assets	13240	158119	28	28378	0.000
Employees	52602	547935	218	118822	0.000
Deposits & Short term Funding	1223904	13422825	3683	2422270	0.000
Capital Price	0.675	4.397	0.102	0.417	0.000
Labor Price	0.188	0.937	0.031	0.082	0.000
Funding Price	0.020	0.052	0.005	0.007	0.000
Z-score^S	60.375	743.399	4.677	71.466	0.000
Z-score^R	27.104	355.875	2.065	32.460	0.000
Market Share	0.020	0.195	0.000	0.039	0.000
Ownership	0.853	1	0	0.355	0.000
Listed	0.290	1	0	0.454	0.000
Assets	1364125	15647829	3947	2732153	0.000
GDP	28596	49351	9398	12650	0.000

Note: monetary amounts are in CNY millions. Z-score^S is based on the standard deviation of ROA, and Z-score^R is based on the range of ROA.

5. Results

5.1 Parameter estimation results

Using FRONTIER 4.1, we get the parameter estimation results for the SFA and inefficiency effects model, with these shown in Tables 3. Model 1 and 2 are stochastic frontier profit models with risk constraints, whereas model 3 omits the risk constraints. Results from the two different empirical specifications are generally consistent with each other.

Table 3. Parameter estimate results for the SFA models

	Model 1 (z-score based on the standard deviation of ROA)		Model 2 (z-score based on the range of ROA)		Model 3 (risk free)	
parameter	coefficient	t-ratio	coefficient	t-ratio	coefficient	t-ratio
Z-score^S (δ_1)	0.265*** (0.062)	4.258				
Z-score^R (δ_1)			0.006** (0.003)	2.000		
Market Share (δ_2)	6.123** (2.604)	2.351	7.383 (4.646)	1.589	3.646 (3.146)	1.159
Ownership (δ_3)	1.267*** (0.432)	2.932	2.799** (1.250)	2.240	2.158*** (0.331)	6.510
Listed banks (δ_4)	-0.464 (0.333)	-1.391	-0.805*** (0.260)	-3.096	-0.430** (0.192)	-2.236
Assets (δ_5)	-0.541*** (0.081)	-6.686	-0.300*** (0.115)	-2.604	-0.386*** (0.101)	-3.812
per capita GDP (δ_6)	-2.862*** (0.414)	-6.917	-2.020*** (0.470)	-4.282	-2.005*** (0.356)	-5.638
sigma-squared	0.767*** (0.095)	8.101	0.692*** (0.200)	3.461	0.596*** (0.147)	4.068
gamma	0.955*** (0.009)	110.974	0.960*** (0.012)	78.178	0.943*** (0.018)	53.462
log likelihood function	-105.311		-104.717		-108.504	
LR test of the one-sided error	166.855		168.076		171.246	
mean efficiency	0.745		0.744		0.729	

Notes: Figures in parenthesis are standard-error. ***, **,* signify significance levels at 1%, 5% and 10%, respectively.

Table 3 shows that the coefficient of risk taking variable δ_1 is positive and significant at the 1% level in model 1 and 5% level in model 2, indicating a significant positive correlation between risk and inefficiency. That is, the lower the z-score (the higher risk taking), the lower the profit efficiency. All inefficiency effect variables in model 1 are significant.

The effect of market share (δ_2) is significantly positive at the 10% level in model 1, which suggests that increased market share is not conducive to improved bank profit efficiency.

Parameter δ_3 is positive and significant at the 1% level in model 1 and at the 3% level in model 2, reflecting the important effects of property rights reform. In the development process, optimizing property rights structure is still a fundamental direction of Chinese banking reform and development.

The dummy for listed bank (δ_4) is significantly negative, indicating that obtaining a public listing has played a significant role on promoting banks' performance. Going public is a successful experience of developed countries, whose purpose is to establish a modernized financial enterprise system, optimizing the governance structure, led to improve their management level. Currently, a large number of small and medium commercial banks are waiting for IPO. The relevant regulatory authority should strengthen supervision and provide orderly guidance, to ensure the healthy and stable development of China's banking. The inefficiency effects of both assets (δ_5) and per capita GDP (δ_6) are found to be negative and significant at the level 1% in both models, indicating that asset growth and a favorable macroeconomic environment with higher GDP growth help to improve bank performance.

The efficiency scores generated by the risk-constrained model are higher, on average, than those from the model that ignores risk. This shows us that taking account of risk improves the reliability of our efficiency estimates, consistent with earlier research as far back as Hughes & Mester (1993).

5.2 Efficiency estimation results

Relative efficiency scores of sample banks in model 1 are reported in Table 4. To save space, here we do not report the estimated efficiencies of model 2. For comparison, we report the estimated efficiencies of model 3 in the appendix 2.

Table 4. Efficiency score of 38 banks from 2002 to 2015 in model 1

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	mean
HSB							0.842	0.915	0.945	0.961	0.939	0.929	0.931	0.930	0.924
CCB	0.835	0.933	0.940	0.923	0.903	0.938	0.918	0.923	0.947	0.945	0.924	0.929	0.921	0.914	0.921
SJB								0.895	0.902	0.870	0.920	0.923	0.943	0.946	0.914
BOCC	0.952	0.853	0.903	0.923	0.911	0.940	0.921	0.910	0.924	0.909	0.880	0.911	0.900	0.900	0.910
BOC	0.813	0.921	0.836	0.866	0.866	0.848	0.855	0.894	0.928	0.912	0.894	0.921	0.913	0.901	0.883

ICBC	0.807	0.747	0.846	0.846	0.836	0.899	0.875	0.907	0.944	0.936	0.919	0.923	0.925	0.925	0.881
CMB	0.901	0.778	0.818	0.771	0.849	0.931	0.922	0.783	0.860	0.886	0.911	0.915	0.890	0.898	0.865
NBYZ						0.821	0.669	0.838	0.912	0.933	0.929	0.902	0.892	0.845	0.860
BONB			0.766	0.758	0.785	0.846	0.834	0.751	0.812	0.814	0.881	0.880	0.895	0.900	0.827
CITIC	0.812	0.745	0.811	0.812	0.729	0.848	0.806	0.709	0.894	0.918	0.849	0.871	0.787	0.791	0.813
IBC	0.559	0.685	0.714	0.676	0.618	0.782	0.803	0.883	0.929	0.900	0.916	0.905	0.894	0.914	0.798
BORZ							0.510	0.638	0.776	0.891	0.919	0.924	0.908	0.761	0.791
EGB						0.703	0.694	0.604	0.921	0.750	0.818	0.865	0.815	0.853	0.780
BOCD				0.260	0.193	0.819	0.906	0.925	0.901	0.923	0.920	0.923	0.927	0.881	0.780
BOGL								0.709	0.860	0.755	0.853	0.911	0.691	0.502	0.754
BOCQ				0.425	0.820	0.868	0.634	0.733	0.753	0.507	0.810	0.915	0.880	0.885	0.748
FJHX					0.804	0.832	0.541	0.646	0.874	0.879	0.845	0.815	0.618	0.544	0.740
CEB	0.544	0.518	0.480	0.654	0.630	0.841	0.666	0.740	0.832	0.878	0.906	0.884	0.891	0.889	0.740
PDD	0.768	0.661	0.606	0.585	0.510	0.668	0.712	0.703	0.828	0.832	0.842	0.853	0.868	0.894	0.738
ABC	0.505	0.431	0.541	0.393	0.522	0.924	0.651	0.788	0.942	0.932	0.918	0.926	0.919	0.905	0.736
GDSD				0.223	0.319	0.362	0.743	0.824	0.949	0.950	0.942	0.927	0.914	0.919	0.734
SHRC						0.249	0.851	0.796	0.666	0.751	0.831	0.830	0.796	0.833	0.734
BODG			0.252	0.327	0.643	0.766	0.807	0.777	0.831	0.799	0.837	0.934	0.904	0.871	0.729
BOSH	0.448	0.550	0.703	0.565	0.617	0.847	0.707	0.672	0.700	0.700	0.786	0.818	0.836	0.853	0.700
BRCB							0.296	0.463	0.481	0.766	0.869	0.872	0.927	0.927	0.700
BONJ	0.203	0.274	0.394	0.613	0.739	0.750	0.884	0.854	0.890	0.871	0.708	0.822	0.853	0.839	0.692
DYB						0.333	0.381	0.524	0.805	0.762	0.872	0.859	0.841	0.821	0.689
BOHZ			0.333	0.594	0.712	0.755	0.744	0.633	0.701	0.726	0.796	0.840	0.720	0.658	0.684
BOLZ							0.465	0.582	0.765	0.777	0.666	0.641	0.806	0.639	0.668
JSWJ								0.495	0.732	0.806	0.694	0.661	0.691	0.572	0.665
CMSB	0.467	0.388	0.394	0.467	0.544	0.586	0.542	0.519	0.849	0.888	0.909	0.893	0.903	0.898	0.661
HXB		0.625	0.639	0.572	0.485	0.527	0.393	0.475	0.585	0.709	0.819	0.875	0.868	0.892	0.651
HKB			0.088	0.233	0.555	0.534	0.593	0.663	0.876	0.891	0.850	0.883	0.756	0.834	0.646
CZSB						0.358	0.344	0.466	0.684	0.673	0.822	0.793	0.764	0.743	0.627
BOWZ				0.308	0.808	0.831	0.686	0.650	0.738	0.685	0.532	0.546	0.473	0.499	0.614
DODL				0.185	0.325	0.930	0.773	0.763	0.858	0.676	0.747	0.701	0.265	0.240	0.588
FDB					0.188	0.120	0.629	0.325	0.526	0.636	0.709	0.840	0.861	0.809	0.564
CGFB	0.362	0.082	0.334	0.147	0.080	0.678	0.439	0.639	0.803	0.847	0.847	0.738	0.671	0.558	0.516
mean	0.641	0.613	0.600	0.547	0.615	0.714	0.687	0.711	0.819	0.822	0.843	0.855	0.823	0.800	

As shown in Table 4, the estimated profit efficiencies are distributed between 0.08 and 0.961, indicating that the bank efficiencies are quite different across the study period. Huishang Bank Co Ltd (HSB) is the best performing bank with average efficiency level at 0.924; it outperforms the lowest efficient China Guangfa Bank Co Ltd (CGFB) by 79%. We found that the 4 large state-owned commercial banks (CCB, BOCC, BOC and ICBC) are among the most 6 efficient banks, as their mean efficiencies ranked 2, 4, 5, and 6. As for joint-stock banks, China Merchants Bank (CMB) is the most efficient, ranked 7 among all 38 sample banks. We also noticed that the most efficient Huishang Bank Co Ltd is one of city and rural commercial banks (C&RBs), but most of these are less efficient than the state-owned commercial banks.

In order to compare and analyze the performance gap and evolution, the average estimated profit efficiencies for the different bank types are plotted in Figures 1 and 2 for Models 1 and 3 respectively.

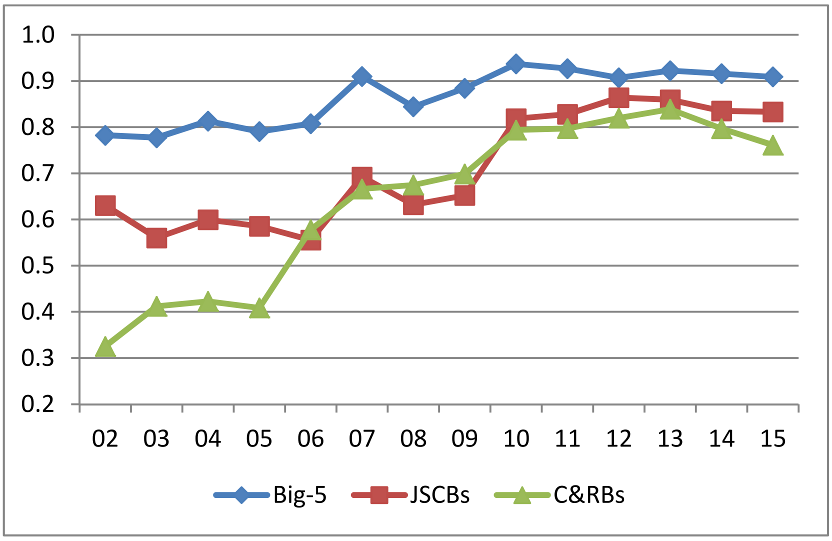

Fig 1. Mean profit efficiencies by bank type from 2002 to 2015 (Model 1).

From the trends shown in Figures 1 and 2, we find that, regardless of risk taking, the average banking profit efficiency shows an upward trend for most of the study period.

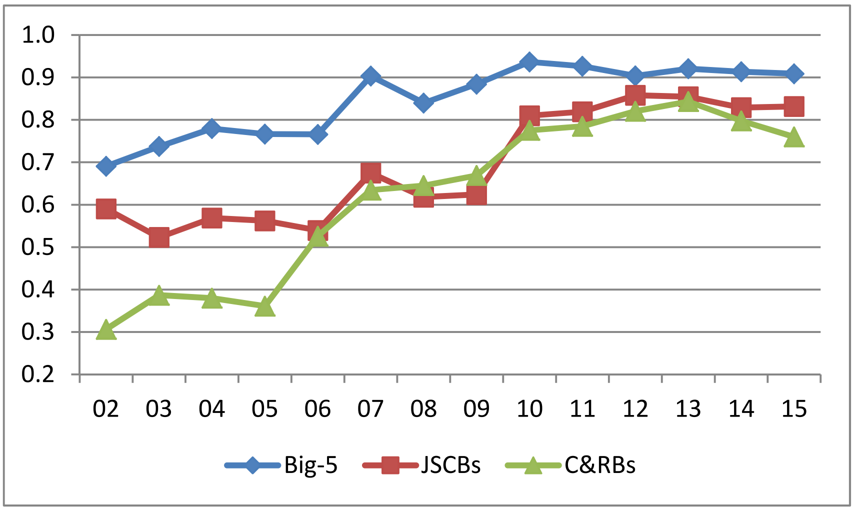

Fig 2. Mean profit efficiencies by bank type from 2002 to 2015 (Model 3)

The big 5 are the best performing banks in both model 1 and 2, but particularly in Model 1 where the profit efficiencies of Big-5 are stable and more than 0.8 nearly every year. The possible explanation is that because the Big-5 banks dominate the banking system in terms of total assets, deposits, branch network and employees, they have some monopolistic advantage. Another possible reason is the persistence of government intervention and reform efforts on banks' operations, such as stripping off NPLs and massive capital injection. The finding is similar to Chen et al. (2015), and in contrast to the mainstream literature on the relationship between state ownership and efficiency. C&RBs are the least efficient banks especially in the first three years. A possible explanation is that only a small number of better performed C&RBs are included in our sample during the early years.

We also found that, exception for Big-5 and JSBCs, C&RBs show a significant downward trend in efficiency in the two latest years. The results are consistent with the general expectation that Chinese banking is facing "tough times". After the "golden ten years" of rapid expansion and high profit, alongside liberalization of financial markets liberalization and interest rates, and marketization, competition in Chinese banking is becoming increasingly fierce. This will inevitably have negative impacts on the performance of commercial banks, especially small and medium banks. Only through constant financial innovation, improvement of management capacity and new profit growth point, can the small and medium banks get sustainable development in the future.

6. Robustness tests

6.1 Likelihood ratio (LR) test

We employ the generalized likelihood ratio (LR) statistic to test the correctness of empirical model specification. We define a log likelihood ratio statistic λ:$\lambda = -2[L(H_0) - L(H_1)]$. Then, under unconstrained conditions we estimate the model to obtain $L(H_1)$ of the alternative hypothesis. Finally, under the given respective constraints, we estimate the model to obtain $L(H_0)$ under null hypothesis. If the null hypothesis H_0 is true, the statistic λ is subject to asymptotic chi-square distribution or mixed chi-square distribution. The test results for Model 1 are shown in Table 5.

To save space we only report the results for the tests for model 1. The significance of threshold for hypothesis 1, 2, 3, 4, 5 and 6 are all significant at the 1% level. Here we refer to the calculation results of Kodde (1986).

Table 5.Hypothesis test results for model 1.

Null Hypothesis H_0	log likelihood function $L(H_0)$	log likelihood function $L(H_1)$	LR Statistics (λ)	Threshold(CV)	DOF	Test Results
1. $H_0: \alpha_{11}=\alpha_{22}=\alpha_{12}=\beta_{22}=\beta_{33}=\beta_{23}=\rho_{12}=\rho_{22}=\rho_{13}=\rho_{23}=\theta_2=\phi_2=\phi_{11}=\phi_{12}=\phi_{22}=\phi_{23}=0$	-105.311	-168.509	126.396	31.353	16	Reject
2. $H_0: \theta_1=\theta_2=0$	-105.311	-113.305	15.988	8.273	2	Reject
3. $H_0: \gamma=\eta=\mu=0$	-133.304	-144.048	77.474	10.501	3	Reject
4. $H_0: \eta=0$	-133.304	-144.042	77.461	5.412	1	Reject
5. $H_0: \mu=0$	-133.304	-128.692	46.762	5.412	1	Reject
6. $H_0: \phi_1=\phi_2=\phi_{11}=\phi_{12}=\phi_{22}=\phi_{23}=0$	-133.304	-108.504	6.385	16.074	6	Reject

In Table 5, hypothesis 1 is rejected at the 1% significance level. This shows that compared to a simple Cobb-Douglas function, a Fourier function better describes the structure and variation characteristics of Chinese Banking efficiency. Hypothesis 2 is also rejected at the 1% significance level, indicating the sample banks' obvious technological change during the study period. Hypothesis 3 is rejected at the 1% significance level, which confirms the presence of the technical inefficiency effect. Hypothesis 4 is rejected, indicating that the bank's efficiencies change over time, meaning that we should take account of time in our model. Hypothesis 5 is rejected, which means U_i is subject to a truncated normal distribution. Hypothesis 6 is rejected, indicating that risk taking has a significant impact on bank performance, and the risk constrained model is superior to the risk-free model.

In summary, all assumptions have been tested at the 1% significance level, indicating that the empirical specification of the model is reasonable. This confirms our choice of the SFA model shown in equation 4 as the appropriate empirical specification for this study.

6.2 Additional robustness tests

We run an additional set of robustness tests of our main findings in which we specify alternative risk taking variables and alter the data sample.

First, we define the equity to total assets ratio (E/A ratio) as bank risk taking characteristic (Spong et al., 1995; Williams and Nguyen, 2005), and rerun the efficiency analysis using risk constraint model (model 4) and risk-free model (model 5) respectively. As shown in table 6, the coefficient of risk taking variable is positive and significant at the 1% level, again indicating a significant positive correlation between risk and inefficiency. The mean efficiency in model 4 is higher than that of model 5 by 5.3%.

Moreover, we re-estimate our model exclusive of the rural commercial banks (RCBs) in our data sample. These banks are small relative to the other banks that may be characterized by different production technologies. That is not shown for reasons of brevity. The results are generally consistent with the reported results for the combined sample.

Table 6. Robustness test results for model 1.

	Model 4(E/A ratio)			Model 5(risk-free)		
parameter	coefficient	standard-error	t-ratio	coefficient	standard-error	t-ratio
E/A ratio (δ_1)	0.265***	0.062	4.258			
Market Share (δ_2)	6.123**	2.604	2.351	3.646	3.146	1.159
Ownership (δ_3)	1.267***	0.432	2.932	2.158***	0.331	6.510
Listed banks (δ_4)	-0.464	0.333	-1.391	-0.430**	0.192	-2.236
Assets (δ_5)	-0.541***	0.081	-6.686	-0.386***	0.101	-3.812
per capita GDP (δ_6)	-2.862***	0.414	-6.917	-2.005***	0.356	-5.638
sigma-squared	0.767***	0.095	8.101	0.596***	0.147	4.068
gamma	0.955***	0.009	110.974	0.943***	0.018	53.462
log likelihood function		-135.324			-163.721	
LR test of the one-sided error		211.095			224.608	
mean efficiency		0.739			0.702	

***, **,* signify significance levels at 1%, 5% and 10%, respectively.

7. Conclusion

This paper has investigated the impacts of risk taking, market structure and governance structure on bank profit efficiency, applying stochastic frontier models in a one-stage analysis to an unbalanced panel dataset of 38 commercial banks in China. We draw the following conclusions.

Firstly, regardless of risk-taking effects, the Big-5 are the most profit-efficient and with stable efficiency. The efficiency of the small and medium banks shows improvement and convergence, but began to decline in the last two years. Secondly, comparing the estimation results of risk constrained and risk free models, we found out that ignoring the impacts of risk would result in significant underestimation of bank efficiency. Thirdly, the inefficiency effect of the risk taking variable is significantly positive, indicating that the higher the risk, the lower is bank profit efficiency. Fourthly, other control variables show us that openness to foreign investment, greater asset size and a better macroeconomic environment are conducive to improvement in bank efficiency, although market share and ownership structure are not.

The theoretical significance of these finding is that excluding the impacts of risk would result in estimation bias, undermining the robustness of the study of bank efficiency. Its practical significance is that, to maintain stable development, commercial banks cannot ignore risk management when they try to pursue financial performance and asset expansion. The Chinese financial market is now fully open, and becoming increasingly competitive. Against the background of interest rate market-oriented reform and continuous rising potential risk, key questions for further sustained and stable development are how to improve banking risk management capability and optimize governance structure.

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Appendix 1: list of banks in study

Bank	Abbreviation	Bank type
Agricultural Bank of China	ABC	Big Bank
Bank of China	BOC	Big Bank
China Construction Bank	CCB	Big Bank
Industrial & Commercial Bank of China	ICBC	Big Bank
Bank of Communications	BOCC	Big Bank
China Everbright Bank Co Ltd	CEB	JSCB
China Guangfa Bank Co Ltd	CGFB	JSCB
Hua Xia Bank co., Limited	HXB	JSCB
Shanghai Pudong Development Bank	PDD	JSCB
Industrial Bank Co Ltd	IBC	JSCB
China Merchants Bank Co Ltd	CMB	JSCB
China Minsheng Banking Corporation	CMSB	JSCB
China CITIC Bank Corporation Limited	CITIC	JSCB
China Zheshang Bank Co Ltd	CZSB	JSCB
Evergrowing Bank Co Ltd	EGB	JSCB
Bank of Nanjing	BONJ	CCB
Bank of Shanghai	BOSH	CCB
Fudian Bank Co Ltd	FDB	CCB
Bank of Dongguan	BODG	CCB
Bank of Chengdu Co Ltd	BOCD	CCB
Dongying Bank Co Limited	DYB	CCB
Fujian Haixia Bank Co Ltd	FJHX	CCB
Hankou Bank	HKB	CCB
Bank of Hangzhou Co Ltd	BOHZ	CCB
Huishang Bank Co Ltd	HSB	CCB
Bank of Liuzhou Co Ltd	BOLZ	CCB
Bank of Ningbo	BONB	CCB
Bank of Rizhao	BORZ	CCB
Bank of Dalian	BODL	CCB
Bank of Guilin Co Ltd	BOGL	CCB
Shengjing Bank	SJB	CCB
Bank of Wenzhou Co Ltd	BOWZ	CCB
Bank of Chongqing	BOCQ	CCB
Beijing Rural Commercial Bank Co Ltd	BRCB	RCC
Guangdong Shunde Rural Commercial Bank Company Limited	GDSD	RCC
Ningbo Yinzhou Rural Cooperative Bank	NBYZ	RCC
Shanghai Rural Commercial Bank	SHRC	RCC
Jiangsu Wujiang Rural Commercial Bank	JSWJ	RCC

Appendix 2: Efficiency score of 38 banks from 2002 to 2015 in model **3**

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	mean
HSB							0.815	0.906	0.943	0.961	0.941	0.927	0.928	0.932	0.919
SJB								0.878	0.889	0.867	0.919	0.921	0.947	0.948	0.910
BOCC	0.954	0.846	0.897	0.923	0.914	0.945	0.921	0.911	0.921	0.904	0.865	0.906	0.901	0.905	0.908
CCB	0.684	0.925	0.944	0.922	0.893	0.934	0.906	0.918	0.947	0.945	0.923	0.927	0.913	0.914	0.907
BOCC	0.739	0.917	0.812	0.849	0.841	0.822	0.841	0.890	0.931	0.917	0.894	0.922	0.917	0.902	0.871
ICBC	0.714	0.686	0.833	0.823	0.761	0.880	0.857	0.901	0.943	0.935	0.917	0.921	0.925	0.927	0.859
CMB	0.886	0.742	0.801	0.754	0.832	0.928	0.921	0.753	0.840	0.878	0.912	0.917	0.889	0.900	0.854
NBYZ						0.801	0.641	0.822	0.906	0.932	0.919	0.894	0.886	0.838	0.849
CITIC	0.770	0.708	0.783	0.785	0.703	0.829	0.784	0.664	0.892	0.919	0.842	0.865	0.769	0.778	0.792
BONB			0.603	0.613	0.700	0.855	0.813	0.731	0.796	0.803	0.884	0.880	0.896	0.903	0.790
IBC	0.517	0.641	0.674	0.642	0.589	0.760	0.791	0.880	0.923	0.888	0.902	0.902	0.894	0.912	0.780
BOCD				0.229	0.180	0.756	0.895	0.916	0.898	0.929	0.924	0.926	0.931	0.882	0.770
EGB						0.696	0.721	0.525	0.918	0.729	0.801	0.855	0.798	0.847	0.765
BORZ							0.460	0.527	0.699	0.884	0.914	0.924	0.909	0.744	0.758
BOGL								0.665	0.840	0.741	0.857	0.914	0.653	0.482	0.736
BOCQ				0.411	0.787	0.853	0.603	0.708	0.735	0.474	0.805	0.905	0.888	0.888	0.732
GDSD				0.218	0.314	0.350	0.728	0.812	0.951	0.952	0.943	0.932	0.919	0.923	0.731
CEB	0.504	0.472	0.459	0.638	0.629	0.830	0.652	0.714	0.824	0.876	0.909	0.879	0.887	0.886	0.726
FJHX					0.774	0.813	0.492	0.610	0.872	0.875	0.832	0.792	0.593	0.526	0.718
SHRC						0.285	0.834	0.718	0.576	0.664	0.838	0.842	0.827	0.862	0.716
PDD	0.717	0.606	0.558	0.556	0.510	0.611	0.655	0.669	0.809	0.824	0.837	0.848	0.865	0.896	0.712
BODG			0.208	0.296	0.553	0.707	0.785	0.785	0.848	0.793	0.817	0.936	0.898	0.862	0.707
ABC	0.363	0.312	0.412	0.316	0.418	0.934	0.673	0.802	0.941	0.931	0.920	0.926	0.912	0.895	0.697
BRCB							0.278	0.447	0.480	0.753	0.867	0.876	0.933	0.931	0.695
BONJ	0.213	0.271	0.390	0.580	0.701	0.718	0.872	0.843	0.885	0.864	0.807	0.841	0.863	0.847	0.692
BOSH	0.399	0.502	0.678	0.552	0.608	0.828	0.676	0.645	0.710	0.712	0.788	0.837	0.845	0.871	0.690
DYB						0.306	0.347	0.471	0.799	0.691	0.863	0.853	0.835	0.809	0.664
BOHZ			0.318	0.544	0.660	0.711	0.714	0.617	0.686	0.709	0.800	0.842	0.709	0.649	0.663
JSWJ								0.454	0.717	0.802	0.680	0.721	0.679	0.534	0.655
BOLZ							0.431	0.542	0.731	0.781	0.662	0.657	0.819	0.611	0.654
CMSB	0.419	0.360	0.370	0.437	0.513	0.558	0.520	0.500	0.838	0.886	0.909	0.893	0.904	0.901	0.644
HXB		0.584	0.599	0.538	0.463	0.509	0.372	0.459	0.567	0.692	0.814	0.874	0.864	0.899	0.633
HKB			0.081	0.213	0.513	0.502	0.550	0.645	0.874	0.893	0.831	0.900	0.746	0.830	0.632
CZSB						0.347	0.323	0.461	0.695	0.657	0.805	0.782	0.760	0.742	0.619

BOWZ				0.282	0.773	0.777	0.661	0.632	0.718	0.663	0.515	0.530	0.461	0.489	0.591
DODL				0.177	0.297	0.929	0.750	0.744	0.851	0.666	0.746	0.689	0.263	0.239	0.577
FDB					0.186	0.114	0.583	0.283	0.477	0.610	0.692	0.845	0.869	0.819	0.548
CGFB	0.320	0.071	0.306	0.147	0.076	0.677	0.440	0.616	0.792	0.844	0.849	0.730	0.658	0.554	0.506
mean	0.586	0.576	0.564	0.519	0.584	0.696	0.666	0.686	0.807	0.812	0.841	0.856	0.820	0.797	