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

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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 convergence trend, but decline in the late two years. During the estimation process, ignoring risk factors will lead to significant underestimation of the efficiency score. Risk's inefficiency effects are significantly positive, indicating that the higher the risk, the more inefficiency effects.

Key words: Risk Taking, Commercial Bank, Profit Efficiency, Empirical Analysis

1. Introduction

Against a background of rapid macroeconomic 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. ICBC became the largest bank of the world 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, the 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. Despite this, many bank analysts believe the real NPL situation in China's banking sector is far more severe 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 of risk control and performance level plays a crucial role to China's economic development and social stability.

Beyond doubt, China's banking sector has seen the end of its golden age. In particular, 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. In addition, the recent financial crisis has generated renewed interest into how the institutional and regulatory environment influence bank risk taking and performance (Houston et al., 2010). This also motivates further study about the potential interrelationships between bank risks and efficiency.

The current 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 in the sample period has shown an increasing trend for most of the time but a declining trend over the latter two years.

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 test. Section 7 draws conclusions.

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). However, empirical evidence about the impacts of risk taking on Chinese commercial bank efficiency is relatively scarce.

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, Chang and Chiu, 2006) 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. Altunbas et al.(2007) analyze the interrelationship between capital, risk and efficiency for a large sample of European banks between 1992 and 2000. Based on information including the internal risk of bank management and the external environmental risk factors, Chiu

and Chen (2009) adopt a three-stage approach to estimate the efficiency of 29 banks in Taiwan for the period from 2002 to 2004. The results indicate that the super-efficiency of privately-owned banks and publicly-owned banks are worse when adjusted by internal and external risks. Including a risk factor as a non-discretionary input variable, Sufian (2010) explores the impacts of risks on the technical and scale efficiency estimates of Chinese commercial banks using DEA.

Employing Granger-causality methodology 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 the non-performing loan measure of risk. Sun and Chang (2011) evaluate the role of risk in determining 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 Gulf Cooperation Countries (GCC) and three non-GCC countries over the period 2002–2010. Efficiency and default risk are measured using SFA and distance to default (Merton's model) respectively. 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.

Unlike the previous two-stage DEA or SFA methods, in recent years, there are some innovative methodological approaches taking risk factors into consideration in computing 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 on 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. In order to capture credit risk, NPLs are defined as an undesirable output.

Following the same idea as Glass et al.(2014) and Epure and Lafuente (2015), by 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 into consideration both radial and non-radial factors. They find that most of the inefficient banks have an inefficiency factor caused primarily by too many NPLs (risk). When banks pursue efficiency, it is needed to evaluate the potential risk they have. Efficiency and risk occur simultaneously.

In summary, the efficiency of China's banking sector is still controversial 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). One is standard profit function where profit is expressed as a function of input and output prices. The other is alternative profit function where profit is expressed as a function of input prices and output quantities. We use an alternative profit function to establish the empirical

model. As for model specification, in order to avoid estimation bias (Fries and Taci, 2005) resulted in the two-stage procedure. This study adopts an one-stage approach proposed by Battese and Coelli (1995).

The original formula of this model is as follows:

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

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 truncation 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 use the following formulation of the profit function:

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

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:

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

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).

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

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:

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

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 variable. The specific variable definitions and meaning will be further described below.

4. Variable and data

4.1 Variable Selection

We first need to decide the inputs used by banks, and the resulting output(s) produced. We adopt the intermediation approach, where a bank is regarded as a financial intermediary. Capital, labor and funds are specified as inputs and operating income as the output.

Risk taking characteristics are represented by the equity to total assets ratio (E/A ratio) (Williams and Nguyen, 2005). The higher the E/A ratio, the lower the capital risk a bank faces. Previous literature generally shows a positive association between the level of capital and efficiency (Spong et al., 1995).

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}	(the equity to total assets ratio)×100
$Year_{06}$	1 represents a market fully opened to foreign banks, 0 means the market is closed
MS	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 collect 38 Chinese commercial banks' latest financial data, including big-5 banks (Bank of China, Agricultural Bank of China, Industrial & Commercial Bank of China, China Construction Bank, Bank of Communications), 10 joint-stock banks (JSCBs, Shanghai Pudong Development Bank, China CITIC Bank, China Minsheng Banking, China Everbright Bank, Evergrowing Bank, China Guangfa Bank, China Merchants Bank, Hua Xia Bank, China Zheshang Bank, Industrial Bank), 18 large-scale city commercial banks (CCBs) and 5 rural and cooperative commercial banks (RCCs, Shanghai Rural Commercial Bank, Jiangsu Wujiang Rural Commercial Bank, Ningbo Yinzhou Rural Cooperative Bank-Yinzhou Bank, Guangdong Shunde Rural Commercial Bank, Beijing Rural Commercial Bank). The data mainly come from Bankscope, except for number of employees and other missing data which come from bank annual reports because they are unavailable in that database.

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 of 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 of related variables are shown in Table 2.

Table 2. Descriptive statistics

Variables	Mean	Maximum	Minimum	Std. Dev.
Profit	20407	285398	7	46708
Gross Loans	689200	8209951	2243	1395567
Other Earning Assets	494958	4944532	240	933341
Fixed Assets	13240	158119	28	28378
Employees	52602	547935	218	118822
Deposits & Short term Funding	1223904	13422825	3683	2422270
Capital Price	0.675	4.397	0.102	0.417
Labor Price	0.188	0.937	0.031	0.082
Funding Price	0.020	0.052	0.005	0.007

E/A ratio	5.609	14.182	0.001	1.930
$Year_{06}$	0.718	1	0	0.450
MS	0.020	0.195	0.000	0.039
Ownership	0.853	1	0	0.355
Listed	0.290	1	0	0.454
Asset	1364125	15647829	3947	2732153
GDP	28596	49351	9398	12650

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 and Table 4. Model 1 is a stochastic frontier profit model with risk constraints, whereas model 2 omits the risk constraints. Results from the two different empirical specifications are generally consistent with each other.

Table 3. Parameter estimation results of the SFA models

	Model 1(risk)			Model 2(risk-free)		
parameter	coefficient	standard-error	t-ratio	coefficient	standard-error	t-ratio
α_0	10.759***	1.358	7.921	9.451***	1.251	7.555
α_1	-0.447	0.327	-1.369	-0.599*	0.343	-1.746
α_2	0.008	0.253	0.031	-0.016	0.289	-0.054
β_2	0.192	0.449	0.429	0.030	0.394	0.077
β_3	-0.545*	0.340	-1.673	0.446	0.299	1.492
α_{11}	0.166***	0.034	4.834	0.116***	0.035	3.281
α_{22}	0.093***	0.031	3.053	0.025	0.026	0.978
α_{12}	-0.066**	0.028	-2.329	-0.002	0.026	-0.086
β_{22}	0.160	0.135	1.185	0.050	0.139	0.358
β_{33}	-0.115	0.079	-1.459	-0.259***	0.073	-3.554
β_{23}	0.129	0.089	1.451	0.271***	0.091	2.993
ρ_{12}	-0.001	0.053	-0.017	-0.012	0.049	-0.245
ρ_{13}	-0.065	0.062	-1.042	-0.011	0.061	-0.181
ρ_{22}	-0.059	0.046	-1.288	-0.043	0.045	-0.960

ρ_{23}	0.066	0.056	1.191	0.004	0.054	0.069
θ_1	0.021	0.024	0.866	0.040	0.025	1.600
θ_2	-0.006**	0.003	-2.105	-0.006**	0.003	-2.290
ϕ_1	-1.706***	0.628	-2.715			
ϕ_2	0.499***	0.180	2.777			
ϕ_{11}	0.056	0.082	0.687			
ϕ_{12}	-0.080	0.070	-1.140			
ϕ_{22}	0.083	0.125	0.669			
ϕ_{23}	0.432***	0.103	4.190			
δ_0	24.258***	3.364	7.212	16.610***	3.133	5.301
δ_1	0.291***	0.062	4.679			
δ_2	-0.812***	0.187	-4.346	-0.674**	0.287	-2.345
δ_3	5.030***	1.374	3.661	3.841	3.702	1.038
δ_4	1.614***	0.373	4.332	2.409***	0.360	6.696
δ_5	-0.394*	0.217	-1.815	-0.419*	0.245	-1.710
δ_6	-0.518***	0.077	-6.746	-0.396***	0.083	-4.763
δ_7	-2.217***	0.350	-6.337	-1.447***	0.297	-4.872
sigma-squared	0.784***	0.097	8.126	-1.447***	0.297	-4.872
gamma	0.956***	0.008	115.373	0.639***	0.159	4.017
log likelihood function		-133.304			-161.524	
LR test of the one-sided		215.135			229.001	
mean efficiency		0.741			0.706	

***, **, * 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, indicating a significant positive correlation between risk and inefficiency. That is, the lower the E/A ratio (the higher risk taking), the lower the profit efficiency. All six inefficiency effect variables in model 1 have passed the significance test.

The significant negative inefficiency effect of variable δ_2 (market is open to foreign investment) suggests that an open market is conducive to improved bank profit efficiency. In contrast, the inefficiency effect of market share (δ_3) is significantly positive at the 1% level, which means that increase of market share is not conducive to improved bank profit efficiency. δ_4 is positive and significant at the 1% level in both models 1 and 2, reflecting the important effects of property right reform on bank efficiency. 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_5) is significantly negative, indicating that obtaining a public listing has played a significant role in 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 wait 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_6) and per capita GDP (δ_7) are found to be negative and significant in both models, indicating that asset growth and a favorable macroeconomic environment with higher GDP growth help to improve bank performance.

Comparing the efficiency calculation results from the two models, the banking performance is significantly different.The mean efficiency score is 0.741 in model 1 (risk constraint model), while it's only 0.706 in model 2 (risk free model). This shows that ignoring the impacts of risk taking, will result in significantly underestimation of bank profit efficiency. The mean efficiency of sample banks is here underestimated by 4.943%.

5.2 Efficiency estimation results

Relative efficiency score of sample banks in model 1 are reported in Table 4. To save space, we do not report the estimated efficiencies of model 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

BOCC	0.958	0.895	0.885	0.883	0.889	0.925	0.914	0.914	0.915	0.903	0.859	0.902	0.894	0.896
ICBC	0.748	0.861	0.912	0.869	0.752	0.859	0.870	0.899	0.939	0.934	0.922	0.924	0.922	0.919
CCB	0.877	0.919	0.937	0.896	0.866	0.905	0.895	0.908	0.937	0.937	0.921	0.924	0.909	0.906
ABC	0.510	0.474	0.790	0.628	0.805	0.960	0.757	0.868	0.942	0.936	0.928	0.932	0.918	0.902
BOC	0.584	0.868	0.758	0.809	0.777	0.779	0.819	0.877	0.924	0.916	0.898	0.920	0.908	0.891
CEB	0.570	0.625	0.715	0.857	0.881	0.912	0.732	0.840	0.855	0.888	0.922	0.893	0.892	0.872
CGFB	0.461	0.119	0.671	0.292	0.104	0.835	0.618	0.858	0.876	0.886	0.891	0.839	0.808	0.703
HXB	0.927	0.680	0.738	0.708	0.660	0.756	0.455	0.624	0.811	0.787	0.877	0.910	0.901	0.915
PDD	0.811	0.691	0.678	0.719	0.726	0.864	0.857	0.832	0.869	0.860	0.868	0.880	0.880	0.899
IBC	0.555	0.754	0.818	0.811	0.776	0.802	0.835	0.911	0.932	0.909	0.910	0.906	0.899	0.906
CMB	0.874	0.833	0.876	0.831	0.789	0.923	0.924	0.877	0.906	0.910	0.923	0.914	0.894	0.901
CMSB	0.526	0.502	0.505	0.650	0.829	0.593	0.596	0.511	0.881	0.893	0.918	0.902	0.909	0.897
CITIC	0.810	0.717	0.852	0.831	0.777	0.680	0.564	0.747	0.909	0.903	0.833	0.875	0.809	0.813
BONJ	0.296	0.365	0.524	0.687	0.779	0.427	0.706	0.739	0.811	0.830	0.786	0.839	0.881	0.855
BOSH	0.421	0.710	0.837	0.631	0.644	0.863	0.735	0.788	0.817	0.789	0.857	0.871	0.862	0.869
FDB		0.228	0.292	0.289	0.226	0.131	0.575	0.340	0.632	0.632	0.783	0.897	0.803	0.823
BOCD			0.333	0.423	0.751	0.847	0.840	0.839	0.895	0.805	0.853	0.928	0.886	0.815
CZSB			0.002	0.100	0.342	0.434	0.432	0.540	0.515	0.613	0.837	0.835	0.843	0.825
EGB			0.678	0.583	0.730	0.919	0.819	0.743	0.902	0.816	0.849	0.877	0.863	0.876
BODG			0.142	0.282	0.237	0.898	0.809	0.890	0.918	0.930	0.933	0.931	0.934	0.893
DYB			0.109	0.251	0.357	0.390	0.419	0.646	0.883	0.520	0.768	0.833	0.809	0.824
FJHX			0.355	0.365	0.856	0.907	0.713	0.495	0.811	0.840	0.841	0.853	0.763	0.709
HKB			0.072	0.215	0.683	0.429	0.471	0.671	0.879	0.906	0.870	0.881	0.748	0.809
HZUR			0.443	0.618	0.715	0.784	0.826	0.594	0.775	0.787	0.869	0.880	0.778	0.723
HSB			0.214	0.608	0.739	0.950	0.671	0.861	0.945	0.960	0.937	0.905	0.906	0.914
BONB			0.738	0.739	0.756	0.626	0.685	0.786	0.811	0.815	0.896	0.900	0.907	0.902
GDSD			0.773	0.384	0.590	0.617	0.825	0.633	0.917	0.928	0.918	0.911	0.874	0.872
NBYZ			0.239	0.307	0.458	0.894	0.806	0.871	0.918	0.925	0.910	0.848	0.824	0.744
SHRC			0.167	0.254	0.217	0.255	0.825	0.776	0.525	0.693	0.840	0.844	0.847	0.883
BOLZ				0.403	0.042	0.564	0.609	0.666	0.829	0.737	0.695	0.703	0.635	0.490
BORZ				0.368	0.301	0.412	0.452	0.655	0.829	0.902	0.923	0.923	0.916	0.805
BODL				0.226	0.372	0.933	0.787	0.827	0.906	0.790	0.871	0.840	0.358	0.264
BOHZ				0.200	0.396	0.722	0.773	0.885	0.908	0.900	0.930	0.931	0.948	0.947
BOWZ				0.409	0.846	0.834	0.800	0.723	0.701	0.743	0.607	0.637	0.549	0.634
BRCB				0.492	0.575	0.685	0.472	0.688	0.675	0.878	0.907	0.920	0.936	0.938
BOCQ				0.394	0.758	0.872	0.707	0.821	0.862	0.633	0.875	0.831	0.913	0.907
BOGL					0.201	0.373	0.449	0.647	0.847	0.810	0.904	0.928	0.814	0.621

As shown in Table 4, the estimated profit efficiencies are distributed in [0.002, 0.958], indicating that the bank efficiency is quite different across the study period. China Construction Bank (CCB) is the best performing bank with average efficiency level at 0.910; it outperforms the lowest performing Fudian Bank (FDB) by 56%.We found that, among the most 5 efficient banks, there are 4 large state-owned commercial banks (CCB, BOCC, ICBC and BOC), with their mean efficiencies ranked 1, 2, 4, and 5. As for joint-stock banks, China Merchants Bank (CMB) is the most efficient, ranked 3 among all 38 sample banks. We also noticed that the performance of most city commercial banks (CCBs) is quite different and lower than that of other types of bank.

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

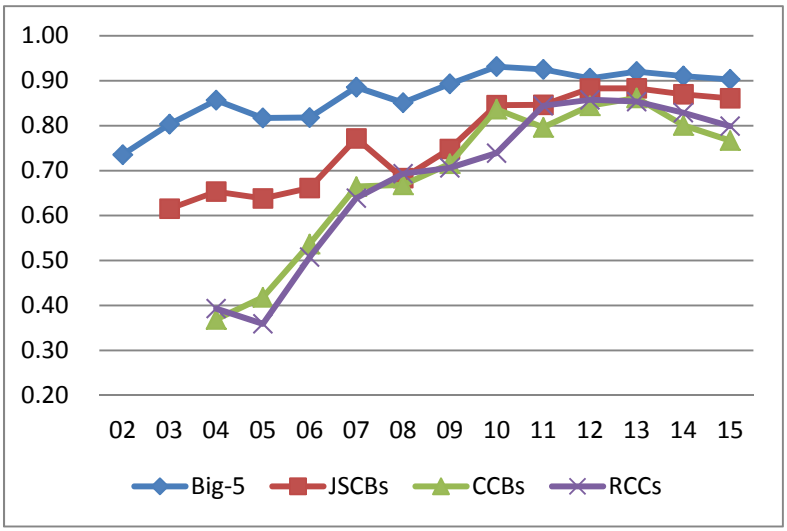

Fig 1. Mean profit efficiencies by bank type from 2002 to 2015 (Model 1).

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.

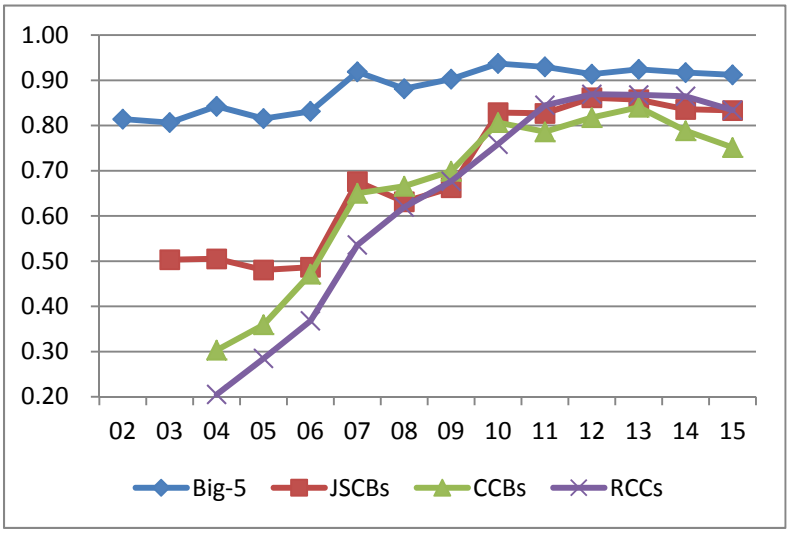

Fig 2. Mean profit efficiencies by bank type from 2002 to 2015 (Model 2)

Big-5 are the best performing banks in both models, but particularly in Model 2 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 dominate the banking system in terms of total asset, deposits, branch network and employees, they have some monopoly 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. (2005), and in contrast to the mainstream literature on the relationship between state ownership and efficiency. CCBs and RCCs are the least efficient banks especially in the first three years. A possible explanation is that only a small number of better performed CCBs and RCCs are included in our sample during the early years.

We also found that, exception for Big-5 and JSBCs, CCBs and RCCs 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:

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 of Model 1 are shown in Table 5:

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. $H_0 : \alpha_{11}=\alpha_{22}=\alpha_{12}=\beta_{22}=\beta_{33}=\beta_{23}=\rho_{12}=\rho_{22}=\rho_{13}=\rho_{23}=\theta_2=\phi_2=\phi_{11}=\phi_{12}=\phi_{22}=\phi_{23}=0$	-133.304	-230.929	195.250	31.353	16	Reject
2. $H_0 : \theta_1=\theta_2=0$	-133.304	-152.759	38.910	8.273	2	Reject
3. $H_0 : \gamma=\eta=\mu=0$	-133.304	-209.936	153.264	10.501	3	Reject
4. $H_0 : \eta=0$	-133.304	-209.922	153.237	5.412	1	Reject
5. $H_0 : \mu=0$	-133.304	-140.635	14.663	5.412	1	Reject
6. $H_0 : \phi_1=\phi_2=\phi_{11}=\phi_{12}=\phi_{22}=\phi_{23}=0$	-133.304	-153.425	40.242	16.074	6	Reject

To save space we only report the robust test of 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).

In Table 5, hypothesis 1 is rejected at the 1% significance level. This shows that compared to a simple Cobb-Douglas function, Fourier function is better to describe 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 played a significant role impact on banking performance, and the risk constraint 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.

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 related 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 opened, 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.

References

Altunbas Y, Carbo S, Gardener EPM, Molyneux P. Examining the relationships between capital, risk and efficiency in European banking. *European Financial Management* 2007; **13**(1): 49-70.

Altunbaş Y, Chakravarty SP. Frontier cost functions and bank efficiency. *Economics Letters* 2001; **72**(2): 233-40.

Barr RS, Seiford LM, Siems TF. Forecasting bank failure: a non-parametric frontier estimation approach. *Recherches Économiques de Louvain/Louvain Economic Review* 1994; **60**(4): 417-29.

Barros CP, Managi S, Matousek R. The technical efficiency of the Japanese banks: non-radial directional performance measurement with undesirable output. *Omega* 2012; **40**(1): 1-8.

Battese GE, Coelli TJ. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics* 1995; **20**(2): 325-32.

Berger AN, DeYoung R. Problem loans and cost efficiency in commercial banks. *Journal of Banking and Finance* 1997; **21**(6): 849-70.

Berger AN, Humphrey DB. Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research* 1997; **98**(2): 175-212.

Berger AN, Klapper LF, Turk-Ariss R. Bank Competition and Financial Stability. *Journal of Financial Services Research* 2009; **35**(2): 99-118.

Berger AN, Mester LJ. Inside the black box: What explains differences in the efficiencies of financial institutions? *Journal of Banking and Finance* 1997; **21**(7): 895-947.

Bonin JP, Hasan I, Wachtel P. Bank performance, efficiency and ownership in transition countries. *Journal of Banking and Finance* 2005; **29**(1): 31-53.

Chen M-J, Chiu Y-h, Jan C, Chen Y-C, Liu H-H. Efficiency and Risk in Commercial Banks–Hybrid DEA Estimation. *Global Economic Review* 2015; **44**(3): 335-52.

Chiu Y-H, Chen Y-C. The analysis of Taiwanese bank efficiency: incorporating both external environment risk and internal risk. *Economic Modelling* 2009; **26**(2): 456-63.

Chortareas GE, Girardone C, Ventouri A. Financial freedom and bank efficiency: Evidence from the European Union. *Journal of Banking and Finance* 2013; **37**(4): 1223-31.

Elyasiani E, Mehdian S, Rezvanian R. An empirical test of association between production and financial performance: the case of the commercial banking industry. *Applied Financial Economics* 1994; **4**(1): 55-60.

Epure M, Lafuente E. Monitoring bank performance in the presence of risk. *Journal of Productivity Analysis* 2015; **44**(3): 265-81.

Fang Y, Hasan I, Marton K. Bank efficiency in South‐Eastern Europe. *Economics of Transition* 2011; **19**(3): 495-520.

Fiordelisi F, Marques-Ibanez D, Molyneux P. Efficiency and risk in European banking. *Journal of Banking and Finance* 2011; **35**(5): 1315-26.

Fries S, Taci A. Cost efficiency of banks in transition: Evidence from 289 banks in 15 post-communist countries. *Journal of Banking and Finance* 2005; **29**(1): 55-81.

Garza-García JG. Determinants of bank efficiency in Mexico: a two-stage analysis. *Applied Economics Letters* 2012; **19**(17): 1679-82.

Glass JC, McKillop DG, Quinn B, Wilson J. Cooperative bank efficiency in Japan: A parametric

distance function analysis. *The European Journal of Finance* 2014; **20**(3): 291-317.
Gunay ENO. Risk incorporation and efficiency in emerging market banks during the global crisis: evidence from Turkey, 2002-2009. *Emerging Markets Finance and Trade* 2012; **48**(sup5): 91-102.
Holod D, Lewis HF. Resolving the deposit dilemma: A new DEA bank efficiency model. *Journal of Banking and Finance* 2011; **35**(11): 2801-10.
Hou X, Wang Q, Zhang Q. Market structure, risk taking, and the efficiency of Chinese commercial banks. *Emerging Markets Review* 2014; **20**: 75-88.
Houston JF, Lin C, Lin P, Ma Y. Creditor rights, information sharing, and bank risk taking. *Journal of Financial Economics* 2010; **96**(3): 485-512.
Jiang C, Yao S, Zhang Z. The effects of governance changes on bank efficiency in China: A stochastic distance function approach. *China Economic Review* 2009; **20**(4): 717-31.
Kumbhakar SC, Lovell CK. Stochastic frontier analysis: Cambridge University Press; 2003.
Kwan S, Eisenbeis RA. Bank risk, capitalization, and operating efficiency. *Journal of Financial Services Research* 1997; **12**(2-3): 117-31.
Lozano-Vivas A, Pasiouras F. The impact of non-traditional activities on the estimation of bank efficiency: international evidence. *Journal of Banking and Finance* 2010; **34**(7): 1436-49.
Mester LJ. A study of bank efficiency taking into account risk-preferences. *Journal of Banking and Finance* 1996; **20**(6): 1025-45.
Ozdincer B, Ozyildirim C. Determining the factors of bank performance with a focus on risk and technical efficiency. Proceedings of the 2nd WSEAS International Conference on Management, Marketing and Finances; 2008; 2008. p. 31-9.
Saeed M, Izzeldin M. Examining the relationship between default risk and efficiency in Islamic and conventional banks. *Journal of Economic Behavior and Organization* 2014.
Sufian F. The impact of risk on banks' technical and scale efficiency: empirical evidence from the Chinese banking sector. *IUP Journal of Financial Economics* 2010; **8**(1/2): 82.
Sun L, Chang T-P. A comprehensive analysis of the effects of risk measures on bank efficiency: Evidence from emerging Asian countries. *Journal of Banking and Finance* 2011; **35**(7): 1727-35.
Williams J, Nguyen N. Financial liberalisation, crisis, and restructuring: A comparative study of bank performance and bank governance in South East Asia. *Journal of Banking and Finance* 2005; **29**(8): 2119-54.
Xiaogang C, Skully M, Brown K. Banking efficiency in China: Application of DEA to pre-and post-deregulation eras: 1993–2000. *China Economic Review* 2005; **16**(3): 229-45.
Yao S, Han Z, Feng G. Ownership Reform, Foreign Competition and Efficiency of Chinese Commercial Banks: A Non‐parametric Approach. *The World Economy* 2008; **31**(10): 1310-26.