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Risk, capital and efficiency in Chinese Banking

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Abstract

We assess the relationship between bank efficiency, risk and capital for a sample of Chinese commercial banks employing three efficiency indexes and four risk indicators under a three stage least square method in a panel data framework. The empirical evidence suggests that there is a positive and significant relationship between risk (loan-loss provision as a fraction to total loans or LLPTL) and efficiency in Chinese banking industry, while the relationship between risk (Z-score) and level of capitalization is negative and significant.

Key words: efficiency, risk, capital, SUR, Chinese banks.

JEL classification: E5, E52, G21

1. Introduction

The banking sector in China plays an important role in the development of financial system and the economy as a whole. Since 1997 several rounds of reforms have been started by Chinese government to increase bank efficiency and create a competitive environment in the banking sector. In other words, all the banks are forced to operate closer to the best practice or efficient production function. However, Hellmann *et al*. (2000) argue that increase in competition will result in greater risk-taking behaviour due to the fact that market power of banks is reduced and their charter values are decreased (Salas and Saurina, 2003; Goddard and Wilson, 2009)[1]. The capital adequacy plays a more and more important role for the purpose of counterbalance the risk.

A number of studies have investigated the impact of capital (Gropp and Heider, 2010), operating efficiency (Casu and Girardone, 2009) on bank risk[2]. Furthermore, there are few studies assessing the relationship between risk, capital and efficiency for European banking area[3]. Surprisingly, there is no study examining the relationship between capital, risk and efficiency for Chinese banking industry. The investigation on the relationship between them becomes very important because of the financial crisis happened from 2007 in Asia[4].

Two important issues in Chinese banking industry are considered in this paper. First, the relationship between bank efficiency and risk is examined. The negative relationship is expected by the fact that lower levels of efficiency will force banks to boost their returns through increasing the levels of credit risk; on the other hand,

[1] Their finding is in direct contrast with Boyd and De Nicolo (2005) who argue that the relationship between intense competition and increased bank's risk taking behaviour is weak.
[2] The impact of bank competition on bank risk and efficiency is analyzed by previous literature (see Boyd and De Nicolo, 2005; De Nicolo and Lucchetta, 2009; Casu and Girardone, 2009).
[3] See Altunbas *et al.*, 2007; Fiordelisi *et al*., 2011b.
4 See Festic *et al*., 2011.

increases of banks' credit risk levels which involves additional costs and managerial efforts lead to declines in banks' levels of technical efficiency. Further, the impact of bank capital on the trade off between bank risk and efficiency is assessed. Banks tend to have lower capital levels due to the fact that higher levels of efficiency provide them advantage to increase their capital levels in the future. On the other hand, banks seem to be thinly capitalized because lower levels of efficiency induce bank managers to balance their higher operating costs with lower volumes of funding via expensive capital. Eventually, capital and efficiency have influences on the risk-taking behaviour of banks. Efficient banks with higher capital levels tend to allocate less funds to monitor loans which results in higher levels of credit risk, while inefficient banks with lower capital levels tend to increase the levels of credit risk in order to maximize their revenues. To deal with these issues, we extend previous literature and assess the relationship between efficiency, risk and capital levels in Chinese banking sector. We use large dataset of Chinese banks over the period 2003-2009. Our main variables of interest include different measures of bank risk, three different measures of bank efficiency (technical, pure technical and scale efficiency) and bank productivity.

According to 2009 annual report from China Banking Regulatory Commission (CBRC), the non-performing loan ratio of Chinese banks drops dramatically from nearly 20% in 2003 to 1.58% at the end of 2009, while large proportion of non-performing loans is from the state-owned commercial banks. Further, Yao and Jiang (2010) suggest that the state-owned commercial banks are least efficient comparing to the joint-stock and city commercial banks in China over the period 1995-2008. Hence, it is interesting to examine whether higher risk decreases the bank efficiency, and lower efficiency induces Chinese banks to take on higher risk.

At the end of 2009, the capital adequacy ratio of Chinese banks reaches 11.4% which is higher than the international level; this higher level of capitalization is largely attributed to the capital injection by the government especially to the state-owned commercial banks. According to 2009 Almanac of China's Finance and Banking report (China Finance Society, 2009), during the period of 2003-2008, the Chinese government injects capitals to the state-owned commercial banks in different forms such as using the foreign reserve, writing-off the non-performing loans, etc. This free capital injection to the banks may reduce bank managers' efforts which leads to a decline in bank efficiency and an increase in bank risk.

Our paper makes several contributions to the literature on the relationship between bank efficiency, capital and risk in Chinese banking. First, this study includes the latest banking data from 2003-2009; this includes the last round of banking reform in China which focuses on the efficiency improvement in financial institutions. Second, comparing with other related studies which focus on either cost efficiency[5] or profit efficiency[6] for US or European banking industry, this is the first empirical study which estimates the technical, pure technical, scale efficiencies and productivity index. It is assumed that efficiency and productivity have same relationship with bank capital and risk levels. In addition, we contribute to the existing literature by using different risk indicators. In other words, the accounting ratio which derives from banks' financial statements (loan loss provision to total loans) is used as the measurement of bank risk. We complement this measure with three alternative risk indicators which are (i) volatility of ROA, (ii) volatility of ROE and (iii) Z-score. Further, we fill in the gap from previous empirical work (see Das and Ghosh, 2004; Altunbas et al., 2007; Deelchand and Padgett, 2009) by controlling most comprehensive bank

[5]See Kwan and Eisenbeis, 1997; Berger and De Young, 1997; Williams, 2004; Altunbas *et al*., 2007.
[6] See Berger and Bonaccorsi di Patti, 2006.

specific, industry specific and macroeconomic variables, which are supposed to influence the efficiency/productivity-capital-risk relationship. Finally, with regards to the econometric modelling framework, we use the three stage least square estimation. OLS estimation, which is employed by previous studies in this area, is not a robust method as it ignores the correlation of error term across equations. Furthermore, comparing to the research undertaken by Fiordelisi *et al*. (2011b) for Europe, who use the Granger causality methodology, our selected method is used to examine whether we can obtain similar results. Recent papers investigate the efficiency of Chinese banking industry (see Ariff and Can, 2008; Fu and Heffernan, 2007; Berger et al. 2009; among others) using a standard methodology (i.e. they use two stages analysis under 1) DEA or SFA method to estimate efficiency and 2) OLS regression to investigate the determinants of efficiency).This is the first study which examines the empirical relationship between efficiency, risk and capital in Chinese banking sector.

The rest of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the main hypotheses of interest in this study. Section 4 describes the modelling framework on the relationship between risk, capital and efficiency/productivity. Section 5 discusses the data followed by section 6 which presents the empirical results, while section 7 summarizes and concludes the paper.

2. Literature review

The examinations regarding the effect of bank capital regulations on banks' risk-taking behaviour focused on the United States according to the early line of the empirical research[7]. These early studies mainly concern the issue whether the

[7] See Peltzman, 1970; Mayne, 1972.

existence of flat-rate deposit insurance induces banks to take on excessive risk. The empirical findings of these studies are doubtful about the effectiveness of banking capital regulations on banks' target capital ratios. They emphasize the importance of controlling other factors to limit the risk-taking behaviour such as the deposit insurance flat fee rate or the level of nominal interest rate[8].

The new wave of studies concerning the effect of bank capital regulations on banks' risk-taking behaviour started after the introduction of the 1988's Basle Accord on international bank capital. These studies mainly focus on the United States banking sector[9]. The findings indicate that the financing decisions made by a significant subset of banks are influenced by the regulatory minimum capital constraints[10].

The recent empirical studies from Shrieves and Dahl (1992), Editz *et al*. (1998), and Rime (2001) suggest that capital regulations in banking have been effective in increasing capital ratios without shifting their portfolio and off-balance-sheet exposure towards riskier assets. Demsetz *et al*. (1996) and Salas and Saurina (2003) report a negative effect of capital on the levels of credit risk taken by banks; this is in line with the moral hazard hypothesis. However, Haq and Heaney (2012) argue that there is evidence of U-shape relationship between bank capital and credit risk. Overall, there is no consensus on the issue whether the overall banking risk can be reduced by increasing the capital ratio.

The empirical studies concerning the effect of bank capital regulations on banks' risk-taking behaviour and the literature dealing with bank efficiency are linked by Kwan and Eisenbeis (1997) using a simultaneous equation framework. They provide

[8] See Marcus, 1983.
[9] For non-US countries see Barrios and Blanco (2003).
[10] See Wall and Peterson (1988) and Shrieves and Dahl (1990).

evidence that efficiency and capital are relevant determinants of bank risk. According to Hughes and Moon (1995), efficiency is an important variable when evaluating the relationship between risk and capital. For instance, the efficient banks are more flexible in terms of their capital levels and overall risk profile, while less efficient banks normally are more likely to take on extra risk to compensate for the loss returns because of moral hazard considerations.

The Granger-causality method is employed by Berger and De Young (1997) to investigate the problem loans-cost efficiency-capital relationship for a sample of US banks over the period 1985-1994. The empirical findings suggest that declines in cost efficiency precede increases in problem loans especially for the banks with lower levels of capital; in addition, the higher levels of problem loans lead to a decrease in cost efficiency.

Recent studies are conducted by Williams (2004), Altunbas *et al*. (2007) and Fiordelisi *et al*. (2011b). Granger-causality technique is used by Williams (2004) to examine the relationship between problem loans, cost efficiency and capital for a sample of European saving banks over the period 1990-1998. He finds that the quality of loans is poor for the banks which are not well-managed (i.e. banks with lower efficiency). Further, the Seeming Unrelated Regression (SUR) is used by Altunbas *et al*. (2007) to investigate the relationship between capital, loan loss provision and cost efficiency for a sample of European banks over the period 1992-2000. In contrast to William (2004), they report that banks with higher efficiency tend to take on higher levels of risk while less efficient banks seem to have higher capital levels and lower levels of credit risk. Fiordelisi *et al*. (2011b) use Granger-causality technique to assess the relationship between capital, efficiency and risk for a sample of European commercial banks over the period 1995-2007. The results indicate that

inefficient banks typically have higher risk levels and higher capital levels increase the bank efficiency. Overall, there is no empirical research investigating the relationship between risk, efficiency and capital in Chinese banking industry.

3. Main hypotheses of the relationship between capital and risk

Before introducing the empirical model, several hypotheses explaining the relationship between bank risk, capital and efficiency are illustrated.

Bad management hypothesis: this is labelled by Berger and De Young (1997) and Williams (2004) suggesting that higher costs will be incurred for the banks with lower levels of efficiency due to the fact that credit is inadequately monitored and operating expenses are not inefficiently controlled. Because of the credit, operational, market and reputational problems, declines in efficiency will temporarily lead to increases in banks' risk.

Bad luck hypothesis: this is put forward by Berger and De Young (1997) arguing that it is the external exogenous events rather than managers' skills or their risk-taking appetite that lead to increases in problem loans for the banks. The increases in risk incur additional costs and managerial efforts. Thus, we expect that increases in banks' risk precede technical efficiency and productivity declines under this hypothesis.

Moral hazard hypothesis: this is suggested by Jeitschko and Jeung (2005) indicating that bank managers tend to take on more risk when the banks have lower levels of capital or the banks are less efficient. The moral hazard problem arising from the presence of informational friction and the existence of agency problem will make

bank managers take on higher risk. In contrast, the cost reducing practices will be adopted for the banks with higher levels of capital and less moral hazard incentives.

Banks are forced by the regulators to hold higher levels of capital when risk undertaken by banks increases; this is due to the fact that the cost for issuing fresh equity at short notice can be avoided by holding additional capital above the regulatory minimum (Peura and Keppo, 2006). On the other hand, the requirement to hold higher levels of capital from regulatory authority can be responded by banks through increasing the portfolio risk.

4. The methodological framework

We rely on the three stage least square estimation to investigate the relationship between bank risk, capital and efficiency/productivity as it takes into account both endogeneity and the cross correlation between the error terms.

In order to disentangle the relationship between bank capital, efficiency/productivity and risk, we estimate the following equations:

$$RISK_{it} = \beta_0 + \beta_1 CAP_{it} + \beta_2 EFF/PROD_{it} + \beta_3 Bank_{it} + \beta_4 INDUSTRY_{it} + \beta_5 MACRO_{it} + \varepsilon_{it} \quad (1)$$

$$CAP_{it} = \delta_0 + \delta_1 EFF/PROD_{it} + \delta_2 RISK_{it} + \delta_3 BANK_{it} + \delta_4 INDUSTRY_{it} + \delta_5 MACRO_{it} + \varepsilon_{it} \quad \textbf{(2)}$$

$$EFF/PROD_{it} = \gamma_0 + \gamma_1 CAP_{it} + \gamma_2 RISK_{it} + \gamma_3 BANK_{it} + \gamma_4 INDUSTRY_{it} + \gamma_5 MACRO_{it} + \varepsilon_{it} \quad \textbf{(3)}$$

Where the *i* subscript denotes the cross-sectional dimension across banks,and *t* denotes the time dimension. $RISK$ is the variable accounting for bank's risk, CAP is the equity to total assets ratio . $EFF/PROD$ is the technical, pure technical, scale efficiencies or Malmquist productivity index. $Bank$, $INDUSTRY$, and $MACRO$ are the

bank-specific, industry-specific and macroeconomic factors influencing the efficiency/productivity-capital-risk relationship and ε_{it} is the random error term.

Eq. (1) tests whether efficiency or productivity and capital temporarily precede variations in bank risk. Eq. (2) assesses if efficiency or productivity and risk temporarily precede variations in bank capital, while Eq. (3) examines whether level of capital together with bank risk reflect the changes in bank efficiency or productivity.

We measure the individual bank risk by using the ratio between loan-loss provision and total loans. A higher level of this ratio indicates higher bank risk. A limitation to measure risk calculating from the accounting data, as suggested by Rime (2001) and Shrieves and Dahl (1992), is that providing the portfolio quality can be accurately reflected by these measures, and therefore managers are more likely to have some time discretion which is exercised in a way to minimize cost. They also argue that this measurement is quite problematic for the banks which do not have public trade securities (in our case, the majority of Chinese banks do not have public traded securities). In order to check the robustness of the results, we use three alternative measures of banks' risk positions which are:(i) volatility of ROA, (ii) volatility of ROE and (iii) Z-score. The volatility of ROA and ROE are calculated for each bank over the examined period (2003-2009) while the Z-score is obtained as the ratio between a bank's return on assets plus equity capital /total assets and the standard deviation of the return on assets. A higher figure of volatility of ROA or ROE represents higher risk, while higher figure of Z-score indicates that risk is low.

Capital is calculated as the ratio of book value of equity to total assets. The individual bank technical efficiency is measured as a maximum of a ratio of weighted outputs to weighted inputs, and it is calculated using the non-parametric Data Envelopment

Approach (DEA) CCR model[11], while the pure technical and scale efficiencies are derived from DEA BCC model, and the productivity is measured by the Malmquist productivity index. Besides capital, risk and efficiency/productivity, we also control for comprehensive bank-specific, industry-specific and macroeconomic variables; these variables are important in explaining the capital-risk-efficiency/productivity relationship.

5. Data Description

Our banking data is composed of annual figures from 101 Chinese banks over the period 2003-2009 with totally over 170 observations. The banks used in this study are five state-owned commercial banks, twelve joint stock commercial banks and eighty four city commercial banks. Table 1A and Table 1B present some information regarding the structure of Chinese banking system, i.e. the difference among state-owned commercial banks, joint-stock commercial banks, city commercial banks in terms of their ownership, business scope and their assets (percentage to the total banking industry assets) over the period 2003-2009. Since not all banks have available information for all years, we opt for an unbalanced panel not to lose degrees of freedom. The bank specific information is mainly obtained from Bankscope database maintained by Fitch/IBCA/Bureau Van Dijk, which is considered as the most comprehensive database for research in banking. The industry specific and macroeconomic variables are retrieved from the website of China Banking Regulatory Commission (http://www.cbrc.gov.cn) and the World Bank database (http://data.worldbank.org). Table 2 describes the variables used in this study.

[11] Technical efficiency is estimated using four outputs (total loans, securities, total deposits and non-interest income) and three inputs (total cost which includes price of labour, price of funds and price of capital).

<<Table 1---about here>>

<<Table 2—about here>>

Table 3 presents the summary statistics of all variables. The mean of LLPTL(ratio of loan loss provision over total loans) is 0.0092 (less than 1%) which suggests that through several rounds of banking reforms in China, the Chinese banks have increased the ability to manage the risk. The low risk of Chinese banking sector can also be explained by the fact that the four Asset Management Companies (AMCs) write-off the non-performing loans for the state-owned banks under the government direction. Comparing the Mean of different risk measures, the highest and lowest values are achieved by the Z-score and volatility of ROA, which are 44.17 and 0.0038, respectively. In addition, according to the Min and Max values, the difference of Z-score in different years among banks is huge. The difference of capital positions among banks in different years is relatively large with lowest value of -14 and highest value of 31. According to the values of the standard deviation, there is a substantial difference of productivity than efficiency in Chinese banking sector over the examined period. Correlation among the variables is usually negligible suggesting that our models are unlikely to suffer from major multicollinearity problems[12]. Furthermore, the expected impacts of comprehensive variables on risk, capital, efficiency/productivity are described in Table 4.

<<Table 3---about here>>

<<Table 4—about here>>

[12] Estimated correlations coefficients are available upon request from the authors.

6. Empirical results and discussion

Empirical results derived from the simultaneous estimations using technical efficiency as the dependent variable are reported in Table 5. The empirical results show that there is a negative and significant relationship between risk (Z-score) and capitalization. In the context of the Chinese banking industry, the finding can be explained by the fact that banks with higher levels of capital are more capable of absorbing the losses accumulated from non-performing loans which reduces the risk, while banks with higher levels of risk need larger amounts of capital to compensate the losses which leads to lower levels of capital. We further report that the relationship between risk (LLPTL) and technical efficiency is significant and positive. In order to minimize the input invested in producing certain amount of output (achieving higher technical efficiency), Chinese banks reduce their efforts to check the credit and monitor the loans which leads to higher risk. On the other hand, higher levels of risk because of lacking of monitoring and screening increase the volumes of loans generated by Chinese banks which precedes increases in technical efficiency. We also find that size and technical efficiency are positively related in Chinese banking industry. The state-owned commercial banks have larger size in terms of total assets; they have comprehensive branches around the country and the amount and variety of business engaged by them are substantially more than joint-stock and city commercial banks. Also, they have the ability and advantage to reduce the costs from economies of scale and scope. In other words, they can generate the same amount of outputs using fewer inputs which leads to higher efficiency. Furthermore, we suggest that liquidity, taxation and labour productivity are significantly and negatively related to technical efficiency of Chinese banks. Chinese banks with higher volumes of loans need more deposits to deal with the daily withdraws from

customers; the increase in the deposit interest rate (in order to attract more depositors) increases the price of funds which leads to a decline in bank efficiency. Higher taxation paid by banks reduces the managers' incentives and efforts to control the costs which leads to increases in the input expenses and decreases in bank efficiency. The labours with higher productivity require higher wages or salaries, the resulted increase in the price of labour increases the input cost in banking operating which precedes a decline in bank technical efficiency in China. In terms of the industry-specific variables, the results indicate that more concentrated banking market precedes a decrease in technical efficiency of Chinese banking industry. That is, in a highly concentrated market, bank managers have less incentive to improve the efficiency. Furthermore, when risk is measured by LLPTL, volatility of ROA and ROE, the results indicate that banks with larger size (in terms of total assets) have lower capital positions, while banks in a highly concentrated and developed banking sector are normally better capitalized. As reported previously, higher concentrated banking market leads to a decline in bank efficiency. Hence, bank managers normally balance the higher costs with higher levels of capitalization because the Chinese government injects capitals to the banks for free.

<<Table 5---about here>>

Table 6 reports the results of the relationship between bank capital, pure technical efficiency and risk in Chinese banking. The results show that most of the variables are consistent comparing with the findings in Table 5. However, when the relationship between capital, risk and scale efficiency is examined (Table 7), the findings show that liquidity has a positive impact on the level of capitalization of Chinese banks. Furthermore, bank concentration and development of banking market are positively related to bank capital (when risk is measured by LLPTL,

volatility of ROA and volatility of ROE). Although the risk management ability has improved significantly, the volume of non-performing loans is still higher especially for the state-owned commercial banks due to the fact the government still has influence or controls on the banks' operation especially the credit allocation. Larger volumes of loans are allocated to the state-owned enterprises with lower profitability and lower probability of loan repayment. Capital works as a cushion to absorb these losses. In other words, more loans made by Chinese banks (lower liquidity) decreases the levels of capitalization. In a higher concentrated and developed banking market where competition is relatively lower, Chinese banks should take on higher risk (higher LLPTL) in order to obtain higher profits which is in line with the competition-stability hypothesis; Chinese government may inject capitals to the banks to counterbalance the risk.

<<Table 6---about here>>

<<Table 7---about here>>

In addition, Table 8 shows the results using the Malmquist productivity index, instead of efficiency, as an explanatory variable. We find that there is a significant and positive relationship between liquidity and capital which confirms our previous finding. This is also in line with Altunbas *et al*. (2007) for European banking.

In terms of the industry specific variables, we find a significant and positive relationship between concentration and capital (when risk is measured by LLPTL, volatility of ROA and volatility of ROE) which is in line with Fiordelisi *et al*. (2011b) for Europe. However, Fiordelisi *et al*. (2011a) find that there is no effect of concentration on capital in terms of a large sample of investment banks in ten large developed countries. Furthermore, we find that higher developed banking sector improves the

bank productivity in China, however, Chinese bank productivity is lower in a higher developed stock market. Higher developed banking sector indicates that there is a higher demand for banking services, and therefore, increases in the volumes of customers improve the bank productivity. Whereas the developed stock market provides more opportunities for investors to obtain funds from stock market rather than banks, decreases in the numbers of customers to banks make some of the staffs redundant, thus decreases the bank productivity. Finally, in terms of the macroeconomic environment, annual inflation and GDP growth rates are found to be positively related to Chinese bank productivity. Technological improvement, one source of GDP growth, improves the production method in banking operation which precedes an increase in bank productivity. The positive impact of inflation on bank productivity can be explained by the fact that in the inflation environment, the amount of depositors will decrease because of the erosion on the value of money. In order to engage in more activities to obtain higher profits and have stronger competitive power, the bank managers tend to contribute more efforts to increase the bank productivity.

<<Table 8---about here>>

7. Summary and Conclusion

In this paper, we assess the relationship between bank efficiency/productivity, capital and risk for Chinese commercial banking industry. We look into this relationship deeply and differently by including three different indexes of efficiency, productivity and four indicators of bank risk. We contribute to the empirical literature by using Chinese banking data over 2003-2009, the period of which focuses on creating a more competitive environment and increasing bank efficiency.

The empirical evidence suggests that there is a significant and negative relationship between risk (Z-score) and capitalization, while the relationship between risk (LLPTL) and technical/pure technical efficiency of Chinese banks is significant and positive. In terms of the bank-specific variables, we find that bigger banks (in terms of total assets) have higher technical and pure technical efficiencies, while Chinese banks with higher liquidity levels have lower technical and pure technical efficiencies. Furthermore, in a higher concentrated banking market, the technical and pure technical efficiencies of Chinese banks are lower. With regards to the relationship between risk, capital and bank productivity, the results suggest that banks with higher liquidity levels are more capitalized. Finally, we report that inflation and GDP growth rates have positive impacts on bank productivity in China.

In addition to the gains from extending previous work on the relationship between efficiency, risk and capital, we strongly believe that our empirical results may be helpful for the Chinese government and banking regulatory authority to make relevant policies. In particular, Chinese banks should be encouraged to engage in lending activities with higher risk, and help increase competition (decrease concentration) in banking sector. Finally, Chinese banking sector should be further developed and stock market should be better controlled.

Appendix A

A.1. Efficiency estimation

The efficiency estimates in this study have been obtained using the Data Envelopment Analysis (DEA). DEA, which is originated by Charnes, Cooper and Rhodes (1978), known as CCR model, is a linear programming technique. The CCR model measures the efficiency of each Decision Making Units (DMUs) that is obtained as a maximum of a ratio of weighted outputs to weighted inputs. This denotes that the less input invested in producing the given output, the more efficient of the production. The CCR model presupposes that there is no significant relationship between the scale of operation and efficiency by assuming Constant Return to Scale (CRS). The CRS assumption is only suitable when all DMUs are operating at an optimal scale.

Banker *et al*. (1984) extend the CCR model by relaxing the CRS assumption. The resulting "BCC" model was used to assess the efficiency of DMUs characterized by Variable Return to Scale (VRS). The VRS assumption provides the measurement of purely technical efficiency (PTE), which is the measurement of technical efficiency devoid of the scale efficiency effect. The CCR model can be expressed as follow:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ &\text{subject to} \\ &-y_i + Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &\lambda \geq 0 \end{aligned} \qquad (1)$$

Where θ is a scalar and λ is a N×1 vector of constants, Y represents all input and output data for N firms, x_i are individual inputs and y_i the outputs for the i th firm. The

efficiency score for each DMU is given by θ; it takes a value between 0 and 1, which indicates the efficiency level.

The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint, N1'λ=1, to provide:

$$\begin{aligned}
&\min_{\theta,\lambda} \theta, \\
&\text{subject to} \\
&-y_i + Y\lambda \geq 0, \\
&\theta x_i - X\lambda \geq 0, \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned} \qquad (2)$$

Where N1 is an $N \times 1$ vector of ones. This approach forms a convex hull of intersecting plans which envelop the data points more tightly than the CRS conical hull; this provides pure technical efficiency scores which are greater than or equal to those obtained using the CRS model. If the efficiency scores obtained from CRS model and VRS model are different, this indicates that the DMU has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS technical efficiency (TE) score and the CRS TE score. The relationship between CRS and VRS is given below:

$$TE_{CRS} = TE_{VRS} \times SE \qquad (3)$$

A.2. **The measurement of productivity in the Chinese banking industry**

The output-oriented Malmquist method[13] defined by Caves *et al*. (1982) is used to derive the TFP growth and it is estimated using DEA by Fare *et al.* (1994). Let us assume that there are *n* observations using *m* inputs to produce L outputs.

Denote $X^n = (X_1^n, X_2^n .....X_m^n) \in R^m$, $Y^n = (Y_1^n, Y_2^n .....Y_l^n) \in R^L$

The production technology can be written as:

$F = \{(Y, X) : X\, can produce Y\}$ which describes the set of feasible input-output vectors.

The input sets of production technology can be written as:

$PT(Y) = \{X : (Y, X) \in F\}$ which describe the sets of input vectors that are feasible for each output vector.

The output Malmquist TFP productivity index[14] can then be expressed as:

$$M_o(x^s, y^s, x^t, y^t) = \left[\frac{D_o^s(x^t, y^t)}{D_o^s(x^s, y^s)} \frac{D_o^t(x^t, y^t)}{D_o^t(x^s, y^s)} \right]^{\frac{1}{2}} \quad (4)$$

where M_0 measures the productivity change between period *s* and *t*; $D_o^s(x^t, y^t)$ represents the distance from the period *t* observation to the period *s* technology. $M_0 \rangle 1$ indicates positive TFP growth from period *s* to period *t*, while $M_0 \langle 1$ indicates a decline and $M_0 = 1$ indicates constant TFP growth.

[13] We employ the output-oriented Malmquist index due to the fact that the regulators are more concerned about the bank's output (see Delis et al., 2011).

[14] To estimate the bank productivity using the Malmquist index, we use the same inputs and outputs as discussed earlier in the paper (see footnote 11).

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Table 1A. the difference among state-owned, joint-stock and city commercial banks in China

Banks	Ownership and business scope
State-owned commercial banks	Fully central government owned (finance the big state-owned enterprises)
Joint-stock commercial banks	Local government as well as private and state-owned enterprises (their businesses mainly oriented to the small and medium size enterprises).
City commercial banks	Local government, enterprises and residents (most of them focus their businesses in the city where they were founded).

Table 1B. The assets of different ownerships of banks over the period 2003-2009 (RMB: Billion)

Years/Banks	State-owned commercial banks(percentage to the total banking industry assets)	Joint-stock commercial banks(percentage to the total banking industry assets)	City commercial banks(percentage to the total banking industry assets)
2003	16051.17(58%)	2959.86(10.7%)	1462.17(5.3%)
2004	17981.67(57%)	3647.6(11.5%)	1705.63(5.4%)
2005	21005(56%)	4465.49(11.9%)	2036.69(5.4%)
2006	24236.35(55%)	5444.59(12.4%)	2593.79(5.9%)
2007	28007.09(53%)	7249.4(13.8%)	3340.48(6.4%)
2008	31835.8(51%)	8809.5(14.1%)	4131.97(6.6%)
2009	40089.02(50.9%)	11784.98(15%)	5680.01(7.2%)

Source: China Banking Regulatory Commission (CBRC), 2009.

Table 2. Description of variables used in the study

Variables	Acronym	Definition
Risk	LLPTL	Loan-loss provision as a fraction to total loans
	Volatility of ROA	Standard deviation of ROA
	Volatility of ROE	Standard deviation of ROE
	Z-score	Ratio between a bank's return on assets plus equity capital/total assets and the standard deviation of the return on assets
EFF	TE	Technical efficiency
Capital	CAP	Book value of capital to total assets
Bank-specific variables		
Profitability	ROA	Return on Assets
Size	SIZE	Logarithm of total assets
Loan to total assets	Liquidity	Ratio of loan to total assets
Tax to pre-tax profit	TAXATION	Rtio of tax to pre-tax profit
Non-traditional activity	OBSOTA	Ratio of off-balnce-sheet items to total assets
Labour	LP	Ratio of gross total revenue to number of employees
Industry specific variables		
Concentration	C(3)	The ratio of large three banks in terms of total assets to the total assets of the banking industry
Banking sector development	BSD	The ratio of banking industry assets over GDP
Stock market development	SMD	Ratio of stock market capitalization over GDP
Macroeconomics		
Inflation	IR	Annual inflation rate
GDP growth	GDPG	Annual GDP growth rate

Notes (Sources of the above data):

- Bank-specific variables (includes risk and capital) are from Bankscope
- Indestry-specific variables are from China Banking Regulatory Commission (CBRC, 2009)
- Macroeconomic variables are from World bank database

Table 3. Descriptive statistics of all variables

Variables	Mean	S.D	Min	Max
Risk(LLPTL)	0.0092	0.0067	-0.0019	0.042
Volativity of ROA	0.0038	0.0038	0	0.029
Volatility of ROE	0.11	0.5	0	5.12
Z-score	44.17	245.52	-5184.29	475
Efficiency	0.89	0.05	0.733	1
Productivity	1.006	1.1	0.579	1.699
Capital	5.11	2.97	-14	31
ROA	0.007	0.006	-0.04	0.089
Size	4.67	0.95	0.71	7.07
Liquidity	53.39	9.35	17.97	83.25
Taxation	0.41	0.37	-4.56	3.18
Off-balance-activity	0.199	0.11	0.00014	0.67
Labour productivity	0.008	0.004	3.00e-06	0.019
Concentration	14.54	1.95	10.19	16.29
Banking sector development	51.98	15.49	16.86	63
Stock market development	77	49.47	31.9	184.1
Inflation	2.5	2.17	-0.77	5.86
GDP growth	11	1.72	9.1	14.2

Table 4. Expectation of the impacts of comprehensive variables on risk, capital, efficiency/productivity in Chinese banking industry

	Risk	Capital	Efficiency/productivity
Profitability	-	-	+
Size	+	-	+
Liquidity	-	-	-
Taxation	+	+	-
Non-traditional activity	-	+	+
Labour productivity	-	-	+
Concentration	-	-	+
Banking sector development	+	+	?
Stock market development	+	+	+
inflation	-	-	-
GDP growth	-	-	+

Notes: "-"represents negative impact, "+"represents positive impact, and "?" represents no priori expectation.

Table 5. Three stage least square estimation for the relationship between bank capital, technical efficiency and risk-taking in the Chinese banking

	Model where risk=Z-score			Model where risk=LLPTL			Model where risk=VOA			Model where risk=VOE		
	Eq.1 Y=Z-score	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=LLPTL	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOA	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOE	Eq.2 Y=capital	Eq.3 Y=efficiency
risk		0.001*** (8.07)	-1.24e-06 (-0.35)		-37.42 (-0.93)	1.42** (2.28)		46.66 (1.10)	0.123 (0.18)		-0.32 (-1.04)	0.0006 (0.13)
efficiency	-691.7 (-0.4)	4.82 (1.05)		0.02** (2.28)	7.57 (1.59)		0.002 (0.18)	6.66 (1.43)		0.147 (0.13)	6.79 (1.45)	
cap	241*** (8.07)		0.002 (1.05)	-0.0001 (-0.93)		0.002 (1.59)	0.0001 (1.10)		0.002 (1.43)	-0.019 (-1.04)		0.002 (1.45)
ROA	-15656 (-0.84)	-6.18 (-0.14)	0.32 (0.41)	-0.156* (-1.92)	-30.83 (-0.71)	0.251 (0.37)	0.06 (0.81)	-27.12 (-0.64)	-0.03 (-0.04)	-8.35 (-0.80)	-26.96 (-0.63)	-0.014 (-0.02)
Size	-257** (-2.13)	-0.38 (-1.35)	0.032*** (7.23)	-0.002*** (-4.15)	-1.14*** (-4.10)	0.032*** (8.09)	-0.001** (-2.23)	-1.02*** (-3.80)	0.03*** (7.69)	0.03 (0.45)	-1.06*** (-4.03)	0.03*** (7.78)
Liquidity	12.99 (0.82)	-0.09** (-2.48)	-0.002*** (-2.85)	0.0002** (2.37)	-0.039 (-1.14)	-0.002*** (-3.95)	-0.0001* (-1.66)	-0.04 (-1.18)	-0.002*** (-3.58)	-0.001 (-0.15)	-0.045 (-1.34)	-0.002*** (-3.63)
Taxation	76.68 (0.21)	-0.902 (-1.07)	-0.05*** (-3.22)	0.004** (2.42)	-0.756 (-0.85)	-0.04*** (-3.04)	-0.0006 (-0.39)	-0.903 (-1.04)	-0.04*** (-2.68)	0.02 (0.09)	-0.93 (-1.06)	-0.037*** (-2.69)
OBSOTA	307.2 (0.28)	3.75 (1.47)	0.05 (1.08)	-0.0005 (-0.12)	4.02* (1.73)	0.014 (0.37)	0.0096** (2.33)	3.62 (1.54)	0.01 (0.27)	0.154 (0.27)	4.12* (1.79)	0.011 (0.31)
LP	-103*** (-4.01)	94.09 (1.51)	-2.03* (-1.79)	-0.087 (-0.77)	-34.18 (-0.57)	-1.61* (-1.72)	0.012 (0.12)	-34.42 (-0.58)	-1.81* (-1.93)	15.21 (1.04)	-29.03 (-0.49)	-1.82* (-1.94)
C(3)	-73.13 (-0.42)	0.57 (1.43)	-0.019*** (-2.60)	0.003*** (3.50)	0.977** (2.31)	-0.022*** (-3.30)	-0.0007 (-0.91)	0.902** (2.21)	-0.018*** (-2.80)	0.054 (0.53)	0.89** (2.18)	-0.018*** (-2.83)
BSD	8771** (2.03)	7.64 (0.75)	-0.13 (-0.72)	0.011 (0.56)	26.18** (2.53)	-0.19 (-1.18)	-0.0055 (-0.30)	26.12** (2.54)	-0.195 (-1.17)	1.21 (0.47)	26.26** (2.55)	-0.196 (-1.18)
SMD	-6.06 (-0.75)	-0.005 (-0.24)	-0.0004 (-1.24)	0.00006 (1.47)	-0.004 (-0.19)	-0.0004 (-1.24)	-0.00002 (-0.62)	-0.005 (-0.25)	-0.0003 (-0.90)	0.001 (0.27)	-0.006 (-0.29)	-0.0003 (-0.91)
IR	350** (1.97)	-0.101 (-0.24)	0.002 (0.32)	-0.0005 (-0.62)	0.396 (0.91)	0.001 (0.13)	0.0002 (0.26)	0.414 (0.96)	-0.0003 (-0.04)	0.022 (0.20)	0.43 (1.00)	-0.0002 (-0.04)
GDPG	307.65 (1.13)	-0.103 (-0.16)	0.02 (1.53)	-0.003** (-2.13)	-0.08 (-0.12)	0.02* (1.77)	0.0007 (0.56)	-0.0005 (-0.00)	0.014 (1.35)	-0.036 (-0.22)	0.02 (0.03)	0.014 (1.36)
Const.	-18319 (-1.54)	-18.18 (-0.65)	1.23** (2.49)	-0.042 (-0.78)	-61.77** (-2.18)	1.39*** (3.17)	0.026 (0.52)	61.55** (-2.18)	1.4*** (3.15)	-3.16 (-0.45)	-61.36** (-2.18)	1.41*** (3.17)
Obs.	142	142	142	175	175	175	177	177	177	177	177	177
Chi2	177***	138.32***	106.86***	57.04***	57.72***	118.62***	22.55**	60.22***	112.55***	7.69	60.05***	112.52***

Notes: T-statistics in ( ); *,,*** denote statistical significance at 10%, 5% and 1% levels, respectively**

Table 6. Three stage least square estimation for the relationship between bank capital, pure technical efficiency and risk-taking in the Chinese banking

	Model where risk=Z-score			Model where risk=LLPTL			Model where risk=VOA			Model where risk=VOE		
	Eq.1 Y=Z-score	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=LLPTL	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOA	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOE	Eq.2 Y=capital	Eq.3 Y=efficiency
risk		0.001*** (8.09)	-4.31e-07 (-0.13)		-38.93 (-0.98)	1.17** (2.03)		45.19 (1.07)	0.127 (0.20)		-0.307 (-1.01)	-0.001 (-0.21)
efficiency	-278.3 (-0.13)	5.93 (1.22)		0.02** (2.03)	9.5* (1.87)		0.002 (0.20)	8.58* (1.72)		-0.257 (-0.21)	8.6 (1.72)	
cap	243*** (8.09)		0.002 (1.22)	-0.0001 (-0.98)		0.002* (1.87)	0.0001 (1.07)		0.002* (1.72)	-0.02 (-1.01)		0.002* (1.72)
ROA	-14659 (-0.79)	-7.77 (-0.18)	0.45 (0.62)	-0.16** (-1.97)	-31.08 (-0.72)	0.32 (0.51)	0.06 (0.79)	-26.82 (-0.63)	0.084 (0.13)	-8.36 (-0.80)	-26.72 (-0.63)	0.084 (0.13)
Size	-277** (-2.31)	-0.4 (-1.43)	0.03*** (7.11)	-0.002*** (-4.01)	-1.18*** (-4.30)	0.03*** (7.99)	-0.001** (-2.24)	-1.06*** (-3.99)	0.028*** (7.68)	0.042 (0.63)	-1.10*** (-4.20)	0.027*** (7.77)
Liquidity	13.36 (0.85)	-0.09** (-2.51)	-0.001** (-2.43)	0.0001** (2.27)	-0.039 (-1.15)	-0.002*** (-3.49)	-0.0001* (-1.67)	-0.04 (-1.19)	-0.002*** (-3.16)	-0.002 (-0.23)	-0.045 (-1.35)	-0.002*** (-3.22)
Taxation	87.34 (0.24)	-0.86 (-1.03)	-0.045 (-3.23)	0.004** (2.38)	-0.71 (-0.80)	-0.04*** (-3.07)	-0.0006 (-0.38)	-0.86 (-0.99)	-0.036*** (-2.76)	0.005 (0.02)	-0.885 (-1.02)	-0.04*** (-2.77)
OBSOTA	393.06 (0.36)	3.72 (1.47)	0.04 (0.88)	-0.0006 (-0.13)	4.2* (1.83)	0.006 (0.16)	0.009** (2.31)	3.82 (1.64)	0.002 (0.06)	0.151 (0.27)	4.3* (1.88)	0.004 (0.10)
LP	-104*** (-4.04)	95.6 (1.54)	-1.89* (-1.80)	-0.09 (-0.80)	-34.85 (-0.58)	-1.42 (-1.63)	0.014 (0.14)	-34.77 (-0.59)	-1.59* (-1.84)	14.61 (1.01)	-29.65 (-0.50)	-1.58* (-1.81)
C(3)	-66.68 (-0.39)	0.57 (1.45)	-0.02** (-2.36)	0.003*** (3.43)	0.99** (2.35)	-0.02*** (-3.06)	-0.0007 (-0.91)	0.91** (2.24)	-0.02*** (-2.62)	0.047 (0.47)	0.896*** (2.21)	-0.02*** (-2.63)
BSD	8892** (2.05)	7.81 (0.77)	-0.14 (-0.80)	0.011 (0.54)	26.42* (2.56)	0.18 (-1.18)	-0.005 (-0.30)	26.38* (2.58)	-0.18 (-1.18)	1.13 (0.44)	26.5* (2.59)	-0.18 (-1.18)
SMD	-5.77 (-0.71)	-0.005 (-0.24)	-0.0004 (-1.11)	0.0001 (1.44)	-0.003 (-0.16)	-0.0003 (-1.16)	-0.00002 (-0.63)	-0.005 (-0.23)	-0.0002 (-0.85)	0.001 (0.25)	-0.005 (-0.26)	-0.0003 (-0.86)
IR	347.5* (1.96)	-0.094 (-0.23)	0.001 (0.14)	-0.0005 (-0.60)	0.4 (0.92)	-0.0001 (-0.01)	0.0002 (0.27)	0.417 (0.97)	-0.001 (-0.16)	0.022 (0.20)	0.43 (1.01)	-0.001 (-0.15)
GDPG	297.63 (1.10)	-0.1 (-0.16)	0.014 (1.30)	-0.003** (-2.08)	-0.097 (-0.14)	0.016 (1.58)	0.0007 (0.56)	-0.012 (-0.02)	0.012 (1.20)	-0.03 (-0.19)	0.008 (0.01)	0.012 (1.21)
Const.	-18874 (-1.58)	-19.61 (-0.71)	1.24*** (2.68)	-0.04 (-0.75)	-63.98** (-2.26)	1.36*** (3.33)	0.026 (0.51)	-63.77** (-2.27)	1.37*** (3.33)	-2.61 (-0.37)	-63.46** (-2.26)	1.37*** (3.33)
Obs.	143	143	143	176	176	176	178	178	178	178	178	178
Chi2	186***	144***	100.91***	56.50***	61.81***	113.8***	22.45**	64.15***	109.45***	7.77	63.98***	109.46***

Notes: T-statistics in ( ); *,,*** denote statistical significance at 10%, 5% and 1% levels, respectively**

Table 7. Three stage least square estimation for the relationship between bank capital, scale efficiency and risk-taking in Chinese banking

	Model where risk=Z-score			Model where risk=LLPTL			Model where risk=VOA			Model where risk=VOE		
	Eq.1 Y=Z-score	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=LLPTL	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOA	Eq.2 Y=capital	Eq.3 Y=efficiency	Eq.1 Y=VOE	Eq.2 Y=capital	Eq.3 Y=efficiency
risk		0.001*** (8.08)	-9.33e-06 (-1.38)		-26.28 (-0.66)	0.89 (0.81)		48.14 (1.13)	0.55 (0.46)		-0.313 (-1.02)	0.003 (0.32)
eff	-1408 (-1.38)	0.4 (0.17)		0.004 (0.81)	-2.17 (-0.80)		0.002 (0.46)	-2.36 (-0.88)		0.21 (0.32)	-2.19 (-0.82)	
cap	239.56*** (8.08)		0.0005 (0.17)	-0.0001 (-0.66)		-0.002 (-0.80)	0.0001 (1.13)		-0.002 (-0.88)	-0.02 (-1.02)		-0.002 (-0.82)
ROA	-16188 (-0.88)	-4.68 (-0.11)	-1.13 (-0.75)	-0.15* (-1.88)	-29.54 (-0.68)	-0.497 (-0.41)	0.06 (0.81)	-27.98 (-0.65)	-0.66 (-0.55)	-8.26 (-0.79)	-27.67 (-0.65)	-0.61 (-0.51)
Size	-274.14*** (-2.69)	-0.23 (-0.94)	0.005 (0.60)	-0.002*** (-3.47)	-0.91*** (-3.77)	0.007 (0.94)	-0.001** (-2.49)	-0.82*** (-3.51)	0.006 (0.82)	0.03 (0.59)	-0.87*** (-3.76)	0.005 (0.73)
Liquidity	13.7 (0.90)	-0.099*** (-2.84)	0.0001 (0.06)	0.0001* (1.84)	-0.06* (-1.71)	-0.0002 (-0.24)	-0.0001* (-1.76)	-0.05* (-1.65)	-0.0001 (-0.07)	-0.001 (-0.19)	-0.06* (-1.83)	-0.0001 (-0.13)
Taxation	105.92 (0.30)	-1.14 (-1.41)	0.005 (0.19)	0.003** (1.98)	-1.09 (-1.25)	0.002 (0.10)	-0.001 (-0.43)	-1.16 (-1.36)	0.0054 (0.23)	0.013 (0.06)	-1.19 (-1.40)	0.005 (0.21)
OBSOTA	276.36 (0.25)	4.01 (1.58)	-0.072 (-0.81)	-0.0002 (-0.05)	4.18* (1.80)	-0.063 (-0.96)	0.0096** (2.34)	3.73 (1.59)	-0.07 (-1.03)	0.16 (0.29)	4.24* (1.84)	-0.06 (-0.98)
LP	-101152*** (-4.01)	85.04 (1.38)	0.45 (0.21)	-0.12 (-1.10)	-47.19 (-0.79)	0.89 (0.53)	0.0099 (0.10)	-47.28 (-0.81)	0.75 (0.46)	14.86 (1.03)	-42.21 (-0.72)	0.72 (0.44)
C(3)	-65.04 (-0.39)	0.49 (1.24)	-0.003 (-0.18)	0.002*** (3.07)	0.82** (1.97)	-0.004 (-0.31)	-0.001 (-0.97)	0.78* (1.95)	-0.001 (-0.10)	0.052 (0.52)	0.77* (1.91)	-0.002 (-0.15)
BSD	8842** (2.06)	7.05 (0.69)	0.02 (0.06)	0.007 (0.37)	24.99** (2.41)	-0.047 (-0.16)	-0.0057 (-0.31)	25.02** (2.43)	-0.036 (-0.12)	1.19 (0.47)	25.15** (2.44)	-0.04 (-0.15)
SMD	-5.88 (-0.74)	-0.007 (-0.35)	-0.0002 (-0.30)	0.00005 (1.30)	-0.007 (-0.35)	-0.0002 (-0.33)	-0.00002 (-0.64)	-0.007 (-0.36)	-0.0001 (-0.24)	0.001 (0.27)	-0.008 (-0.39)	-0.0001 (-0.27)
IR	349.78** (1.98)	-0.09 (-0.22)	0.005 (0.34)	-0.0005 (-0.62)	0.41 (0.94)	0.003 (0.22)	0.0002 (0.26)	0.42 (0.97)	0.002 (0.18)	0.021 (0.20)	0.43 (1.01)	0.002 (0.18)
GDPG	301.16 (1.12)	-0.02 (-0.03)	0.008 (0.36)	-0.002* (-1.89)	0.07 (0.10)	0.008 (0.40)	0.0007 (0.57)	0.103 (0.16)	0.005 (0.28)	-0.035 (-0.22)	0.12 (0.19)	0.006 (0.31)
Const	-17719 (-1.53)	-12.74 (-0.47)	0.89 (0.94)	-0.02 (-0.35)	-49.61* (-1.77)	1.04 (1.33)	0.026 (0.53)	-50.25* (-1.81)	1.01 (1.30)	-3.17 (-0.46)	-50.06* (-1.80)	1.04 (1.33)
Obs.	143	143	143	176	176	176	178	178	178	178	178	178
Chi2	190.50***	141.46***	10.72	52***	58.05***	9.91	22.65**	61.23***	9.52	7.83	60.92***	9.41

Notes: T-statistics in ( ); *,,*** denote statistical significance at 10%, 5% and 1% levels, respectively**

Table 8. Three stage least square estimation for the relationship between bank capital, productivity and risk-taking in Chinese banking

	Model where risk=Z-score			Model where risk=LLPTL			Model where risk=VOA			Model where risk=VOE		
	Eq.1 Y=Z-score	Eq.2 Y=capital	Eq.3 Y=productivity	Eq.1 Y=LLPTL	Eq.2 Y=capital	Eq.3 Y=productivity	Eq.1 Y=VOA	Eq.2 Y=capital	Eq.3 Y=productivity	Eq.1 Y=VOE	Eq.2 Y=capital	Eq.3 Y=productivity
risk		0.001*** (8.07)	0.00001* (1.78)		34.76 (0.56)	1.1 (0.58)		11.71 (0.23)	1.09 (0.70)		-0.34 (-1.48)	0.002 (0.23)
prod	2562.23* (1.78)	-2.34 (-0.87)		0.003 (0.58)	1.54 (0.45)		0.005 (0.70)	1.59 (0.47)		0.34 (0.23)	1.73 (0.52)	
cap	358.53*** (8.07)		-0.004 (-0.87)	0.001 (0.56)		0.001 (0.45)	0.00005 (0.23)		0.001 (0.47)	-0.07 (-1.48)		0.002 (0.52)
ROA	-40481 (-0.64)	177.47 (1.55)	-0.14 (-0.03)	-1.27*** (-5.68)	190.58 (1.23)	-0.67 (-0.14)	1.19*** (4.51)	136.22 (0.95)	-3.53 (-0.81)	-93.23 (-1.64)	114.88 (0.88)	-2.09 (-0.52)
Size	-407.3*** (-3.39)	0.26 (1.09)	0.009 (0.93)	-0.0001 (-0.35)	-0.33 (-1.29)	0.005 (0.60)	-0.002*** (-4.64)	-0.31 (-1.12)	0.007 (0.86)	0.03 (0.27)	-0.32 (-1.29)	0.005 (0.61)
Liquidity	21.42 (1.04)	-0.095*** (-2.60)	0.0003 (0.18)	0.0003 (0.43)	-0.11** (-2.33)	0.001 (0.49)	-0.0003*** (-3.13)	-0.1** (-2.13)	0.001 (0.70)	-0.03 (-1.26)	-0.11** (-2.48)	0.001 (0.54)
Taxation	1772 (1.41)	0.45 (0.19)	-0.087 (-0.92)	-0.005 (-1.22)	2.99 (1.11)	-0.085 (-1.04)	0.013** (2.33)	2.69 (0.98)	-0.106 (-1.28)	-0.86 (-0.74)	2.48 (0.94)	-0.092 (-1.13)
OBS OTA	-2455 (-1.86)	6.05** (2.53)	-0.04 (-0.41)	0.007 (1.36)	5.99** (2.09)	-0.045 (-0.51)	0.02*** (3.39)	6.02** (2.01)	-0.06 (-0.66)	0.89 (0.71)	6.42** (2.31)	-0.041 (-0.47)
LP	-118903*** (-4.18)	81.9 (1.44)	2.51 (1.09)	-0.29*** (-2.60)	-115.4* (-1.67)	0.7 (0.33)	0.088 (0.65)	-126.83* (-1.91)	0.28 (0.14)	21.16 (0.72)	-115.77* (-1.76)	0.34 (0.17)
C(3)	129.25 (-0.68)	0.43 (1.23)	-0.03* (-1.83)	0.003*** (3.86)	0.91** (1.97)	-0.03* (-1.82)	-0.002** (-2.27)	1.03** (2.38)	-0.02 (-1.50)	0.13 (0.71)	1.03** (2.47)	-0.023* (-1.73)
BSD	-1745 (-0.21)	4.22 (0.28)	1.44** (2.41)	0.012 (0.38)	8.05 (0.41)	1.46** (2.51)	-0.03 (-0.65)	9.22 (0.48)	1.47*** (2.60)	0.35 (0.04)	8.84 (0.46)	1.45** (2.56)
SMD	16.83 (1.06)	-0.002 (-0.06)	-0.003*** (-2.85)	0.0001 (1.07)	0.02 (0.61)	-0.003*** (-2.80)	-0.00004 (-0.56)	0.03 (0.68)	-0.003*** (-2.72)	0.008 (0.47)	0.03 (0.73)	-0.003*** (-2.78)
IR	-67.34 (-0.19)	-0.27 (-0.41)	0.06** (2.23)	-0.0001 (-0.08)	-0.35 (-0.42)	0.06** (2.31)	-0.0001 (-0.07)	-0.34 (-0.41)	0.057** (2.31)	-0.04 (-0.10)	-0.35 (-0.42)	0.057** (2.32)
GDPG	-544.51 (-1.00)	0.066 (0.07)	0.11*** (2.70)	-0.003 (-1.36)	-0.71 (-0.55)	0.1*** (2.68)	0.001 (0.51)	-0.8 (-0.64)	0.095* (2.58)	-0.203 (-0.37)	-0.84 (-0.68)	0.097*** (2.64)
Const	6213.68 (0.29)	-9.44 (-0.24)	-2.71* (-1.73)	-0.024 (-0.28)	-14.93 (-0.29)	-2.7* (-1.78)	0.08 (0.80)	-17.85 (-0.36)	-2.74* (-1.85)	1.17 (0.05)	-16.14 (-0.33)	-2.67* (-1.80)
Obs.	143	143	143	176	176	176	178	178	178	178	178	178
Chi2	188.92	142.19***	25.54	122.23***	42.71***	29.78***	81.06***	42.81***	30.31***	10.26	45.90***	29.74***

Notes: T-statistics in ( ); *,,*** denote statistical significance at 10%, 5% and 1% levels, respectively**

- We examine the relationship between efficiency, risk and capital in Chinese banking industry.

- There is a positive and significant relationship between risk and efficiency.

- The relationship between risk (Z-score) and level of capitalization is negative and significant.