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Do capital requirements affect bank efficiency? Evidence from China

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Abstract

This paper contributes to the debate on the effect of capital requirements on bank efficiency. We study the relation between capital ratio and bank efficiency for Chinese banks over the period 2004−2009, taking advantage of the profound regulatory changes in capital requirements that occurred during this period to measure the exogenous impact of an increase in the capital ratio on banks' cost efficiency. We find that such an increase has a positive effect on cost efficiency, the size of which depends to an extent on the bank's ownership type. Our results therefore suggest that capital requirements can improve bank efficiency.

JEL Codes: G21, G28

Keywords: bank, capital requirements, efficiency, China

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1 Introduction

The recent financial crisis served to remind us that a well-performing banking system is essential to certain fundamental aspects of the economy, such as credit supply, and plays an important role in contributing to economic stability. To promote a sound financial system, regulators require banks to hold sufficient amounts of capital to absorb losses and to limit moral hazard behavior.

This prudential regulation could also have downsides, which raises a concern as to its implementation. Higher capital ratios might impose tradeoffs in terms of liquidity creation (Berger and Bouwman, 2009), lending, and output growth (Angelini, 2011, BCBS, 2010).

A primary impact of a capital adequacy requirement is its influence on bank efficiency, which has proven to be one of the most direct contributors to financial stability via its effects on bank failures, future problem loans, and risk-taking (Berger and DeYoung, 1997; Podpiera and Weill, 2008; Podpiera and Podpiera, 2008; Fiordelisi, Marques-Ibanez and Molyneux, 2011).

Theory offers opposing views on the effect of capital ratios on bank performance. A strand of literature finds a positive effect, which may derive from reduced moral hazard between shareholders and debtholders. Due to the limited liability of shareholders, low capital ratios increase their incentives to take on excessive risk. This behavior is reinforced by explicit or implicit government guarantees of deposits. A higher capital ratio thus reduces risk-shifting and increases shareholders' incentive to control risk. Moreover, by increasing the surplus generated in the bank-borrower relationship and by improving monitoring incentives, capital ratios have a positive effect on bank's profitability (Holmstrom and Tirole, 1997; Allen, Carletti and Marquez, 2011; Mehran and Thakor, 2011).

Another strand of literature, in contrast, suggests a negative effect of capital on bank performance. Agency costs between managers and shareholders tend to inflate when capital ratios are higher due to the discipline rendered by debt repayment on managers' behavior (Calomiris and Kahn, 1991).

Determining which effect dominates thus remains an empirical question. The literature has however presented us with mixed evidence. In a seminal paper, Berger and Bonaccorsi di Patti (2006) analyzed the relation between bank capital and efficiency in the US banking industry from 1990 to 1995. Fiordelisi, Marques-Ibanez and Molyneux (2011)

tested the relationship between capital ratio and bank efficiency in the European banking industry over the period 1995−2007. These studies report contradictory findings: Berger and Bonaccorsi di Patti (2006) find that lower capital ratios are associated with higher efficiency; Fiordelisi, Marques-Ibanez and Molyneux (2011) find the opposite.

This study contributes to the literature by analyzing the effect of higher capital ratios on cost-efficiency in the Chinese banking industry. The Chinese case provides a unique framework to measure the direct effect of capital adequacy regulation on banks' behavior, due to the extensive transformation of the banking system in the last decade.

In 2004, the first regulation on capital adequacy requirements was implemented. From 2004 to 2008, the industry changed from one in which less than 10% of the banks met the new capital adequacy requirements to one in which nearly all of them comply with the regulatory requirements (CBRC, 2010). This adjustment of bank capital adequacy ratios under pressure from the regulator enables us to measure precisely how banks' performance was affected by the transformation of the period.

This paper thus provides two contributions to the literature on the efficiency-impact of bank capital. First, we note that a common problem with these former studies is the difficulty of assessing the role of prudential regulations since the majority of banks in the periods studied had capital in excess of the required amounts (Berlin, 2011). As stated by Berger and Bonaccorsi di Patti (2006, p. 1068): 'Most banks are well above the regulatory capital minimums, and [the] results are based primarily on differences at the margin, rather than the effects of regulation.' Gropp and Heider (2010) indeed show, for a sample of U.S. and European banks over the period 1991 to 2004, that capital regulation was a second-order determinant of banks' capital structures. Another problem with the studies of the efficiency-impact of capital ratios is the potential reverse causality, from efficiency level to capital, that has been observed.

By studying the effect of capital regulation in China, we are able to resolve both problems. China provides a natural experiment to test the effect of capital adequacy regulation, as banks have been pressured by the state to cope with totally new prudential regulation since 2004. This provides a unique opportunity to directly measure the effect of new capital regulation on bank efficiency. Moreover, as the banks were obliged to adapt to the

new regulation in a very short space of time, the changes in capital ratios can be assumed to be exogenous[1] (i.e. the direct effect of change in prudential regulation).

To investigate this issue, we measure cost efficiency on a sample of Chinese banks, including all major commercial banks, using data from Bankscope supplemented by hand-collected information. We analyze the relation between capital and cost efficiency via the one-step stochastic frontier model proposed by Battese and Coelli (1995).

The rest of the paper is organized as follows. Section 2 presents the related literature, Section 3 reviews capital adequacy regulation in China, and Section 4 describes the data and methodology. Section 5 presents the main results, and robustness checks are performed in Section 6. Section 7 concludes.

2 Related literature

In this section, we review empirical papers dealing with the effect of capital regulation on bank performance and summarize the literature on efficiency of the Chinese banking sector.

2.1 Capital adequacy requirements and bank performance

Capital adequacy requirements are one of the main regulatory tools for the banking system. They are expected to perform two main duties. First, their 'risk sharing function' acts as a buffer against losses, which protects depositors and limits the recourse to deposit insurance. Second, they limit the moral hazard issue of shareholders incentive to take on excessive risk in order to maximize share value.

A few studies measure the impact of capital ratio levels on bank efficiency.

Berger and Bonaccorsi di Patti (2006) study the relation between capital ratios and profit efficiency in the US banking industry over the period 1990−1995. Using the parametric distribution-free approach, they find that higher capital ratios have a negative effect on efficiency

Fiordelisi, Marques-Ibanez and Molyneux (2011) study the relation between bank efficiency, risk and capital ratios. Their paper is thus broader than an assessment of the ef-

[1] The validity of this assumption is tested in section 6 devoted to robustness checks.

ficiency-impact of capital ratios. They use Granger-causality tests in a GMM dynamic panel framework to examine consider three dimensions of efficiency − cost efficiency, revenue efficiency, and profit efficiency − and notably examine reverse causality, both from efficiency to capital and from capital to efficiency. They find that the less efficient banks tend to take on more risk and that better capitalized banks perform better in terms of efficiency.

Both of these papers are of relevance for an analysis of the relation between capital and efficiency. However they provide limited evidence on the specific link between capital and cost efficiency, as they also focus on profit efficiency. We would emphasize that cost efficiency and profit efficiency (a broad concept taking account of both cost efficiency and revenue efficiency) are two different concepts − albeit look-alikes. Berger and Mester (1997) find no positive correlation between cost and profit efficiency. Profit efficiency not only does not account of banks' managerial performance but it is also influenced by market power, which is not directly under the control of management. Cost efficiency can thus be considered a better proxy for managerial performance. Moreover, the literature shows that degradation in cost efficiency has negative implications for financial stability, but we have no evidence on the effect of profit efficiency on financial stability.

Our paper instead focuses on the link between capital and cost efficiency, and employs the unique case of China banking regulation to directly measure the effect of regulation on bank performance. Since the previous literature has concentrated on the US and European banking systems, they work with samples in which most of the banks' capital ratios exceed the regulatory requirement. The situation is the reverse for China in the period studied here. The exogenous change in Chinese banks' capital ratios due to new capital adequacy regulations eliminates the concern about reverse causality from efficiency to capital ratio and allows us to directly estimate the efficiency-effect of capital regulation.

Some other studies analyze the relationship between capital ratios and other performance metrics. A notable one is the recent paper by Berger and Bouwman (forthcoming), which looks at the impact of capital adequacy requirements on bank performance during financial crises by focusing on three dimensions of performance: survival, market share and profitability. Their sample is composed of all US banks from 1984 to 2009. They find that higher capital ratios help banks to survive and to increase their market shares and profitability.

Finally, another strand of literature analyzes the effectiveness of supervisory practice and regulation (see Barth, Caprio and Levine, 2004, 2006; Beck, Demirgüc-Kunt and Levine, 2006). Barth et al. (2010) study whether bank supervision, regulation and monitoring enhance or impede banks' operating efficiency in 72 countries over the period 1999−2007. They notably find that a more stringent capital requirements (measured by an indicator variable) is positively associated with bank efficiency. Chortareas, Girardone and Ventouri (2012) use the same capital regulatory index to measure the effect of capital stringency on cost-efficiency in 22 EU countries over the period 2000−2008. They show that strengthening capital regulation improves bank efficiency.

2.2 Bank efficiency in China

A vast literature on bank efficiency in China has evolved over the years. Using non-parametric DEA, Chen, Skully and Brown (2005) study the effects of the 1995 deregulation of the banking system on the cost efficiency of 43 Chinese banks over the period 1993−2000. They find that efficiency depends on ownership type: large state-owned banks and small joint-stock commercial banks are more efficient than medium-sized joint-stock commercial banks. Large inefficiencies are found in the Chinese banking sector, with mean annual cost efficiency scores ranging from 42.6% to 58.2%.

Fu and Heffernan (2007) measure cost efficiency of Chinese banks over the period 1985−2002 using the stochastic frontier approach. Their sample includes 14 banks: four state-owned banks and ten joint-stock commercial banks. They provide evidence that joint-stock commercial banks are more efficient than state-owned banks. They also find large inefficiencies in the banking sector, with mean efficiency scores ranging from 40% to 52%, depending on the distributional assumptions.

Berger, Hasan and Zhou (2009) analyze 38 Chinese banks over the period 1995−2003 and estimate cost efficiency and profit efficiency using the stochastic frontier approach. The effect of ownership on bank efficiency in China is the main focus of their study. Large state-owned banks appear to be the least efficient group of banks, foreign banks the most efficient. They obtain mean efficiency scores of 89.7% for cost efficiency and 47.6% for profit efficiency.

Fungáčová, Pessarossi and Weill (2013) study the link between competition and cost efficiency over the period 2002−2011 based on a sample of 76 Chinese banks. Apply-

ing the stochastic frontier approach, they find that efficiency improves over the period but that it is not influenced by the degree of competition in the banking system. Mean cost efficiency varies from 67.23% to 74.56% during the period.

In conclusion, the literature on banking efficiency in China shows that ownership affects efficiency; in particular, large state-owned banks tend to be less efficient and foreign banks more efficient. Thus, our study also takes into account bank ownership as a determinant of inefficiency.

3 Capital adequacy requirements in China

At the end of 1990, a large part of the Chinese banking system was virtually bankrupt (Lardy, 1998). During the last decade, Chinese banks underwent major reforms in terms of risk management, corporate governance and capital adequacy requirements. Most banks were recapitalized and cleared of their non-performing loans. The largest commercial banks conducted IPOs. To complete the modernization of its banking system, the Chinese regulator also took action to adapt its supervision and prudential regulation to international standards.

A dramatic step was taken in February 2004 when the China Banking Regulatory Commission (CBRC) issued the *Regulation governing capital adequacy of commercial banks*. Before this regulation, "the concepts of capital and capital adequacy were not on the mind of neither bank managers nor bank regulators and capital constraints were unheard of"[2] (Cousin, 2011, p.183). Banks have focused on attracting deposits in an environment where deposit growth was the sole solution for funding new assets. As a consequence, prudential regulation relied solely on the maximum loan-to-deposit ratio, which was set at 75%.

The 2004 capital adequacy regulation thus seems like a revolution in the Chinese banking industry. It, for the first time, defined capital requirements with a precise method of calculus (Desombre and Chen, 2004). The minimum ratios were to be at least 8% for capital adequacy and 4% for core capital adequacy (article 7). Some of the Basel II rules were also included in the 2004 prudential regulation. Risk weighting was notably closer to

[2] Although the PBOC had previously published a minimum capital ratio of 8% in the *Commercial Banking Law*, no details were given as calculation method or definition of components. Moreover, compliance was not enforced. As a consequence, this previous capital legislation was simply ignored by bank managers and regulators.

the Basel II than the Basel I approach, market risk was taken into account, and information disclosure referred to the Basel II requirements.

Moreover, the regulation defined precisely what actions the CBRC could take to force banks to comply. Notably, the CBRC obtained the power to issue a supervisory letter to an undercapitalized bank, with a roadmap and timeframe to restore the level of capital. In case of non-compliance with the regulation, the CBRC could restrict the asset growth of the undercapitalized bank, force it to reduce the proportion of risky assets in its balance sheet, restrict the purchase of fixed assets, impede the payment of dividends to shareholders, and restrict the opening of new branches or launching of new products. As a consequence, much pressure has been put on commercial banks to comply with the new capital regulation (Cousin, 2011).

This regulation had a direct consequence: at the end of 2003, only 8 commercial banks were compliant with Basel I capital requirements, whereas almost all commercial banks (accounting for 99.9% of banking assets) were compliant at the end of 2008 (CBRC, 2010). Thus, the implementation of the new regulation in 2004 induced banks to quickly cope with the new situation. This exogenous increase in capital ratios is a rather unique event for a banking industry.

Since 2004, prudential regulation in China has been continuously aimed at reaching the current international standards. The initial notice on the implementation of Basel II in China was published in October 2008. Since then the CBRC has also taken steps to implement Basel III accords in the Chinese banking industry (Cousin, 2012).

Nevertheless, challenges remain to fully implement prudential regulation in China. They notably concern risk and capital management, data and information disclosure, availability of loss data, and the lack of independence of supervisors (Cousin, 2011).

4 Data and methodology

4.1 Data

We use bank-level financial statement data for Chinese commercial banks provided by Bankscope, a financial database maintained by Bureau Van Dijk. Whenever there are missing values or variables, we collect the corresponding data from the bank's annual reports on its website. Our final sample comprises 294 observations accounting for 100 Chinese banks. The data cover all the major commercial banks in China. The period for capital ratios is 2004−2008, as banks have experienced major changes in their capital ratios in complying with the capital requirement regulation. The capital ratio has been winsorized at 2 and 98% to eliminate outliers[3]. As we expect the capital ratio to affect efficiency over time, we use the one-year lag between capital ratio and efficiency[4]. Thus, our study estimates cost-inefficiencies over the period 2005−2009. The descriptive statistics of the main variables are presented in Table 1.

4.2 Methodology

4.2.1 Efficiency estimation

Distance from an efficient cost frontier can be measured using a non-parametric technique such as Data Envelopment Analysis (DEA) or a parametric technique such as the stochastic frontier approach. In this paper, we rely mainly on the stochastic frontier approach[5] to measure cost efficiency in the Chinese banking industry. In using a parametric measure we rely on econometric tools to estimate the industry's cost frontier. The main advantage, compared to a non-parametric approach, is in separating inefficiencies from external random shocks or data measurement errors.

Two approaches are proposed in the literature to study determinants of banking efficiency. The two-step approach, which involves first the estimation of the cost frontier, predicts efficiency by decomposing the error term between its random and inefficiency

[3] We also checked that the results were robust after trimming at the 2 and 98% the data for capital ratio. Results are available upon request.
[4] The results, available upon request, proved to be robust when we did not use a one-year lag between capital ratio and inefficiency.
[5] We will however check the robustness of our results by employing DEA in Section 6.

components. The second step is the regression of efficiency scores on a set of explanatory variables.

This approach entails some econometric problems. The first step assumes that the inefficiency terms are identically distributed, whereas the second-step regression assumes that the distributions of inefficiency terms are conditional on a set of explanatory variables. Secondly, including explanatory variables in a second-step regression means that the first-step frontier estimation might suffer from omitted variables bias if the explanatory variables are correlated with the variables of the cost frontier model.

We instead employ the 'one-step approach' proposed by Battese and Coelli (1995) for panel data, which solves these issues by simultaneously estimating the cost frontier and modeling the inefficiency term as a function of several explanatory variables. The general framework can be expressed as

$$TC_{it} = f(Y_{it}, P_{it}) + \varepsilon_{it} \quad (1)$$

where TC_{it} represents total cost for bank *i* at time *t*, Y_{it} is the vector of outputs, P_{it} the vector of input prices, and ε_{it} the error term. The error term is the sum of a random error component v_{it} , representing external shocks or data measurement errors, and a positive cost-inefficiency term u_{it}. The v_{it} is assumed to be i.i.d and normally distributed with mean 0 and standard deviation σ_v^2. u_{it} follows a truncated normal distribution (at zero) with mean $z_{it}\delta$ and standard deviation σ^2, where z_{it} is a vector of explanatory variables associated with bank inefficiency over time and δ is a vector of parameters to be estimated. Consequently, the u_{it} are independently but not identically distributed, as they are each expressed as a function of z_{it}:

$$u_{it} = z_{it}\delta + W_{it} \quad (2)$$

where W_{it} is a random variable defined by the truncation of the $N(0, \sigma^2)$ distribution, with the point of truncation $-z_{it}\delta$.

The coefficients in equations (1) and (2) are then estimated simultaneously using the method of maximum likelihood.

We follow the intermediation approach for the specification of inputs and outputs. This approach assumes that the bank collects deposits to transform them with labor and capital into loans. Two outputs are included in the cost function, total loans and other earn-

ing assets. We employ three input prices: price of borrowed funds (interest expenses/total deposits), price of labor (personnel expenses/total assets) and price of physical capital (other operating expenses/fixed assets). Following Berger, Hasan and Zhou (2009), Fungáčová, Pessarossi and Weill (2013) and others, we employ a translog form to model the cost function of banks. We impose homogeneity conditions by normalizing total costs, price of labor, and price of physical capital, by the price of borrowed funds.

The cost frontier is given by

$$\ln\left(\frac{TC}{w_3}\right) = \beta_0 + \sum_m \alpha_m y_m + \sum_n \beta_n \ln\left(\frac{w_n}{w_3}\right) + \frac{1}{2}\sum_m \sum_j \alpha_{mj} \ln y_m \ln y_j + \frac{1}{2}\sum_n \sum_k \beta_{nk} \ln\left(\frac{w_n}{w_3}\right) \ln\left(\frac{w_k}{w_3}\right) + \sum_n \sum_m \gamma_{nm} \ln\left(\frac{w_n}{w_3}\right) \ln y_m + \sum_t \theta_t Year_t + \epsilon \quad (3)$$

where TC is total costs (computed as the sum of interest expenses, personnel expenses, and other operating expenses), y_m is the m[th] bank's output (m=1,2), w_n is the n[th] input price (n=1,2), and w_3 is the price of borrowed funds. For simplicity of presentation, the indices for each bank have been dropped. The model estimates one common cost frontier over the period with time dummies included ($Year_t$).

4.2.2 Determinants of efficiency

We use the following equation in the one-step model to explain the inefficiency term u_{it} from equation (2):

$$u_{it} = \delta_0 + \delta_1 Capital\ ratio_{it-1} + \delta_2 LSCB_i + \delta_3 JSCB_i + \delta_4 CCB_i + \delta_5 FOR_i + \delta_6 Bank\ size_{it} + W_{it} \quad (4)$$

where u_{it} is cost inefficiency of bank *i* in year *t*, $Capital\ ratio$ is the capital ratio of bank *i* in the previous year, computed as the book value of equity over total assets, LSCB, JSCB, CCB and FOR are dummy variables that take account of the bank's ownership type. $LSCB$

is equal to one if the bank is one of the 'Big Five' large state-owned banks[6] and zero otherwise. *JSCB* is equal to one if the bank is one of the twelve joint-stock commercial banks and zero otherwise. *CCB* is equal to one if the bank is a city commercial bank and zero otherwise. *FOR* is equal to one if the bank is a foreign bank and zero otherwise. Rural commercial banks are the ownership category omitted from the regression. $Bank\ size$ is computed as the natural logarithm of total assets in RMB million.

5 Results

This section presents the main results of the paper. First, we consider the main estimations. Then we provide additional estimations to check whether the efficiency-effect of capital is dependent on ownership type and size.

5.1 Main estimations

Table 2 presents our main estimations on the effect of capital ratio on banks' cost-inefficiency. The dependent variable is cost inefficiency and the key explanatory variable is the capital ratio. Estimation of inefficiency and coefficients of the determinants of inefficiency are obtained in a single step, following Battese and Coelli (1995). We perform several estimations. The first model considers only the capital ratio as an independent variable (column 1). The second model adds in ownership variables (column 2). The third considers only the capital ratio and size (column 3). Finally the fourth adds in ownership variables and size (column 4) to the initial model, so that the fourth model can be considered the key one, which includes all the tested explaining variables.

We observe that capital ratio negatively affects cost inefficiency, i.e. capital ratio has a positive effect on bank efficiency. The result obtains for all estimations in that it remains unchanged after controlling separately and simultaneously for bank size and ownership type. We then show that banks with higher capital ratios have greater efficiency. This conforms with the hypothesis of less moral hazard in shareholders' behavior if their stakes in the bank are larger.

[6] Namely, Industrial Commercial Bank of China (ICBC), Agricultural Bank of China (ABC), China Construction Bank (CCB), Bank of China (BoC) and Bank of Communications (BoCom).

As discussed by Berger and Bonaccorsi di Patti (2006), this result should not be interpreted as a rejection of the hypothesis of higher agency costs between managers and shareholders when the capital ratio is higher. More precisely, it reflects the fact that the decrease in moral hazard between shareholders and debtholders is larger than the increase in agency costs between managers and shareholders. This is reflected in the net effect of capital ratio on bank performance, as we observe that a higher capital ratio has a positive effect on cost efficiency.

The results also show that larger banks perform better, as the variable *Bank size* is negatively associated with cost-inefficiency. This result corroborates previous findings on bank efficiency (e.g. Chen, Skully and Brown, 2005; Berger, Hasan and Zhou, 2009).

Moreover, we find that ownership also influences the cost efficiency of Chinese banks as in previous studies (e.g. Berger, Hasan and Zhou, 2009). Notably, joint-stock banks and foreign banks are more efficient than other banks in our sample.

5.2 Additional estimations

We now assess how the positive effect of capital ratio on cost efficiency depends on two bank characteristics: ownership and size. As noted in the previous section, the results should be interpreted as a net effect of capital ratio on bank performance, which encompass two opposing effects: an increase of agency costs between managers and shareholders, as the disciplinary-impact of debt declines, and a decrease in moral hazard between shareholders and debt-holders. The different forms of shareholders, with different implications for corporate governance, enable us to assume that agency costs and moral hazard may have different degrees of impact, depending on the ownership type. Consequently, the net effect of capital ratio on bank efficiency might differ, depending on the bank's ownership type. Regarding size, Berger and Bouwman (forthcoming) also argue that the effect of capital ratio on bank performance can differ, depending on the size of the bank. They find that smaller banks benefit more from an increase in capital than larger banks. Thus one may wonder whether size influences the link between capital and efficiency.

Table 3 presents results of interactions between ownership, size and capital ratio. Each of the five columns of the table considers one interaction term between capital ratio and one explaining variable (one of the four ownership dummy variables or *Bank size*).

We overall find that, despite controlling for the interaction between capital ratio and ownership, capital ratio still has a positive effect on cost efficiency for all bank categories. Nevertheless, the effect of capital ratio on efficiency differs for two ownership categories: city commercial banks and foreign banks. On the one hand, we find that being a city commercial bank has a positive effect on cost inefficiency, but an increase in capital ratio for this bank-category reduces cost inefficiency. Thus, city commercial banks with low capital ratios appear to be particularly less efficient, but this effect diminishes as the capital ratio increases. On the other hand, foreign banks with low levels of capital ratios appear to be more efficient, but efficiency decreases as the capital ratio increases.

Thus the net effect of capital ratio on bank performance appears to depend to some extent on the ownership category of the bank. Why do higher capital ratios foster efficiency for city commercial banks and reduce efficiency for foreign banks? We propose the following explanations.

Most city commercial banks have local government as their majority or sole shareholder. However, as government-owned entities, they might benefit from an implicit guarantee by the central government in case of financial distress. This situation potentially increases moral hazard between shareholders and stakeholders, as they do not directly share the costs of the bailout but earn the benefits of investment choices[7]. In such a situation, one might well suspect that moral hazard issues are much more important than agency costs between managers and shareholders, which could explain why the net effect of capital ratio on city commercial banks cost efficiency is positive.

Contrary to government-owned banks, foreign banks should not benefit from an implicit government guarantee in China. This feature should reduce moral hazard problems between shareholders and debtholders in foreign banks. Suspicions might obtain to the effect that agency costs between managers and shareholders are more important than the moral hazard issue discussed above for this category of banks. This could explain why the net effect of an increase of capital ratio is a decrease in cost efficiency for foreign banks. This could reflect the fact that the increase in agency costs between managers and shareholders is more important than the reduction in moral hazard between shareholders and debt-holders.

[7] City commercial banks might for example favor inefficient firms in their lending decisions in order to promote local government's political objectives such as low unemployment, which might be detrimental for bank efficiency.

Finally, in considering the impact of size on the relation between capital ratio and bank efficiency, we do not obtain a significant coefficient for the interaction term between capital ratio and *Bank size*. Thus the net effect of capital on bank performance does not appear to depend on bank size.

6 Robustness checks

We perform two types of robustness checks.

First, we check whether our main result depends on our efficiency metric. Previous literature has shown that this choice influences efficiency scores (Berger and Humphrey, 1997; Weill, 2004). In particular the use of the non-parametric DEA can lead to very different efficiency scores than those for parametric techniques such as the stochastic frontier approach. We then use DEA to obtain an alternative measure of cost efficiency, for which the main advantage is not requiring an assumption about the form of the cost function. However, contrary to the stochastic frontier approach, it does not allow us to disentangle inefficiency from random shocks. As a consequence, the total distance between the cost frontier and the bank's effective total cost is viewed as inefficiency. Furthermore, in analyzing the determinants of DEA cost efficiency scores, we must rely on the two-step approach where we compute efficiency scores in the first stage and then regress efficiency scores on independent variables.

We then estimate DEA cost efficiency scores and perform a second stage regression including bank random effects and time dummy variables. One should note that, contrary to the one-step approach of Battese and Coelli (1995), the dependent variable in the second step is cost efficiency. The interpretation of the sign is thus the opposite of that for the previous estimations, as we now expect a positive sign for the coefficient of *Capital ratio*. Table 4 reports the results of the regression of DEA efficiency scores. We observe again that *Capital ratio* has a positive impact on efficiency. Then our main finding is robust to the use of an alternative technique to estimate efficiency. We also find again a positive impact of bank size on cost efficiency, but we do not find that ownership influences efficiency.

Our second robustness check concerns the possibility of endogeneity between capital ratio and cost efficiency. Previous studies on the link between capital and efficiency have employed various methodologies to tackle the potential endogeneity between capital

and efficiency. In our study, the capital ratio is considered exogenous due to the Chinese banking reforms implemented between 2004 and 2008. To check on whether this assumption is reasonable, we re-ran our model in a system Generalized Method of Moments (GMM) framework.

We use the system GMM estimators developed for dynamic panel models by Arellano and Bover (1995) and Blundell and Bond (1998) and the two-step system GMM estimator with Windmeijer (2005)'s corrected standard error and include dummy variables for years. Concerning cost efficiency measurement, we employ a two-step approach with two alternative measures of efficiency obtained from the stochastic frontier approach and with DEA.

Table 5 shows that our results are robust to endogeneity concerns. It confirms that Capital ratio can be treated as exogenous in the Chinese banking sector over the period 2004−2008. We find the same main conclusion: *Capital ratio* has a positive effect on efficiency for both of our measures of cost efficiency. Regarding the other variables, ownership only influences efficiency when measured with stochastic frontier approach but not when measured with DEA. In comparison with our main estimations, we still find that foreign banks are more efficient than other banks, but we now observe that large state-owned banks are less efficient than other banks. This result is however consistent with the literature on efficiency in the Chinese banking sector.

7 Conclusion

This study presents evidence on the debate on the effect of capital requirement regulation on bank efficiency. While the theoretical literature includes opposing views on the effect of more stringent capital requirements on bank efficiency, we focus on the regulatory changes in capital requirements that affected all Chinese commercial banks over the period 2004−2008. This period coincides with the first implementation of bank capital adequacy requirements in China. It provides us with a natural test of the effect of this regulation on bank efficiency.

We show that an increase in the capital ratio improves cost efficiency on average. This effect depends to some extent on the bank's ownership type, but not on its size.

Thus, our findings suggest that capital requirements not only strengthen financial stability by providing a larger capital buffer, but also improve bank efficiency by lowering

moral hazard between shareholders and debt-holders. Thus, the prudential regulation on capital requirements does not appear to suffer from a tradeoff between bank performance and increasing the soundness of the financial sector.

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Tables

Table 1 Descriptive statistics

	N	Mean	Std. Dev.	Minimum	Maximum
Cost frontier variables					
Total costs, RMBm	294	16 547	44 277	2	252 823
Total loans, RMBm	294	358 653	925 924	31	5 728 626
Other earning assets, RMBm	294	320 299	905 379	18.5	5 920 271
Price of fund, interest expenses/total deposits	294	0.017	0.007	0.001	0.046
Price of labor, personnel expenses/ total assets	294	0.006	0.002	0.001	0.021
Price of capital, other operating expenses/total assets	294	1.110	1.686	0.055	17.086
Total assets, RMBm	294	695 674	1 852 926	90	11 785 053
Efficiency score, %	294	83.330	12.978	30.225	97.738
Determinants of inefficiency					
Capital ratio, book value of equity/total assets	294	0.075	0.084	0.005	0.514
LSCB (large state-owned commercial bank)	294	0.085	0.279	0	1
JSCB (joint-stock commercial banks)	294	0.180	0.385	0	1
CCB (city commercial banks)	294	0.554	0.498	0	1
FOR (foreign banks)	294	0.112	0.316	0	1
RCB (rural commercial banks)	294	0.068	0.252	0	1
Bank size. log of total assets in RMBm	294	11.229	2.202	4.495	16.282

Table 2 Main estimation: Effect of capital ratio on cost-inefficiency

This table reports estimates of the determinants of cost-inefficiency using the Battese and Coelli (1995) one-step model. Capital ratio is computed as book value of equity divided by total assets; LSCB, JSCB, CCB and FOR are dummy variables representing the different bank ownership categories in China. Rural commercial bank is the omitted ownership category. Bank size is computed as the logarithm of total assets. Standard errors are given in brackets. '***', '**' and '*' denote statistical significance at the 1, 5 and 10% levels.

	Cost inefficiency			
	(1)	(2)	(3)	(4)
Intercept	0.285**	0.290***	3.181***	2.308***
	(0.118)	(0.099)	(0.549)	(0.309)
Capital ratio	−2.838***	−2.674***	−3.661***	−2.964***
	(0.643)	(0.981)	(0.770)	(0.458)
LSCB		−0.268		0.031
		(0.293)		(0.268)
JSCB		−0.665**		−0.332***
		(0.274)		(0.131)
CCB		0.073		−0.070
		(0.081)		(0.085)
FOR		−0.263		−0.597***
		(0.223)		(0.194)
Bank size			−0.266***	−0.175***
			(0.055)	(0.025)
N	294	294	294	294
Log-likelihood	79.441	56.607	112.356	121.744

Table 3 Interactions between ownership, size and capital ratio

This table reports estimates of the determinants of cost-inefficiency using the Battese and Coelli (1995) one-step model. Capital ratio is computed as book value of equity divided by total assets; LSCB, JSCB, CCB and FOR are dummy variables representing the different bank ownership categories in China. Rural commercial bank is the omitted ownership category. Bank size is computed as the logarithm of total assets. Standard errors are given in brackets. '***', '**' and '*' denote statistical significance at the 1, 5 and 10% levels.

	Cost inefficiency				
	(1)	(2)	(3)	(4)	(5)
Intercept	2.453***	2.308***	2.410***	2.459***	2.486***
	(0.403)	(0.315)	(0.291)	(0.310)	(0.410)
Capital ratio	−3.077***	−2.965***	1.160	−3.634***	−6.215**
	(0.456)	(0.461)	(0.747)	(0.588)	(3.194)
LSCB	−0.297	0.031	0.109	−0.010	−0.117
	(0.667)	(0.260)	(0.181)	(0.192)	(0.359)
Capital ratio × LSCB	−1.972				
	(3.551)				
JSCB	−0.417**	−0.337**	−0.282**	−0.329**	−0.324***
	(0.192)	(0.142)	(0.133)	(0.150)	(0.122)
Capital ratio × JSCB		0.118			
		(1.042)			
CCB	−0.083	−0.070	0.187**	−0.067	−0.077
	(0.084)	(0.085)	(0.093)	(0.083)	(0.078)
Capital ratio × CCB			−4.944***		
			(0.960)		
FOR	−0.646***	−0.596***	−1.473***	−1.579***	−0.653***
	(0.233)	(0.199)	(0.215)	(0.456)	(0.204)
Capital ratio × FOR				4.010***	
				(1.458)	
Bank size	−0.189***	−0.175***	−0.205***	−0.187***	−0.194***
	(0.037)	(0.026)	(0.025)	(0.025)	(0.038)
Capital ratio × Bank size					0.367
					(0.345)
N	294	294	294	294	294
Log-likelihood	122.002	121.744	126.467	124.141	121.920

Table 4 Robustness check: Alternative measure of cost efficiency DEA

This table reports estimates of the determinants of cost-inefficiency with random effects at bank level. Cost efficiency is estimated using DEA. Time dummies are included. Capital ratio is computed as book value of equity divided by total assets; LSCB, JSCB, CCB and FOR are dummy variables representing the different bank ownership categories in China. Rural commercial bank is the omitted ownership category. Bank size is computed as the logarithm of total assets. Standard errors are given in brackets. '***', '**' and '*' denote statistical significance at the 1, 5 and 10% levels.

	Cost efficiency
Intercept	−0.554***
	(0.180)
Capital ratio	0.756***
	(0.240)
LSCB	0.052
	(0.118)
JSCB	0.059
	(0.084)
CCB	−0.025
	(0.067)
FOR	−0.115
	(0.083)
Bank size	0.074***
	(0.015)
N	294
Log-likelihood	119.45

Table 5 Robustness check: Estimations with system GMM

This table reports estimations of determinants of cost efficiency using the stochastic frontier approach (SFA) and DEA. We use the two-step GMM estimator with Windmeijer (2005)'s corrected standard error (in brackets) to control for potential endogeneity between capital ratio and efficiency. Arellano-Bond tests for autocorrelation (AR1/AR2) have the null hypothesis of no autocorrelation and are applied to the differenced residuals. The Hansen J-test has the null hypothesis "the instruments as a group are exogenous." Time dummies are included. Capital ratio is computed as book value of equity divided by total assets; LSCB, JSCB, CCB and FOR are dummy variables representing the different bank ownership categories in China. Rural commercial bank is the omitted ownership category. Bank size is computed as the logarithm of total assets. Standard errors are given in brackets. '***', '**' and '*' denote statistical significance at the 1, 5 and 10% levels.

	Cost efficiency SFA	Cost efficiency DEA
	(1)	(2)
Intercept	33.697*	−1.374**
	(15.374)	(0.563)
Capital ratio	62.470*	2.992**
	(34.822)	(1.286)
LSCB	−8.926*	−0.218
	(4.918)	(0.193)
JSCB	3.058	−0.012
	(2.802)	(0.084)
CCB	−0.201	0.052
	(3.081)	(0.066)
FOR	10.294**	−0.223
	(4.223)	(0.138)
Bank size	2.847***	0.142***
	(1.074)	(0.045)
N	294	294
P value AR1/AR2	0.162/0.69	0.496/0.102
P value Hansen	0.497	0.955

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