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Bank Efficiency in China, Rent Seeking versus X-inefficiency: A non-parametric Bootstrapping Approach

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**Abstract**

This study demarcates cost-inefficiency in Chinese banks into X-inefficiency and rent-seeking-inefficiency. A protected banking market not only encourages weak management and X-inefficiency but also public ownership and state directed lending encourages moral hazard and bureaucratic rent seeking. This paper uses bootstrap non-parametric techniques to estimate measures of X-inefficiency and rent-seeking inefficiency for the 4 state owned banks and 11 joint-stock banks over the period 1997-2004. In contrast to other studies of the Chinese banking sector, the paper argues that reduced inefficiency is an indicator that the competitive threat of the opening up of the banking market in 2007 has produced tangible benefits in improved performance. This paper finds evidence of declining trend in both types of inefficiency.

**Keywords**: Bank Efficiency, China, X-inefficiency; DEA. Bootstrapping

**JEL codes**: D23, G21, G28

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## 1. Introduction

As China prepares for full integration into WTO in 2007, the Chinese banking system is poised to break free from the residual vestige of state control with a series of recent and planned IPO listings of the major state banks and increased stake holdings by foreign banks of the smaller commercial banks. The strategy of allowing a larger stake holding in the Chinese banking system by foreign banks as a means of improving efficiency has a good academic pedigree. The link between privatization and efficiency improvement in former government owned enterprises is now very much an established finding (Megginson and Netter, 2001). The link between privatization of banking and efficiency improvement is an emerging research area (see Megginson, 2005 for a survey).

Given the impending listing of the major state owned banks and the tacit acceptance of larger stakes by foreign banks in the smaller commercial banks, it is not surprising that bank efficiency in China has become a popular subject of research in recent years. A number of studies of Chinese banking efficiency have been published in Chinese scholarly journals[1] but to date there have been only a few studies that are available to non-Chinese readers[2].

The Chinese banking system remains relatively protected until 2007. While the gradualist economic reform policies of Deng Xiaoping have transformed management practice and corporate efficiency in the manufacturing sector, it can be argued that the mindset of the corporatist thinking in management continues in much of the state owned enterprises (SOEs) in China, including its banks.

[1] For example Qing and Ou, (2001); Xu, Junmin, and Zhensheng, (2001); Wei and Wang, (2000); Xue and Yang, (1998) and Zhao (2000) have used non-parametric methods while

[2] A recent exception is a study using non-parametric methods by Chen et. al. (2005) and parametric methods by Fu and Heffernan (2005)

Inefficiency relative to 'best practice' is usually blamed on bad management and poor motivation. Following Leibenstein (1966) this efficiency gap is termed 'X-inefficiency'. In the context of an economy that has only recently begun to open its banking sector, this paper argues that a significant cause of bank inefficiency is ‘rent seeking’ behavior, rather than X-inefficiency.

This research has two objectives. First it aims to decompose the measure of efficiency in Chinese banks into Technical Efficiency (TE), and Cost Efficiency (CE). Proponents of the X-efficiency (XE) view argue that TE is consistent with XE. However, with reference to the minimum cost point of operation, overall efficiency must be measured in terms of cost efficiency. This paper argues that while the underutilization of factors is consistent with the notion of X-inefficiency, the wrong factor-mix is indicative of 'rent-seeking'. The decomposition of cost inefficiency into X-inefficiency (technical inefficiency) and rent-seeking inefficiency allows us to examine their evolution over the sample period.

Second, this paper aims to provide an inferential capability to the point-estimates of efficiency through the use of bootstrapping methods. The question this part of the analysis poses is, are the measures of relative efficiency significantly different from the benchmark? Are the measures of X-inefficiency and 'rent-seeking' statistically significant? The threat of entry of foreign banks into the Chinese market should lead to improved management, which will result in improved technical efficiency and lower cost-inefficiency as incumbent banks attempt to cut costs and consolidate their balance sheets.

This paper is organized on the following lines. The next section outlines the background to the Chinese banking system. Section 3 discusses the literature and outlines the non-parametric method of estimating bank efficiency. Section 4 discusses the concept of X-inefficiency and the implications for its measurement in the context of banking. Section 5 discusses the data and methodology of bootstrapping as applied to the non-parametric method. Section 6 discusses the results and section 7 concludes.

## 2. Chinese Banking

The metamorphosis of the Chinese banking system from the monolithic system based around a single bank that was the instrument of socialist planning, to something resembling a modern banking system, occurred in 1979[3]. Prior to 1979, the role of the banks was to provide credit to state-owned enterprises. In 1979 the monopolistic position of the Peoples Bank of China (PBOC) was removed with the establishment of three specialized banks in the early 1980s that took over its banking business. The Agricultural Bank of China (ABOC) took over the business of providing credits to the rural sector, The Bank of China (BOC) took over foreign currency transactions, and the China Construction Bank (CCB) took over financing the construction sector. A fourth specialized bank, the Industrial and Commercial Bank of China was set up in 1984 that eventually took over the commercial business of the PBOC in 1994. The 1980s saw the setting up of other commercial banks, joint-stock banks, and state-owned investment banks. The Commercial Bank Law of 1995 ushered in a two-tier banking system. At the apex sits the PBOC and below it the commercial banks that is subject to prudential regulations and supervision by the PBOC. Policy banks were officially separated from commercial banks, although in reality because of a lack of a branch network, the commercial banks continued with policy lending (Chen et. al 2005). From 1996 onwards, foreign banks were allowed to

[3] An extensive review of the Chinese banking system can be found in Shirai (2002), and Allen, Qian and Qian (2005a) (2005b)

open branches across China but their business was still confined to the non-RMB market. Limited interest rate deregulation followed.

In 2005, the Chinese banking system consisted of some 30,000 institutions, including 3 policy banks, 4 state-owned commercial banks, 13l joint-stock commercial banks, 115 city commercial banks, 238 operational entities of foreign banks and the rest made up of urban and rural credit cooperatives and other financial institutions.

Like many economies that have undeveloped financial and capital markets, the banking sector in China plays a pivotal role in financial intermediation. Table 1 below shows that the ratio of total bank deposits to GDP has increased from 99.1%, in 1997, to 180.5% in 2004. The market is absolutely dominated by the four state owned banks, although their share of the market has been decreasing steadily through gains made by the Joint-stock banks.

**Table 1: The Chinese banking Market**

| Variable | 1997 | 2002 | 2004 |
|---|---|---|---|
| Total Deposits to GDP | 99.1% | 149.9%[a] | 190.5%[a] |
| SOB Employment | 1,394.8 thousand | 1,467.8 thousand | 1,409 thousand[e] |
| SOB Market share % assets | - | 71.4% | 54.1% |
| ROAA SOB* | 0.24% | 0.19% | 0.55% |
| Cost-Income Ratio SOB* | 93.3%[c] | 61.9% | 45.4% |

Sources: IMF *International Financial Statistics*, Annual Accounts, *The Banker*, China Regulatory Banking Corporation website, *Almanac of China's Finance and Banking*, a) Including foreign currency deposits, e) estimated, * weighted average by asset share, c) two state owned banks only

Faced with the potential of increased competition from the end of 2006 onwards, the big banks have begun the process of restructuring and reducing unit costs.

Employment in the state-owned banks has declined from a peak number of 1,468 thousand in 2002, return on average assets have shown some improvement (partly as a result of the removal of a proportion of NPLs from the balance sheet and its transference to asset management companies and partly through a greater flexibility in setting loan rate margins). Significantly, the major banks have worked to reduce costs as shown in the sharp reduction in the weighted average cost-income ratio.

Up until 1995, control of the banking system remained firmly under the government and its agencies[4]. Under state control, the banks in China served the socialist plan of directing credits to specific projects dictated by political preference rather than commercial imperative. Since 2001 foreign banks and financial institutions were allowed to take a stake in selected Chinese banks. While control of individual Chinese banks remain out of reach for the foreign institution[5], the pressure to reform management, consolidate balance sheets, improve risk management and reduce unit costs has increased with greater foreign exposure. Table 2 shows the extent of foreign ownership of individual banks.

The theory of market contestability (Baumol, 1982) suggests that incumbent banks will restructure weak balance sheets, reduce costs, and improve efficiency in preparation for the threat of entry. Chinese banks should exhibit less inefficiency, whichever way measured, in 2004 than in 1997.

[4] According to La Porta, et. al (2002), 99% of the 10 largest commercial banks were owned and under the control of the government in 1995.

[5] There is a cap of 25% on total equity held by foreigners and a maximum of 20% for any single investor, except in the case of joint-venture banks

**Table 2: Foreign Bank Ownership Stake**

| Chinese Bank | Foreign Bank - Stake % | Announcement Date |
|---|---|---|
| Bank of Shanghai | HSBC - 8% | December 2001 |
| Shanghai Pudong Bank | Citigroup - 4.6% | December 2003 |
| Fujian Asia Bank | HSBC - 50% | December 2003 |
| Industrial Bank | Hang Seng - 16% | April 2004 |
| Bank of Communications | HSBC - 19.9% | June 2004 |
| Xian City Comm. Bank | Scotia Bank - 12.4% | October 2004 |
| Jinan City Comm. Bank | C Bank of Australia - 11% | November 2004 |
| Shenzen Develop. Bank | Newbridge Cap - 17.9% | December 2004 |
| Minsheng Bank | Temasek - 4.6% | January 2005 |
| Hangzhou City Com Bank | C Bank of Australia - 19.9% | |
| China Construction Bank | Bank of America - 9%<br>Temasek - 5.1% | June 2005 |
| Bank of China | RBS - 5%, UBS - 1.6%. Temasek - 10% | August 2005 |
| ICBC | Goldman Sachs, Allianz, American Express - 10% | August 2005 |
| Nanjing City Com. Bank | BNP Paribas - 19.2% | October 2005 |
| Hua Xia Bank | Deutsche bank - 9.9%<br>Sal Oppenheim Jr. - 4.1% | October 2005 |

Source: *Business Week* October 31, 2005

## 3. Methodology and Literature Review

Most studies of banking efficiency have focussed on the developed economies[6]. While there have been some studies of other Far Eastern economies[7], the number is small in comparison. Indeed, of Berger and Humphrey's (1997) survey of 130 studies of frontier analysis in 21 countries, only 8 were about developing and Asian countries (including 2 in Japan). Studies on US financial institutions were the most common, accounting for 66 out of 116 single country studies.

[6] Drake and Hall (2003), Cavallo and Rossi (2002), Elyasiani and Rezvanian (2002), Maudos et al. (2002), Drake (2001) Altunbas and Molyneux (1996) and Molyneux and Forbes (1993)

[7] See Rezvanian and Mehdian (2002), Hardy and di Patti (2001), Karim (2001), Laevan (1999), Katib and Matthews (1999), Chu and Lim (1998), Bhattacharyya et al. (1997) and Fukuyama (1995)

The basis of the non-parametric method of Data Envelope Analysis (DEA) is the extension by Charnes et al. (1978) (CCR)[8] of the single input-output model of Farrell (1957) to a multiple input-output generalisation. Technical efficiency (TE) is measured as the ratio of projected output (on the efficient frontier) to actual input used. There are a number of papers that describe the methodology of DEA as applied to banking[9], what follows is a brief description.

Let us say that there are *N* banks. Let $z_i$ represent the input matrix of the i[th] bank, and $y_i$ represent its output matrix. Let the *KxN* input matrix be denoted *Z* and the *MxN* output matrix be denoted *Y*. The efficiency measure of each of the N banks is maximised by the DEA searching for the ratio of all weighted outputs over all weighted inputs, where the weights are selected from the dual of the linear programming problem specified as:

$$\min_{q,l} q$$

subject to

$$\begin{aligned} -y_i + Yl &\geq 0 \\ qz_i - Zl &\geq 0 \\ l &\geq 0 \end{aligned} \qquad (1)$$

where $l$ is a $Nx1$ vector of constants $q$ is a scalar and is the economic efficiency score of the i[th] bank ($0 < q < 1$).

The estimation of cost efficiency involves the comparison of minimum cost at the optimal factor ratios to actual cost at the observed factor ratios. The minimisation exercise becomes:

$$\min_{l, z_i} w_i z_i^*$$

subject to

$$\begin{aligned} -y_i + Yl &\geq 0 \\ z_i^* - Zl &\geq 0 \end{aligned} \qquad (2)$$

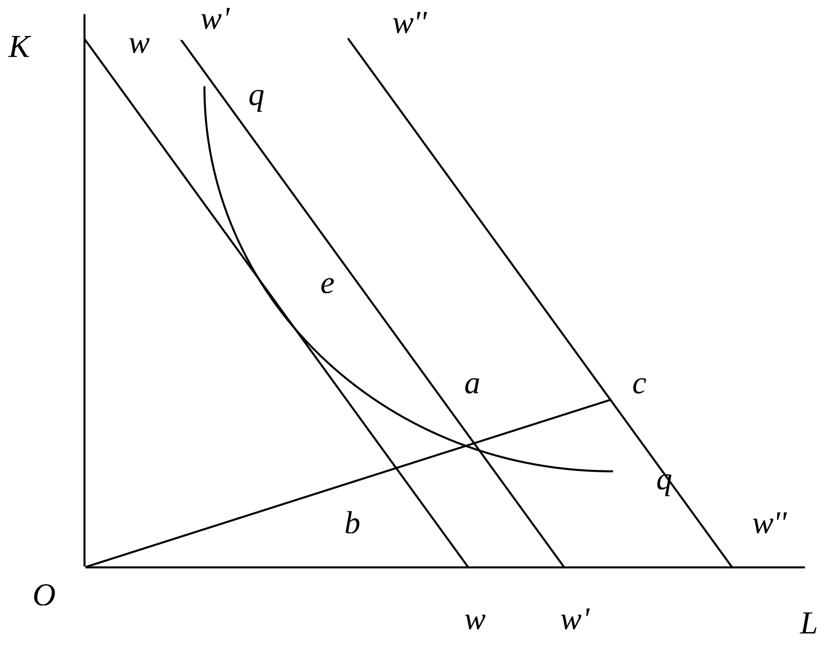
[8] Charnes et. al (1978) popularised the DEA method.Tavares (2002) produces a bibliography of DEA (1978-2001). There are 3203 DEA authors whose studies cover a wide range of fields. Banxia.com also compiles DEA papers from 1978 to the present.

[9] The most recent being Drake (2004)

where $w_i$ is a vector of input prices for the $i^{th}$ bank and $z_i^*$ is the cost minimising vector of inputs for the $i^{th}$ bank. A graphical illustration helps to differentiate the two concepts in the case of CRS.

Figure 1 shows an isoquant *qq* producing a given output with factor inputs *x* and *n* and isocost *ww*, which traces the ratio of factor prices. The efficient cost minimising position is shown at *e* where *ww* is tangential to *qq*. Employing a factor combination shown by point c, which is to the right of the isoquant *qq* indicates that the firm is technically inefficient. Efficiency is decomposed into technical efficiency and allocative efficiency (AE).

**Figure 1: Technical Efficiency and Allocative Efficiency**




Technical efficiency is measured by the ratio $Oa/Oc$. The cost to the firm is shown by $w''w''$ which is parallel to *ww* and passes through point c. Cost efficiency

(CE) is measured by *Ob/Oc* and *Ob/Oa* gives AE. It can be seen therefore from this decomposition that under CRS;

$$AE = \frac{CE}{TE} \qquad (3)$$

However, the CCR model under the assumption of CRS is only appropriate when all banks are at the optimal scale. This requires that the Decision Making Units (DMUs) operate on the flat portion of the long run average cost curve. However, scale inefficiency can be estimated by altering the CCR model to allow for variable returns to scale (VRS). Banker et. al (1984) (BCC) account for scale effects by estimating the most productive scale size for each DMU while identifying its technical efficiency[10]. Therefore technical efficiency is further decomposed into measures of pure technical efficiency (PTE) and scale efficiency (SE). Hauner (2005) demonstrates that under the assumption of VRS, cost efficiency (CE) can be further decomposed by the formula;

$$CE = AE.SE.TE \qquad (4)$$

DEA constructs a non-parametric frontier of the best practices amongst the decision-making units (DMUs). An efficiency score for each DMU is measured in relation to this frontier. An efficiency score is constructed under both CRS and VRS. If the efficiency score of each bank produced by these models differ significantly, then the banks are said to experience variable returns to scale (Avkiran, 1999). In the case of VRS, a model can be orientated either by using input minimisation (efficiency gain through input reduction) or output maximisation (efficiency gain from output expansion).

[10] Coelli (1996) shows that the use of the CRS specification when some of the banks are not operating at the optimal scale will result in measures of technical efficiency that are mixed up with scale efficiency.

DEA is relatively insensitive to model specification (input or output orientation) and functional form[11], however the results are sensitive to the choice of inputs and outputs. The weakness of the DEA approach is that it assumes data are free from measurement errors. Furthermore, since efficiency is measured in a relative way, its analysis is confined to the sample used. This means that an efficient DMU found in the analysis cannot be compared in a straightforward way with other DMUs outside of the sample.

A small but growing industry of efficiency studies of Chinese banks has emerged in recent years, using both DEA and stochastic frontier analysis[12]. The consensus of finding from the DEA studies is threefold. First, because of the continued banking reform programme technical inefficiency has been declining over time. Second, average bank efficiency is lower in the state owned banks (SOBs) than in the joint stock banks. Third, the gap between the two has been narrowing in recent years.

## 4.0 Rent-seeking and X-inefficiency

Berger, Hunter and Timme (1993) argue that X-inefficiency constitutes 20% or more of bank costs. Proponents of the theory of X-efficiency suggest that the familiar average cost curve of a firm is a 'thick band' rather than a thin line. The band defines a range of costs per given level of output, which will depend on the application of pressure and motivation on the personnel employed[13]. Poor motivation and weak pressure resulting in under utilization of factors of production, is part of what Leibenstein (1975) describes as 'organisational entropy'. X-inefficiency arises as a

[11] Hababou (2002) and Avkiran (1999) provide a relatively thorough discussion of the merits and limits of the DEA.
[12] In addition to the papers cited in footnote 1, other studies by Chinese scholars that have used non-parametric techniques include Xu, Junmin and Zhennsheng (2001), Zhang and Li (2001), Fang et. al. (2004). Studies using parametric methods include Zhang, Gu and Di (2005), Chen and Song (2004), Liu and Liu (2004), Sun (2005), Qian (2003), Chi, Sun and Lu (2005), Yao, Feng and Jiang (2004)
[13] See for example Franz (1988)

result of low pressure for performance. Some institutions would be protected by government regulation that would reduce the external pressure from competition. But even with a higher degree of pressure from the environment, firms may have organisational deficiencies so that management signals and incentives are lost in the hierarchy of the organisation.

Studies of bank efficiency have used the terms technical efficiency and X-efficiency interchangeably as if they were the same thing. While similar in concept they are not necessarily the same. The concept of technical efficiency derives its basis from the neo-classical theory of the firm and assumed profit maximising behaviour. A firm or a bank may be technically inefficient for technical reasons such as low training or human capital levels of managers and workers, or the use of inferior or out-of-date technology. The diffusion of new technology is not instantaneous and some firms or banks may lag behind others in the acquisition and utilisation of new technology. With further training and updating of capital, the firm or bank can expect to move towards the efficient frontier. X-inefficiency is not caused by the variability of skills or the time variability of technology diffusion but by the use and organisation of such skills and technology.

Leibenstein and Maital (1992) suggest that X-inefficiency and its composition can be measured through the use of DEA analysis. The partitioning of the efficiency scores enables the differentiation between motivational factors and management deficiency. Leibenstein and Maital (1992) argue that the slack analysis of efficiency is a means of separating the proximate causes of X-inefficiency including management performance[14].

[14] Chen (2001) uses the decomposition to identify management X-inefficiency in Taiwan's banks.

The two main scalars produced by DEA analysis is *theta* (*?*), and *iota* (?). The former measures that portion of X-inefficiency that could be eliminated by the proportional reduction of inputs. However, even after reducing inputs, some inputs may still exhibit slack[15] which is measured by the latter *iota.* Iota measures the total amount of X-inefficiency and therefore the direct management deficiency is measured by *?* – ?. While this partitioning of the DEA score separates out the potential factors that contribute to the overall measure, there is no obvious economic reason as to why the decomposition identifies management deficiency explicitly.

An alternative interpretation of non cost-minimising behaviour is 'rent seeking' in the sense of Buchanan (1980) and Tullock (1967, 1980). Rent seeking in its basic form is the appropriation of surplus in the process of production or exchange without any real contribution to the process of either. Where there are government regulations on enterprise, barriers to entry and other anti-competitive rules, officials have the opportunity to extract rents through the mechanism of bribery and corruption. Therefore the term rent seeking has been generally associated with extortion, bribery and corruption. While it is generally accepted that corruption is fairly widespread in the financial sector in China, a number of high profile cases have made this subject a matter of contemporary concern[16]. The fall-out from a number of well-publicized cases could have the effect of reducing activity in this particular area.

However, a hidden but much more pervasive type of rent seeking is the extraction of larger budgets for bureaucracies and what results in the non-pecuniary rewards to workers in government owned enterprises (Tullock, 1967 and McKenzie and Tullock 1981). The prestige of the senior bureaucrats is enhanced if the size of

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[15] See Zhu (2003) pp. 39-45

[16] The former Governor of the Construction Bank of China Wang Xuebing was sentenced to 12 years jail for accepting bribes of 1.15 million Yuan. The Vice-President of the Bank of China received a suspended death sentence for embezzling 14.5 million Yuan and accepting bribes of 1.4 million Yuan. See also Fan, Rui and Zhao (2006)

the workforce is expanded to be larger than necessary to meet production targets. Similarly, offices are more grandiose, holidays are longer, and benefits are greater and so on.

One way of capturing the extent of bureaucratic rent seeking is to use the decomposition of bank efficiency into the components of cost inefficiency and technical efficiency. We can assume that the manager of a cost-minimising DMU facing a technology described by $q = ef(x, n)$ with costs described as $rx + wn$, where $q$ is output, $x$ and $n$ are factor inputs, $r$ and $w$ are factor prices and $e$ is managerial effort, $(0 < e \leq 1)$, will maximise his utility at the optimum position for the firm. The marginality conditions are given by equation (5) below, which corresponds to $ww$ in figure 1.

$$\frac{f_x}{f_n} = \frac{r}{w} \tag{5}$$

A ray from the origin to the tangency point $e$ on figure 1 defines the optimal factor mix. The demand for factor inputs is given by;

$$\begin{aligned} n^* &= n(q, e, w, r) \\ x^* &= x(q, e, w, r) \end{aligned} \tag{6}$$

Where $\frac{\partial n}{\partial q} > 0, \frac{\partial n}{\partial e} < 0, \frac{\partial n}{\partial w} < 0, \frac{\partial n}{\partial r} > 0, \frac{\partial x}{\partial q} > 0, \frac{\partial x}{\partial e} < 0, \frac{\partial x}{\partial w} > 0, \frac{\partial x}{\partial r} < 0$

Managerial efficiency is 100% if $e$ = 1. However, if $e$ < 1, then the organisation will be to the right of the isoquant shown in figure 1.

The utility function of a rent-seeking bureaucrat would include not just the output of the firm or organisation but also that of a particular factor of production (usually labour and complementary factors such as plush offices and top-grade computers etc.). The utility function of the bureaucrat can be represented by $U = U(q + V(n))$. The bureaucrat minimises costs subject to his preference function. Equation (7) is the Lagrangean.

$$L = rx + wn - l\left(U(ef(x,n) + V(n)) - \overline{U}\right) \qquad (7)$$

From the first-order conditions

$$\frac{f_x}{f_n + V_n} = \frac{r}{w} \qquad (5')$$

Equation (5’) shows a factor mix that favours factor *n* in comparison with the optimal factor mix and is represented by the ray from the origin 0*a*. If *e* < 1, then the organisation will display managerial inefficiency by being on a point off the isoquant but at point 0*c*. The factor mix implied by (5') is $n > n^*$ and $x < x^*$.

From figure 1, we can see that at point '*a*' the DMU is technically efficient but is allocatively inefficient. A bank can organise its input factors to be on its production frontier but be using the wrong factor mix. Rent seeking in monopolistic public utilities involves over-staffing, 'elaborate offices and a lot of trips to important conferences' or 'expensive subsidised restaurants' (McKenzie and Tullock, 1981). The wrong factor mix in the case of the Chinese banking sector can be interpreted as excess staffing. The management of the banks may reduce technical efficiency (X-inefficiency as it has been sometimes interpreted) by moving the cost frontier from *w''w''* to *w'w'*, but would still remain cost inefficient as shown by the gap *ab*/*Oc*. The gap between the minimum cost optimal factor mix and the technically efficient minimum cost associated with the efficient production frontier with the sub-optimal factor mix (or allocative inefficiency) can be interpreted as the inefficiency associated with 'rent seeking'[17].

[17] Crain and Zardkoohi (1980) suggest that X-inefficiency and rent seeking co-exist and that changes to X-inefficiency are offset by equal changes in rent seeking, so that there is a trade-off between one type of inefficiency against another.

## 5.0 Data and Bootstrapping

This study employs annual data (1997-2004) for 15 banks; the four state-owned banks, ten joint-stock commercial banks and one joint-venture bank. Data for one of the joint-stock banks was unavailable for 2004 (China Everbright) and in that year 14 banks data was used. The total sample consisted of 119 bank year observations. The main source of the data was Fitch/Bankscope and the *Almanac of China's Finance and Banking* (various). The choice of banks was based on the fact that they face a common market and compete nationwide. The one joint-venture bank in the sample is an example of a bank that has strong foreign intervention and would according to the consensus of evidence, be expected to exhibit a high level of efficiency, even though it can be argued that as a regional bank it would not necessarily be competing in the same markets as the other banks in the sample. A list of the banks used in the estimation is provided in the appendix.

Two approaches are normally taken in determining what constitutes bank input and output. Under the intermediation approach, bank assets measure outputs and liabilities measure inputs. In contrast, inputs in the production approach are physical entities such as labour and capital. Deposits are a measure of output. In this study, we consider three sets of outputs. First, we use three inputs and three outputs selected under the intermediation approach for the estimation of technical efficiency. Inputs are the number of employees (*LAB*), fixed assets (*FA*) and total deposits (*DEP*). Outputs are total loans (*LOANS*), other earning assets (*OEA*), and other operating income (*NII*). Although the latter variable remains undeveloped in China, it is selected to reflect the growing contribution of non-interest income to banks' total income. Second, we consider the quality of the loan portfolio by stripping out non-performing loans (NPLs) from the stock loans for each bank (*LOANSQ*). In both cases, the vector of inputs is the same as in the first case. The argument for adjusting loans for NPLs is to mitigate the effect of the large loan portfolios held by the big-4 SOBs on the efficiency calculation. The unadjusted loan portfolio would bias the efficiency score upwards for the SOBs which have the largest share of loans but also the highest proportion of NPLs.

The inputs for the construction of cost-efficiency additionally require the factor prices of the relevant inputs above. We distinguish between the price of labour (*PL*), price of fixed capital (*PK*) and the price of funds (*PF*). The price of labour is obtained as the ratio of personnel expenses to employees. The price of fixed capital is operating expenses less personnel expenses divided by fixed assets (less depreciation). The price of funds is obtained from the ratio of interest paid to total funds.

The availability of uniform and comparable data on Chinese banking is a very recent development. Researchers have typically made a number of working assumptions to fill the gaps in data. In general, balance sheet data is available although the data revisions alter the figures from year to year and up until recently the accounting standards of Chinese banks differed from international standards (Ng and Turton 2001). The number of employees are available for the big four state owned banks but not for all of the joint-stock banks over all years. Similarly, the availability of personnel expenses varies across banks. In the years that personnel expenses were not available, the ratio of personnel expenses to total operating expenses in the adjacent year to the missing was applied. In the years where the number of employees was not available, the ratio of labour to fixed assets in the most recent year available was applied[18]. Where there were no personnel expenses available, it was assumed that

[18] Fu and Heffernan (2005) assume that the employee growth matches the growth of total assets and they use the average wage paid by state-owned and other types of financial institutions to estimate labour cost.

the bank faced the same capital costs as banks of comparable size, which gave personnel costs as a residual.

Table 3 presents the summary statistics of the input and output data for 2004 as a snapshot indicator of the scale of the variables used. The high standard deviation is an indication of the dominance of the 4 state owned banks.

**Table3: Output-Input Variables 2004 (million RMB)**

| Variable | Description | Mean | Standard Deviation |
|---|---|---|---|
| *LOANS* | Total stock of loans | 930,026.2 | 1158139.3 |
| *OEA* | Other Earning Assets | 572,112.7 | 698281.2 |
| *NII* | Non-interest income | 3,306.0 | 5083.0 |
| *LOANSQ* | Loans adjusted for NPLs | 861,603 | 972690.4 |
| *LAB* | Number employed (labour) | 110,050.4 | 172260.9 |
| *DEP* | Total Deposits | 1,403,333.1 | 1766172.3 |
| *FA* | Fixed Assets (less depreciation) | 23,455.5 | 30074.6 |
| *PL* | Price of labour | .08 | .046 |
| *PF* | Price of funds | .01 | .020 |
| *PK* | Price of fixed assets | .64 | .279 |

Sources: Fitch/Bankscope, *Almanac of China's Finance and Banking* (various) and author calculations from web sources.

One of the criticisms levelled at the DEA approach is that it produces estimates of efficiency that are not open to statistical inference. In other words if a DMU has a score of 0.95, in what statistical sense is it 5% inefficient relative to the benchmark? Without the capability for statistical inference, non-parametric methods would be weak alternatives to parametric methods of estimating efficiency. However, uncertainties also exist in the estimation of efficiency using DEA. The most obvious uncertainty is what comes from measurement error. Measurement error in the context of data on Chinese banks is particularly marked. There are three potential sources of error; first differences between local bank's accounting procedures and those of international bodies, second differences between local bank's accounting conventions and third, researcher assumptions relating to the generation of missing observations. Other uncertainties arise from the estimation of the efficiency frontier; changes to the inputs and/or outputs can cause large differences in the resulting scores. Furthermore there may be errors in the sampling variation caused by the difficulty in obtaining a sufficiently large and consistent sampling frame.

Simar and Wilson (1998, 2000a, 2000b) propose a bootstrap procedure for non-parametric frontier models. Bootstrapping is based on the notion that if the data can be viewed as a random sample from an underlying population under a model (data generating process - DGP), then the process continuous random draws from the sample under the model generates also random draws from the population. The random raw can be viewed as a pseudo-sample and as a group of new benchmarks to compute the efficiency score for a given point. Following the Simar-Wilson method, 1000 bootstrap values of the individual DMU for all types of efficiency scores are generated in each year. Recent bootstrapping applications to DEA have been conducted by Löthgren and Tambour (1999); in the case of banking efficiency by Casu and Molyneux (2005); and in the case of Chinese rural credit cooperatives, Dong and Featherstone (2004). It is not the intention of this paper to give a detailed explanation of the Simar-Wilson bootstrapping method but a brief description of the method and algorithm is provided in the appendix.

## 6.0 Empirical Results

Table 4 presents the yearly average of the pure DEA scores for each year broken down into Cost inefficiency, X-inefficiency (Technical inefficiency) and Rent seeking inefficiency for all the banks, the state-owned banks (SOB) and Joint-stock banks (JSB), so that Cost inefficiency is the sum of X-inefficiency and Rent-seeking inefficiency. We present the results from both CRS and VRS assumptions. The relatively small sample in each year could bias the scale efficiency estimates, which raises doubts about the VRS assumption[19].

The numbers in table 4 are the starting point for the bootstrap exercise and are only indicators of the scale of the measure. Because they have no inferential capacity, there is little that can be said about them from a statistical basis. The difference in magnitude between the CRS and VRS estimates of relative X-inefficiency could indicate strong scale efficiencies, but this evidence would have to be interpreted with caution given the small number of DMUs per year. There is less difference in the rent-seeking estimates of inefficiency between the two assumptions. What can be said from the figures is that relative X-inefficiency has declined from a high in 1999 under either assumption. Similarly, the implied measure of inefficiency caused by rent seeking has fallen sharply from a high point in 2000 in relative terms.

**Table 4: Mean Inefficiency %, Intermediation Method - CRS and VRS; All banks (All), State-Owned banks (SOB), Joint-Stock banks (JSB)**

| | | X-inefficiency | | | Rent-Seeking | | |
|---|---|---|---|---|---|---|---|
| | | All | SOB | JSB | All | SOB | JSB |
| 1997 | CRS | 5.0 | 3.5 | 1.2 | 3.4 | 5.5 | 7.0 |
| | VRS | 1.4 | 2.7 | 1.0 | 2.9 | 4.7 | 2.2 |
| 1998 | CRS | 3.2 | 1.7 | 3.8 | 6.4 | 6.3 | 6.4 |
| | VRS | 2.6 | 0.5 | 3.4 | 4.7 | 7.0 | 3.8 |
| 1999 | CRS | 10.3 | 16.4 | 8.1 | 14.8 | 7.2 | 17.0 |
| | VRS | 5.8 | 0.5 | 7.8 | 14.1 | 10.0 | 16.9 |
| 2000 | CRS | 7.5 | 16.8 | 4.0 | 17.1 | 8.2 | 20.4 |
| | VRS | 2.8 | 0.6 | 3.7 | 16.2 | 5.2 | 20.2 |
| 2001 | CRS | 6.4 | 20.0 | 1.5 | 14.8 | 7.0 | 17.5 |
| | VRS | 1.1 | 0.3 | 1.4 | 14.8 | 8.5 | 17.2 |
| 2002 | CRS | 4.4 | 11.0 | 2.1 | 5.2 | 10.0 | 3.4 |
| | VRS | 1.0 | 0.3 | 1.2 | 4.8 | 9.1 | 3.2 |
| 2003 | CRS | 3.6 | 10.5 | 1.0 | 5.9 | 13.6 | 3.1 |
| | VRS | 0.9 | 1.0 | 0.9 | 4.1 | 8.2 | 2.6 |
| 2004 | CRS | 4.1 | 11.0 | 1.4 | 6.4 | 11.5 | 4.3 |
| | VRS | 0.6 | 0.7 | 0.3 | 4.6 | 6.2 | 3.9 |
| Average | CRS | 5.6 | 11.4 | 2.9 | 9.3 | 8.7 | 9.9 |
| | VRS | 2.0 | 0.8 | 2.5 | 8.3 | 7.4 | 8.9 |

[19] The cluster of four large state-owned banks biases the scale efficiency estimates for the big-4.

The split between the state-owned banks and the joint-stock banks is more revealing. The results show that the average level of X-inefficiency is high under the CRS assumption for the SOBs but remarkably low under the VRS assumption. This is because size favours scale effects and therefore two of the state owned banks (Bank of China and ICBC) are benchmarks for the full sample and are therefore technically (or X-) efficient and cost efficient. The inefficiency scores for the remaining joint-stock banks confirms the trend that relative X-inefficiency has fallen to negligible levels by 2004. Finally, it would appear that at the end of the period, the average inefficiency created by rent seeking is lower in the case of the joint-stock banks compared with the state-owned banks, but in terms of the averages for the sample as a whole there is little difference.

Table 4 also reveals a surprisingly large increase in average cost-efficiency (X-inefficiency plus rent-seeking inefficiency) in the period 1999-2001. This may be attributable to the activities of the Asset Management Companies set up to strip swathes of non-performing loans from the SOBs. In terms of the technology of the non-parametric method this would be interpreted as a drop in output but with the same factor levels would translate to a decrease in cost efficiency.

In Table 5 we present the results of repeating the efficiency estimation shown in Table 4 after stripping out identified NPLs from the stock of loans for each bank. The argument for stripping out NPLs is twofold. First, the stock of loans is quality adjusted by including only active loans. Ignoring the NPLs highlights the distortions to the estimates of efficiency caused by the activity of the Asset Management companies and the exclusive focus of its operation on the big-4 SOBs. Second, by taking out NPLs we make a small step towards the homogeneity of loans for each bank. Including NPLs in the stock of loans, creates strong size effects, which compounds the bias to scale efficiency of a small sample size. The large SOBs have the largest stock of loans but also the largest amount of NPLs.

The adjustment for NPLs reveals a higher average level of X-inefficiency in the SOBs compared with the JSBs. While the Bank of China and ICBC continue to act as benchmark DMUs, the Agricultural Bank of China and China Construction Bank show a lower average level of technical efficiency under both assumptions. There is little difference between the average level of rent-seeking inefficiency between the SOBs and JSBs over the sample period, but the average level of X-inefficiency of the JSBs is lower than the rent-seeking inefficiency.

**Table 5: Mean Inefficiency %, Intermediation Method (NPL Adjusted) - CRS and VRS; All banks (All), State-Owned banks (SOB), Joint-Stock banks (JSB)**

| | | X-inefficiency | | | Rent-Seeking | | |
|---|---|---|---|---|---|---|---|
| | | All | SOB | JSB | All | SOB | JSB |
| 1997 | CRS | 6.0 | 31.6 | 1.8 | 8.4 | 7.5 | 8.2 |
| | VRS | 1.4 | 10.4 | 1.8 | 2.1 | 2.2 | 2.7 |
| 1998 | CRS | 9.2 | 32.6 | 5.4 | 5.6 | 4.6 | 5.8 |
| | VRS | 3.8 | 11.9 | 4.8 | 3.3 | 4.7 | 3.3 |
| 1999 | CRS | 12.2 | 35.4 | 7.9 | 15.3 | 8.7 | 16.8 |
| | VRS | 6.0 | 8.5 | 7.3 | 14.4 | 6.2 | 16.9 |
| 2000 | CRS | 7.3 | 26.4 | 3.7 | 14.9 | 6.7 | 17.6 |
| | VRS | 2.9 | 6.0 | 3.7 | 13.6 | 3.1 | 17.0 |
| 2001 | CRS | 5.6 | 25.9 | 1.6 | 9.9 | 5.8 | 11.7 |
| | VRS | 1.1 | 5.2 | 1.4 | 9.5 | 5.6 | 11.6 |
| 2002 | CRS | 6.4 | 22.2 | 4.1 | 2.7 | 6.6 | 2.0 |
| | VRS | 2.0 | 4.9 | 2.6 | 3.3 | 6.0 | 3.3 |
| 2003 | CRS | 3.9 | 15.2 | 2.2 | 5.5 | 13.8 | 3.9 |
| | VRS | 1.5 | 4.2 | 1.9 | 3.3 | 5.5 | 3.5 |
| 2004 | CRS | 6.5 | 16.3 | 2.6 | 6.4 | 11.0 | 4.5 |
| | VRS | 2.5 | 4.7 | 1.7 | 3.7 | 3.1 | 3.9 |
| Average | CRS | 7.1 | 25.6 | 3.7 | 8.6 | 8.1 | 8.8 |
| | VRS | 2.7 | 7.0 | 3.2 | 6.7 | 4.6 | 7.8 |

While the estimates of efficiency shown in Tables 4 and 5 produce a picture of gradual improvement in bank efficiency from the beginning of the 21st century, little confidence can be placed on the figures for the lack of appropriate statistical significance. Table 6 presents the results of bootstrap estimation for the CRS assumption only. For reasons of brevity we show four years for both types of output. The reasons for focussing on the results from the CRS assumption are threefold. First, the DEA scores are highly sensitive to the sample size and in particular the assumption of VRS in the case of a small sample which includes a few relatively large banks. The simulations of the pseudo-samples are based on clusters of observations and in the case of the SOBs, amount to only four, which biases the efficiency scores of the big banks upwards.

**Table 6: Bootstrap Estimates of Inefficiency; 2001-2004 (%) CRS**

| Bank | Output | 2001 | | 2002 | | 2003 | | 2004 | |
|---|---|---|---|---|---|---|---|---|---|
| | | X-ineff | Rent | X-ineff | Rent | X-ineff | Rent | X-ineff | Rent |
| ABOC | Loans | 30.4*** | 30.8*** | 19.4*** | 37.5*** | 25.6*** | 35.1*** | 24.1*** | 31.0*** |
| | Adjusted | 49.1*** | 21.6*** | 48.4*** | 22.1*** | 33.7*** | 35.0*** | 35.6*** | 27.4*** |
| CCB | Loans | 46.2*** | 15.1*** | 24.6*** | 27.3*** | 10.1*** | 43.4*** | 15.7*** | 33.1*** |
| | Adjusted | 40.4*** | 18.4*** | 33.1*** | 23.0*** | 10.0*** | 44.2*** | 14.2*** | 35.1*** |
| BOC | Loans | 20.4*** | 27.1*** | 18.2*** | 0 | 18.6*** | 0 | 19.6*** | 0 |
| | Adjusted | 19.6*** | 27.8*** | 18.6*** | 0 | 18.0*** | 0 | 20.4*** | 0 |
| ICBC | Loans | 37.5*** | 13.7*** | 13.5*** | 30.0*** | 19.5*** | 26.5*** | 22.0*** | 25.0*** |
| | Adjusted | 0 | 10.6*** | 0 | 24.6*** | 0 | 26.6*** | 0 | 22.6*** |
| BComm | Loans | 34.0*** | 0 | 21.9*** | 23.8*** | 13.5*** | 33.7*** | 18.0*** | 26.6*** |
| | Adjusted | 33.1*** | 0 | 27.5*** | 21.4*** | 14.9*** | 33.6*** | 16.3*** | 29.1*** |
| CITIC | Loans | 27.1*** | 24.4*** | 31.7*** | 0 | 22.8*** | 12.6*** | 28.6*** | 6.2* |
| | Adjusted | 25.3*** | 21.4*** | 34.3*** | 0 | 22.6*** | 15.3*** | 26.7*** | 8.9*** |
| CMB | Loans | 27.2*** | 24.6*** | 42.1*** | 0 | 42.9*** | 0 | 44.8*** | 0 |
| | Adjusted | 27.5*** | 12.9** | 41.3*** | 0 | 41.5*** | 0 | 46.1*** | 0 |
| CMBCL | Loans | 20.0*** | 27.7*** | 13.4*** | 20.2*** | 15.7*** | 9.7*** | 12.7*** | 15.4*** |
| | Adjusted | 14.0*** | 29.3*** | 13.2*** | 21.1*** | 17.8*** | 8.5*** | 14.7*** | 15.0*** |
| EVERBRT | Loans | 32.1*** | 15.6*** | 31.3*** | 7.7*** | 22.8*** | 13.0*** | - | - |
| | Adjusted | 28.9*** | 17.1*** | 34.9*** | 8.5*** | 28.0*** | 11.0*** | - | - |
| FSB | Loans | 58.8*** | 0 | 26.2*** | 0 | 22.6*** | 0 | 15.5*** | 0 |
| | Adjusted | 57.8*** | 0 | 31.0*** | 0 | 30.0*** | 0 | 21.5*** | 0 |
| GDB | Loans | 20.7*** | 29.7*** | 5.0*** | 4.3*** | 14.3*** | 10.0*** | 10.6*** | 23.7*** |
| | Adjusted | 24.5*** | 20.6*** | 22.4*** | 22.8*** | 16.6*** | 19.8*** | 27.9*** | 14.4*** |
| HUAXIA | Loans | 29.4*** | 27.2*** | 27.3*** | 9.5*** | 13.5*** | 26.2*** | 20.8*** | 18.6*** |
| | Adjusted | 27.5*** | 24.6*** | 26.7*** | 10.2*** | 12.6*** | 28.1*** | 19.7*** | 20.0*** |
| IBCL | Loans | 37.5*** | 13.7*** | 13.5*** | 30.0*** | 19.5*** | 26.4*** | 21.9*** | 25.0*** |
| | Adjusted | 23.5*** | 0 | 21.3*** | 16.8*** | 14.9*** | 22.7*** | 33.5*** | 0 |
| SDB | Loans | 15.3*** | 36.3*** | 12.5*** | 21.8*** | 10.2*** | 23.7*** | 11.8*** | 24.9*** |
| | Adjusted | 17.3*** | 25.9*** | 14.3*** | 23.9*** | 13.5*** | 24.8*** | 8.8*** | 30.6*** |
| SPB | Loans | 27.1*** | 33.8*** | 28.4*** | 8.8*** | 30.8*** | 0 | 31.8*** | 0 |
| | Adjusted | 26.0*** | 28.4*** | 31.8*** | 5.9*** | 32.6*** | 0 | 34.0*** | 0 |
| Average | Loans | 29.4 | 22.3 | 22.4 | 15.5 | 19.8 | 17.2 | 22.1 | 14.6 |
| | Adjusted | 30.6 | 17.2 | 28.5 | 13.3 | 22.2 | 17.9 | 25.1 | 14.5 |

*** significant at 1% level one-tailed test; ** significant at the 5% level one-tailed test; * significant at the 10% level. Estimates not significantly different from zero at the 10% are reported as zero.

Secondly, the evidence of scale economies in banking is mixed. Early studies tended to confirm the existence of constant returns to scale[20], however more recent findings suggest that there are significant scale economies for large banks[21]. Thirdly, the bootstrap estimates under the VRS assumption showed implausibly low levels of cost efficiency and no difference between the estimates of cost efficiency and technical efficiency (no scale or allocative inefficiency) for all but two of the JSBs (for both types of output). The SOBs had implausibly high scores for cost and technical efficiency. Furthermore the estimates of cost efficiency from the CRS estimates are similar to the findings of Fu and Heffernan (2005) for roughly the same sample period using stochastic frontier methods.

The estimates of inefficiency shown in Table 6 are based on the medians rather than the means as the former provide a more robust measure of the scores when the distributions are skewed as in the case of DEA. Table 6 shows that the bootstrap estimates of inefficiency are higher than those obtained from the simple DEA results shown in Tables 4 and 5. The adjusting of loans for NPLs had a significant effect in worsening the X-inefficiency score of the Agricultural Bank of China (ABOC) but improving it to zero in the case of ICBC. The pattern of differences for the JSBs is easier to examine in the aggregate. Three questions can be asked about the bootstrap estimates as a whole. First, is there a significant difference between the level of X- and rent-seeking inefficiency between the SOBs and JSBs and what differences do the NPL adjustment to loans make? Second is their evidence that inefficiency is being reduced over time. Third, if there is evidence of inefficiency reduction, is there a difference between the speed of reduction between the SOBs and JSBs? We explore these questions in turn.

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[20] See Hunter and Timme (1986) and Berger et. al. (1987).
[21] Berger and Mester (1997) and Altunbas and Molyneux (1996).

Table 7 below examines the difference in group means of inefficiency for the whole sample for the two types of banks. It is clear that X-inefficiency is significantly higher in the SOBs than JSBs once NPLs have been stripped out of the loan portfolio. This means that the NPLs in the existing loan portfolio of the SOBs (even after the activity of the asset management companies) disguise a weaker average level of X-efficiency compared with the JSBs. It is also the case that the SOBs exhibit a higher average level of rent seeking inefficiency than the JSBs.

**Table 7: Mean inefficiency, Unadjusted loans and NPL adjusted loans (CRS)**

| Inefficiency | Unadjusted SOB | Unadjusted JSB | t value | Adjusted SOB | Adjusted JSB | t Value |
|---|---|---|---|---|---|---|
| X-ineff | 25.9% | 27.8% | 0.65 | 36.4% | 31.3% | 1.70* |
| Rent | 35.2% | 20.9% | 4.14*** | 30.6% | 18.8% | 3.90*** |

*** significant at the 1%, ** significant at the 5%, * significant at the 10%

The next two questions are addressed by regressing the change in inefficiency on its lagged value. The estimated coefficient on the lagged value of inefficiency can be treated as the parameter of adjustment. A significant negative value indicates that inefficiency is declining (efficiency improving). The larger the absolute value of the parameter, the faster the speed of adjustment. The regressions are conducted as a panel of the form $\Delta Y_{i,t} = a + bY_{i,t-1} + e_{i,t}$ with adjustment for heteroscedasticity. The results are shown in Table 8.

**Table 8: Beta value Inefficiency adjustment, CRS**

| Inefficiency | Bank Group | *b* - Unadjusted | t value | *b* - NPL adjusted | t value |
|---|---|---|---|---|---|
| X-inefficiency | SOB | -1.35 | -17.20*** | -.197 | -3.05*** |
| | JSB | -.902 | -11.26*** | -.543 | -8.29*** |
| | All Banks | -.979 | -13.16*** | -.454# | -8.13*** |
| Rent-seeking | SOB | -.755 | -9.14*** | -.826 | -7.08*** |
| | JSB | -.980 | -10.62*** | -.507 | -5.59*** |
| | All Banks | -.877# | -10.80*** | -.648 | -7.51*** |

# including SOB intercept dummy; *** significant at the 1%

The most important result of Table 8 is that under both definitions of output there is strong statistical evidence of a negative trend in inefficiency. In this respect, the results of this paper differ from the findings of Chen et. al. (2005) who find no discernible trend improvement in cost efficiency[22]. The speed of decline in X-inefficiency (improvement in technical efficiency) is greater for the SOBs than the JSBs, but once output is adjusted for NPLs it can be seen that the speed of decline in X-inefficiency between the two types of banks is reversed. The speed of decline of rent seeking inefficiency is marginally higher for the SOBs in the NPL adjusted case but the difference is minor, possibly because of political pressures that would inhibit downsizing and labour shedding at too fast a rate.

Using parametric methods, Fu and Heffernan (2005) find cost inefficiency in the order of 50% over the period 1993-2002. These findings are consistent with the bootstrap estimates obtained here and also the broad findings of Chinese scholars cited in this paper. Such findings have typically generated a consensus of pessimism about the future of Chinese banking. Our findings suggest grounds for optimism in that in terms of relative efficiency, Table 8 shows that the trend is towards improved performance.

## 7.0 Conclusion

The premise of this paper is that cost inefficiency can be partitioned into X-inefficiency and rent-seeking inefficiency in the spirit of Crain and Zardkoohi (1980). If this premise is accepted, the implication for the current thrust of official bank policy in China is positive. According to Leibenstein (1966), X-efficiency is improved through managerial motivation and external pressure. Impending

[22] Chen et. al (2005) uses a wider data frame of banks, including regional joint-stock banks and international trust and investment companies. It can be argued that the use of DMUs that do not compete in the same geographical market or product is a violation of the homogeneity requirement of DEA.

competition and the deregulation of the Chinese banking market can be expected to motivate managers to improve performance and utilise existing factors of production fully. Competition for well-qualified staff between the different banking firms will raise rewards and attract the best graduates. The potential outflow of the best staff to the higher paying institutions will motivate a greater focus on training, modernization and efficiency.

Bureaucratic rent seeking is a rational response to a particular set of incentives based on protectionist policy. It would be no surprise to learn that over the years of protected growth, as the banks were vessels for the channelling of unprofitable loans to state-owned enterprises, the response of the banking sector was to develop rent seeking strategies and act as employment sponges for the educated youth in China. The dismantling of protection and the invitation to list the state-owned banks and the joint stock banks will alter the incentive structure for managers and consequently there should be a trend reduction in rent-seeking inefficiency.

This paper has argued that in the context of a protected banking sector such as the Chinese banking sector, measures of cost inefficiency can be decomposed into X-inefficiency and rent-seeking inefficiency. We have used non-parametric methods to conduct an analysis of inefficiency in a sample of Chinese banks. The estimates of bank inefficiency were buttressed with bootstrapping techniques to enable statistical inference. In general, the estimates from bootstrapping support the view that relative efficiency has improved. However, we must still interpret the results with caution. The improvement in efficiency is in terms of the benchmark banks, which are themselves 'best-practice' Chinese banks. The real benchmarks should be foreign banks competing on an equal footing or foreign banks operating in their home countries under similar conditions of development and risk.

This paper does not suggest that the Chinese banking system is in good shape to face the threats of post 2007. The argument of this paper is that the threat of an open market to foreign banks has resulted in significant improvements in bank efficiency. The main message of this paper is that while Chinese banks may not be in the best shape they could be to meet the challenges of post 2007, they are in better shape than they have ever been.

**Appendix: DMUs and Bootstrapping Procedure**

**Table of Data 2004**

| Mnemonic | Bank | Earning Assets rmb (million) | Operational Cost rmb (million) | Employment |
|---|---|---|---|---|
| ABOC | Agricultural Bank of China | 3,794,322 | 50,385 | 489,425 |
| BOC | Bank of China | 3,929,961 | 41,915 | 164,193 |
| ICBC | Industrial & Commercial Bank of China | 5,352,093 | 27,999 | 427,221* |
| CCB | China Construction Bank | 3,765,229 | 44,285 | 310,391 |
| CITIC | CITC Industrial Bank | 493,867 | 4,635 | 9,918 |
| HUAXIA | Hua Xia Bank | 297,395 | 2,740 | 7,007 |
| CMB | China Minsheng Bank | 435,761 | 4,470 | 6,382 |
| CMBCL | China Merchant Bank Co Ltd | 587,439 | 6,514 | 17,829 |
| IBCL | Industrial Bank Co Ltd | 331,813 | 3,048 | 7,135* |
| EVERBRT | China EverBright Bank** | 364,784 | 3,830 | 8,569 |
| SDB | Shenzen Development Bank | 198,802 | 2,483 | 8,757* |
| GDB | Gunagdon Development Bank | 310,857 | 5,598 | 11,702 |
| FSB | First Sino Bank | 4,738 | 58 | 258* |
| SPB | Shanghai Pudong Bank | 442,806 | 4,431 | 8,288 |
| BOCOMM | Bank of Communications | 1,085,858 | 13,493 | 54,408 |

* estimated, ** 2003 only

The bootstrap procedure for non-parametric frontier models is set out in Simar and Wilson (1998, 2000a, 2000b). The efficiency scores calculated with the original data are used to construct pseudo data. The bootstrap procedure is based on the idea that there exists a DGP, which can be determined by Monte Carlo simulation. By using the estimated distribution of the DGP to generate a large number of random samples, a set of pseudo estimates of the efficiency scores $\hat{q}_i$ are obtained. However this 'naive' bootstrap yields inconsistent estimates (Simar and Wilson, 2000a). A homogeneous bootstrap procedure that produces consistent values of $\hat{q}_i$ from a kernel density estimate is given in Simar and Wilson (2000b). The bootstrap algorithm is summarised in the following steps. The algorithm is run on MATLAB and the codes are available from the authors on request.

*Step 1.* Compute the original DEA efficiency scores using the linear programming model (equation 1) and let $\hat{d}_i = 1/\hat{q}_i$;

*Step 2.* Since radial distances are used, we will refer to the polar coordinate of the input vector of each DMU x defined by its modulus $w = w(x) = \sqrt{x'x}$ and its angle $h = h(x) \in \left[0, \frac{p}{2}\right]^{K-1}$ where for j=1,…, K-1, $h_i = \arctan(x_{j+1}/x_1)$ if $x_1 > 0$ and $h_i = \frac{p}{2}$ if $x_1 = 0$. Then translate the data into polar coordinates: $(y_i, h_i, \hat{d}_i)$, $i = 1, \ldots, K$. And form the augmented matrix $\tilde{L}$ by: $L = \lfloor y_i \quad h_i \quad \hat{d}_i \rfloor$, $L_R = \lfloor y_i \quad h_i \quad 2 - \hat{d}_i \rfloor$,

$$\tilde{L} = \begin{bmatrix} L \\ L_R \end{bmatrix}$$

*Step 3.* Compute the estimated covariance matrices $\hat{\Sigma}_1$, $\hat{\Sigma}_2$ of $L$ and $L_R$ by

$$\hat{\Sigma}_1 = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \qquad \hat{\Sigma}_1 = \begin{bmatrix} S_{11} & -S_{12} \\ -S_{21} & S_{22} \end{bmatrix}$$

where $S_{11}$ is $(M+N-1)\times(M+N-1)$, $S_{12} = S'_{21}$ is $(M+N-1)\times 1$ and $S_{22}$ is scalar, and compute the lower triangular matrices $L_1$ and $L_2$ such that $\hat{\Sigma}_1 = L_1 L'_1$ and $\hat{\Sigma}_2 = L_2 L'_2$ via the Cholesky decomposition.

*Step 4.* Choose an appropriate bandwidth $h$ as described in Simar and Wilson (2000b) using the information in $\tilde{L}$, $\hat{\Sigma}_1$, $\hat{\Sigma}_2$.

*Step 5*. Draw *K* rows randomly, with replacement from the augmented matrix $\tilde{L}$ and denote the result by the $K \times (M+N)$ matrix $\tilde{L}^*$; compute $\bar{z}^*$, the $K \times 1$ row vector containing the means of each column of $\tilde{L}^*$.

*Step 6*. Use a random number generator to generate a $K \times (M+N)$ matrix $e$ of i.i.d. standard normal pseudo-random variates; let $e_{i.}$ denote the *i*th row of this matrix. Then compute the $K \times (M+N)$ matrix $e^*$ with the *i*th row $e^*_{i.}$ given by $e^*_{i.} = e_{i.} L'_j$ so that $e^*_{i.} \sim N_{M+N}(0, \hat{\Sigma}_j)$ where j=1 if the *i*th row of $\tilde{L}^*$ was drawn from rows 1, . . . , *K* of $\tilde{L}$, or j=2 if the *i*th row of $\tilde{L}^*$ was drawn from rows (*K* + 1), . . . , 2*K* of $\tilde{L}$.

*Step 7*. Compute the $K \times (M+N)$ matrix $\Gamma = (1+h^2)^{-1/2}(M\tilde{L}^* + he^*) + i_K \otimes \bar{z}^*$ where $M = I_K - (1/K) i_K i'_K$ is the usual $K \times K$ centring matrix with $I_K$ denoting an identity matrix of order *K*, $i_K$ an $K \times 1$ vector of ones, and $\otimes$ denotes the Kronecker product.

*Step 8*. Partition $\Gamma$ so that $\Gamma = [g_{i1} \quad g_{i2} \quad g_{i3}]$, where $g_{i1} \in R^M_+$, $g_{i2} \in [0, p/2]^{K-1}$ and $g_{i3} \in (-\infty, +\infty)$ for *i* = 1, . . . , *K*. Define the $K \times (M+N)$ matrix of bootstrap pseudo-data $L^*$ such that the *i* the row $z^*_i$ of $L^*$ is given by

$$z^*_i = \begin{cases} (g_{i1} \quad g_{i2} \quad g_{i3}) & g_{i3} \geq 1 \\ (g_{i1} \quad g_{i2} \quad 2 - g_{i3}) & otherwise \end{cases}$$

*Step 9*. Translate the polar coordinates in $L^*$ to Cartesian coordinates. This yields the bootstrap sample $\{(x^*_i, y^*_i)\}_{i=1}^K$.

*Step 10*. For the given point (*x*, *y*), compute $\hat{q}^*(x, y)$ by solving the DEA program taking $\{(x^*_i, y^*_i)\}_{i=1}^K$ as the benchmarks and compute the bias-corrected efficiency scores $\tilde{q}(x, y) = \hat{q}^2 / \hat{q}^*$

*Step 11.* Repeat Steps 5~11, obtain another group of bias-corrected efficiency scores, reducing the input vector of each DMU x into $\tilde{q}x$. Compute the cost efficiency scores using equation (2) from the reduced inputs and outputs.

*Step 12.* Similar to Step 11, obtain rent-seeking-efficiency scores (the difference between cost-efficiency score and technical (x)-efficiency score)

*Step 13.* Repeat Steps 5~12 *B* (=1000) times to obtain a set of bootstrap estimates $\{\tilde{q}_b(x, y)\}_{b=1}^{B}$ and cost efficiency scores and x-efficiency scores.

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