Available online at www.sciencedirect.com
ScienceDirect
China Economic Review 18 (2007) 35 – 53
China Economic Review

Cost X-efficiency in China's banking sector ☆

Xiaoqing (Maggie) FU [a], Shelagh HEFFERNAN [b,*]

[a] Business Administration, University of Macau, Macau, China
[b] Banking and Finance, Faculty of Finance, Cass Business School, City University, 106 Bunhill Row, London, EC1Y 8TZ, UK

Abstract

Employing the stochastic frontier approach, this paper investigates cost X-efficiency in China's banking sector over the period 1985–2002. The objective is to assess whether different ownership types and banking reforms affect X-efficiency. A two-stage regression model is estimated to identify the significant variables influencing X-efficiency. Overall, the results show that banks are operating 40–60% below the X-efficiency frontier. On average, the joint-stock banks are found to be more X-efficient than the state-owned commercial banks, but individual scores present a far more complex picture. It appears that X-efficiency was higher during the first phase of bank reform. Recent policies aimed at increased privatisation, greater foreign bank participation, and liberalised interest rates should help to improve the cost X-efficiency of China's banks.

JEL classification: G2; G21; G28
Keywords: Stochastic frontier analysis; Cost X-efficiency; Bank reforms; Joint stock banks

1. Introduction

For decades, policy makers, regulators, and managers have been concerned with the issue of how efficiently banks transform their various inputs into multiple financial products and services. In the literature, one of the most common measures used is cost X-efficiency. It involves selecting the optimal scale and mix of inputs, given the output bundle and input prices. To date there has been no published work on measures of cost X-efficiency (hereafter X-efficiency) for Chinese banks, which is the principal objective of this paper. Using a standard parametric method/stochastic cost frontier

☆ We are extremely grateful for comments from the Cass Business School workshop, Peter Andrews, Alec Chrystal, Phil Molyneux, Peter Sinclair, Professor Sir James Mirrlees, seminar participants at the Financial Services Authority, and an anonymous referee. All errors are the responsibility of the authors.
* Corresponding author.
E-mail address: s.a.heffernan@city.ac.uk (S. Heffernan).

1043-951X/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.chieco.2006.10.002

approach, the cost X-efficiency of four state owned and ten joint stock banks is computed for the period 1985–2002. The state owned banks are found to be relatively less cost X-efficient than the joint stocks. However, on average, both groups experience a fall in X-efficiency during a second phase of reforms, though some joint stocks show a significant increase. To further investigate, a two-stage regression model is employed to identify the potential correlates (e.g. bank reform) of X-efficiency. The results suggest a need for policies which increase competition, and reduce moral hazard and other agency problems. The paper is organized as follows. Section 2 provides a brief outline of the current Chinese banking system, followed by a literature review in Section 3. Section 4 describes the data and methodology; the empirical results are reported in Section 5. Section 6 concludes.

2. China's banking system

Until 1978, China operated an economic and financial system based on socialist principles. The People's Bank of China (PBC) not only issued currency, but was the financial hub of each State Economic Plan. In 1978, China embarked on major economic reforms with the objective of increasing economic efficiency and improving resource allocation. In line with most sectors of the economy, the banking system was the focus of significant, albeit gradual, reforms. To date, there have been two stages of reform, from 1979 to 1992, and from 1993 to present.[1] Stage one began with the creation of a "two tier" banking system, consisting of the People's Bank of China (the central bank) and four state owned banks: the Bank of China (BOC),[2] the Agricultural Bank of China (ABC), the China Construction Bank (CCB) and the Industrial and Commercial Bank of China (ICBC). Initially there was a high degree of functional segmentation between them. By 1985, they were allowed to accept deposits and make loans to households and corporates (mainly state owned enterprises — SOEs), via nation-wide branches.[3] By 1986, most had expanded into universal banking, with trust, securities, and insurance affiliates.[4]

Between 1985 and 1992, to promote more competition, the Chinese government permitted the establishment of new "small and medium sized" commercial banks, which initially offered banking services to households and firms, mainly in the regions and cities, This group included the Shenzhen and Guangdong Development banks, the CITIC Industrial Bank, Bank of Communications, China Merchants Bank, China Everbright Bank and Hua Xia Bank.

In 1993 the State Council announced a second stage of bank reforms in the "Decision on Financial System Reform".[5] One objective was to create a competitive commercial banking sector where state banks co-existed along side other forms of banking institutions.[6] Numerous reforms have been implemented since 1993,[7] resulting in a banking system which currently consists of:

- The central bank, PBC: responsible for the implementation of monetary policy, though the State Council (China's equivalent of a cabinet) sets interest rates. The Governor of the PBC is on the committee that advises the State Council.

[1] For more detail on these reforms, see Wu (1998) and Xie and Jiao (2002).

[2] The Bank of China began as a private bank in 1912.

[3] At the end of 1992, each bank had an average of about 30,000 branches and sub-branches, though there were large variations. The ABC had over 56,000 and at the other extreme the BOC had 1,352. The ICBC had just under 32,000.

[4] However, universal banking was short-lived. From 1993 onward, banks had to terminate their securities and insurance operations. This rule was formalised by the Commercial Banking Law, 1995.

[5] Almanac of China's Finance and Banking (1994).

[6] Wu (1998).

[7] Space constraints prevent a review of them here. For more details, see Fu (2004), and Wu (1998).

- The China Banking Regulatory Commission: established in 2003, this body took over the PBC's regulatory function, and is the supervisory authority for banks. The PBC has a financial stability bureau to take decisions about liquidity support in the event of bank runs.
- Three policy banks were established and are funded through issues of state bonds and loans from the PBC.
- Four state-owned commercial banks: provide nationwide wholesale (to large and medium sized enterprises) and retail banking services. Overseas branches have been established to serve Chinese customers abroad.
- Eleven[8] "joint stock" or shareholder owned banks. The state and/or SOEs hold between 60 and 70% of non-tradable shares. Just four of these banks have a small proportion of shares traded on the stock market.[9] Shares are also owned by the private sector, and some foreign concerns. These banks originally offered retail and wholesale banking services in regions, but after reforms in 1993, they were allowed to expand nation-wide.
- City Commercial Banks (111) owned by local government, local enterprises, and households. Commercial banking services (intermediary, settlements, money transfers, etc.) are offered to city-based small and medium sized enterprises and residents, though they are also trying to attract larger firms headquartered in their respective cities, which would normally do business with a state bank. There is some customer overlap with the 758 Urban Credit Cooperatives, though the coops offer basic banking services (taking deposits, making small loans) to residents and small local firms in urban areas.
- Rural Commercial Banks (3): like their urban counterparts but have commercial bank operations in rural areas.
- Rural Credit Coops (35,544): each coop supplies basic banking services to residents and local enterprises based in a particular rural area.
- In 2004, there were roughly 204 foreign bank subsidiaries, which are permitted to provide nation-wide foreign exchange facilities to foreigners and Chinese citizens. They provide Renminbi services in 18 cities (rising to 20 in 2005) as part of China's World Trade Organisation[10] commitment to give foreign banks completely open access to Chinese markets by the end of 2006. Some have acquired small shareholdings in the joint stock banks. For example, Newbridge Financial now owns 15% of Shenzhen Development Bank, and Citicorp has a 5% share in Pudong Development Bank.

These bullet points illustrate that segmentation remained a feature of China's banking system following the second stage of reforms. Table 1 shows some shift in the shares of total loans and deposits between 1992 and 2002. In 2002, the state-owned and joint stock commercial banks together had a market share of about 80% of deposits and 70% loans. The four state banks have market shares well in excess of 50% but since 1992, the joints stocks increased their share in loans and deposits to over 10%. For this reason, this study focuses on estimating the X-efficiency of these banks.

As the discussion above illustrates, China's banking system has been subject to many reforms, the key objective of which was to increase competition and efficiency in that sector. This paper looks at

[8] In 2003, the Yantai House Savings Bank became a new joint stock bank, the China Evergrowing Bank.

[9] The Shenzhen Development Bank was the first to list a minority of its shares on the Shenzhen Stock Exchange in 1991. Three other banks followed between 1999 and 2002.

[10] China became a member of the World Trade Organization in 2001.

Table 1
Market shares of Chinese banks: 1992 and 2002

Banks	Deposits-1992	Deposits-2002	Loans-1992	Loans-2002
Policy banks	NA	0	NA	13%
State-owned-commercial	78%	66%	84%	59%
Joint stock commercial	6%	13%	4%	11%
City commercial	NA	7%	NA	6%
Urban credit coops	3%	1%	2%	0.005%
Rural credit coops	13%	12%	9%	10%
Foreign banks	0.004%	1%	1%	1%
Total	RMB 2742 bn	RMB 16,861 bn	RMB 2759 bn	RMB 13,528 bn

Source: Fu (2004), and Almanac of China's Finance and Banking (1993, 2003).

the latter issue, or more precisely, cost X-efficiency. A more formal definition is supplied in Section 4.1, but a firm is said to be *cost X-efficient* (hereafter X-efficient) if it is producing the maximum output for a given set of inputs and technology. *Cost X-inefficiency* measures any deviation from this and generally arises because of agency problems. Firms become more X-efficient by lowering costs, through, for example, improved management and/or greater employee productivity, which brings them closer to a more efficient way of harnessing a given set of resources. This study contributes to the literature by assessing, for the first time, what happened to the cost X-efficiency of China's banks during the reform periods. Given their objectives, the reforms might well be expected to be associated with an increase cost X-efficiency, though the presence of agency problems could overwhelm any positive effects.

3. Literature review

Quite exhaustive surveys of the literature already exist.[11] For this reason, the review here is confined to studies of X-efficiency in emerging economies where the banking system has been subject to reform. Chen (2001), using data from 1988–97, found banks' X-efficiency had substantially increased in Taiwan's deregulated banking market. Likewise, Hasan and Marton (2003) concluded that bank reforms in Hungary improved X-efficiency scores between 1993 and 1998. Hao, Hunter, and Yang (2001), using data from 1985–1995, reported that financial reforms in Korea had little or no significant effect on banks' X-efficiency. Isik and Hassan (2002) found that following liberalization (1988–1996), Turkish banks' X-efficiency worsened over time, as did Hardy and Patti (2001), when they computed the X-efficiency of all Pakistani banks during a period of deregulation, 1993–1998. Importantly, none of these studies included the People's Republic of China.

Some studies also investigated the relationship between X-efficiency and types of bank ownership, i.e. state versus private. Again, the empirical results are mixed. In their study of Turkey, Isik and Hassan (2002) reported that private banks were more X-efficient than state banks, but in Pakistan and Croatia,[12] state banks were found to be more X-efficient. These mixed results are not surprising, for two reasons. First, the studies are based on data from different

[11] For an extensive review, see Berger and Humphrey (1997), who surveyed 130 X-efficiency studies of various types of financial institutions from 21 countries.
[12] For Pakistan: Hardy and Patti (2001); for Croatia: Kraft and Tirtiroglu (1998).

countries, at different stages of bank reform. Second, agency theory posits that in the presence of asymmetric information, managers act in their own interest rather than that of the principal, in both state owned and listed firms.

4. Methodology and data

4.1. Methodology

Cost X-efficiency measures the extent to which a bank's costs approximate those of the "best practice" or least cost bank, producing an identical output bundle under the same conditions. The measure is derived from a cost function where the dependent variable is each bank's total costs, and the independent variables include the prices of inputs, the quantities of variable outputs, and a composite error term. A general version of this cost function for a bank may be written as

$$C = C(w, y, \varepsilon) \tag{1}$$

where

C	total costs
w	input prices
y	output quantities
ε	u+v
u	an X-inefficiency factor that may raise costs above the best-practice level
v	the random error incorporating the measurement error or a random shock to bank costs, deemed occasional.

The X-inefficiency factor u reflects any failure to minimize the total cost of production, given both the outputs (y) and the factor inputs prices, w. The standard assumption is that the X-inefficiency and random error terms can be multiplicatively separated from the remainder of the cost function. After taking logs on both sides of Eq. (1), the cost function becomes:

$$\ln C = f(w, y) + \ln u + \ln v \tag{2}$$

X-efficiency is defined as the ratio of the predicted minimum costs that would be used if the bank were as efficient as the best-practice bank in the sample facing the same exogenous variables (w, y) to the predicted actual costs, adjusted for random error. Berger and Mester (1997) used a bank-specific measure of X-efficiency as follows:

$$X - \mathrm{EFF}^i = \frac{\hat{C}^{\min}}{\hat{C}^i} = \frac{\exp[\ \hat{f}(w_i, y_i)] \times \exp(\ln\ \hat{u}\min)}{\exp[\ \hat{f}(w_i, y_i)] \times \exp(\ln\ \hat{u}_i)} = \frac{\hat{u}^{\min}}{\hat{u}_i} \tag{3}$$

where

$\hat{C}^{min}$	the predicted minimum costs as used by the best-practice bank;
$\hat{C}_i$	the predicted actual costs;
$\hat{u}^{\min}$	the minimum of the $\hat{u}_i$ across all banks in the sample;
$\hat{u}_i$	the predicted actual cost inefficiency of a specific bank, i.

X-efficiency is the proportion of costs or resources that are used efficiently: an X-EFF ratio of 0.80 would indicate that the bank is 20% less cost efficient relative to the best-practice bank operating under the same conditions. X-efficiency theoretically falls in the interval (0,1], and equals one for a best-practice bank within the observed data. One limitation is that the estimated X-efficiency is a *relative* measure against the best practice bank within the sample. The best practice bank itself may not be efficient when compared to banks outside the sample.

To measure the X-efficiency of Chinese banks, this study adopts the widely used parametric technique — the Stochastic Frontier Approach (SFA). Under the SFA, bank-specific estimates of X-inefficiency, u_i, are obtained by using the distribution of the X-inefficiency term conditional on the estimate of the entire composite error term, as proposed by Jondrow, Lovell, Materov, and Schmidt (1982). The mean of this conditional distribution for the half-normal model is shown as:

$$E(u_i|\varepsilon_i) = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} + \frac{\varepsilon_i\lambda}{\sigma}\right] \tag{4}$$

where

$$\lambda = \sigma_u/\sigma_v$$

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$\phi(\cdot)$ the standard normal density function
$\Phi(\cdot)$ the cumulative standard normal density function

The half-normal assumption for the distribution of X-inefficiencies is relatively inflexible and assumes that most banks are clustered near full X-efficiency. Following Greene (1993), two additional alternatives are used here. One is a model with an exponentially distributed disturbance developed by Aigner, Lovell, and Schmidt (1977),

$$E(u_i|\varepsilon_i) = (\varepsilon_i + \theta\sigma_v^2) + \frac{\sigma_v\phi[(\varepsilon_i+\theta\sigma_v^2)/\sigma_v]}{\Phi[(\varepsilon_i+\theta\sigma_v^2)/\sigma_v]} \tag{5}$$

Stevenson (1980) argued that the assumption of zero mean in Eq. (5) is an unnecessary restriction. He used a truncated-normal model instead of a half-normal model. With a truncated distributed disturbance, the one-sided error term u_i is taken to be the variable obtained by truncating at zero the distribution of a variable with a possibly non-zero mean. The counterpart is obtained by replacing $\varepsilon_i\lambda/\sigma$ with

$$\mu_i^* = \frac{\varepsilon_i\lambda}{\sigma} + \frac{\mu}{\sigma\lambda}\ ^{13} \tag{6}$$

$E(u_i|\varepsilon_i)$ is an unbiased but inconsistent estimator of u_i, since, regardless of N, the variance of the estimator remains non-zero. This model can be estimated using maximum likelihood techniques.

[13] μ is the mode of the normal distribution, which is truncated below at zero. Usually, the meaning of μ is not explained in the banking literature, because it is not informative for purposes of interpreting the model. The reason is that the scaling of the underlying variable is arbitrary — the units of μ are those of σ_u, not natural units.

In line with most of the bank X-efficiency literature this study adopts a translog functional form rather than a more flexible form such as the Fourier-flexible (FF) specification. The FF specification requires more degrees of freedom but with only a few banks and a short history, the Chinese data are limited by comparatively few observations. The translog cost function is specified in Eq. (7), below. Note that in common with the published work in this area, the time and bank subscripts are dropped for ease of exposition.

$$\ln\frac{C}{z^{*}w_3} = \alpha_0 \sum_{p=1}^{4}\beta_p \ln\frac{y_p}{z} + \sum_{m=1}^{2}\delta_m \ln(w_m/w_3) + \frac{1}{2}\sum_{p=1}^{4}\sum_{q=1}^{4}\beta_{pq}\ln\frac{y_p}{z}\ln\frac{y_q}{z} + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\delta_{mn}\ln\frac{w_m}{w_3}\ln\frac{w_n}{w_3} + \sum_{p=1}^{4}\sum_{m=1}^{2}\gamma_{pm}\ln\frac{y_p}{z}\ln\frac{w_m}{w_3} + u + v \quad (7)$$

where

C	total cost
z	total assets
y_p	pth output (p=1,2,3,4)
w_m	mth input price (m=1,2,3).

Eq. (7) summarises a model which employs four outputs (y_1, y_2, y_3, and y_4) and three input prices (w_1, w_2, and w_3). Following common practice, the standard symmetry restrictions apply to this function (i.e.$\beta_{pq}=\beta_{qp}$; $\delta_{mn}=\delta_{nm}$). In common with most of the literature,[14] the cost and input price terms are normalized by w_3. This imposes linear homogeneity to ensure that the cost-minimizing bundle does not change if all input prices are multiplied by the same positive scalar. Thus, only changes in the ratios of the input prices affect the allocation of inputs. Following Hardy and Patti (2001) and others, it is also important to control for any potential bias arising from differences in scale by expressing the cost and output terms as a ratio of total assets, z.

4.2. Data

This study employs annual data (1985–2002) for each of the four state-owned and ten joint-stock commercial banks, listed in Table 2. There are 187 observations; 54 are from the first reform stage (28.9%), and 133 from the second reform stage (71.1%). Unless otherwise stated, all of the data come from the *Almanac of China's Finance and Banking* (various editions).

Table 3 supplies the summary statistics for all variables used in the cost function in Eq. (7). In the literature, two different methods are used to measure bank services. Under the *production approach*, banks are treated as firms which employ capital and labour to produce services for both deposit and loan account holders. Outputs are measured by the number of deposit and loan transactions processed over a given time period, while total costs are defined to include operating expenses and nothing else. Output is treated as a flow, showing the given amount of output produced per unit of time. However the number of deposit and loan accounts is used as a proxy for output because detailed transaction flow data are not generally available. In this event, output is treated as a stock, i.e., a given amount of output at one point in time. The *intermediation approach* treats banks as financial intermediaries between borrowers and depositors rather than producers of loan and deposit

[14] See among others, Berger and Mester (1999), Rudi Vander Vennet (2002), Hasan and Marton (2003), and Kwan and Eisenbeis (1996).

Table 2
China's key commercial banks

Type	Name of bank
State-owned commercial banks	Industrial and Commercial Bank of China (ICBC)
	Agricultural Bank of China (ABC)
	Bank of China (BOC)
	China Construction Bank (CCB)
Joint-stock commercial banks	Bank of Communication (BOCOM)
	CITIC Industrial Bank (CITICIB)
	China Merchants Bank (CMB)
	Shenzhen Development Bank (SDB)
	Guangdong Development Bank (GDB)
	Industrial Bank (IB, known as Fujian Industrial Bank before March 2003)
	China Everbright Bank (CEB)
	Hua Xia Bank (HXB)
	Shanghai Pudong Development Bank (SPDB)
	China Minsheng Banking Corporation (CMBC)

Source: Almanac of China's Finance and Banking (2003).

services. Output is treated as a stock and measured by the value of loans and investments. Total costs include operating costs plus interest costs. However, neither of these approaches completely captures the function performed by banking institutions (see Heffernan, 2005). Following Humphrey (1992), Berger (1993), and Esho (2001), the intermediation approach is adopted here. However, based on a suggestion made by Berger and Humphrey (1997), it is modified to capture the dual role played by deposits, i.e. they are treated as both inputs (used to fund loans) and outputs (providing services to depositors such as security, liquidity, and interest on some types of deposits).

Some authors have augmented outputs by including off-balance-sheet (OBS) activities (e.g., Jagtiani, Nathan, & Sick, 1995; Stiroh, 2000; Vander Vennet, 2002). They argue that bank output may be understated if measured solely by the banks' balance sheets, especially with the growth of derivatives and asset backed securitization. To address this problem, these studies have added non-interest income as a proxy for OBS activity. For completeness, this study includes non-interest income as one of the outputs, even though Chinese banks (and many banks in the West[15]) are far less active in the newer forms of OBS business.

Another issue is whether the efficiency models should be controlled for differences in output quality. For example, banks with more problem loans are likely to incur higher costs associated with the extra monitoring and negotiating, and they may also have to pay higher rates for deposits and other sources of funds. Such differences will be picked up as variations in bank X-inefficiency. Proxies used to measure these bank-level differences in output quality include some measure of loan losses.[16]

However, the case for including these types of measures depends on the extent to which they are exogenous. If, for example, non-performing loans (NPLs) are largely due to negative macroeconomic shocks (bad luck), then they should be controlled for. However, it is more likely there is a high degree of endogeneity due to poor risk management, cutting back on screening and monitoring, or making loan decisions without anticipating changes in the business cycle.[17] Berger

[15] For example, Obay (2000) finds 200 US commercial banks accounted for 85% of the securities business, and of these, 5 had a 60% market share.

[16] Interest rates were subject to rigid state controls (hence are group invariant) and there are no data on rental rates.

[17] For example, the volume of non-performing loans (NPLs—Clark & Siems, 2002); provisions for loan losses (Drake & Hall, 2002); the ratio of non-performing loans to total loans (Altunbas, Liu, Molyneux, & Seth, 2000); or risk-weighted assets (DeYoung & Nolle, 1996).

Table 3
Variables used to estimate X-efficiency unit: million RMB

Variable	Description	Mean	Standard deviation
C	Total costs	6317	11,948.2
y_1	Total deposits	159,056.8	231,466.1
y_2	Total loans	143,498.4	192,872.1
y_3	Total investments	24,637.9	53,000.4
y_4	Non-interest income	1324.2	2668.2
w_1	Price of funds	0.021	0.020
w_2	Price of fixed assets	0.287	0.214
w_3	Price of employees	0.004	0.002
z	Total assets	254,431.3	327,102.2

Sources: Almanac of China's Finance and Banking (1986–2003), China Statistical Yearbook (2003).
Notes:
1. All financial variables measured in millions of constant 1985 RMB.
2. Total costs (C): operating costs plus interest costs, including costs of funds, fixed assets, and labour.
3. Total assets (z): all assets listed on the left-hand side of the balance sheet.
4. Total deposits (y_1): short-term deposits, short-term savings deposits, fiscal deposits, long-term deposits, and long-term savings deposits.
5. Total loans (y_2); short-term loans, trade bills, bills discounted, medium and long-term loans, and impaired loans; excludes loan loss reserves.
6. Total investments (y_3): short-term investment, trading securities, securities held under Repo agreement, and long-term investment, while excluding investment loss reserves.
7. Non-interest income (y_4): operating income less interest income.
8. The cost of funds (w_1): the ratio of total interest expenses on borrowed funds to total borrowed funds. Total interest expenses on borrowed funds include interest paid on total deposits plus interest paid on interbank borrowing. Total borrowed funds include total deposits, borrowing from central bank, deposits from banks, borrowing from banks, borrowing from non-bank financial institutions, deposits against other credit facilities, bonds issued, and long-term borrowing.
9. The cost of employees (w_3): the ratio of total expenses on employees to the number of employees. Total expenses on employees are unavailable, so two categories of average wage are applied here: the annual average wages paid by state-owned and other types of financial institutions, respectively. Though the number of employees at the four state banks, and some joint stock banks is known, the data are incomplete for 6 of the joint stock banks. Following Altunbas, Liu, Molyneux, and Seth (2001), Rezvanian and Mehdian (2002), and Vander Vennet (2002), it is assumed that the growth rate of employee numbers is the same as that of the total assets for a given bank.
10. The cost of fixed assets (w_2): the ratio of total expenses on the fixed assets to total fixed assets. Total fixed assets = gross fixed assets less depreciation. Total expenses on the fixed assets = operating expenses less expenses on employees. During this period, banks could purchase and/or rent their offices and branches, but there is not information on the proportion rented or purchased. Therefore, neither interest nor rental rates, even if available, [18] would provide an accurate measure a bank's opportunity cost of capital. Thus, the approach taken here was to relate the *flow* of costs to the *flow* of factor prices. The flow factor price for capital is the actual rental rate for a rented building, or the imputed rate if acquired. Expenses on fixed assets reflect the true capital/rental, i.e. depreciation expenses if the building has been purchased (or rental if rented) plus the relative maintenance and material costs. Accounting conventions for depreciation ensure the expenses from purchases of capital, etc are smoothed out over a long period of time. Hence the w_2 variable is a reasonable proxy for *flow* of (physical) factor prices. The regressor (total cost) is a good measure of the *flow* of cost for the same reasons.

and Mester (1997) found the X-efficiency estimates of (6000) US banks to be roughly the same using either the average ratio of NPLs to total loans in a given state or a bank's own NPL ratio. Berger and deYoung (1997) and other studies reported mixed evidence on the exogeneity of NPLs

[18] Part of the "Basel 2" Agreement encourages banks to use the full economic cycle as part of the decision-making process in loans. See the Bank for International Settlements (2004).

Table 4
X-efficiency estimates (1985–2002)

Period	1985–2002			1985–1992			1993–2002		
Model	H	E	T	H	E	T	H	E	T
All sample banks									
Mean	0.407	0.516	0.461	0.435	0.554	0.487	0.395	0.501	0.451
S.D.	0.191	0.191	0.175	0.172	0.155	0.157	0.198	0.202	0.181
State commercial banks									
Mean	0.352	0.463	0.413	0.410	0.532	0.465	0.305	0.408	0.370
S.D.	0.157	0.167	0.148	0.144	0.134	0.132	0.153	0.172	0.148
Joint-stock commercial banks									
Mean	0.442	0.549	0.492	0.473	0.587	0.519	0.434	0.541	0.485
S.D.	0.203	0.198	0.184	0.204	0.179	0.186	0.203	0.202	0.184

Note: H: the half-normal model, E: exponential model, and T: truncated-normal model.

and other similar variables. In light of these findings, and the lack of reliable Chinese data on individual banks' non-performing loans, they are excluded from this study.

5. Empirical results

5.1. X-efficiency estimates

The parameter estimates of the stochastic frontier regression may be found in Appendix 1. The inefficiency residual u of the regression is used to derive the X-efficiency estimates. Table 4 summarises the X-efficiency estimates for the full sample, the state banks, and the joint stocks. There is some variation in the scores depending on the model being used. Though different assumptions explain the varying sample mean efficiencies, both the Pearson and Spearman correlation coefficients between pairs of efficiency estimates are significant with high values (Table 5). Thus, the scores obtained from the three models are consistent with each other and no one model is superior. Table 4 shows that for the whole sample, the exponential model yields an X-efficiency score of 52%; 41% under the half-normal model. Thus, for a given level of output, the banks could use inputs more efficiently and so reduce costs by between 48% and 59%. Over the entire period, the joint-stock banks are, on average, about one-fifth more X-efficient than the state banks, though both groups experience a decline in X-efficiency between the first and second stages of bank reform.

Though it must be stressed that comparing results across different studies can be problematic, based on a survey of studies, the average cost X-efficiency figure is 68% for emerging markets and 85% for the developed economies.[19] However the work by Hardy and Patti (2001) on Pakistan produced an average X-efficiency score of 36.5%, which dropped from 55% to 27% following the implementation of reforms.

Table 6 provides the X-efficiency scores of the individual banks, which have been coded because of the sensitive nature of the information. Two state banks experienced very small and insignificant rises in X-efficiency over the two periods. Two others show significant declines of 23–24% during the first and second reform phases. Of the six joint stocks with sufficient data, one sustained a significant 15% increase in X-efficiency but two others suffered significant declines of

[19] Source: The figures are obtained from a survey of studies on X-efficiency for developed and developing countries. See Fu (2004), Table 3.1.

Table 5
Correlation between the X-efficiency estimates

	Pearson's correlation coefficients ( ): *p*-values		Spearman's rank correlation coefficients ( ): *p*-values	
Distribution assumption	Half-normal	Exponential	Half-normal	Exponential
Exponential	0.987 (0.000)		0.999 (0.000)	
Truncated-normal	0.998 (0.000)	0.989 (0.000)	0.998 (0.000)	0.999 (0.000)

11% and 44%, respectively. Though not significant, two others experienced quite large declines, of 10% and 21% and one a rise of 7%. Thus, the results for the six joint stocks are very much a mixed bag. Focusing on the significant changes only, phase two of the reforms is consistent with reduced cost X-efficiency for the state and joint stock banks, though one joint stock managed to move closer to the efficiency frontier.[20] Thus, an important task is to explain why X-efficiency declined for most banks during a period of reform which aimed to increase competition and efficiency.

5.2. Potential correlates of X-efficiency

To shed further light on this question, and following increasingly common practice,[21] a two-stage regression was performed to explore the relationship between the X-efficiency estimates and a set of economic and financial variables. This procedure has its limitations. Berger and Mester (1997) argue this analysis is suggestive but not necessarily conclusive, because X-efficiency, the dependent variable, is obtained from an estimate and its standard error is not taken into account in the subsequent regression. Thus, it is only possible to draw inferences about correlation, not causality.

The estimating equation for the two-stage procedure appears below. In common with the published work in this area, the time and bank subscripts are dropped for ease of exposition.

$$X - \mathrm{EFF} = \alpha + \beta_1 \mathrm{OWN} + \beta_2 \mathrm{REFORM} + \beta_3 \mathrm{PF/TA} + \beta_4 \mathrm{TL/TA} + \beta_5 \mathrm{TI/TA} + \beta_6 \mathrm{NI/PR} + \varepsilon \quad (8)$$

where

OWN an ownership dummy, 0 for state-owned and 1 for joint-stock;
REFORM a reform dummy, 0 and 1 for banks in the 1st and 2nd reform stages, separately;
PF/TA purchased funds (non-deposit funds) over total assets;
TL/TA total loans over total assets;
TI/TA total investment over total assets;
NI/PR non-interest income over pre-tax profits.

The independent variables are selected based on findings from previous studies[22] and on available data. The REFORM and OWN dummies test for whether differences in ownership

[20] Furthermore, there is no information on four of the joint stocks for which data are unavailable, in most cases because the bank was created during the second phase of reform.
[21] e.g.: Berger and Mester (1997), Hasan and Marton (2003).
[22] Isik and Hassan (2002), Berger and Mester (1997).

Table 6
Individual bank X-efficiency scores (1st and 2nd reform stages)

Bank name	Reform stage	Half normal model			Exponential model			Truncated normal model		
		Mean	S.D.	*t*-stat. (*p*-value)	Mean	S.D.	*t*-stat. (*p*-value)	Mean	S.D.	*t*-stat. (*p*-value)
SB-1	1	0.40	0.11	0.13 (0.90)	0.53	0.10	0.01 (0.90)	0.46	0.10	0.26 (0.79)
	2	0.41	0.20		0.53	0.20		0.48	0.20	
SB-2	1	**0.43**	0.17	**4.06 (.0009)**	**0.54**	0.16	**4.46 (.0004)**	**0.47**	0.15	**3.93 (.0012)**
	2	**0.20**	0.06		**0.28**	0.09		**0.27**	0.06	
SB-3	1	0.35	0.07	0.86 (0.86)	0.48	0.08	0.75 (0.46)	0.42	0.07	0.83 (0.42)
	2	0.39	0.11		0.52	0.11		0.45	0.10	
SB-4	1	**0.46**	0.20	**3.71 (.0019)**	**0.58**	0.18	**4.21 (.0007)**	**0.52**	0.18	**3.76 (.0017)**
	2	**0.22**	0.06		**0.31**	0.08		**0.29**	0.05	
JS-1	1	**0.41**	0.18	1.92 (.0759)	**0.53**	0.16	2.02 (.0619)	**0.46**	0.16	**1.92 (0.075)**
	2	**0.56**	0.13		**0.67**	0.11		**0.59**	0.12	
JS-2	1	**0.33**	0.07	**3.60 (.0032)**	**0.46**	0.08	**3.42 (.0045)**	**0.39**	0.07	**3.27 (.0060)**
	2	**0.22**	0.04		**0.32**	0.07		**0.29**	0.05	
JS-3	1	**0.74**	0.20	**5.95 (.0002)**	**0.82**	0.15	**5.31 (.0005)**	**0.76**	0.18	**5.83 (.0002)**
	2	**0.30**	0.07		**0.43**	0.08		**0.37**	0.06	
JS-4	1	0.53	0.25	0.93 (0.36)	0.64	0.21	0.94 (0.36)	0.57	0.23	0.94 (0.36)
	2	0.43	0.18		0.54	0.18		0.48	0.16	
JS-5	1	0.63	0.02	0.96 (0.36)	0.74	0.02	1.05 (0.32)	0.65	0.02	0.88 (0.40)
	2	0.44	0.27		0.53	0.27		0.49	0.25	
JS-6	1	0.37	0.01	0.29 (.7735)	0.51	0.01	0.19 (0.85)	0.42	0.01	0.33 (0.75)
	2	0.44	0.22		0.55	0.20		0.49	0.19	
JS-7	1	Na	Na	Na	Na	Na	Na	Na	Na	Na
	2	0.61	0.12		0.72	0.09		0.65	0.10	
JS-8	1	Na	Na	Na	Na	Na	Na	Na	Na	Na
	2	0.33	0.14		0.45	0.17		0.40	0.14	
JS-9	1	Na	Na	Na	Na	Na	Na	Na	Na	Na
	2	0.44	0.27		0.52	0.27		0.49	0.24	
JS-10	1	Na	Na	Na	Na	Na	Na	Na	Na	Na
	2	0.54	0.18		0.66	0.15		0.59	0.16	

Note: (1) Na means that either there is no such bank in that reform stage or data is not available. (2) *t*-stat. denotes *t*-statistics deriving from the Mean Equality Test. It tests whether the differences in mean scores between the two reform stages are significantly different from each other. (3) Bold typeface for values indicates significantly different from each other at the 10% level. *P* values appear in ( ).

structure and/or either stage of the reform process significantly influenced X-efficiency. The question of whether different output mixes affect X-efficiency is tested using the variables TL/TA (loans), TI/TA (investments), and NI/PR (non-interest income) while PF/TA measures whether X-efficiency is affected by dependence on purchased funds.

Table 7 provides the summary statistics for each of the variables, and Table 8 reports the results from estimating Eq. (8). The results of both Pearson's and Spearman's correlation coefficients generally support the findings of the two-stage regression, with the odd exception, discussed below.

The coefficients on the output mixes are insignificant for loans (TL/TA) and investments (TI/TA). The coefficient on NI/PR is negative, but not significant; nor is the Pearson test. Spearman's correlation coefficient is negative and significant for 2 of the 3 models but positive and significant under the truncated-normal model. Thus, the evidence on the effects of a change in the banks' non-interest income on X-efficiency is mixed and weak.

Table 7
Variables used in the two-stage regression model

Variable	Description	Mean	S.D.
X-EFF-H	X-efficiency under half-normal distribution	0.407	0.191
X-EFF-E	X-efficiency under exponential distribution	0.516	0.191
X-EFF-T	X-efficiency under truncated-normal distribution	0.461	0.175
PF/TA	Purchased funds (non-deposit funds) over total assets	0.186	0.098
TL/TA	Total loans over total assets	0.540	0.126
TI/TA	Total investment over total assets	0.095	0.072
NI/PR	Non-interest income over pre-tax profits	1.544	3.168

Sources: Almanac of China's Finance and Banking (1986–2003).
Note: X-efficiency scores are derived from previous regressions.

The coefficient on PF/TA is significantly negative: an increase in the proportion of purchased (non-deposit) funds reduces X-efficiency, probably because this form of funding is normally more costly than deposits.[23] During the two stages of reform, the dependence on purchased funds (PF/TA) dropped from 25% to 20% for state banks, and from 21% to 15% for joint-stocks. So in the second stage, X-efficiency should have increased, all else equal. The decline in average X-efficiency means the reduced dependence on purchased funds was more than offset by other factors reducing X-efficiency. The ownership and reform dummies help to identify what these factors might be.

The positive, significant coefficient on the ownership dummy (under all three distribution assumptions) is indicative of relatively greater X-efficiency among the joint-stocks compared to the state banks, which is consistent with the aggregate X-efficiency scores reported in Table 4. It suggests that significance tests on the change in scores between the two reform periods (see Table 6) somewhat overstate the similarities between the state and joint stock banks, possibly because four of the ten joint stocks were excluded from these tests. Of these four banks, three had X-efficiency scores in the second reform period that were well above the average of 0.39, ranging from 0.44 to 0.63.

The coefficient for the reform dummy is significantly negative,[24] as is the Spearman correlation coefficient. The Pearson statistic is negative but not significant. Nonetheless most of the results suggest stage one contributed more to X-efficiency than stage two reforms, which is in line with the earlier observation that X-efficiency was higher during the first phase of the reforms.

Exploring the reasons behind the results for the two dummy variables sheds further light on cost X-efficiency in China in the period up to 2002. Recall from section two that X-efficiency often stems from agency problems. In China, there is little doubt that despite reform, managerial incentives were undermined by state lending policies and a lack of clarity about bankruptcy procedures. The State Council only recently (late 2003) accepted the principle of private ownership, which may explain why China's private equity markets are still embryonic. In 1994, three policy banks were established to fill the gap created by the absence of private capital. Nonetheless, the state-owned banks continued to be pressured into playing a special role in China's economic system, with a sizeable proportion of their loans going to loss making state-owned enterprises.

This situation increased the amount of bad debt held by the "big four" state banks. Official estimates put non-performing loans at one quarter of total loans, while Whally (2003) claims they were as high as 50% to 60%. The World Bank (2002) estimated that to restore the banking system to financial health, the stock of government debt would have to increase from 20% to 75% of

[23] For the last two decades, the average cost of raising funds has been 87% of total costs.
[24] Again, for the three different distribution assumptions.

Table 8
X-efficiency correlates

Variable	Half-normal model			Exponential model			Truncated-normal model		
	Regression coefficients [S.E.] (*p*-values)	Pearson's correlation coefficients (*p*-values)	Spearman's correlation coefficients (*p*-values)	Regression coefficients (*p*-values)	Pearson's correlation coefficients (*p*-values)	Spearman's correlation coefficients (*p*-values)	Regression coefficients [S.E.] (*p*-values)	Pearson's correlation coefficients (*p*-values)	Spearman's correlation coefficients (*p*-values)
Constant	**0.519** [0.084] (0.000)			**0.636** [0.083] (0.000)			**0.567** [0.076] (0.000)		
OWN	**0.078** [0.030] (0.009)	**0.229** (0.002)	**0.217** (0.003)	**0.076** [0.029] (0.010)	**0.221** (0.002)	**0.216** (0.003)	**0.068** [0.027] (0.014)	**0.221** (0.002)	**0.215** (0.003)
REFORM	**−0.127** [0.036] (0.001)	−0.097 (0.188)	**−0.136** (0.063)	**−0.140** [0.036] (0.000)	−0.127 (0.823)	**−0.132** (0.072)	**−0.116** [0.033] (0.001)	−0.094 (0.199)	**−0.129** (0.079)
PF/TA	**−0.555** [0.145] (0.000)	**−0.264** (0.000)	**−0.230** (0.002)	**−0.553** [0.144] (0.000)	**−0.254** (0.000)	**−0.238** (0.001)	**−0.525** [0.132] (0.000)	**−0.271** (0.000)	**−0.242** (0.001)
TL/TA	0.007 [0.112] (0.951)	−0.005 (0.946)	−0.020 (0.782)	0.011 [0.111] (0.925)	0.003 (0.966)	−0.022 (0.770)	0.010 [0.102] (0.926)	−0.002 (0.979)	−0.020 (0.791)
TI/TA	0.299 [0.228] (0.191)	0.043 (0.555)	0.054 (0.467)	0.327 [0.226] (0.150)	0.032 (0.667)	0.055 (0.453)	0.276 [0.208] (0.187)	0.044 (0.550)	0.060 (0.413)
NI/PR	0.001 [0.004] (0.884)	−0.038 (0.601)	**−0.222** (0.002)	−0.001 [0.004] (0.887)	−0.060 (0.412)	**−0.218** (0.003)	0.001 [0.004] (0.824)	−0.031 (0.670)	**0.201** (0.006)
Adj. R^2	0.15			0.16			0.15		
F-statistics	**5.48** (0.000)			**5.82** (0.000)			**5.48** (0.000)		

Note: 1. OWN = an ownership dummy, 0 for state-owned and 1 for joint-stock; REFORM = reform dummy, 0 for banks in the period 1985–1992; 1 for banks in the period 1993–2002; PF/TA = purchased funds (non-deposit funds)/total assets; TL/TA = total loans/total assets; TI/TA = total investment/total assets; NI/PR = non-interest income/pre-tax profits. 2. The *F*-statistic tests the hypothesis that the slope coefficients (excluding the intercept) in the regression jointly equal to zero. 3. Results at 1–5% significant level of confidence are in **bold**. 4. Standard errors are in brackets, and *p* values are in parentheses.

GDP, and its servicing is likely to be a serious burden for the government.[25] These banks are, by any measure, effectively insolvent, but continue to function because of an implicit guarantee that they will not be allowed to fail. These arguments are supported by the size of loans and capital injections made by the government and central bank to the four state banks. Between 1998 and 2003, capital injections amounted to RMB642.47 bn ($77.60 bn).[26] In 2003, two state banks (BOC and CCB) received RMB372.47 bn ($45 bn). Overall, it is estimated that between 1998 and 2005, the state has injected over $260 billion bailing out the banking sector.[27]

To summarise, China is in the unique position of having largely insolvent but highly liquid state banks. Liquidity ratios average about 57% for the big four, similar to those of the big four UK banks.[28] Not only is the savings rate high (30% of GDP), but customers are content to keep their deposits at these banks because they are confident the state will always come to their aid. Likewise, state banks remain unconcerned about loans to loss making SOEs, because they are deemed to have an implicit government guarantee. This has serious moral hazard implications. Managers of the state banks have few incentives to practice good risk management techniques. Borrowers, in turn, have little motivation to make their firms profitable and repay the loans. Depositors think it is the job of the state to protect their deposits.

By contrast the joint-stock banks were established to facilitate the development of an efficient banking system, and it is rare for them to be involved with the implementation of state policy. The joint stocks might therefore be expected to be relatively more X-efficient than the state banks. On the other hand, a high percentage of non-traded shares in these banks are held by the state or state owned enterprises. This could hinder the achievement of greater efficiency. The loan quality of the joint stocks appears higher, but the ratio of non-performing loans to total loans is still appreciable. At the end of 2002, the official estimate was 12.39%, though again, the private estimates are much higher.

Though this ratio is much lower than that of the state banks, the question is why it is high by international standards: a "safe" ratio is considered to lie between 1 and 3%. The answer is two fold, and interdependent. The first is that although there are no official figures, it is well known that the large shareholders of these banks (e.g. provincial governments, SOEs) pressure managers into making loans. Interference of this sort must undermine the quality of a bank's loan book. Furthermore the PBC lends large sums to the joint stocks — in 2002, they totalled RMB3.82 billion ($461 million). Between 1998 and 2002, the joint stocks received RMB62.64 billion ($7.57 billion).[29] Though a fraction of what the state banks received, the joint stocks are much smaller both in terms of assets and market share. Second, managers and depositors at the joint stocks may believe the government will always rescue them, with corrosive effects on incentives and efficiency.

Two other factors, common to both state owned and joint stock banks, compounded the problems arising from poor incentives. First, the state maintains a tight control over interest rates.[30] This leaves these banks with little opportunity to raise revenues through changes in loan/deposit rates, and no avenue, apart from non-price features, in which they can compete. In the absence of a competitive market, it is not surprising X-efficiency scores are relatively low.

[25] Source: World Bank (2002), p.36.
[26] Source: Almanac of China's Finance and Banking (2003).
[27] Source: The Economist (2005), p. 93.
[28] Source: *Bankscope*. The liquidity ratio is defined as net loans to total assets, and has been averaged over 2000 to 2002.
[29] Source: Almanac of China's Finance and Banking (1999–2003).
[30] Banks have always been given some discretion in the setting of loan rates for small and medium sized enterprises (SMEs). Until 1998 it was the central bank rate plus a premium added by the bank, up to a limit of 10%, for commercial banks and 40% for rural credit cooperatives. These limits were raised in 1998, and again in 1999: the respective rates were 30% and 50%, respectively.

The second factor is the poor quality of management. In October, 2005, following the inspection of 11 banks, the China Banking Regulatory Commission (2005) expressed concern about high NPL ratios and reported that some of these banks consistently under report bad loans, violate rules on the issue of loans, fail to monitor outstanding loans, and ignore regulations. Unsound accounting practices include unreliable reporting of profits and losses, "unreasonable" expenditures, and weak management of assets. The CBRC is committed to penalising banks (and senior management) that do not comply with regulations.[31] However they too are deficient in well trained staff, and as long as the Communist Party appoints senior managers, it will be difficult to enforce sanctions and/or remove poor managers from office.

To the extent that a combination of the above problems contributed to reduced cost X-efficiency, recent reforms may help to alleviate them. In 2002, the State Council announced a protracted process of gradual interest rate reform. Foreign currency deposit rates are now negotiable and the aim is to liberalise all loan and deposit rates. In October 2004, the ceiling on commercial loan rates was effectively lifted, which will not only encourage more competition, but crucially mean banks increase rates the more risky the borrower.

In 2004, the Bank of China and the China Construction Bank were converted to joint stock banks, to enable some of their shares to be listed on the stock market. The privatization of the state owned banks appears to mark a third phase of bank reform, which, based on somewhat limited findings, should be welcomed. Recall that four of the joint stock banks have some of their shares listed. A *t*-test showed that two of the three joint stocks showed a rise in their respective cost-efficiency scores after their shares were listed — one significantly so. X-efficiency fell for a third bank, but this may be because it was listed relatively early (1991) and its efficiency gains were recorded then.[32] The China Construction Bank was listed in October 2005, at a share price of HK $2.35. Prior to this listing, the Bank of America and Temasek were, respectively, sold 9% and 5% of CCBs shares. The October flotation saw another 12% of its shares sold to foreign investors.[33] The remaining 74% of shares are in the hands of several SOEs including the Central Huijin Investment Company (62.59%).[34] The continued dominance of state-related firms as owners may explain why, at the end of the first trading day, the customary share price increase did not materialize, suggesting that investors were pessimistic about its prospects.

The state has also allowed foreign financial institutions to invest in state and joint stock banks. The years 2004–5 saw HSBC, the Royal Bank of Scotland, the Bank of America, Temasek (the investment authority for the state of Singapore), Goldman Sachs, American Express, Merrill Lynch, and Allianz take stakes in the BOC, Bank of Communications, the CCB and the ICBC. Though it is early days and the investments do not give these banks anything close to a controlling interest, risk management and other expertise they bring with them should help to improve efficiency.

6. Conclusions

Employing the stochastic frontier approach, this paper investigated cost X-efficiency in China's banking sector over the period 1985–2002. Similar results were obtained for all three disturbance distributions: half-normal, exponential, and truncated-normal. The grand mean

[31] Source: CBRC (2005).

[32] The fourth bank was not listed until 2002, so no test could be done.

[33] Source: The Economist (2005), p.93. The limit on foreign ownership of a bank is currently 25%.

[34] Others include one of Central Huijin's wholly owned subsidiaries (China Jianyin Investment Ltd), the State Grid, the Shanghai Bao Steel Group, the China Yangtze Power Co, and other individual and institutional investors.

X-efficiency in China's banking sector ranged between 41% and 52%. Equivalently, on average, the banks, for a given level of output, could have raised their X-efficiency (by reducing costs) by up to 59% had they been operating on the X-efficiency frontier. In aggregate, the joint-stock banks were found to be *relatively* more X-efficient than the state banks.

The econometric findings also pointed to a decline in X-efficiency during the second phase of bank reform. Individual scores were compared between the two stages of reform. Two of the four state banks showed significant declines in X-efficiency, as did two joint stocks. Two other joint stocks experienced an increase, one significantly so. Though four joint stocks could not be tested because they were relatively new, three had above average scores during the second phase of reform.

In light of these mixed findings, especially for the joint stock group, a two-stage regression model was estimated to identify the potential correlates of X-efficiency. The results suggest X-efficiency among China's banks might improve if more state banks were converted to joint-stock ownership and the dependence on purchased funds is reduced. Relatively low X-efficiency may also be traced to agency problems arising from the absence of sanctions on senior management, and state interference in lending policies, combined with implicit and explicit central bank/government guarantees. Strict controls on most interest rates made it even more difficult to manage risk and discouraged competition. The empirical evidence showed that cost X-efficiency improves with the listing of banks' shares, possibly because managers are more answerable to shareholders. Recent moves to decontrol interest rates may stimulate greater efficiency, as could the expertise provided by foreign banks that have recently invested in state and joint stock banks. Whether this third phase of bank reform will improve cost X-efficiency is a question that can only be answered by further research in this area.

Appendix A. Stochastic frontier regression parameter estimates

Independent variable	Description	Half-normal model	Exponential model	Truncated-normal model
		Parameter estimates (*p*-values)	Parameter estimates (*p*-values)	Parameter estimates (*p*-values)
Constant		2.025 (0.0050)	2.118 (0.0028)	2.208 (0.0040)
Lny1	Total deposits	0.489 (0.3439)	0.550 (0.2780)	0.582 (0.2632)
Lny2	Total loans	0.577 (0.3375)	0.649 (0.2809)	0.778 (0.2042)
Lny3	Total investments	0.149 (0.0369)	0.152 (0.0342)	0.163 (0.0274)
Lny4	Non-interest income	0.109 (0.2914)	0.102 (0.3099)	0.103 (0.3183)
Lnw1	Price of funds	1.152 (0.0000)	1.170 (0.0000)	1.193 (0.0000)
Lnw2	Price of fixed assets	−0.447 (0.0974)	−0.465 (0.0759)	−0.493 (0.0644)
Lny1lny1/2	Total deposits * total deposits/2	−0.974 (0.0111)	−0.971 (0.0118)	−0.990 (0.0104)
Lny1lny2	Total deposits * total loans	0.270 (0.4281)	0.253 (0.4564)	0.309 (0.3746)
Lny1lny3	Total deposits * total investments	−0.012 (0.8996)	−0.011 (0.9058)	−0.007 (0.9396)
Lny1lny4	Total deposits * non-interest income	−0.021 (0.6303)	−0.023 (0.6016)	−0.022 (0.6252)
Lny2lny2/2	Total loans * total loans/2	0.918 (0.0523)	0.913 (0.0615)	0.932 (0.0660)
Lny2lny3	Total loans * total investments	0.032 (0.7333)	0.031 (0.7546)	0.034 (0.7382)
Lny2lny4	Total loans * non-interest income	−0.035 (0.3898)	−0.030 (0.4733)	−0.030 (0.4713)
Lny3lny3/2	Total investments * total investments/2	0.010 (0.1103)	0.010 (0.1309)	0.010 (0.1205)
Lny3lny4	Total investments * non-interest income	−0.006 (0.4158)	−0.006 (0.4099)	−0.006 (0.3933)

(continued on next page)

Appendix A (*continued*)

Independent variable	Description	Half-normal model	Exponential model	Truncated-normal model
		Parameter estimates (*p*-values)	Parameter estimates (*p*-values)	Parameter estimates (*p*-values)
Lny4lny4/2	Non-interest income* non-interest income/2	0.010 (0.0644)	0.010 (0.0778)	0.010 (0.0809)
Lnw1lnw1/2	Price of funds* price of funds/2	0.131 (0.0000)	0.134 (0.0000)	0.136 (0.0000)
Lnw1lnw2	Price of funds* price of fixed assets	−0.087 (0.0467)	−0.092 (0.0324)	−0.094 (0.0352)
Lnw2lnw2/2	Price of fixed assets* price of fixed assets/2	0.082 (0.2612)	0.085 (0.2311)	0.088 (0.2240)
Lny1lnw1	Total deposits* price of funds	−0.099 (0.3011)	−0.092 (0.3347)	−0.096 (0.3185)
Lny2lnw1	Total loans* price of funds	0.012 (0.9135)	0.015 (0.8890)	0.039 (0.7184)
Lny3lnw1	Total investments* price of funds	0.008 (0.7381)	0.008 (0.7169)	0.010 (0.6869)
Lny4lnw1	Non-interest income* price of funds	0.021 (0.1567)	0.020 (0.1697)	0.020 (0.1683)
Lny1lnw2	Total deposits* price of fixed assets	−0.115 (0.4320)	−0.136 (0.3414)	−0.134 (0.3627)
Lny2lnw2	Total loans* price of fixed assets	0.065 (0.6423)	0.051 (0.7166)	0.025 (0.8631)
Lny3lnw2	Total investments* price of fixed assets	−0.020 (0.2313)	−0.021 (0.1966)	−0.023 (0.1824)
Lny4lnw2	Non-interest income* price of fixed assets	−0.025 (0.2865)	−0.023 (0.3266)	−0.023 (0.3471)
Variance parameters for compound error				
λ, θ, λ [a]		1.399 (0.0008)	19.879 (0.248)	0.978 (0.3632)
σ, σ_v, σ [b]		0.141 (0.0000)	0.094 (0.0000)	0.128 (0.3288)
μ/σ_u				0.069 (0.9946)
Adjusted R^2		0.98	0.98	0.98
Log-likelihood		153.91	153.81	153.77
Iteration completed		38	39	36

[a] Half-normal model estimates λ, exponential model estimates θ, and truncated-normal model estimates λ again.
[b] Half-normal model estimates σ, exponential model estimates σ_v, and truncated-normal model estimates σ again.

References

Aigner, D., Lovell, K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production models. *Journal of Econometrics*, *6*, 21−37.

Altunbas, Y., Gardener, E. P. M., Molyneux, P., & Moore, B. (2001). Efficiency in European banking. *European Economic Review*, *45*, 1931−1955.

Altunbas, Y., Liu, M., Molyneux, P., & Seth, R. (2000). Efficiency and risk in Japanese banking. *Journal of Banking and Finance*, *24*, 1605−1628.

Bank for International Settlements, Basel Committee on Banking Supervision. (2004). International Convergence of Capital Measurement and Capital Standards. Can be downloaded from. www.bis.org.

Berger, A. N. (1993). Distribution-free estimates of efficiency in the U.S. banking industry and tests of the standard distributional assumptions. *Journal of Productivity Analysis*, *4*, 261−292.

Berger, A. N., & DeYoung, R. (1997). Problem loans and cost efficiency in commercial banks. *Journal of Banking and Finance*, *21*(6), 849−870.

Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operation Research*, *98*, 175−212.

Berger, A. N., & Mester, L. J. (1997). Inside the black box: What explains differences in the efficiencies of financial institutions? *Journal of Banking and Finance*, *21*, 895−947.

Berger, A. N., & Mester, L. J. (1999). *What explains the dramatic changes in cost and profit performance of the U.S. banking industry?* Working paper no. 99-1 University of Pennsylvania: The Wharton School.

Chen, T. Y. (2001). An estimation of X-inefficiency in Taiwan's banks. *Applied Financial Economics*, *11*, 237−242.

China Banking Regulatory Commission (CBRC). (2005). The supervisory boards of major state-owned banking institutions completed and submitted the 2004 Annual Examination Reports.www.cbrc.gov.cn 4/10/2005.

China Finance Society, *Almanac of China's Finance and Banking (Annual)*, Beijing: China Financial Publishing House.
Clark, J. A., & Siems, T. F. (2002, November). X-Efficiency in banking: Looking beyond the balance sheet. *Journal of Money, Credit and Banking*, *34*(4), 987−1013.
DeYoung, R., & Nolle, D. E. (1996, November). Foreign-owned banks in the United States: Earning market share or buying it? *Journal of Money, Credit and Banking*, *28*(4), 622−636.
Drake, L., & Hall, M. J. B. (2002). Efficiency in Japanese banking: An empirical analysis. *Journal of Banking and Finance*, *27*(5), 891−917.
Esho, N. (2001). The determinants of cost efficiency in cooperative financial institutions: Australian evidence. *Journal of Banking and Finance*, *25*, 941−964.
Fu, Xiaoqing (2004), *Efficiency and Competition in China's Banking Sector*, PhD Thesis—Cass Business School, City University, London, UK.
Greene, W. H. (1993). The econometric approach to efficiency analysis. In H. O. Fried, C. A. K. Lovell, & S. S. Schmidt (Eds.), *The measurement of productive efficiency.* New York: Oxford University Press.
Hardy, D. C., & Patti, E. B. (2001). *Bank reform and bank efficiency in Pakistan.* IMF working paper, WP/01/138.
Hao, J., Hunter, W. C., & Yang, W. K. (2001). Deregulation and efficiency: The case of private Korean banks. *Journal of Economics and Business*, *53*, 237−254.
Hasan, I., & Marton, K. (2003). Development and efficiency of the banking sector in a transitional economy: Hungarian experience. *Journal of Banking and Finance*, *27*(12), 2249−2271.
Heffernan, S. A. (2005). *Modern banking.* England: John Wiley & Sons Ltd.
Humphrey, D. B. (1992). Flow versus stock indicators of banking output: Effects on productivity and scale economy measurement. *Journal of Financial Services Research*, *6*, 115−135.
Isik, I., & Hassan, M. K. (2002). Technical, scale and allocative efficiencies of Turkish banking industry. *Journal of Banking and Finance*, *26*, 719−766.
Jagtiani, J., Nathan, A., & Sick, J. (1995). Scale economies and cost complementarities in commercial banks: On- and off-balance-sheet activities. *Journal of Banking and Finance*, *19*, 1175−1189.
Jondrow, J., Lovell, C. A. K., Materov, I. S., & Schmidt, P. (1982). On estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, *19*, 233−238.
Kraft, E., & Tirtiroglu, D. (1998). Bank efficiency in Croatia: A stochastic-frontier analysis. *Journal of Comparative Economics*, *26*, 282−300.
Kwan, S. H., & Eisenbeis, R. A. (1996). An analysis of inefficiencies in banking: A stochastic cost frontier approach. *Economic Review*, *Vol. 2*. (pp. 16−27): Federal Reserve Bank of San Francisco.
National Bureau of Statistics of China, *China Statistical Yearbook (Annual)*, Beijing: China Statistical Press.
Obay, L. (2000). *Financial innovation in the banking industry: The Case of asset securitisation.* London: Garland Publishing.
Rezvanian, R., & Mehdian, S. (2002). An examination of cost structure and production performance of commercial banks in Singapore. *Journal of Banking and Finance*, *26*, 79−98.
Stevenson, R. E. (1980). Likelihood functions for generalised stochastic frontier estimation. *Journal of Econometrics*, *13*, 57−66.
Stiroh, K. J. (2000). How did bank holding companies prosper in the 1990s? *Journal of Banking and Finance*, *24*, 1703−1745.
The Economist. (2005, October). A great big banking gamble. *The Economist*, *29*, 93−96.
Vander Vennet, R. (2002, February). Cost and profit efficiency of financial conglomerates and universal banks in Europe. *Journal of Money, Credit and Banking*, *34*(1), 254−282.
Whally, J. (2003, December). Liberalization in China's key service sectors flowing WTO accession: Some scenarios and issues of measurement. *NBER working paper series, No. 10143*.
World Bank (2002). *Transition: The first ten years.* Washington: The World Bank.
Wu, X. (Ed.). (1998). *China's financial industry in the new stage of financial reform.* Tianjin: Tianjin People's Press.
Xie, P., & Jiao, J. (2002). *The reform of Chinese commercial banks.* Beijing: The Economics and Science Press.