Ownership Reform and Efficiency of Nationwide Banks in China

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Abstract. This research analyses the efficiency of China's banks using the data envelopment analysis (DEA). The Chinese government began its reforms of the banking industry reform since 1978. Our data set contains twelve banks in China during the period of 1996 to 2003. All nominal variables are transformed into real variables in the 2003 prices. There are twelve banks including four state-owned specialised banks, three policy-related banks and five nationwide joint-equity commercial banks. First, DEA approach is used to estimate the efficiency scores of these twelve banks in each year in China. Second, the Tobit regression is used to analyse how the environmental variables affect the efficiency scores of these twelve banks. The following are the study's empirical findings: (1) Nationwide joint-equity commercial banks have significantly higher overall technical and scale efficiencies but lower pure technical efficiency than state-owned specialised banks. (2) The marginal increasing relation exists between deposit-loan ratio and allocative efficiency. (3) Small-sized banks have higher cost, allocative, overall technical, and pure technical efficiencies than large-sized banks. (4) These twelve banks have lower cost, overall technical, pure technical, and scale efficiencies after the 2001 WTO participation. (5) These twelve banks have lower cost efficiency after the 1997 Asian financial crisis. (6) As a whole, these twelve banks in China have significantly increasing overall technical and scale efficiencies from 1996 to 2003.

Keywords: data envelopment analysis (DEA), ownership, cost efficiency, allocative efficiency, overall technical efficiency, pure technical efficiency

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1. Introduction

Before the 1978 banking reform, there was a mono-banking system in China. Specially, all banks on China were treated as a financial agency or division of local administration body. The banking system guaranteed the fulfilment of the national production plans but had no incentive to compete with each other. The People's Bank of China (PBC) combined the function of monetary, banking and commercial business affairs. The whole banking industry was regulated by strictly cash and credit plans formulated by the State Planning Commission.

The 1978 Third Plenary Session of Eleventh Central Committee of the Communist Party of China (CPC) made the decision to make major reforms in China's banking system. The committee created four specialised banks independent of the PBC. Those four specialised banks are Agriculture Bank of China (ABC), People's Construction Bank of China (PCBC), Bank of China (BOC) and Industrial and Commercial Bank of China (ICBC). After that decision, PBC designed to provide specific services for designated sector of the economy.

In 1985 the State Council of People's Republic of China (PRC) permitted the establishment of nationwide joint-equity commercial banks. The equity was identified by investment shares of state-owned enterprises. An example such an entity is the Guangdong Development Bank established in 1988 and then covered into a shareholding banks in 1992. Its shareholders are the Ministry of Finance, Bank of China Group in Hong Kong, and Hong Kong Chinese Banking Group. By the end of 1999, there were fourteen nationwide joint-equity commercial banks.

In 1993, the Third Midterm Meeting of the Fourteenth Convention of the Chinese Communist Party decided to create three state policy-related banks to handle the guidance loans task of specialised banks and to transform the state-owned specialised banks into exclusive stated-owned commercial banks. The transformation, however, is far away from being neat and complete. The policy-related banks continue to lack sufficient branch networks and capital necessary to effectively engage in policy lending to the extent the state-owned banks did.

The financial regulations reform followed the transition of physic entities. Chinese government published its financial accounting system and rules in 1993 for

the transparency of cash flow and financial statement of banking industry. Until 2000, the Ministry of Finance of PRC announced the 'Baking Finance Accounting System' because of its important and specific character than others. It is obvious the all levels of banks in China did not have uniformed accounting regulations before 2000 and it also created the difficulties of data collection.

In the China's transition process from a planned economy (i.e., a command economy) to a socialist market economy evoked the need for a restructuring of its financial system because a mature financial system one can control the speed and scale of economic transition. Although China joined the World Trade Organization (WTO) in October 2001, it is the world's third-largest trading nation behind the US and Japan in 2004 (Alibaba.com 2005). For economic transition in China, the banking system reform plays a decisive role. To make the transition process smooth, before massive privatisation the economic environment must be improved first [e.g. Tian, 2000].

In earlier research, bank efficiency has received much attention in the literatures. Most researchers aim different topics or issues on bank efficiency from the viewpoints of a specific economy, financial management system, and policy impacts, etc. With respect to bank efficiency in an economy, Aly et al. [1990] calculated the overall technical, pure technical, allocative, and scale efficiencies of 322 banks in U.S. by the non-parametric approach (DEA). Maudos, Pastor and Perez [2002] analysed cost and profit efficiency of banks in ten countries of the European Union during the period of 1993 to 1996 by the panel data frontier approach. Jemric and Vujcic [2002] evaluate bank efficiency in Croatia by using the DEA approach during the 1996-2000 periods. Sathye [2003] measures the productive efficiency of banks in India during the period of 1997 to 1998 by DEA.

With respect to the effect of financial management system on a bank's efficiency, Timme [1992] finds that inclusion of the bank CEO position significantly lowers cost efficiency of banks. Mester [1995] investigates the efficiency of banks operating in the Third Federal Reserve District and takes into account the quality and riskiness of outputs by using stochastic cost frontier approach during the period of 1991 to 1992. Beccalli, Casu and Girardone [2003] investigate the link between alternative efficiency measures and the market performance of financial institutions, which

concentrate stock price on their study, and provide the further evidence on bank efficiency by defining alternative efficiency measures.

With respect to policy impacts on bank efficiency, Hardy and Patti [2001] evaluated the efficiency of banks after the major financial reform in the last 1980s by regression analysis in Pakistan during the period of 1981 to 1992. Sturm and Williams [2003] take the impact of foreign bank entry in account on banking efficiency in Australia during the post-deregulation period of 1988 to 2001 by data envelopment analysis, Malmquist Indices, and stochastic frontier analysis. Chen, Skully and Brown [2005] evaluate the cost, technical, and allocative efficiency of forty-three banks in China during the 1993-2000 period by DEA approach.

There are several existing literatures discussing about ownership in earlier studies. Mercan et al. [2003] present a financial performance index for commercial banks. The index helps to observe the effect of scale and of the mode of ownership such as domestic, private, and foreign bank behaviour, furthermore, and those effects on bank performance in developing economy. The average DEA performance-index values of state-owned banks represented lower performance than private and foreign banks, the efficiency index of large-scale banks is lower than median-scale and small-scale banks, and the average DEA performance-index values of state-owned banks are worst after the financial crisis in 1994. Li, Hu and Chiu [2004] derive a theoretical framework to predict possible rankings in bank's technical efficiency of different ownership structure. They find that the ranking of overall mean efficiency in each year, from highest to lowest, was mixed banks, public banks, and private banks besides in 1998, the efficiency of commercial banks in Taiwan performed worse after Asian financial crisis in 1997, and an inverted U-shape relation exists between government shareholding and technical efficiency. Hu, Li and Chiu [2004] derive a theoretical model to predict the relationship between non-performing loan ratios (NPLs) and government shareholdings can be downward-sloping, upward-sloping, U-shaped, and inverted U-shaped. They found that the rate of NPLs decreases as government shareholdings in a bank rises, while thereafter it increases. Wang, Huang and Lai [2005] apply several DEA models including CCR, BCC, Bilateral, Slack-Based Measure, and the FDH model to evaluate the relative efficiency of banks in China. Their major finding was that private banks have high efficiency

than state-owned banks.

This research aims to extend the established literatures to analyse the cost, allocative, overall technical, pure technical, and scale efficiency of China banking industry by using a nonparametric approach - data envelopment analysis (DEA). We classify the ownership of banks into three types: state-owned specialised, policy-related, and nationwide joint-equity commercial banks in China. The objectives of this study are followings: First, we review the reform processes and reform policy of China's banking industry. Second, we collect financial information and build the database of China's banking industry. Third, we evaluate the cost, allocative, overall technical, pure technical, and scale efficiencies of banks in China. Forth, we understand the factors of bank's inefficiency scores in China. Fifth, we observe the impacts of the Asian financial crisis in 1997 and WTO participation in 2001.

2. Methodology

2.1 Methodology of Data Envelopment Analysis

Data envelopment analysis involves the use of linear programming methods to construct a non-parametric piece-wise surface over the data. Farrell [1957] propose the piece-wise linear convex approach to frontier estimation but only a few authors in the two decades following his paper. Boles [1996] and Afrait [1972] advise mathematical programming methods which could achieve the task, but not achieve very wide attention until the paper by Charnes, Cooper, and Rhodes [1978] in which the terms data envelopment analysis (DEA) was first used. Similar reviews of the methodology are presented by Seiford and Thrall [1990] and Seiford [1996]. Nowadays, there exists a large amount of papers which extended and applied the DEA methodology.

Charnes, Cooper and Rhodes [1978] propose a constant-returns-to-scale (CRS) model. Banker, Charnes and Cooper [1984] instead assume variable return to scale (VRS). In the input-orientated CRS DEA model, we can assume there are data on K inputs and M outputs for each of N firms. For the i-th firm these are represented by the column vectors x_i and y_i. The K×N input matrix X and the M×N output matrix

Y represent the data for all N firms. The input-oriented CRS DEA model then solves the following linear programming problem for *i* firm in each year:

$$\begin{aligned} &\min_{\theta,\lambda} \ \theta, \\ &\text{s.t. } -y_i + Y\lambda \geq 0, \\ &\quad \theta x_i - X\lambda \geq 0, \\ &\quad \lambda \geq 0, \end{aligned} \tag{1}$$

where θ is a scalar and λ is a N×1 vector of constants.

The value of θ is used as the efficiency score for the *i*-th firms that satisfied $0 \leq \theta \leq 1$. The value of unity indicates a point on the frontier and hence a technically efficient firm, according to Farrell's [1957] definition. The DEA problem in equation 1 takes the i-th firms and then seeks to radially contract the inputs vector, x_i, as much as possible, while still remaining within the feasible input set. The inner-boundary of this set determined by the observed data points is a piece-wise linear iso-quant. The radial contraction of the input vector, x_i, produces the projected point, ($X\lambda$, $Y\lambda$), on the frontier of this technology. This projected point is a linear combination of these observed data points. The constraints in equation 1 confirm this projected point cannot lie outside the feasible set. To illustrate the efficiency measurement, for example, Figure 1 can interpret that C and D are the efficient firms which define the frontier such that A and B are inefficient firms. The Farrell's [1957] measure of overall technical efficiency (OTE) explains the efficiency of the firms A and B as $\overline{OA'} / \overline{OA}$ and $\overline{OB'} / \overline{OB}$.

[Figure 1 inserts here]

Banker, Charnes and Cooper [1984] suggest an extension of the CRS DEA model to account for variable-returns-to-scale situations. Since not all firms are operating at the optimal scale, they may further decompose the overall technical efficiency into pure technical efficiency (PTE) times scale efficiency (SE). In the VRS model, there is one differentiation from CRS by adding the convexity constraint, N1'λ, to equation 1. Hence, the input-oriented VRS model then solves the following linear programming problem for *i* firm in each year:

$$\begin{aligned} &\min_{\theta,\lambda} \ \theta, \\ &\text{s.t. } -y_i + Y\lambda \geq 0, \\ &\quad \theta x_i - X\lambda \geq 0, \\ &\quad N1'\lambda = 1, \\ &\quad \lambda \geq 0, \end{aligned} \tag{2}$$

where N1 is an N×1 vector of ones. The convexity constraint ($N1'\lambda=1$) ensures that an inefficient firm is only benchmarked against firms of the similar size. The scale efficiency measure for each firm can be done by conducting both CRS and VRS DEA computations. The TE score obtained from CRS DEA can decompose into two components: scale inefficiency and pure inefficiency. If there is a difference in the OTE and PTE scores for i-th firms, this indicates that the firms have scale inefficiency. However, we can be used to calculate the difference between the OTE and PTE scores to evaluate the scale inefficiency. In Figure 2, we use a one-input and one-output example to illustrate scale inefficiency.

[Figure 2 inserts here]

The difference between these two TE measures, $\overline{P_C P_V}$, is due to scale inefficiency. These concepts can be expressed in ratio efficiency measures as:

$$\text{OTE} = \overline{AP_c} / \overline{AP}, \ \text{PTE} = \overline{AP_V} / \overline{AP}, \ \text{SE} = \overline{AP_c} / \overline{AP_V}; \tag{3}$$

$$\text{OTE} = \text{PTE} \times \text{SE}. \tag{4}$$

The overall technical efficiency can be further decomposed into pure technical efficiency and scale efficiency. This scale efficiency measure can be approximately explained to the ratio of the average product of a firm operating at the point P_V to the average product of the point operating at a point of optimal scale (point R).

There are some extensions of these basic CRS and VRS DEA models. If price information is available, such as cost minimization, then it can measure allocative efficiency and technical efficiency. This study also uses data envelopment analysis to estimate the cost efficiency of China banking industry. The cost minimization CRS DEA model solves the following linear programming problem for *i* firm in each

year:

$$\begin{aligned} &\min_{\lambda,\, x_i} w_i' x_i^* \\ \text{s.t.}\quad &-y_i + Y\lambda \geq 0, \\ &x_i^* - X\lambda \geq 0, \\ &\lambda \geq 0, \end{aligned} \tag{5}$$

where w_i is a vector of input prices for the i-th firms and x_i* is the cost-minimizing vector of input quantities for i-th firms. The cost efficiency of DMU i may be obtained from:

$$CE_i = w_i' x_i^* / w_i' x_i. \tag{6}$$

The allocative efficiency of DMU i can also be defined as:

$$AE_i = CE_i / OTE_i. \tag{7}$$

Farrell [1957] proposes a definition of 'economic efficiency' which is actually the cost efficiency, consisting of technical efficiency and allocative efficiency. Farrell used two inputs and a single output under the assumption of constant returns to scale. In Figure 3, we use Farrell's concept to illustrate the construction and decomposition of cost efficiency.

[Figure 3 inserts here]

The overall technical efficiency of a bank is measured by the ratio $\overline{0Q}/\overline{0P}$. It also takes a value between zero and one. If the input price ratio, represented by the slope of the iso-cost line, is also known, allocative efficiency may be calculated. The allocative efficiency of the firm operating at point P is defined to be the ratio $\overline{0R}/\overline{OQ}$. However, the economic efficiency, also represented by cost efficiency, is defined to be the ratio $\overline{0R}/\overline{OP}$. All three efficiency indices lie between zero and one.

2.2 Data Description

This study uses panel data from 1996 to 2003 which includes two outputs, three

inputs, and input prices to estimate the cost efficiency of twelve banks in the Cost-DEA model. We also use some environmental variables by Tobit regression analysing how affect the cost inefficiency. As Table 1 shows, there are twelve banks including four state-owned specialized banks, three state policy-related banks and five state-owned joint-equity commercial banks.

[Table 1 inserts here]

Two output variables include the investment (Y_1) and lending (Y_2). Three input variables include savings (X_1), member of employee (X_2), and the net fixed assets (X_3). Three input price variables include funding price (P_F), labor price (P_L), and capital price (P_K). All data is compiled from the balance sheets, income statements and employment calculation which disclosed in Almanac of China's Finance and Banking from 1984 to 2004. Variables Y_1, Y_2, X_1, X_2, X_3, P_F, P_L, and P_K have been transformed into real variables by the GDP deflators using 2003 as the base year.

The definition of each variable is listed as below:

1. Definition of output variables:

(1) Investment (Y_1) is defined by the items of long-term, short-term, and securities investment shown in the balance sheets of each bank.
(2) Lending (Y_2) is the items of lending but deducts the number of non-performing loans shown in balance sheet of each banks.

2. Definition of input and input price variables:

(1) Saving (X_1) and funding price (P_F)

Savings (X_1) stands for the number of every deposit, loans from other banks and the interests that banks paid for loans or deposits. It is defined as total input of banks. The interest expenses of banks also defined as 'Cost of Funds'. The number of interest expenses can be found in the Income Statement disclosed by each bank in the Almanac of China's Finance and Banking. The funding price (P_F) stands for the

price of each unit of saving the banks collected from others:

Funding price (P_F) = cost of funds / savings (X_1).

(2) Employees (X_2) and labour price (P_L):

The expenses paid to their employees by banks are defined as labour cost. The labour price (P_L) is labour cost divided by member of employees:

Labour price (P_L) = labour cost / employee (X_2).

(3) Net fixed assets (X_3) and capital price (P_K):

The net fixed assets disclosed in the balance sheets of banks. Operating expenses without labour cost are defined as capital cost. The capital price (P_K) is capital cost divided by net fixed assets:

Price of fixed assets (P_K) = operating expenses / net fixed assets (X_3).

The definition and description of these variables are as depicted in Table 2.

[Table 2 inserts here]

3. Definition of Environmental variables

(1) Duration (DUR): It stands for the establishment duration of bank and is calculated from the year its license was issued by People Bank of China to the year 2003.

(2) Bank classification (SHARE, POLICY): This variable represented by dummy variable because the classification of China's banks in our data categorized to state-owned specialized banks, state policy-related banks, and state-owned joint-equity commercial banks. The state-owned joint-equity commercial banks belong to the share-allocation system but the state-owned specialized banks and the state policy-related banks don't. Therefore, in our study, the nationwide joint-equity commercial banks can be represented by SHARE = 1 and the state policy-related bank can be represented by POLICY = 1. Finally, the state-owned specialized banks can be represented by LARGE = 0 and SMALL = 0 in Tobit

regression.

(3) Deposit-loan Ratio (DLR, DLR^2): At first, according to balance sheet of twelve banks from 1996 to 2003 in the Almanac of China's Finance and Banking, we calculate each bank's deposit-loan ratio for eight years period. The deposit-loan ratio of banks is total loans divided by total deposits:

Deposit-loan ratio (DLR) = total loans / total deposits.

Second, we want to know what relationship between deposit-loan ratio and value of inefficiency. Therefore, we use deposit-loan ratio squared (DLR^2) and deposit-loan ratio into Tobit regression.

(4) Bank size (SIZE): At first, according to balance sheet of twelve banks from 1996 to 2003 in the Almanac of China's Finance and Banking, we calculate average assets of each bank for eight years periods from 1996 to 2003. We classified these twelve banks into two groups. The dummy variable, SIZE = 0, represents those banks whose average assets over five hundred billions RMB. Otherwise, SIZE = 1 represents those bank whose total assets under five hundred billions RMB.

(5) WTO participation (WTO): The dummy variable WTO = 0 represents the period before China participating the World Trade Organization. The dummy variable WTO = 1 represents the period after China participating the World Trade Organization.

(6) Asian financial crisis (CRISIS): The dummy variable, CRISIS = 0, represents the period before 1997 Asian financial crisis happens and the dummy variable. Otherwise, CRISIS = 1 represents the period after 1997 Asian financial crisis happens.

(7) Time (TIME): The variable TIME indicates the year for an observation.

The definition and description of these variables are as depicted in Table 3.

[Table 3 inserts here]

3. Empirical Results

At the beginning of the DEA approach, we must use the Pearson correlations to

examine whether the relationship of the input and output variables obey the isotonic hypothesis. As the Table 4 shows, a significant positive relation exits between input and output variables, which means the isotonic hypothesis exists. Hence, the DEA approach can be used to evaluate the bank efficiency.

[Table 4 inserts here]

3.1 OTE analysis

Our empirical findings regarding overall technical efficiency bring the following observations:

1. In 1996, Export-Import Bank of China, China Minsheng Banking Corporation, and CITIC Industrial Bank are the three with the most overall technical efficient than other banks.
2. In 1997, Export-Import Bank of China, China Minsheng Banking Corporation, CITIC Industrial Bank, Agricultural Development Bank of China, and China Everbright Bank are the five with the most overall technical efficient than other banks.
3. In 1998, Export-Import Bank of China, Agricultural Development Bank of China, China Minsheng Banking Corporation, and China Everbright Bank are the four with the most overall technical efficient than other banks.
4. In 1999, Export-Import Bank of China, China Minsheng Banking Corporation, and Bank of Communication are the three with the most overall technical efficient than other banks.
5. In 2000, Bank of China, Export-Import Bank of China, Agricultural Development Bank of China, China Minsheng Banking Corporation, Bank of Communication, CITIC Industrial Bank, and China Everbright Bank are the seven with the most overall technical efficient than other banks.
6. In 2001, China Everbright Bank is the most overall technical efficient than other banks.
7. In 2001, 2002 and 2003, China Development Bank is the most overall technical efficient than other banks.

3.2 PTE and SE Analysis

Our empirical findings regarding pure technical efficiency and scale efficiency bring the following observations:

1. In 1996, eight banks besides Agricultural Bank of China, Bank of Communication, and China Everbright Bank are the most pure technical efficient. However, Agricultural Development Bank of China, China Minsheng Banking Corporation, and CITIC Industrial Bank are the most scale-efficient than other banks.
2. In 1997, nine banks besides Agricultural Bank of China, People's Construction Bank of China, and Hua Xia Bank are the most pure technical efficient. However, Export-Import Bank of China, Agricultural Development Bank of China, China Minsheng Banking Corporation, CITIC Industrial Bank, and China Everbright Bank are the most scale-efficient than other banks.
3. In 1998, ten banks are the most pure technical efficient besides People's Construction Bank of China and Hua Xia Bank. However, Export-Import Bank of China, Agricultural Development Bank of China, China Minsheng Banking Corporation, and China Everbright Bank are the most scale-efficient than other banks.
4. In 1999, nine banks besides People's Construction Bank of China, China Development Bank, and Hua Xia Bank are the most pure technical efficient. However, Export-Import Bank of China, China Minsheng Banking Corporation, and Bank of Communication are the most scale-efficient than other banks.
5. In 2000, nine banks besides Construction Bank of China, China Development Bank, and Hua Xia Bank are the most pure technical efficient. However, Bank of China, Export-Import Bank of China, Agricultural Development Bank of China, China Minsheng Banking Corporation, Bank of Communication, CITIC Industrial Bank, and China Everbright Bank are the most scale-efficient than other banks.
6. In 2001, seven banks besides Agricultural Development Bank of China, China Minsheng Banking Corporation, Bank of Communication, CITIC Industrial Bank, Hua Xia Bank, and China Everbright Bank are the most pure technical efficient. However, China Development Bank and China Everbright Bank are the most scale-efficient than other banks.
7. In 2002, Industrial and Commercial Bank of China, Bank of China, People's Construction Bank of China, Export-Import Bank of China, and China

Development Bank are the most pure technical efficient. However, China Development Bank is only the most scale-efficient than other banks.

8. In 2003, Industrial and Commercial Bank of China, Bank of China, Export-Import Bank of China, Agricultural Development Bank of China, China Development Bank, and China Minsheng Banking Corporation are the most pure technical efficient. However, China Development Bank is only the most scale-efficient than other banks.
9. State-owned specialised banks are in decreasing returns to scale stage during the period from1996 to 2003, implying that they may reduce the production scale in improve their scale efficiencies.

3.3 CE and AE Analysis

Our empirical findings regarding cost efficiency and allocative efficiency bring the following observations:

1. In 1996, Export-Import Bank of China, China Minsheng Banking Corporation, and CITIC Industrial Bank are the most cost-efficient and much higher allocative efficiency than other banks.
2. In 1997, Export-Import Bank of China, Agricultural Development Bank of China, and CITIC Industrial Bank are the most cost-efficient and much higher allocative efficiency than other banks.
3. In 1998, Export-Import Bank of China and China Minsheng Banking Corporation are the most cost-efficient and possess much allocative efficiency than other banks.
4. In 1999, Export-Import Bank of China, China Minsheng Banking Corporation, and CITIC Industrial Bank are the most cost-efficient and have higher allocative efficiency than other banks.
5. In 2000, Bank of China, Export-Import Bank of China, CITIC Industrial Bank, and China Minsheng Banking Corporation are the most cost-efficient and have higher much allocative efficiency than other banks.
6. In 2001, 2002 and 2003, China Development Bank is the most cost-efficient and has higher allocative efficiency than other banks.
7. We also discovered that five share-allocation Financial Institutions have kept reducing their cost efficiency since 2000.

The efficiency scores in DEA approach are shown from Tables 5 to 12.

[Tables 5~12 insert here]

3.4 Peer Analysis

According to peer counts of DEA reports, we find that Agricultural Development Bank of China is the most to be peered in 1996 and 1998. In 1997, Agricultural Development Bank of China, Industrial and Commercial Bank of China, and Bank of China are the most peered, which are also stated-owned specialised and policy-related banks. In 1999 Export-Import Bank of China and China Minsheng Banking Corporation are the most peered, among which China Minsheng Banking Corporation is of share-allocation. In 2000, Export-Import Bank of China and China Everbright Bank are the most peered. Moreover, share-allocation banks are gradually peered by other banks. In 2001, China Development Bank and China Everbright Bank are the most to be peered. In 2002 and 2003, China Development Bank is the most to be peered.

3.5 Tobit Regression Results

We incorporate three environmental variables to find how they influence the efficiency scores of twelve banks in China. The cost, allocation, overall technical, pure technical and scale efficiency scores are between zero and unity. The higher the efficiency score is, the more efficient the bank will be. Hence, we use the Tobit regression with a left censored bound of zero and right censored bound of unity to estimate the following empirical model:

$$\begin{aligned}
CE_{it} &= \beta_0 + \beta_1 DUR_{it} + \beta_2 SHARE_{it} + \beta_3 POLICY_{it} + \beta_4 DLR_{it} + \beta_5 DLR_{it}^2 \\
&\quad + \beta_6 SIZE_{it} + \beta_7 WTO_{it} + \beta_8 CRISIS_{it} + \beta_9 TIME_{it} + u_{it}, \\
AE_{it} &= \beta_0 + \beta_1 DUR_{it} + \beta_2 SHARE_{it} + \beta_3 POLICY_{it} + \beta_4 DLR_{it} + \beta_5 DLR_{it}^2 \\
&\quad + \beta_6 SIZE_{it} + \beta_7 WTO_{it} + \beta_8 CRISIS_{it} + \beta_9 TIME_{it} + u_{it}, \\
OTE_{it} &= \beta_0 + \beta_1 DUR_{it} + \beta_2 SHARE_{it} + \beta_3 POLICY_{it} + \beta_4 DLR_{it} + \beta_5 DLR_{it}^2 \\
&\quad + \beta_6 SIZE_{it} + \beta_7 WTO_{it} + \beta_8 CRISIS_{it} + \beta_9 TIME_{it} + u_{it}, \\
PTE_{it} &= \beta_0 + \beta_1 DUR_{it} + \beta_2 SHARE_{it} + \beta_3 POLICY_{it} + \beta_4 DLR_{it} + \beta_5 DLR_{it}^2 \\
&\quad + \beta_6 SIZE_{it} + \beta_7 WTO_{it} + \beta_8 CRISIS_{it} + \beta_9 TIME_{it} + u_{it},
\end{aligned}$$

$$SE_{it} = \beta_0 + \beta_1 DUR_{it} + \beta_2 SHARE_{it} + \beta_3 POLICY_{it} + \beta_4 DLR_{it} + \beta_5 DLR_{it}^2 + \beta_6 SIZE_{it} + \beta_7 WTO_{it} + \beta_8 CRISIS_{it} + \beta_9 TIME_{it} + u_{it},$$

where β_0 is the constant term; u_{it} is the error term following a normal distribution. The Tobit regression results are shown as follows.

[Tables 13~17 insert here]

Under the 1% level, the dummy variable, SHARE, has a significantly positive effect on overall technical and scale efficiencies but has a significantly negative effect on pure technical efficiency under the 5% level. Other things being equal, the nationwide joint-equity commercial bank with share-allocation system has lower pure technical efficiency but has higher overall technical and scale efficiencies than state-owned specialised banks in China. Under the 10% level, the dummy variable, POLICY, has a significantly positive effect on scale efficiency. From the highest to the lowest, the scale efficiency rankings are: nationwide joint-equity commercial banks, policy-related banks, and state-owned specialised banks. Although nationwide joint-equity commercial banks have lower pure technical efficiency than the state-owned specialised banks, it has higher overall technical and scale efficiencies than the state-owned specialised banks.

Under the 5% level, square of deposit-loan ratio has significantly positive impact on allocative efficiency. Therefore, a marginal increasing relation exists between deposit-loan ratio and allocative efficiency.

Under the 1% level, the dummy variable of SIZE has significantly positive effects on cost and allocative efficiencies; moreover, it has the same effect on overall technical efficiency under the 5% level and on pure technical efficiency under the 10% level. Therefore, small-sized banks have significantly higher cost, allocative, overall technical, and pure technical efficiencies than large-sized banks.

Under the 1% level, these twelve banks after WTO participation have significantly negative effects on cost, overall technical, and scale efficiencies. Moreover, its have the same effect on pure technical efficiency under the 10% level. Therefore, the cost, overall technical, pure technical, and scale efficiencies of these

twelve banks in China are worse after WTO participation.

Under the 10% level, these twelve banks after Asian financial crisis have a significantly negative effect on cost efficiency. Therefore, the cost efficiency of these twelve banks in China is worse after Asian financial crisis.

Under the 1% level, the variable TIME has a significantly positive effect on overall technical and scale efficiencies. These twelve banks in China have significantly increasing overall technical and scale efficiencies from 1996 to 2003.

4. Concluding Remarks

The Chinese government started the share-allocation reform of banking industry since 1979. First, the reform of share allocation in China does not equal to property right reallocation. Second, the share-allocation reforms are managerial reforms, especially the ownership never transferred from state-owned to the private. Third, after the Third Plenary Session of the Fourteenth Central Committee of Communist Party of China, the communism asserted "to define the property right; to clarify the line between duty and authority; to separate government and enterprise; to manage in a scientific way." All the state-owned enterprises in China have been changing from their improvement reform of modern enterprises system to the newly definition of share-allocation reforms.

The data set contains twelve nationwide banks in China during the period of 1996 to 2003, with a comparison between the stated-owned and share-allocation reformed banks. The major findings are followings:

Nationwide joint-equity commercial banks are share-allocation reformed banks. The scale efficiency rankings from the highest to the lowest are: nationwide joint-equity commercial banks, policy-related banks, and state-owned specialised banks. Moreover, nationwide joint-equity commercial banks have lower pure technical efficiency but have higher overall technical efficiency than state-owned specialised banks. Therefore, if the Chinese government wants to improve the bank's overall technical and scale efficiencies, the best way is that bank's ownership transfers from the specialised to share-allocation system. However, share allocation

reform is significantly adverse to pure technical efficiency. Share allocation reform has no significant impact on cost and allocative efficiencies.

A marginal increasing relation exists between deposit-loan ratio and allocative efficiency. Therefore, the higher deposit-loan ratio is, the higher allocative efficiency will be.

Small-sized banks are China Export-Import Bank, China Minsheng Banking Corporation, CITIC Industrial Bank, Hua Xia Bank, and China Everbright Bank. Small-sized banks have higher cost, allocative, overall technical, and pure technical efficiencies and it also imply that these banks operate efficiently at cost minimization during the period of 1996 to 2003.

The overall technical, pure technical, and scale efficiencies of these twelve banks in China after the 2001 WTO participation are worse. Moreover, the cost efficiency of these twelve banks in China also gets worse after the 1997 Asian financial crisis.

If the Chinese government improves statistical and relevant systems, we hope to get more economic information in the future and may study other Chinese financial institutions such as rural credit cooperatives. Furthermore, the number of samples can also be increased and environmental variables such as the number of branch banks, government shareholdings, and ATM numbers are also available for future research.

Finally, owing to the limitation of not being able to collect detailed information from foreign banks, the discussion cannot be kept on in this study. After China entered the WTO in 2001, it promises to keep opening its financial markets to all member states. Pressure from foreign banks will continue to increase since China's accession to the WTO. The effects for foreign banks to enter the Chinese market are also an interesting topic for further studies.

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Table 1. Classification and Names of Subject Banks

Classification	Name of Banks
A. State-owned specialised banks	1. Industrial and Commercial Bank of China (ICBC)
	2. Agriculture Bank of China (ABC)
	3. People's Construction Bank of China (PCBC)
	4. Bank of China (BOC)
B. Policy-related banks	5. China Export-Import Bank (CEXIMB)
	6. Agricultural Development Bank of China (ADBC)
	7. China Development Bank (CDB)
C. Nationwide joint-equity commercial banks (share-allocation)	8. China Minsheng Banking Corporation (CMBC)
	9. Bank of Communication (BOCOM)
	10. CITIC Industrial Bank (CITICB)
	11. Hua Xia Bank (HXB)
	12. China Everbright Bank (CEB)

Table 2. Description of Input-Output Variables

Variable	Definition	Unit	Explanation
Y_1	Investment	100 million RMB	The sum of investment, bonds, and stocks held by each bank.
Y_2	Lending	100 million RMB	The total lending minus default loans.
X_1	Savings	100 million RMB	The number of every deposit, loans from other banks and the interests which banks paid for loans or deposits.
X_2	Employees	Person	Annual employment of each bank.
X_3	Funds	100 million RMB	The net fixed assets.
P_F	Funding price	100 million RMB	Cost of funds divides savings.
P_L	Labour price	100 million RMB	The labour cost divides employees.
P_K	Capital price	100 million RMB	Cost of capital divides net fix assets.

Table 3. Description of Environmental Variables

Variable	Definition	Unit	Explanation
DUR	Duration	Years	The establishment duration of bank
SHARE, POLICY	Bank classification	0 or 1	SHARE=$\begin{cases}1 & \text{share-allocation}\\ 0 & \text{otherwise}\end{cases}$ POLICY=$\begin{cases}1 & \text{policy-related}\\ 0 & \text{otherwise}\end{cases}$
DLR, DLR^2	Deposit-loan Ratio	None	Total loans divided by total deposits.
SIZE	Bank size	0 or 1	SIZE=$\begin{cases}1 & \text{small}\\ 0 & \text{large}\end{cases}$
WTO	WTO participation	0 or 1	WTO=$\begin{cases}1 & \text{after WTO}\\ 0 & \text{before WTO}\end{cases}$
CRISIS	Asian financial crisis	0 or 1	CRISIS=$\begin{cases}1 & \text{after WTO}\\ 0 & \text{before WTO}\end{cases}$
TIME	Time	year	The year for an observation

Table 4. Pearson Correlations

Correlations	Investment	Lending	Savings	Employees	Funds
Investment	1.000	0.728*** (0.000)	0.757*** (0.000)	0.583*** (0.000)	0.673*** (0.000)
Lending	0.728*** (0.000)	1.000	0.944*** (0.000)	0.904*** (0.000)	0.900*** (0.000)
Savings	0.757*** (0.000)	0.944*** (0.000)	1.000	0.850*** (0.000)	0.895*** (0.000)
Employees	0.583*** (0.000)	0.904*** (0.000)	0.850*** (0.000)	1.000	0.911*** (0.000)
Funds	0.673*** (0.000)	0.900*** (0.000)	0.895*** (0.000)	0.911*** (0.000)	1.0000

Note: * represents significance at the 1% level.**

Table 5. Efficiency Scores of Chinese Banks in 1996

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.131	0.855	0.154	1.000	0.154	drs
2	Agricultural Bank of China	State-owned	0.076	0.767	0.100	0.790	0.126	drs
3	Bank of China	State-owned	0.350	0.741	0.472	1.000	0.472	drs
4	China Construction Bank	State-owned	0.130	0.658	0.198	1.000	0.198	drs
5	Export-Import Bank of China	State-owned	1.000	1.000	0.658	1.000	0.658	irs
6	Agricultural Development Bank of China	State-owned	0.981	0.981	1.000	1.000	1.000	crs
7	China Development Bank	State-owned	0.632	0.861	0.734	1.000	0.734	irs
8	China Minsheng Banking Corporation	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
9	Bank of Communications	Share-allocation	0.394	0.720	0.547	0.773	0.708	drs
10	CITIC Industrial Bank	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
11	Hua Xia Bank	Share-allocation	0.465	0.740	0.628	0.941	0.668	irs
12	China Everbright Bank	Share-allocation	0.654	0.833	0.785	0.890	0.882	irs

Table 6. Efficiency Scores of Chinese Banks in 1997

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.174	0.924	0.188	1.000	0.188	drs
2	Agricultural Bank of China	State-owned	0.076	0.600	0.127	0.533	0.238	drs
3	Bank of China	State-owned	0.437	0.834	0.523	1.000	0.523	drs
4	China Construction Bank	State-owned	0.143	0.677	0.212	0.862	0.246	drs
5	Export-Import Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
6	Agricultural Development Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
7	China Development Bank	State-owned	0.623	0.954	0.658	1.000	0.653	irs
8	China Minsheng Banking Corporation	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
9	Bank of Communications	Share-allocation	0.431	0.544	0.792	1.000	0.792	irs
10	CITIC Industrial Bank	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
11	Hua Xia Bank	Share-allocation	0.281	0.898	0.313	0.359	0.871	irs
12	China Everbright Bank	Share-allocation	0.746	0.746	1.000	1.000	1.000	crs

Table 7. Efficiency Scores of Chinese Banks in 1998

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.291	0.833	0.350	1.000	0.350	drs
2	Agricultural Bank of China	State-owned	0.180	0.758	0.237	1.000	0.237	drs
3	Bank of China	State-owned	0.185	0.926	0.200	1.000	0.200	drs
4	China Construction Bank	State-owned	0.194	0.753	0.257	0.929	0.277	drs
5	Export-Import Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
6	Agricultural Development Bank of China	State-owned	0.547	0.547	1.000	1.000	1.000	crs
7	China Development Bank	State-owned	0.414	0.672	0.617	1.000	0.617	irs
8	China Minsheng Banking Corporation	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
9	Bank of Communications	Share-allocation	0.500	0.603	0.829	1.000	0.829	drs
10	CITIC Industrial Bank	Share-allocation	0.773	0.986	0.784	1.000	0.784	drs
11	Hua Xia Bank	Share-allocation	0.437	0.907	0.481	0.500	0.962	irs
12	China Everbright Bank	Share-allocation	0.690	0.690	1.000	1.000	1.000	crs

Table 8. Efficiency Scores of Chinese Banks in 1999

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.291	0.635	0.458	1.000	0.458	drs
2	Agricultural Bank of China	State-owned	0.204	0.418	0.488	1.000	0.488	drs
3	Bank of China	State-owned	0.584	0.755	0.773	1.000	0.773	drs
4	China Construction Bank	State-owned	0.135	0.591	0.228	0.838	0.273	drs
5	Export-Import Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
6	Agricultural Development Bank of China	State-owned	0.257	0.727	0.354	1.000	0.354	drs
7	China Development Bank	State-owned	0.092	0.473	0.193	0.631	0.306	irs
8	China Minsheng Banking Corporation	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
9	Bank of Communications	Share-allocation	0.539	0.539	1.000	1.000	1.000	crs
10	CITIC Industrial Bank	Share-allocation	0.835	0.964	0.866	1.000	0.866	drs
11	Hua Xia Bank	Share-allocation	0.512	0.853	0.600	0.628	0.956	irs
12	China Everbright Bank	Share-allocation	0.165	0.219	0.751	1.000	0.751	irs

Table 9. Efficiency Scores of Chinese Banks in 2000

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.625	0.749	0.835	1.000	0.835	drs
2	Agricultural Bank of China	State-owned	0.224	0.451	0.498	1.000	0.498	drs
3	Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
4	China Construction Bank	State-owned	0.102	0.658	0.154	0.950	0.162	drs
5	The Export-Import Bank of China	State-owned	1.000	1.000	1.000	1.000	1.000	crs
6	Agricultural Development Bank of China	State-owned	0.192	0.192	1.000	1.000	1.000	crs
7	China Development Bank	State-owned	0.075	0.331	0.227	0.837	0.271	irs
8	China Minsheng Banking Corporation	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
9	Bank of Communications	Share-allocation	0.670	0.670	1.000	1.000	1.000	crs
10	CITIC Industrial Bank	Share-allocation	1.000	1.000	1.000	1.000	1.000	crs
11	Hua Xia Bank	Share-allocation	0.580	0.933	0.622	0.746	0.834	irs
12	China Everbright Bank	Share-allocation	0.283	0.283	1.000	1.000	1.000	crs

Table 10. Efficiency Scores of Chinese Banks in 2001

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.119	0.651	0.182	1.000	0.182	drs
2	Agricultural Bank of China	State-owned	0.040	0.512	0.079	0.866	0.091	drs
3	Bank of China	State-owned	0.160	0.746	0.215	1.000	0.215	drs
4	China Construction Bank	State-owned	0.115	0.641	0.180	1.000	0.180	drs
5	Export-Import Bank of China	State-owned	0.490	0.979	0.500	1.000	0.500	irs
6	Agricultural Development Bank of China	State-owned	0.067	0.101	0.659	1.000	0.659	drs
7	China Development Bank	State-owned	1.000	1.000	1.000	1.000	1.000	crs
8	China Minsheng Banking Corporation	Share-allocation	0.143	0.451	0.317	0.575	0.551	irs
9	Bank of Communications	Share-allocation	0.072	0.328	0.218	0.221	0.990	drs
10	CITIC Industrial Bank	Share-allocation	0.220	0.850	0.259	0.275	0.942	irs
11	Hua Xia Bank	Share-allocation	0.072	0.535	0.135	0.337	0.399	irs
12	China Everbright Bank	Share-allocation	0.102	0.102	1.000	1.000	1.000	crs

Table 11. Efficiency Scores of Chinese Banks in 2002

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.185	0.649	0.285	1.000	0.285	drs
2	Agricultural Bank of China	State-owned	0.070	0.500	0.139	0.857	0.163	drs
3	Bank of China	State-owned	0.252	0.690	0.365	1.000	0.365	drs
4	China Construction Bank	State-owned	0.145	0.560	0.258	1.000	0.258	drs
5	Export-Import Bank of China	State-owned	0.594	0.923	0.644	1.000	0.644	irs
6	Agricultural Development Bank of China	State-owned	0.072	0.153	0.473	0.509	0.930	irs
7	China Development Bank	State-owned	1.000	1.000	1.000	1.000	1.000	crs
8	China Minsheng Banking Corporation	Share-allocation	0.180	0.399	0.452	0.684	0.660	irs
9	Bank of Communications	Share-allocation	0.125	0.352	0.356	0.566	0.628	drs
10	CITIC Industrial Bank	Share-allocation	0.291	0.900	0.323	0.335	0.966	irs
11	Hua Xia Bank	Share-allocation	0.205	0.478	0.428	0.656	0.653	irs
12	China Everbright Bank	Share-allocation	0.274	0.678	0.403	0.463	0.871	irs

Table 12. Efficiency Scores of Chinese Banks in 2003

Bank ID	Bank Name	Ownership	CE	AE	OTE	PTE	SE	RTS
1	Industrial and Commercial Bank of China	State-owned	0.255	0.609	0.419	1.000	0.419	drs
2	Agricultural Bank of China	State-owned	0.102	0.483	0.210	0.823	0.255	drs
3	Bank of China	State-owned	0.332	0.710	0.467	1.000	0.467	drs
4	China Construction Bank	State-owned	0.186	0.583	0.320	0.969	0.330	drs
5	Export-Import Bank of China	State-owned	0.463	0.704	0.658	1.000	0.658	irs
6	Agricultural Development Bank of China	State-owned	0.062	0.093	0.672	1.000	0.672	irs
7	China Development Bank	State-owned	1.000	1.000	1.000	1.000	1.000	crs
8	China Minsheng Banking Corporation	Share-allocation	0.349	0.385	0.907	1.000	0.907	irs
9	Bank of Communications	Share-allocation	0.153	0.612	0.250	0.505	0.496	drs
10	CITIC Industrial Bank	Share-allocation	0.444	0.883	0.503	0.549	0.916	drs
11	Hua Xia Bank	Share-allocation	0.190	0.524	0.362	0.705	0.513	irs
12	China Everbright Bank	Share-allocation	0.304	0.771	0.395	0.467	0.847	irs

Table 13. Factors of Cost efficiency

Variables	Coefficient	Standard Error	t-ratio	P-value
DUR	0.0033	0.0031	1.05	0.294
SHARE	0.0960	0.1123	0.86	0.395
POLICY	0.0409	0.1325	0.31	0.758
DLR	0.0126	0.0279	0.45	0.652
DLR^2	0.0020	0.0014	1.39	0.169
SIZE	0.3289	0.0842	3.91	< 0.001***
WTO	-0.5130	0.1318	-3.89	< 0.001***
CRISIS	-0.2139	0.1165	-1.84	0.070*
TIME	0.0557	0.0372	1.49	0.139
Constant	0.2192	0.1272	1.72	0.089*
		R-square	0.66	

Note: *** represents significance at the 1% level;

* represents significance at the 10% level.

Table 14. Factors of Allocative efficiency

Variables	Coefficient	Standard Error	t-ratio	P-value
DUR	0.0031	0.0027	1.13	0.260
SHARE	-0.1513	0.0996	-1.52	0.133
POLICY	-0.0895	0.1177	-0.76	0.449
DLR	-0.0255	0.0251	-1.02	0.312
DLR^2	0.0028	0.0013	2.13	0.036**
SIZE	0.3355	0.0750	4.47	< 0.001***
WTO	-0.1474	0.1172	-1.26	0.212
CRISIS	-0.1176	0.1038	-1.13	0.260
TIME	-0.0151	0.0331	-0.46	0.649
Constant	0.8124	0.1132	7.18	< 0.001***
		R-square	0.73	

Note: *** represents significance at the 1% level;

** represents significance at the 5% level.

Table 15. Factors of Overall Technical Inefficiency

Variables	Coefficient	Standard Error	t-ratio	P-value
DUR	0.0020	0.0030	0.67	0.505
SHARE	0.3121	0.1104	2.83	0.006***
POLICY	0.1066	0.1293	0.82	0.412
DLR	0.0410	0.0317	1.29	0.199
DLR^2	0.0009	0.0018	0.50	0.617
SIZE	0.1695	0.0838	2.02	0.046**
WTO	-0.6917	0.1332	-5.19	<0.001***
CRISIS	-0.1800	0.1166	-1.54	0.126
TIME	0.1013	0.0373	2.71	0.008***
Constant	0.1745	0.1256	1.39	0.168
		R-square	0.69	

Note: *** represents significance at the 1% level;

** represents significance at the 5% level.

Table 16. Factors of Pure Technical Inefficiency

Variables	Coefficient	Standard Error	t-ratio	P-value
DUR	-0.0001	0.0054	-0.04	0.972
SHARE	-0.4913	0.1888	-2.60	0.011**
POLICY	-0.1812	0.2306	-0.79	0.434
DLR	0.0284	0.0640	0.44	0.659
DLR^2	0.0008	0.0039	0.22	0.826
SIZE	0.2365	0.1388	1.70	0.092*
WTO	-0.4108	0.2168	-1.89	0.061*
CRISIS	0.0539	0.1975	0.27	0.785
TIME	0.0094	0.0615	0.15	0.878
Constant	1.2752	0.2246	5.68	< 0.001***
		R-square	0.29	

Note: *** represents significance at the 1% level;

** represents significance at the 5% level;

* represents significance at the 10% level.

Table 17. Factors of Scale Inefficiency

Variables	Coefficient	Standard Error	t-ratio	P-value
DUR	0.0023	0.0024	0.97	0.334
SHARE	0.5398	0.0891	6.05	< 0.001***
POLICY	0.1912	0.1041	1.84	0.070*
DLR	0.0416	0.0251	1.66	0.101
DLR^2	0.0003	0.0014	0.23	0.819
SIZE	0.1016	0.0677	1.50	0.137
WTO	-0.4963	0.1084	-4.58	< 0.001***
CRISIS	-0.1428	0.0943	-1.51	0.134
TIME	0.0833	0.0303	2.75	0.007***
Constant	0.1523	0.1013	1.50	0.136
		R-square	0.95	

Note: *** represents significance at the 1% level;

* represents significance at the 10% level.

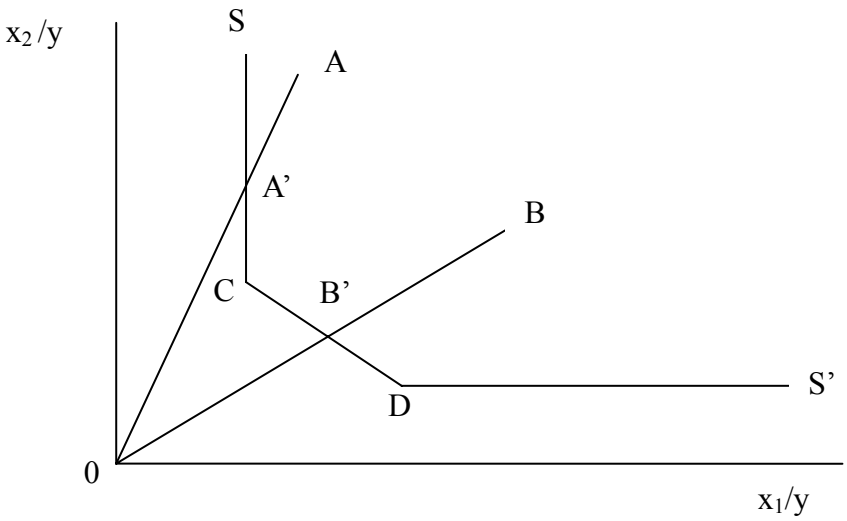

Figure 1. Efficiency Measurement in the CRS DEA Model

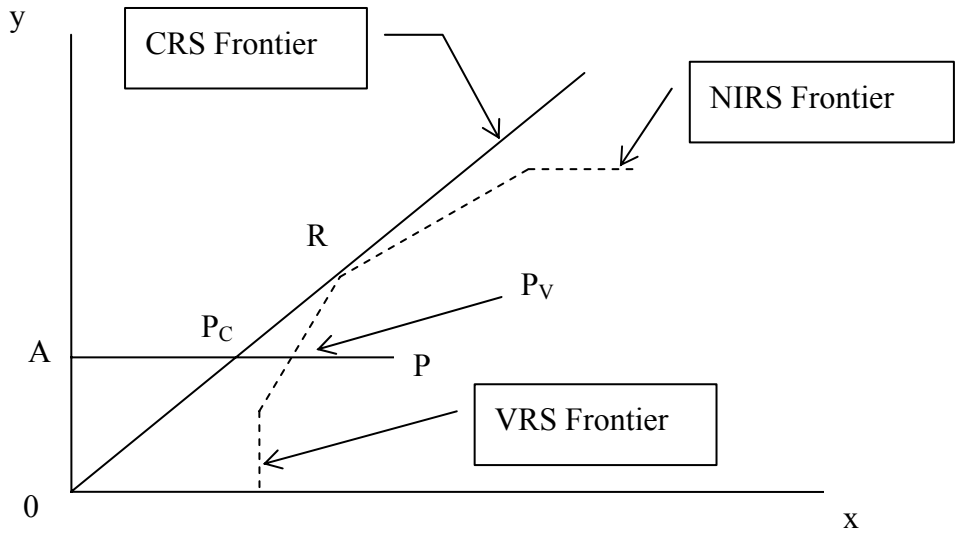

Figure 2. Pure Technical Efficiency and Scale Efficiency

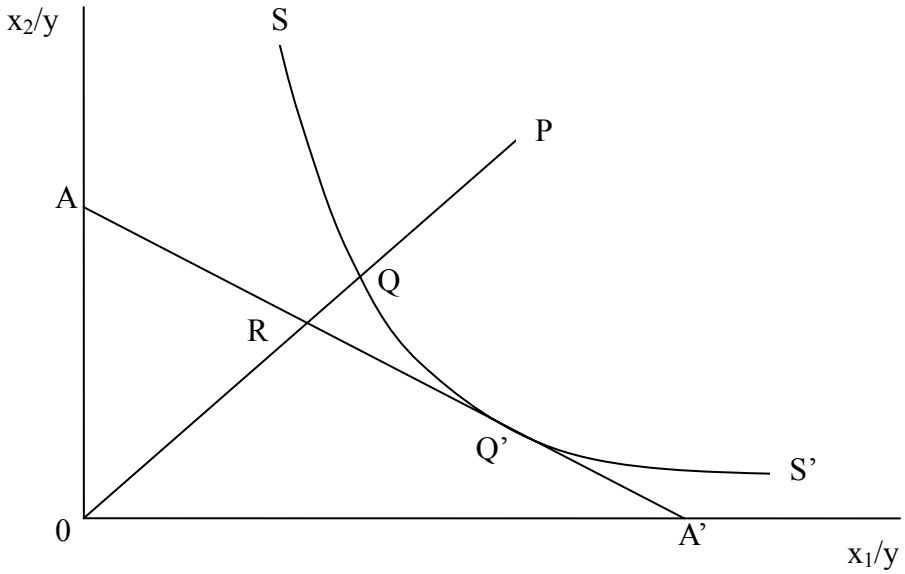

Figure 3. Cost Efficiency, Technical Efficiency, and Allocative Efficiency