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EFFICIENCY IN THE VIETNAMESE BANKING SYSTEM: A DEA DOUBLE BOOTSTRAP APPROACH

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Abstract

This study analyses bank efficiency in Vietnam from 1999 to 2009. We use a unique data sample that allows us to capture the development of the Vietnamese banking sector over the last decade. We apply an advanced methodological approach introduced by Simar and Wilson (2007) to examine bank efficiency in Vietnam. An integral part of the analysis is to explore the determinants of bank efficiency. The results indicate that large and very large banks are more efficient than small and medium sized banks with small banks having the lowest efficiency scores in the system. We also argue that banks with large branch networks and those that have been in existence for a long time are less efficient than other banks.

Keywords: Banking; Efficiency; DEA; Two-stage double bootstrap method; Vietnam.

JEL classification: G21.

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1. Introduction

Vietnam has become one of Asia's economic success stories in recent years with average economic growth of 7.8% per annum in the last decade. The Vietnamese banking system plays a key role in the economic system. The banking system is a backbone of the Vietnamese economy and contributes about 16% to 18% towards annual Gross Domestic Product (GDP). Despite the relatively long transition process of the banking system, Vietnamese banks remain undercapitalized. The regulatory reforms are rather slow, which remain a problem for its further development (Dinh and Kleimeier, 2007).

Efficiency at the unit level has become a contemporary major issue, due to the increasingly intense competition, globalisation, technological innovation and increased deregulation (Dietsch and Weill, 2000; Molyneux and Williams, 2005; Alam, 2001; Bonin *et al.,* 2005, Fries and Taci, 2005). Therefore it is important for banking regulators and market analysts to have sufficient relevant information that aids in the identification of actual or potential problems in the banking systems and individual banks. Such information is also valuable in order to compare competitiveness and efficiency of banking systems in Vietnam. If there is significant inefficiency in the sector, in general, and in different groups of banks, in particular, there may be room for structural changes, increased competition, mergers and acquisitions.

There have been a few empirical studies that estimate bank efficiency in Vietnam see, for example, Nguyen, 2007; Nguyen and De Borger, 2008. We contribute to this empirical literature by using an extensive panel data set of 48 Vietnamese commercial banks during the period from 1999 to 2009. Such a large sample and relatively long period allow us to capture the changes over the financial crisis. No previous study of Vietnam uses such an extensive data set that covers both the pre and post crisis periods.

The objective of our study is threefold. First, we analyse bank efficiency in Vietnam by applying an advanced semi-parametric two stage method introduced by Simar and Wilson (2007) – no previous study of Vietnam has applied this superior method. Second, we identify the determinants of bank efficiency. Third, we provide a detailed analysis of bank efficiency for different ownership structures and bank size.

The paper is structured as follows. The next section details developments in the Vietnamese banking system in the period from 1986 to 2009 while section 3 provides a brief review of the previous empirical literature on bank efficiency. Section 4 focuses on methodology and data. Empirical results are presented in section 5 and section 6 provides a conclusion of the main findings.

2. The Vietnamese banking system during 1986-2009

From 1986 the Vietnamese banking system was transformed from a mono to two-tier banking system. The two-tier banking system has the State Bank of Vietnam as the central bank (tier 1) and four specialised state owned banks (tier 2). Order No. 218/CT dated 23rd July 1987 was the first decision on the State Bank of Vietnam operation mechanism and organisation apparatus, turning the State Bank of Vietnam's branches into public commercial banks. After that, the Council of Ministers promulgated the Decision No. 53/HDBT on 26th March 1988. The first round of the reform had been completed with the launching of new business accounting mechanisms. This reform linked banking change to inflation control. The state management of money, credit and banking services was clearly detached. The State Bank of Vietnam was only in charge of state management functions and all other banking institutes doing business. The function of the State Bank of Vietnam involved the monetary, credit and banking operation of the entire country so as to stabilise the value of the currency and promote economic growth. State owned banks became more independent and, in principle, bore responsibility for their profits and losses that were not transferred to the State Bank of Vietnam as before (Nguyen and Pham, 1994: 18 and Kousted *et al.*, 2005: 12). On 1st October 1990, the Decree-Laws on the State Bank and Decree-Laws on Banks, Credit Operatives and Finance Companies came into force and was the second round of reform, which led to the first appearance of joint stock commercial banks, joint venture commercial banks and branches of foreign banks.

In Table 1, we show a dynamic growth of commercial banks in Vietnam. With extended networks in almost all provinces and larger cities, state owned commercial banks have a competitive edge in providing banking services. Although joint stock commercial banks increased their numbers immediately after their appearance in 1990 (in 2009 there were 37 joint stock commercial banks), the leading positions in the market still belong to state owned commercial banks. Three out of five state owned commercial banks accounted for 45% of customer deposits, 41% of total assets and 51% of customer loans of the banking system in 2009 (see Nguyen and Stewart, 2013). State owned commercial banks were originally sector departments under the State Bank of Vietnam, with specified lending programmes to state owned enterprises which were based on government policies.

Non-state owned commercial banks consist of joint stock commercial banks, branches of foreign banks, joint venture commercial banks and foreign commercial banks[1]. Unlike state owned commercial banks a number of joint stock commercial banks make profits due to good performance. Joint stock commercial banks have achieved average returns on equity between 15% and 30% from 1999 to 2009. Being less than 15 years old joint stock commercial banks are relatively young and they can be divided into three groups: (1) the top five large urban banks; (2) a smaller group of banks that are either growing rapidly or have established a niche; and (3) twelve small rural joint stock commercial banks. The top five urban banks are, Techcombank, Sacombank, VIBBank, Asia Commercial Bank, and East Asia Commercial Bank. The smaller urban joint stock commercial banks include, HabuBank, Viet A Bank and Saigon Bank. Small rural commercial banks were all transformed into city commercial banks at the end of 2010, such as, An Binh Bank, Saigon-Hanoi Bank, Petrolimex Group Bank, Dai A Bank, etc. These banks developed throughout the country, not just in rural areas, and with help from big business and foreign investors they also performed well in the 2000s. The number of branches of foreign banks increased from 18 banks in 1995 to 48 banks in 2009. However, each foreign bank normally has one branch in either Hanoi or Ho Chi Minh City. Hence, their assets, loans and deposits are very small compared to state owned commercial banks, joint stock commercial banks and joint venture commercial banks. Despite Foreign Direct Investment in US dollar terms growing by a factor of eight between 1990 and 2005, foreign companies are still hesitant in deciding whether or not to choose domestic banks when they enter this new market. The number of joint

[1] Foreign commercial banks normally transformed out of branches of foreign banks. Data on assets, loans and deposits of branches of foreign banks are very small compared to other banks. Therefore, in our application non-state owned commercial banks consist of joint stock commercial banks, joint venture commercial banks and one foreign commercial bank.

venture commercial banks has increased slightly from four to six banks between 1995 and 2009. The first foreign commercial bank (being HSBC) had a license to set up a wholly foreign-owned bank from 2008 (see Nguyen and Stewart, 2013).

The credit growth rate of the banking system increased to 37.8% in 2007 and peaked at an alarming 63% in the first quarter of 2008 (WB, 2008: 3). This has been the highest growth rate within the past decade. When the inflation rate and trade balance deficit had become more serious, the government applied a traditional tightening of monetary policy in order to reduce money supply circulation, which affected the banking system. Compulsory measures were necessary for banks to reorganise and strengthen their organisations.

Table 2 shows data on loans, assets, deposits, capital and non-performing loans of the Vietnamese banking system (state owned commercial banks and non-state owned commercial banks) from 1999 to 2009. On the whole, loans, assets, deposits and capital increased gradually over the period. Vietnamese banks were burdened by a high volume of non-performing loans, particularly during the 1990s, however these generally decreased from 1999 to 2009. Non-performing loans of non-state owned commercial banks are typically lower than those of state owned commercial banks.

In terms of regulation, the State Bank of Vietnam aims to create a banking supervision development (following Basel) from 2010 onwards. Meanwhile, the coverage, measures and procedures of banking supervision and monitoring are to be reformed in accordance with the development of internet technologies and banking technology. This will be done by applying key principles of international standards on banking supervision (Basel I and Basel II). The old capital adequacy ratio standards for banks in Basel I and Basel II are 8% and 12%, respectively. The capital adequacy ratio for the Vietnamese commercial banks is to be adjusted to 9% (as Circular No. 13/TT-NHNN dated 20th May 2010 of the State Bank of Vietnam).

3. Literature review

Empirical research on bank efficiency in transition economies has been intensive in last decade. Bonin *et al*. (2005) applied a stochastic frontier approach to analyse the effects of bank ownership on bank efficiency and concluded that foreign banks are more cost-efficient than other banks. Fries and Taci (2005) also employed a stochastic frontier approach to investigate efficiency in 15 transition countries. They concluded that foreign banks show higher cost efficiency compared with domestic banks and that state-owned commercial banks exhibit the lowest efficiency among the group analysed. They stressed that cost efficiency of small- and medium- sized domestic banks differ significantly from foreign and state-owned banks. De Haas and Van Lelyveld (2006) found that foreign banks have had a stabilising effect on total credit supply in Central and Eastern European countries. Staikouras *et al*. (2008) analysed the cost efficiency by applying a stochastic frontier approach in six transition European countries over the period 1998-2003. They concluded that foreign banks and banks with higher foreign bank ownership involvement show higher efficiency.

In Vietnam, after the transition in 1986 the empirical research on bank efficiency used a small unrepresentative number of banks and covered only a short time period. The problem of data collection made it difficult for researchers to investigate the issue through non-parametric methods. The research of Nguyen (2007) measured efficiency by employing data envelopment analysis (DEA). His research has been applied to a sample of only 13 banks in Vietnam over the period of 2001-2003. Nguyen and De Borger (2008) considered single bootstrap efficiency and the Malmquist Index for 15 banks for the period of 2003-2006. No previous study has explicitly applied the double bootstrap method of Simar and Wilson (2007) on the Vietnamese banking system, our paper does. Vietnam's economy in general and the banking system in particular faced difficult times in 2001 and 2008 (Global crisis). By restricting time spans, previous studies could not provide a comparative analysis of efficiency pre- and post- crisis. In contrast, our more extensive data set is available before and after the crisis (1999 – 2009) and therefore can assess the impact of the crisis on efficiency.

In addition, the previous research on Vietnamese banking efficiency did not consider state owned commercial banks as dominant in the banking system. The efficiency scores of banks by type (state owned commercial banks and non-state owned commercial banks) and asset size (small, medium, large and very large banks) have not been previously considered, whereas we do. Further, it has been suggested by various writers that researchers can adopt any measure of output for the financial firm as long as the measure is consistent with the researcher's goal (Sealey and Lindley, 1977: 1252). Previous research on the Vietnamese banking system that has used core labour and deposits as inputs includes Nguyen (2007) and Nguyen and De Borger (2008). Nguyen (2007) employed the two outputs of interest and non-interest income and Nguyen and De Borger (2008) added consumer loans as an output. However, due to limited data, neither of these papers employed purchased funds data as an input or business loans data as an output, which we do. Our research is the first to estimate level of bank efficiency in Vietnam using all the required inputs and outputs as suggested by the intermediation approach (see Berger and Mester, 1997).

Nguyen (2007) argued that the average cost efficiency of their sample of banks was about 60.6%, and the average annual growth of the Malmquist index[2] was negative, being –2.2% over the study period. Conversely, total factor productivity increased by 5.7% between 2001 and 2003, while total factor productivity in 2003 was 15.1% higher than in 2002. This total factor productivity improvement was achieved primarily by greater technical efficiency and, to some extent, by technological advancement. He also argued that the technical efficiency of the Vietnamese banking system declined from 0.912 in 2001 to 0.895 in 2002. Nguyen and De Borger (2008) found that the productivity of Vietnamese banks tended to decrease over their (small) sample period, except for the year 2005 – although the bootstrapping results indicate that the productivity change between 2004 and 2005 was not significant. However, neither Nguyen (2007) or Nguyen and De Borger (2008) considered the impacts of explanatory variables on the inputs and outputs, whereas we do.

The Simar and Wilson (2007) DEA bootstrap procedure for estimating efficiency has been applied recently by, for example, Barros *et al.* (2008) and Brissimis *et al.* (2008). In the first stage, DEA is used to estimate the relative efficiency scores in the sample using, alternatively, constant returns to scale (Charnes *et al.*, 1978) and variable returns to scale (Banker *et al.*, 1984). In the second stage, the Simar and Wilson (2007) procedure is applied to bootstrap the DEA scores with a truncated regression. Using this approach enables us to obtain more reliable evidence compared to previous studies analysing bank efficiency (see Barros *et al.*, 2008). Firstly, the true efficiency score is not observed directly, rather it is empirically estimated. Secondly, the empirical estimates of the efficiency frontier are

[2] The Malmquist index is an extension of DEA (see Grifell-Tatje and Lovell, 1994).

obtained based on the chosen sample of banks, thereby ruling out some efficiency production possibilities not observed in the sample (Simar and Wilson, 2007). Thirdly, the DEA two-stage procedure also depends upon other explanatory variables, which are not taken into account in the first-stage efficiency estimation. This implies that the error term must be correlated with the second-stage explanatory variables. Fourthly, the domain of the efficient score is restricted to the zero-one interval, which should be taken into account in the second-stage estimation stage. The method introduced by Simar and Wilson (2007) overcomes these difficulties by adopting a procedure based on a double bootstrap that enables consistent inference within models and explains efficiency scores while simultaneously producing confidence intervals (Barros *et al.*, 2008: 3-4). Therefore, bias-corrected double bootstrap efficiency methods are preferred for inference (Simar and Wilson, 2007).

Based on Simar and Wilson's (2007) double bootstrap procedure, Barros *et al.* (2008) investigated commercial banks operating in thirteen EU countries between 1993 and 2003. They found that legal tradition and foreign ownership have implications for public policy. Competition can be enhanced by policies designed to increase foreign bank penetration. Further, location does not affect performance significantly. Instead efficiency is explained by bank size and the relative importance of a bank's traditional activities. Brissimis *et al.* (2008) employed Simar and Wilson's (2007) bootstrap procedure to examine 364 banks from ten newly acceded EU countries between 1994 and 2005. Their results indicate that both banking sector reform and competition exert a positive impact on bank efficiency, while the effect of reform on total factor productivity growth is significant only toward the end of the reform process. The effect of capital and credit risk on bank performance is in most cases negative, while it seems that higher liquid assets reduce efficiency.

4. Methodology and data

As discussed above we apply Simar and Wilson's (2007) method in a two-stage procedure to estimate efficiency in the Vietnamese banking system. In the first stage, we adopt DEA to estimate the relative efficiency scores in the sample using, alternatively, constant returns to scale and variable returns to scale. In the second stage, we apply the Simar and Wilson (2007) procedure to bootstrap the DEA scores with a truncated bootstrapped regression. We use both Algorithms 1 and 2 of Simar and Wilson (2007), which are discussed in the Appendix. The bias-corrected Algorithm 2 is preferred and used for inference (see Simar and Wilson, 2007). Explanatory variables (assets, non-performing loans, branch networks, the number of years since establishment and city banks) are also included in the second stage for estimation. Efficiency scores are investigated using asset size (small, medium, large and very large banks) and bank type (state owned commercial banks, joint stock commercial banks and joint venture commercial banks). We investigate, using the semi-parametric model of Simar and Wilson (2007), the level of efficiency of the Vietnamese banking system as a whole and for the sub-samples: state owned commercial banks and non-state owned commercial banks (joint stock commercial banks, joint venture commercial banks and foreign commercial banks). This is the first time that an extensive panel data set has been employed to examine efficiency in the Vietnamese banking system. Our data set includes 48 Vietnamese commercial banks over the period 1999 to 2009. We use the package *FEAR* developed by Simar and Wilson (2010a and 2010b) in the platform *R* to estimate the DEA scores and apply the truncated bootstrap models.

4.1 Input and output specification

There is no simple solution to the problem of input and output specification; reasonable arguments can be made for all approaches. There are two main approaches to the input and output specification of financial institutions, that is, the production approach and the intermediation approach see, for example, Berger and Humphrey, 1997; Matthews and Thompson, 2008. The production approach considers that banks produce accounts of various sizes by processing deposits and loans, incurring in capital and labour costs. Inputs are measured as operating costs and output is measured as number of deposits and loans accounts. The intermediation approach considers banks as transforming deposits and purchased funds into loans and other assets. Inputs are expressed as total operating costs plus interest costs and deposits while output is measured in money units.

These two approaches have been applied in different ways depending on the availability of data and the purpose of the study. We assume that the Vietnamese banking system behaves as the transformer of deposits and purchased funds into customer loans and other loans. Therefore, we use the intermediation approach classified by Berger and Mester (1997). This choice is also due to the availability of data. All the data are indices of bank i in year t. Inputs are: (i) staff, measured by the number of employees; (ii) purchased funds are deposits from the State Bank of Vietnam and other banks in the system; and (iii) customer deposits (or core deposits), which are described as total deposits from corporate and private customers. Outputs include: (i) customer loans, which are total loans for the corporate and private sectors; (ii) other loans: all other loans except customer loans; and (iii) securities, defined as investment and trading securities of the bank (Berger and Mester, 1997). Table 3 reports the characteristics of inputs and outputs. The first column lists the names of the variables while columns 2 to 6 reports various statistics including the mean, median, standard deviation, minimum value and maximum value.

4.2 Bootstrap two-stage procedure

In the first stage, the technical efficiency of banks is estimated, using DEA in order to establish which bank is the most efficient. Their rankings are based on productivity in the period 1999-2009. In the second stage, the Simar and Wilson (2007) procedure is used to bootstrap the DEA scores with a truncated bootstrapped regression (Barros *et al.*, 2008).

Stage 1

Consider the *j*th bank with outputs and inputs Y_{rj}, X_{ij} (that are all positive) where U_r and V_i are the variable weights to be determined by the solution of the problem below (Charnes *et al.*, 1978: 430).

$$\text{Max } \hat{\delta}_0 = \frac{\sum_{r=1}^{s} U_r Y_{r,0}}{\sum_{i=1}^{m} V_i X_{i,0}} \quad \textbf{(1)}$$

Subject to:

$$\frac{\sum_{r=1}^{s} U_r Y_{r,j}}{\sum_{i=1}^{m} V_i X_{i,j}} \leq 1; \text{ j = 1, 2,..., n} \quad \textbf{(2)}$$

$U_r, V_i \geq 0$; r = 1, 2, …, s; i = 1, 2, …, m

The true efficiency score, $\hat{\delta}_0$, is not observed directly, rather it is empirically estimated. Many studies have used a two-stage approach, where efficiency is estimated in the first stage, and then the estimated efficiencies (or ratios of estimated efficiencies, Malmquist indices, and many others) are regressed on covariates (typically different from those used in the first stage) that are viewed as environmental variables (see Simar and Wilson, 2007 and Barros *et al.*, 2008). Simar and Wilson (2007) criticised this two-stage method because the DEA efficiency estimates are biased and serially correlated, therefore invalidating conventional inferences in the second stage. Simar and Wilson (2007) proposed a procedure, based on a double bootstrap, which provides a confidence interval for the efficiency estimates and yields consistent inferences for factors explaining efficiency.

Stage 2

In this study, to implement the bootstrap procedure for DEA we assume that the original data is generated by a data generating process and that we are able to simulate this process by using a new (pseudo) data set that is drawn from the original data set (step 3.3 in Algorithm 2, which is discussed in the Appendix). We then re-estimate the DEA model with this new data (steps 4 and 5 in Algorithm 2 – see the Appendix). By repeating this process 2000 times[3] (step 2 in Algorithm 1 and step 6 in Algorithm 2 – see the Appendix) we are able to derive an empirical distribution of these bootstrap values (Balcombe *et al.*, 2008: 1921). One hundred bootstrap replications are used to compute the bias-corrected estimates $\hat{\hat{\delta}}_{i,t}$ (step 3 in Algorithm 2 below)[4]. The efficiency scores, $\hat{\delta}_{i,t}$, of bank i obtained in the first stage are regressed on explanatory variables in the second stage. However, these second-stage estimates are inconsistent and biased and a bootstrap procedure is needed to overcome this problem (Efron and Tibshirani, 1993). The second stage regression is given by:

$$\hat{\delta}_{i,t} = \beta z_i + \varepsilon_i \quad \textbf{(3)}$$

Or, equivalently:

$$\hat{\delta}_{i,t} = \beta_0 + \beta_1 ROA_{i,t} + \beta_2 COA_{i,t} + \beta_3 CITY_{i,t} + \beta_4 LN(TA_{i,t}) + \beta_5 LN(NLCL_{i,t}) + \beta_6 LN(BR_{i,t}) + \beta_7 LN(AGE_{i,t}) + \varepsilon_{i,t} \quad \textbf{(4)}$$

[3] This number of bootstrap replications is used to construct estimated confidence intervals in the two algorithms. Confidence-interval estimation is tantamount to estimating the tails of distributions, which necessarily requires more information. Hall (1986) suggested 1,000 replications for estimating confidence intervals. We followed Simar and Wilson (2007) and use 2,000 replications in our simulations. More accurate estimates can be achieved with a larger number of replications. However, the calculation time also rises when number of replications increase (see Simar and Wilson, 2007: 44).

[4] Simar and Wilson (2007: 44) found that 100 replications are sufficient to compute the bias-corrected estimates which require only computation of a mean and then a difference.

Where: $\hat{\delta}_{i,t}$ represents the efficiency score, estimated in stage 1, and the other independent variables are environmental covariates. When using Algorithm 2, $\hat{\delta}_{i,t}$ is replaced by $\hat{\hat{\delta}}_{i,t}$. Following Berger and Mester (1997), we employ seven explanatory variables in the second stage to determine the factors explaining bank efficiencies. The two financial variables are: (1) profit before tax divided by total assets (ROA) and (2) total costs divided by total assets (COA). Five other characteristics of banks are also considered. CITY is a dummy variable that is equal to one if a bank is transformed from a rural commercial bank to a city commercial bank and zero otherwise. This variable aims to capture efficiency related to transforming banks. LN(TA) is the natural logarithm of total assets and LN(BR) is the natural logarithm of total branches and these provide information about the relationships between efficiency and assets as well as efficiency and branch networks, respectively. LN(AGE) is the natural logarithm of the number of years the bank existed before 2009. Lastly, LN(NLCL) is the natural logarithm of the ratio of non-performing loans to customer loans. More details of environmental variables can be found in Berger and Mester (1997). Summary statistics on these variables over our sample are presented in Table 4.

Percentile bootstrap confidence intervals of the coefficients estimated in the second stage regression can be constructed as follows:

$$\Pr ob(Lower_{\alpha,j} \leq \beta_j \leq Upper_{\alpha,j}) = 1 - \alpha$$

where α is some small value representing the probability of a Type I error (for example, $\alpha = 0.05$ for a 5% level of significance) and $0 < \alpha < 1$. $Lower_{\alpha,j}$ and $Upper_{\alpha,j}$ are calculated using the empirical intervals obtained from the bootstrap values, thus:

$$\Pr ob(-\hat{b}_\alpha \leq \hat{\hat{\beta}}_j^* - \hat{\hat{\beta}}_j \leq -\hat{a}_\alpha) \approx 1 - \alpha$$

where $Upper_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{b}_\alpha$ and $Lower_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{a}_\alpha$.

4.3. Data

We have collected a unique dataset for Vietnamese commercial banks. Our dataset includes 48 Vietnamese commercial banks over the period 1999 to 2009. The data has been collected from the

State Bank of Vietnam and through the annual reports of individual banks. This data set accounts for more than 90% of total customer loans, total customer deposits and total assets. Five of the 48 banks are state owned commercial banks, five are joint venture commercial banks, one is a foreign commercial bank and the remaining 37 are joint stock commercial banks. Several banks established in 2008 and 2009 are included in the data. The number of records each year ranged from a low of 17 banks in 1999 to a high of 46 in 2009. Banks also have differing frequencies of years in the data, see Table 1. There are sixteen banks with data for all years; twelve banks with 4–8 years of data; fourteen banks with 5–7 years of data and five banks with 2–4 years of data (of which three banks were established in 2008 and one bank was founded in 2006). Only one bank (which was transformed from a branch of a foreign bank to a foreign commercial bank in 2008) has one year of data.

5. Empirical results

5.1. Efficiency scores

In Table 5 we present our estimated efficiency scores. The top half of the table reports scores based upon constant returns to scale (CCR) and the lower half gives efficiency measures using variable returns to scale (BCC). The average initial technical efficiency score $\left(\hat{\delta}_{i,t}\right)$ for the whole system is 0.74 assuming constant returns to scale and 0.81 assuming variable returns to scale. From these initial estimates, we apply both Algorithms 1 (to obtain $\delta^{*}_{i,t}$) and 2 $\left(\hat{\hat{\delta}}_{i,t}\right)$ using Simar and Wilson's (2007) method. The two bootstrapping methods produce similar results. Simar and Wilson (2007) pointed out that Algorithm 2 involves only a small increase in computational burden over Algorithm 1 and that the improved performance of Algorithm 2 justifies its use. Results based on Monte Carlo simulation suggest that we should prefer the results from Algorithm 2 over those from Algorithm 1 (see Simar and Wilson, 2007). Hence, we favour these bias-corrected double bootstrap scores and use them for inference.

The average double bootstrap technical efficiency score obtained from Algorithm 2 $\left(\hat{\hat{\delta}}_{i,t}\right)$ for the whole system is 0.68 assuming constant returns to scale (CCR) and 0.75 assuming variable returns to scale (BCC). In 1999 efficiency scores for the whole system were the lowest for the period we cover, being 0.54 (CCR) and 0.58 (BCC). These scores steadily rose to 0.82 (CCR) and 0.90 (BCC) by 2009 demonstrating a substantial increase in the efficiency of the banking system over the period – the peak scores are 0.83 for the CCR measure in 2007 and 0.90 for the BCC measure in 2009. From the column headed "Number of efficient banks" in Table 5 both CCR and BCC measures indicate that only one bank (being the Export Import Commercial Bank) out of a total of seventeen banks was on the efficient frontier in 1999. According to the CCR (BCC) efficiency measure 8 (21) out of 46 banks were on the efficient frontier in 2009. This confirms the general increase in banking efficiency over the period. The BCC score measures pure technical efficiency reflecting management skills and its average score is higher than for the CCR measure.[5] On the other hand the CCR score measures overall technical efficiency (Gollani and Roll, 1989). The ratio of the CCR and BCC measures enables the estimation of scale efficiency that reflects both managerial skills and scale effects.

Efficiency in the whole banking system did not unambiguously rise every year: the two exceptions being 2001–2002 and 2007–2008. Between 2001 and 2002 the CCR efficiency score remained unchanged at 0.59 (although the BCC measure rose from 0.64 to 0.67). Nguyen (2007) also found that Vietnamese banking efficiency did not rise in this period, indeed, his results indicated a decline from 0.912 in 2001 to 0.895 in 2002. His results were based upon input and output data for thirteen commercial banks whereas our results are based on a much larger sample of 25 – 27 banks in this period. We therefore believe our results to be more reliable and infer that Nguyen (2007) exaggerates the decline in efficiency in this period. Nevertheless, we find that the number of banks on the efficient frontier fell from 4 (5) in 2001 to 0 (3) in 2002 according to the CCR (BCC) measure. We note that during this period of the development of the banking system there was a passage of banking reform in 2002 which could have affected bank efficiency. Further, non-performing loans still accounted for 7.06% of total loans in 2002 before sharply plummeting to 4.74% in 2003 (see SBV, 2005).

The CCR (BCC) efficiency score fell from 0.83 (0.89) in 2007 to 0.80 (0.88) in 2008. Prior to 2006 the average growth of GDP was 7.8% per year. GDP growth was 8.5% and 6.2% in 2007 and 2008, respectively. The banking system had provided a great capital source for the economy, making up approximately 16% – 18% of GDP annually, which was almost equivalent to 50% of the total

[5] While the DEA CCR and BCC measures indicate some differences in efficiency patterns there is a clear general positive correlation between them, as illustrated in Figure 1.

investment capital of the whole country. However, the global financial crisis that began at the end of 2007 and the beginning of 2008 appears to have had an impact on the efficiency scores. The banking system encountered many difficulties, resulting from a loss of balance in the source and use of funds, and the rapid increase in credit growth. Moreover, tightening monetary policy caused many banks to become weaker. After 2008, the Vietnamese economy, in parallel with the global economy, recovered and this is reflected in the 2009 efficiency scores. The CCR (BBC) score increases from 0.80 (0.88) in 2008 to 0.82 (0.90) in 2009.

Tables 6 and 7 report $\hat{\hat{\delta}}_{i,t}$ average efficiency scores categorised by asset size and bank type. In Table 6, total assets in 2009 are used to group banks into small (assets less than 20,000 billion Vietnamese Dong), medium (assets from 20,000 to 50,000 billion Vietnamese Dong), large (assets from 50,000 to 100,000 billion Vietnamese Dong) and very large (assets more than 100,000 billion Vietnamese Dong) categories. The results indicate that large and very large banks are more efficient than small and medium banks because they generally have larger values of $\hat{\hat{\delta}}_{i,t}$.

Very large banks include the four biggest state owned commercial banks and two biggest joint stock commercial banks (namely the Asia Commercial Bank and Sacombank) in terms of customer loans, total assets and customer deposits. Large banks comprise the five big joint stock commercial banks: Techcombank, Export-Import Bank, Military Bank, Maritime Banks, and Vibbank. Medium banks contain the remaining state owned commercial banks, and the five other joint stock commercial banks. Small banks are all of the joint venture commercial banks and newly established banks. Large banks have the highest average CCR efficiency measure (being 0.73) throughout the 11 years. The CCR average efficiency score of very large banks (0.71) is lower than that of large banks but their BCC average score is much higher (being 0.86 compared to 0.78). Three banks in the very large group, including the Bank for Foreign Trade, Asia Commercial Bank and Sacombank, received awards from foreign organisations regarding their business. Small banks and medium sized banks have average efficiency scores that are similar (both are 0.65 according to the CCR measure and 0.70 and 0.71, respectively, for the BCC measure). Medium sized banks and large banks were strongly affected by the crisis in 2008 with their efficiency scores falling substantially between 2007 and 2008. The CCR (BCC) efficiency score of medium sized banks declined from 0.84 (0.93) in 2007 to 0.77 (0.88) in 2008 and

0.75 (0.85) in 2009. Large bank CCR efficiency scores fell from 0.86 (0.94) to 0.80 (0.90) between 2007 and 2008 although they recovered to 0.87 (0.95) in 2009. The crisis had a more modest impact on very large banks with CCR efficiency scores falling from 0.83 to 0.81 between 2007 and 2008 while the BCC measure remained unchanged at 0.94 during the same period. Small bank efficiency was not adversely affected by the crisis with the CCR measure unchanged at 0.81 between 2007 and 2008 and the BCC score rising from 0.85 to 0.87 in this period. Both small and very large banks efficiency scores rose (according to both measures) between 2008 and 2009. Small banks and medium sized banks generally have lower efficiency scores than large and very large banks.

In Table 7 we present efficiency measures by bank type. It is evident that joint venture commercial banks have the highest average CCR score of 0.74 followed by state owned commercial banks with a score of 0.70 and joint stock commercial banks with a score of 0.67. However, state owned commercial banks have the highest average efficiency score according to the BCC measure, being 0.86, followed by joint venture commercial banks with a score of 0.77 and joint stock commercial banks with a score of 0.72. Joint stock commercial banks are by far the most numerous in the banking system and their average score seems to be affected by some small and inefficient banks. Non-state owned commercial banks (joint stock commercial banks, joint venture commercial banks and foreign commercial banks) have an average CCR (BCC) efficiency score of 0.72 (0.76), see the footnote of Table 7, while the corresponding score for state owned commercial banks is 0.70 (0.86). This indicates that the state owned commercial banks have higher managerial skills (what BCC measures) if they are less efficient assuming overall technical efficiency (what CCR measures) compared with non-state owned commercial banks.

In the first period where bank efficiency of the whole banking system did not rise (being 2001 – 2002) we find the following patterns by bank type. Joint stock commercial banks were the only bank type whose efficiency did not rise between 2001 and 2002, the CCR efficiency score fell from 0.57 in 2001 to 0.55 in 2002 while the BCC score remained unchanged at 0.59 in this period. Hence, joint stock commercial banks are primarily responsible for the decline in the overall banking system’s efficiency at this time. Nevertheless, the efficiency scores of state owned commercial banks and joint venture commercial banks only rose gradually in this period, suggesting a more general malaise in efficiency at this time.

In the global financial crisis period of 2007 – 2008 there is clear evidence that the efficiency scores of joint stock commercial banks declined and some evidence, if ambiguous, that state owned commercial banks efficiency deteriorated. The CCR (BCC) efficiency scores of joint stock commercial banks declined sharply from 0.83 (0.90) to 0.78 (0.86) between 2007 and 2008. The CCR efficiency measure of state owned commercial banks fell from 0.87 in 2007 to 0.86 in 2008 whereas the BCC score rose from 0.98 in 2007 to 1.00 in 2008. However, unlike the other two bank types the efficiency score for state owned commercial banks did not recover in 2009 with the CCR measure falling to 0.83 – the BCC measure remained unchanged at 1.00. This suggests that state owned commercial banks delayed recovery from the crisis was not due to weakness of managerial skills (BCC) rather it was because of their leading role in the economy of deposits and loans weakening. In contrast, joint venture commercial banks' CCR (BCC) efficiency score dramatically increased from 0.75 (0.78) in 2007 to 0.89 (0.90) in 2008. These episodes confirm the general relative weakness of joint stock commercial banks in terms of efficiency.

Table 8 shows the efficiency scores of each of the 48 Vietnamese banks averaged over the period 1999 to 2009, assuming constant returns to scale (CCR), variable returns to scale (BCC) and scale efficiency. Only two joint stock commercial banks (being the TienPhong Bank and BaoViet Bank) and one foreign commercial bank (HSBC Vietnam) are on the efficient frontier (with an efficiency score of 1.00) during our sample period. It should be noted that TienPhong Bank and BaoViet Bank were both established in 2008 while HSBC Vietnam transformed from a branch of a foreign bank to a foreign commercial bank in 2009. They performed well in the first years of operation after the financial crisis (at the end of 2007 and beginning of 2008). While other longer established banks have been on the efficient frontier in some years their average scores are lower than those of the newly found banks. As discussed above, during the periods 2001–2002 and 2007–2008 almost all banks efficiency scores fell. While some banks are efficient in certain years the average scores over the whole period indicate that all banks are relatively inefficient (or have experienced periods of relative inefficiency).

5.2. Regression results on environmental variables

In this section, we regress the favoured DEA efficiency scores on our environmental variables (using the model specified in **(4)** except with $\hat{\hat{\delta}}_{i,t}$ as the dependent variable) and obtain the coefficients shown in the second (CCR) and third (BCC) columns of Table 9.

Regarding the control variables, profit before tax divided by total assets (ROA) has a positive and significant coefficient at the 5% level for both measures of efficiency. This implies that banks with a high ratio of profit over assets are likely to be more efficient than others. Total costs divided by total assets (COA) is not a significant determinant of efficiency for both the CCR and BCC measures. Thus, banks with relatively high costs are no more or less efficient than those with lower costs. Total assets (LNTA) and the variable that identifies institutions that transformed from rural to city commercial banks (CITY) both have a positive and significant coefficient in the regression for the CCR efficiency score, however, neither are significant determinants of the BCC efficiency score. Hence, raising total assets appears to be an effective tool for increasing overall technical bank efficiency (which CCR measures) if not managerial skills (which BCC measures). Further, the ten or so institutions that transformed from rural commercial banks to city commercial banks in the 2000s have also significantly raised overall technical bank efficiency if not managerial skills. The non-performing loans variable (LNNLCL) is an insignificant determinant of both measures of efficiency. In contrast, the number of branches (LNBR) and the number of years since establishment (LNAGE) both have negative and significant coefficients in the equations for both efficiency measures. This indicates that banks with a relatively small number of branch networks (such as joint venture commercial banks or newly established banks) and those that have been in existence for a comparatively short period of time are more efficient than older banks and those with larger branch networks.

6. Conclusions

The results of our analysis suggest that the average technical efficiency score for the whole Vietnamese banking system using the traditional method is 0.74 for the constant returns to scale measure and 0.81 with the variable returns to scale measure. These values are 0.68 and 0.75, respectively, after applying Simar and Wilson's (2007) superior double bootstrap method. These more accurate estimates indicate a lower level of efficiency compared with the traditionally used method. We find that while bank efficiency generally rose over the period it did not increase every year, for example, between 2001 and 2002 as well as 2007 and 2008. For 2001 – 2002 our finding is consistent with the results obtained by Nguyen (2007) in the sense that overall efficiency (CCR) does not rise, although we do not observe the clear decline in efficiency that he identifies. We believe our inference is more accurate because it is based on a substantially larger sample of banks and a superior estimation method. Between 2007 and 2008, a period that has not been examined previously, we find that efficiency declined according to both measures (CCR and BCC) and attribute this to the effect of the global financial crisis on the banking system.

In terms of asset size, large and very large banks are, on average, more efficient than small and medium sized banks. Regarding bank type, joint venture commercial banks exhibit greater overall efficiency (CCR measure) than state owned commercial banks that, in turn, are more efficient than joint stock commercial banks. However, the ranking according to the BCC measure, which distils managerial skills, is that state owned commercial banks are the most efficient, followed by joint venture commercial banks and then joint stock commercial banks. Non-state owned commercial banks (being joint stock commercial banks, joint venture commercial banks and foreign commercial banks) are more efficient than state owned commercial banks assuming overall efficiency. The average BCC efficiency scores of state owned commercial banks (0.86) are higher than for non-state owned commercial banks (0.76) suggesting the former exhibit superior efficiency in terms of managerial skills. However, the average CCR efficiency measure of non-state owned commercial banks (0.72) is higher than that of state owned commercial banks (0.70) indicating that the former have, on average, greater overall technical efficiency than the latter.

The Simar and Wilson (2007) double bootstrap efficiency scores are then regressed on environmental variables to identify the main determinants of efficiency. Generally, banks with greater total assets and those that transformed from rural to city commercial banks significantly raise overall efficiency (the CCR measure), if they have no significant impact on managerial skills (the BCC measure). Banks with a greater ratio of profit before tax to total assets are significantly more efficient than those with a lower ratio for both efficiency measures. The number of branches and the number of years since establishment both have a negative and significant effect on (both measures of) efficiency. Hence, banks with fewer branch networks (such as joint venture commercial banks or newly established banks) and/or those that have been in existence for a shorter period of time are more efficient than other banks. The non-performing loans, costs divided by total assets and profit before tax divided by total assets variables are not significant determinants of either measure of efficiency.

A number of policy implications arise out of this paper. The first policy implication concerns the small banks (in terms of asset size) in the system. The results indicate that large and very large banks are more efficient than small and medium sized banks with small banks having the lowest efficiency scores in the system. This suggests that efficiency can be raised by restructuring the banking system to reduce the number of smaller, less efficient banks. Moreover, banks with large branch networks and those that have been in existence for a long time are less efficient than other banks. Hence, efficiency could be increased via merger and acquisitions. Therefore, the State Bank of Vietnam could consider implementing policies for restructuring the system and promoting competition in the banking sector of Vietnam. Our results also indicate that non-state owned commercial banks exhibit greater overall technical efficiency (based on the CCR measure) than state owned commercial banks. Thus, the State Bank of Vietnam could improve efficiency by considering policies to enhance the development of the non-state owned commercial banks in the system.

We stress the limitations of our study. Although, we have set up a unique database, there is a possibility to collect data of the branches of foreign banks even though they account for only a small percentage of the banking system in terms of loans, deposits and assets. The full data might help us to provide more exact results of the efficiency scores. The next step should be to investigate bank efficiency of newly set up commercial banks and the "old" banks. This considers not only ownership structure matters but also the differences in terms of bank efficiency between "new" and "old" banks.

References

Alam, I. (2001). A Non-Parametric Approach for Assessing Productivity Dynamics of Large Banks. *Journal of Money, Credit and Banking, 33*, 121-139.

Ariff, M. and Can, L. (2009). IMF Bank-Restructuring Efficiency Outcomes: Evidence from East Asia. *Journal of Financial Service Research*, 167-187.

Balcombe, K., Fraser, I., Latruffe, L., Rahman, M. and Smith, L. (2008). An application of the DEA double bootstrap to examine sources of efficiency in Bangladesh rice farming. *Applied Economics, 40*, 1919-1925.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. *Management Science, 30*(9), 1078-1092.

Barros, C.P., Caporale, G.M. and Abreu, M. (2008). *Productivity drivers in European banking: Country effects, legal tradition and market dynamics.* London: Brunel University.

Bauer, P.W., Berger, A.N., Ferrier, G.D. and Humphrey, D.B. (1998). Consistency conditions for regulatory analysis of financial institutions: A comparison of frontier efficiency methods. *Journal of Economics and Business, 50*, 85-114.

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

Berger, A.N. and Mester, L.J. (1997). Inside the Black Box: What explains differences in the in the institutions? *Journal of Banking and Finance*, 895-947.

Bonin, P.J., Hasan, I. and Wachtel, P. (2005). Bank performance, efficiency and ownership in transition countries. *Journal of Banking and Finance, 29*, 31–53.

Brissimis, S.N., Delis, M.D. and Papanikolaou, N.I. (2008). Exploring the nexus between banking sector reform and performance: Evidence from newly acceded EU countries. *Journal of Banking and Finance, 32*, 2674-2683.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*, 429-444.

De Haas, R. and Van Lelyveld, I. (2006). Foreign Banks and Credit Stability in Central and Eastern Europe: Friends or Foes? *Journal of Banking and Finance, 30*(7), 1927-1952.

Dietsch, M. and Weill, L. (2000). The evolution of cost and profit efficiency in the European Banking Industry. In H. I. C., *Advances in Banking and Finance* (Vol. 1). JAI Press.

Dinh, T.T.H. and Kleimeier, S. (2007). A credit scoring model for Vietnam's retail banking market. *International Review of Financial Analysis, 16*, 471-495.

Dufhues, T. (2003). Transformation of the financial system in Vietnam and its implications for the rural market - An updated. *Journal of Institutional Innovation, 7*, 29-41.

Efron, B. and Tisbhirani, R.J. (1993). *An introduction to the bootstrap.* New York: Chapman and Hall.

Fare, R. Grosskopf, S. and Lovell, C.A.K. (1994). *Production frontiers.* Cambridge: University Press.

Farrell, M. (1957). The measurement of productivity efficiency. *Journal of Royal Statistical Society, 120*(3), 253-281.

Ferrier, G.D. and Lovell, K.C.A. (1990). Measuring cost efficiency in banking: Econometric and linear programing evidence. *Journal of Econometrics, 46*, 229-245.

Fries, S. and Taci, A. (2005). Cost efficiency of banks in transition: Evidence from 289 banks in 15 post-communist countries. *Journal of Banking and Finance, 29*, 55–81.

Gollani, B. and Roll, Y. (1989). An application procedure for DEA. *Omega International Journal of Management Sciences, 17*, 237–50.

Grabowski, R., Rangan, N. and Rezvanian, R. (1993). Organizational forms in banking: An empirical investigation of cost efficiency. *Journal of Banking and Finance, 17*, 531-538.

Grifell-Tatje, E. and Lovell, C.A.K. (1994). *A generalized Malmquist productivity index.* Athens: University of Georgia.

Hall, P. (1986). On the number of bootstrap simulations required to construct a confidence interval. *The Annals of Statistics*, 1453–62.

Hunter, W.C. and Timme, S.G. (1995). Core deposits and physical capital: A reexamination of bank scale economies and efficiency with quasi-fixed inputs. *Journal of Money, Credit and Banking, 27*(1), 165-185.

IMF. (2009). *World economic outlook.* IMF.

IMF. (2011). *World economic outlook.* IMF.

Kousted, J., Rand, J., Tarp, F., Nguyen, D.T., Nguyen, V.H., Ta, M.T. and Luu, D.K. (2005). *From mono bank to commercial bank: Financial sector reforms in Vietnam.* Singapore: Institute of Southeast Asian Studies.

Koutsomanoli-Filippaki, A., Margaritis, D. and Staikouras, C. (2009). Efficiency and productivity growth in the banking industry of Central and Eastern Europe. *Journal of Banking and Finance, 33*, 557-67.

Matthews, K. and Thompson, J. (2008). *The economics of banking.* Chichester: John Wiley & Sons, Ltd.

Molyneux, P. and Williams, J. (2005). The productivity of European co-operative banks. *Managerial Finance, 31*(11), 26-35.

Nguyen, D.T. and Pham, D.T. (1994). *Vietnamese banking system and its payment modalities.* Hanoi: Statistical Publishing House.

Nguyen, T.N. and Stewart, C. (2013). Concentration and efficiency in the Vietnamese banking system between 1999 and 2009: A structural model approach. *Journal of Financial Regulation and Compliance, 21*(3), 269-283.

Nguyen, V. (2007). Measuring efficiency of Vietnamese commercial banks: An application of Data Envelopment Analysis (DEA). In K. Nguyen, & T. Le, *Technical efficiency and productivity growth in Vietnam.* Hanoi: Publishing House of Social Labour.

Nguyen, X.Q. and De Borger, B. (2008). *Bootstraping efficiency and Malmquist productivity indices: An application to the Vietnamese commercial banks.* Taiwan: Academia Sinica.

SBV. (2005). *Annual Report.* Hanoi: SBV.

SBV. (2008). *Annual Report.* Hanoi: SBV.

SBV. (2009). *Annual Report.* Hanoi: SBV.

Sealey, JR, C.W. and Lindley, J.T. (1977). Inputs, outputs and a theory of production and cost at depository financial institutions. *The Journal of Finance, XXXII*(4), 1251-1266.

Simar, L. and Wilson, P.W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics, 136*, 31-64.

Staikouras, C., Mamatzakis, E., Koutsomanoli-Filippaki, A. (2008). Cost efficiency of the banking industry in the South Eastern European region. *Journal of International Financial Markets, Institutions and Money, 18*(5), 483-497.

VCSC. (2008). *Vietnam banking system: Reality and forecast.* Ho Chi Minh city: VCSC.

WB. (2008). *Taking stock: An update on Vietnam's recent economic development.* Hanoi: Annual Consultative for Vietnam.

WB. (2011). *World development indicators.* World Bank.

Wilson, P. (2010a). *FEAR 1.14 command reference.* South Carolina: Clemson University.

Wilson, P. (2010b). *FEAR 1.14 user's guide.* South Carolina: Clemson University.

Appendix

I.I. Algorithm 1

Step 1 Using original data of outputs, Y_{rj}, and inputs, X_{ij}, (that are all positive) compute DEA efficiency scores $\hat{\delta}_i$

Step 2 Use the method of maximum likelihood to obtain an estimate $\hat{\beta}$ of β as well as an estimate $\hat{\sigma}_\varepsilon$ of σ_ε in the truncated regression of $\hat{\delta}_i$ on z_i (equation **(3)**) using m<n observations where $\hat{\delta}_i > 1$.

Step 3 Loop over the next three steps **([3.1]-[3.3])** 2000 times to obtain a set of bootstrap estimates

$$A = \left\{ \left(\hat{\beta}^*, \hat{\sigma}^* \right)_b \right\}_{b=1}^{2000} :$$

[3.1] For each i=1,...,m, draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^2)$ distribution with left-truncation at $(1 - z_i \hat{\beta})$

[3.2] Again for each i=1,...,m, compute $\delta_i^* = z_i \hat{\beta} + \varepsilon_i$

[3.3] Use the maximum likelihood method to estimate the truncated regression of δ_i^* on z_i, yielding estimates $\hat{\beta}^*, \hat{\sigma}^*_\varepsilon$

Step 4 Use bootstrap values in **A (step 3)** and the original estimates $\hat{\beta}, \hat{\sigma}_\varepsilon$ to construct estimated confidence intervals for each element of β and for σ_ε .

I.I. Algorithm 2

Step 1 Using original data of outputs, Y_{rj}, and inputs, X_{ij}, (that are all positive) compute DEA efficiency scores $\hat{\delta}_i$.

Step 2 Use the method of maximum likelihood to obtain an estimate $\hat{\beta}$ of β as well as an estimate $\hat{\sigma}_\varepsilon$ of σ_ε in the truncated regression of $\hat{\delta}_i$ on z_i using m<n observations where $\hat{\delta}_i > 1$.

Step 3 Loop over the next four steps **([3.1]-[3.4])** 100 times to obtain a set of bootstrap estimates

$$A = \left\{ \left(\hat{\beta}^*, \hat{\sigma}_\varepsilon^* \right)_b \right\}_{b=1}^{100} :$$

[3.1] For each i=1,...,m, draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^2)$ distribution with left-truncation at $(1 - z_i \hat{\beta})$

[3.2] Again for each i=1,...,n, compute $\delta_i^* = z_i \hat{\beta} + \varepsilon_i$

[3.3] Set $x_i^* = x_i, y_i^* = y_i(\hat{\delta}_i / \delta_i^*)$ for all i=1,2,...n.

[3.4] Compute the new technical efficiency $\hat{\delta}_i^*$ by replacing $Y^* = [y_1^*,..., y_n^*], X^* = [x_1^*,...x_n^*]$

Step 4 For each i=1,...,n, compute the bias corrected estimator $\hat{\hat{\delta}}_i$ using bootstrap estimates in step 3.4 and the original $\hat{\delta}_i$

Step 5 Use the maximum likelihood method to estimate the truncated regression of $\hat{\hat{\delta}}_i$ on z_i, yielding estimates $\hat{\hat{\beta}}, \hat{\hat{\sigma}}$

Step 6 Loop over the next three steps **([6.1]-[6.3])** 2000 times to obtain a set of bootstrap estimates $K = \left\{ \left(\hat{\beta}^*, \hat{\sigma}^* \right)_b \right\}_{b=1}^{2000}$:

[6.1] For each i=1,...,n, draw ε_i from the $N(0, \hat{\hat{\sigma}})$ distribution with left-truncation at $(1 - z_i \hat{\hat{\beta}})$

[6.2] Again for each i=1,...,m, compute $\delta_i^{**} = z_i \hat{\hat{\beta}} + \varepsilon_i$

[6.3] Use the maximum likelihood method to estimate the truncated regression of δ_i^{**} on z_i, yielding estimates $\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*$

Step 7 Use bootstrap values in **K (step 6)** and the original estimates $\hat{\hat{\beta}}, \hat{\hat{\sigma}}$ to construct $(1-\alpha)$ estimated confidence intervals for each element of β and for σ_ε

Figure 1 Scatter plot of DEA-CCR and DEA-BCC efficiency scores

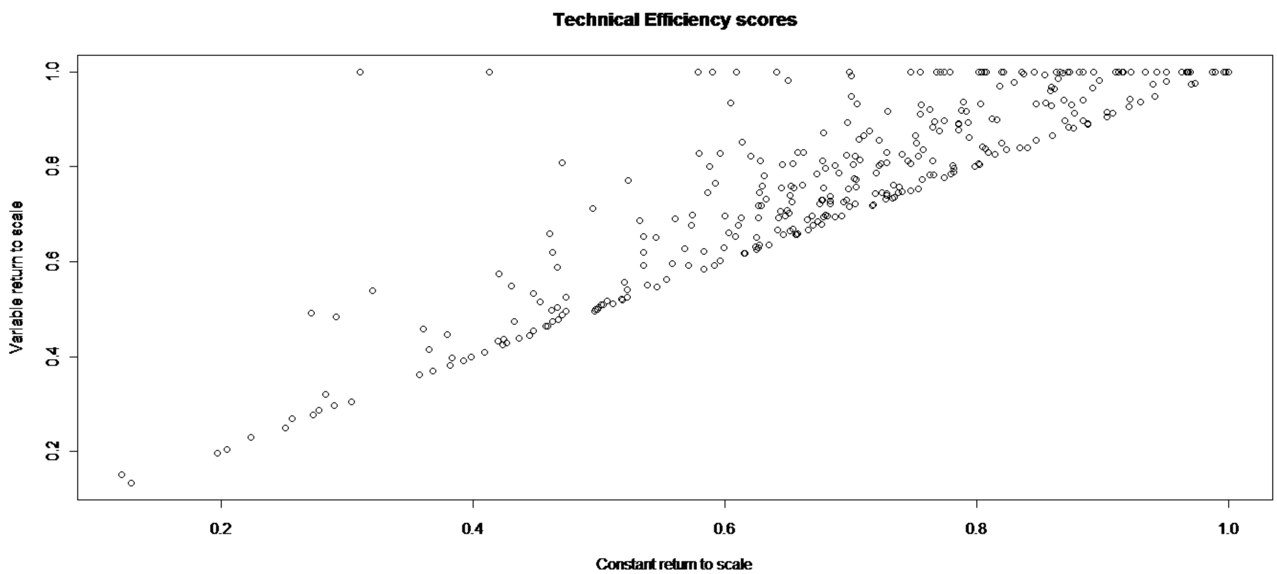

Table 1 The number of commercial banks from 1990 to 2009[6]

Type of banks	1990	1995	2000	2005	2009
State owned commercial banks	4	4	5	5	**5**
Non-state owned commercial banks					
Joint stock commercial banks	0	36	39	37	**37**
Branches of foreign banks	0	18	26	31	**48**
Joint venture commercial banks	0	4	5	5	**6**
Foreign commercial banks	0	0	0	0	**5**
Total	4	62	75	78	101

Sources: Dufhues (2003: 32); SBV (2005, 2008, 2009) and VCSC (2008).

[6] Beside these commercial banks, there are also the Social Policy Bank and Vietnam Development Bank which are operating as non-profit institutions.

Table 2. Data on loans, assets, deposits, capital and non-performing loans of the Vietnamese commercial banks (state owned commercial banks and non-state owned commercial banks) from 1999 to 2009 (Unit: 1,000 Vietnamese Dong)

Year	Bank type	Loans	Assets	Deposits	Capital	Non-performing loans
1999	SOCBs	72,142,247	134,890,858	87,326,439	5,468,772	10.78%
	Non-SOCBs	35,899,360	58,871,839	30,293,986	9,284,887	N/A
2000	SOCBs	108,422,565	200,433,947	127,033,459	5,413,772	10.02%
	Non-SOCBs	41,231,535	75,856,994	43,321,781	10,139,627	9.42%
2001	SOCBs	135,647,621	247,151,769	160,738,302	5,421,134	8.83%
	Non-SOCBs	45,466,715	88,614,974	51,759,565	10,953,034	7.81%
2002	SOCBs	165,921,733	286,860,920	189,313,313	10,061,113	7.62%
	Non-SOCBs	55,296,802	102,590,591	63,658,203	11,152,585	5.41%
2003	SOCBs	214,481,096	367,813,825	237,485,761	14,516,916	5.13%
	Non-SOCBs	74,068,790	130,337,981	79,255,399	12,398,334	3.57%
2004	SOCBs	295,738,175	468,341,918	311,681,861	17,362,940	2.92%
	Non-SOCBs	103,563,777	183,404,071	109,681,322	14,860,054	2.26%
2005	SOCBs	380,850,503	603,540,889	406,957,181	18,429,980	3.81%
	Non-SOCBs	143,449,737	261,307,537	144,499,838	20,009,805	1.42%
2006	SOCBs	435,695,864	731,657,400	524,533,245	18,777,200	3.19%
	Non-SOCBs	212,097,344	430,755,234	229,411,786	35,578,494	1.29%
2007	SOCBs	564,677,195	904,004,852	652,913,108	30,091,997	1.87%
	Non-SOCBs	420,184,441	903,961,807	456,920,152	66,066,418	0.94%
2008	SOCBs	671,732,670	1,078,729,233	775,560,005	39,279,325	2.47%
	Non-SOCBs	534,692,051	1,097,675,565	593,628,040	103,923,040	1.62%
2009[7]	SOCBs	903,718,777	1,320,357,324	869,410,909	61,293,664	N/A
	Non-SOCBs	560,883,667	1,210,244,318	680,665,451	115,192,318	N/A

Note: SOCBs: State owned commercial banks; Non-SOCBs: Non-state owned commercial banks. Sources: SBV (2009); Financial statements of 48 Vietnamese commercial banks.

Table 3 Descriptive statistics of inputs and outputs (Units: 1,000 Vietnamese Dong except for Staff)

Variables	Mean	Median	Std deviation	Minimum	Maximum
Inputs					
1. Staff (People)	2,363.59	485	5,380.34	31	35,135
2. Purchased Funds	4,717,463.63	953,304	9,114,539.41	0	65,317,125
3. Customer Deposits	16,876,982.94	2,801,850	39,407,328.37	796	34,964,4191
Outputs					
4. Customer Loans	15,412,044.60	2,642,000	39,384,206.14	496	372,438,322
5. Other Loans	5,603,227.19	1,029,387	11,005,779.19	226	72,637,734
6. Securities	3,182,009.32	189,737	7,871,634.06	0	44,573,879

Sources: Financial statements of 48 Vietnamese banks in the period of 1999-2009.

[7] We could not collect data of the North Asia Commercial Bank and Vinasiam Bank in 2009.

Table 4 Descriptive statistics of regression variables

Variables	Mean	Median	Std deviation	Minimum	Maximum
Raw data					
1. ROA	0.01	0.01	0.02	-0.09	0.30
2. COA	0.07	0.06	0.06	0	1.24
Other characteristics					
4. CITY (Dummy)	0.18	0	0.39	0	1
5. LNTA	15.43	15.29	1.96	8.57	20
6. LNNLCL	-4.28	-4.28	1.14	-8.81	0
7. LNBR	3.27	3.22	1.52	0	7.74
8. LNAGE	2.68	2.77	0.48	0	3.09

Sources: Financial statements of 48 Vietnamese banks in the period of 1999-2009.

Table 5: Technical efficiency average scores for the whole Vietnamese banking sector: $\hat{\delta}_{i,t}$, $\delta^*_{i,t}$ and $\hat{\hat{\delta}}_{i,t}$

	$\hat{\delta}_{i,t}$	$\delta^*_{i,t}$	Algorithm 1, $\delta^*_{i,t}$ Confidence interval		$\hat{\hat{\delta}}_{i,t}$	Algorithm 2, $\hat{\hat{\delta}}_{i,t}$ Confidence interval		Number of banks	Number of efficient banks
CCR			Lower bound	Upper bound		Lower bound	Upper bound		
1999	0.58	0.52	0.48	0.64	**0.54**	0.46	0.63	17	1
2000	0.66	0.55	0.50	0.67	**0.56**	0.47	0.66	22	1
2001	0.67	0.59	0.57	0.68	**0.59**	0.56	0.67	25	4
2002	0.66	0.56	0.52	0.67	**0.59**	0.52	0.66	27	0
2003	0.68	0.60	0.55	0.69	**0.60**	0.52	0.68	28	2
2004	0.75	0.67	0.62	0.77	**0.68**	0.61	0.77	39	2
2005	0.78	0.70	0.66	0.82	**0.72**	0.66	0.81	41	4
2006	0.80	0.73	0.70	0.86	**0.76**	0.68	0.85	41	7
2007	0.87	0.78	0.76	0.92	**0.83**	0.75	0.91	44	9
2008	0.86	0.77	0.74	0.90	**0.80**	0.72	0.90	46	8
2009	0.87	0.79	0.76	0.92	**0.82**	0.75	0.92	46	8
Mean	0.74	0.66	0.62	0.78	**0.68**	0.61	0.77	34.18	4.18
	$\hat{\delta}_{i,t}$	$\delta^*_{i,t}$	Algorithm 1, $\delta^*_{i,t}$ Confidence interval		$\hat{\hat{\delta}}_{i,t}$	Algorithm 2, $\hat{\hat{\delta}}_{i,t}$ Confidence interval		Number of banks	Number of efficient banks
BCC			Lower bound	Upper bound		Lower bound	Upper bound		
1999	0.65	0.56	0.50	0.68	**0.58**	0.50	0.67	17	1
2000	0.68	0.59	0.54	0.71	**0.60**	0.51	0.70	22	2
2001	0.72	0.64	0.62	0.73	**0.64**	0.61	0.72	25	5
2002	0.72	0.64	0.60	0.75	**0.67**	0.60	0.74	27	3
2003	0.75	0.68	0.63	0.77	**0.68**	0.60	0.76	28	4
2004	0.84	0.76	0.72	0.87	**0.77**	0.71	0.87	39	5
2005	0.87	0.77	0.72	0.88	**0.78**	0.72	0.87	41	8
2006	0.89	0.80	0.77	0.90	**0.83**	0.75	0.89	41	10
2007	0.93	0.84	0.82	0.94	**0.89**	0.81	0.93	44	18
2008	0.92	0.83	0.82	0.95	**0.88**	0.80	0.95	46	13
2009	0.95	0.87	0.83	0.96	**0.90**	0.83	0.96	46	21
Mean	0.81	0.73	0.69	0.83	**0.75**	0.68	0.82	34.18	8.18

Sources: Financial statements of 48 Vietnamese banks in the period of 1999-2009.

Table 6 Technical efficiency scores as the double bootstrap method ($\hat{\hat{\delta}}_{i,t}$) in terms of asset size in 2009

Years	Small banks (Asset: 0-20,000 billion VND)		Medium banks (Asset: 20,000-50,000 billion VND)		Large banks (Asset: 50,000-100,000 billion VND)		Very large banks (Asset: More than 100,000 billion VND)	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
1999	0.51	0.52	0.46	0.47	0.71	0.71	0.49	0.63
2000	0.49	0.50	0.49	0.50	0.76	0.78	0.58	0.69
2001	0.56	0.57	0.46	0.47	0.68	0.71	0.68	0.82
2002	0.55	0.59	0.50	0.54	0.62	0.67	0.73	0.93
2003	0.55	0.64	0.60	0.65	0.59	0.62	0.70	0.86
2004	0.66	0.74	0.68	0.81	0.70	0.74	0.69	0.85
2005	0.72	0.74	0.72	0.80	0.73	0.78	0.73	0.89
2006	0.73	0.77	0.83	0.87	0.75	0.83	0.77	0.94
2007	0.81	0.85	0.84	0.93	0.86	0.94	0.83	0.94
2008	0.81	0.87	0.77	0.88	0.80	0.90	0.81	0.94
2009	0.83	0.89	0.75	0.85	0.87	0.95	0.85	0.99
Mean	0.65	0.70	0.65	0.71	0.73	0.78	0.71	0.86

Table 7 Technical efficiency scores as the double bootstrap method ($\hat{\hat{\delta}}_{i,t}$) in terms of bank type

Years	State owned banks			Joint stock banks			Joint venture banks		
	CCR	BCC	Banks	CCR	BCC	Banks	CCR	BCC	Banks
1999	0.52	0.64	5	0.54	0.56	10	0.54	0.55	2
2000	0.51	0.63	5	0.56	0.58	14	0.69	0.70	3
2001	0.59	0.73	5	0.57	0.59	16	0.69	0.71	4
2002	0.63	0.84	5	0.55	0.59	19	0.71	0.74	4
2003	0.66	0.83	5	0.57	0.60	20	0.72	0.79	4
2004	0.68	0.89	5	0.68	0.75	31	0.68	0.72	4
2005	0.74	0.94	5	0.71	0.75	32	0.82	0.85	4
2006	0.84	0.99	5	0.75	0.80	31	0.77	0.85	5
2007	0.87	0.98	5	0.83	0.90	34	0.75	0.78	5
2008	0.86	1.00	5	0.78	0.86	36	0.89	0.90	5
2009	0.83	1.00	5	0.80	0.88	37	0.92	0.92	5
Mean	0.70	0.86		0.67	0.72		0.74	0.77	

Note: In 2009, HSBC (foreign commercial bank) had average efficiency score of 1 for both CCR and BCC; Mean of non-state owned commercial banks (joint stock commercial banks, joint venture commercial banks and foreign commercial banks: CCR (0.72) and BCC (0.76); Sources: Financial statements of 48 Vietnamese banks in the period of 1999-2009.

Table 8 Technical efficiency average scores as the double bootstrap method ($\hat{\hat{\delta}}_{i,t}$) for the Vietnamese banking system from 1999 to 2009

ID	Bank in groups	DEA-CCR	DEA-BCC	DEA-Scale Index
	State Owned Commercial Banks (5 banks)			
1	Bank for Agriculture and Rural Development	0.57	0.86	0.65
2	Bank for Investment and Development	0.76	0.91	0.83
3	Mekong Housing Bank	0.66	0.76	0.87
4	Bank for Foreign Trade of Vietnam	0.83	0.93	0.89
5	Vietnam Bank for Industry and Trade	0.69	0.86	0.79
	Joint Stock Commercial Banks (37 banks)			
6	Asia Commercial Bank	0.82	0.89	0.92
7	Saigon Thuong Tin Commercial Bank(*)	0.63	0.75	0.83
8	Technological and Commercial Bank Vietnam	0.66	0.72	0.92
9	Export Import Bank	0.79	0.84	0.92
10	Military Commercial Bank	0.81	0.86	0.94
11	Dong A Commercial Bank	0.54	0.63	0.87
12	Saigon Commercial Joint Stock Bank(**)	0.91	0.93	0.98
13	Vietnam International Commercial Bank(*)	0.58	0.66	0.90
14	Hanoi Building Commercial JS Bank	0.79	0.82	0.96
15	Maritime Commercial Bank	0.73	0.78	0.94
16	South East Asia Commercial Bank(**)	0.93	0.96	0.96
17	Vietnam Prosperity Commercial Bank	0.56	0.62	0.91
18	Southern Commercial Bank	0.49	0.57	0.87
19	Saigon Bank for Industry and Trade	0.61	0.67	0.93
20	Orient Commercial Bank(*)	0.53	0.60	0.91
21	North Asia Commercial Bank(**)	0.87	0.90	0.96
22	Housing Development Commercial Bank(*)	0.71	0.74	0.96
23	Nam A Commercial Bank(*)	0.52	0.56	0.93
24	Vietnam Tin Nghia Commercial Bank(**)	0.80	0.81	0.99
25	Gia Dinh Commercial Bank(**)	0.75	0.78	0.95
26	Kien Long Commercial Bank(*)	0.45	0.49	0.92
27	First Commercial Bank(***)	0.88	0.88	0.99
28	An Binh Commercial Bank(**)	0.82	0.90	0.91
29	Saigon-Hanoi Commercial Bank(**)	0.71	0.76	0.94
30	Ocean Commercial Bank(**)	0.89	0.98	0.90
31	Viet A Commercial Bank(*)	0.61	0.66	0.93
32	Nam Viet Commercial Bank(**)	0.82	0.89	0.91
33	Global Petro Commercial Bank(**)	0.81	0.90	0.91
34	Petrolimex Group Commercial Bank(*)	0.72	0.93	0.78
35	Great Trust Commercial Bank(**)	0.64	0.70	0.91
36	Great Asia Commercial Bank(**)	0.83	0.87	0.95
37	Western Commercial Bank(*)	0.76	0.79	0.96
38	Mekong Development Bank(*)	0.72	0.73	0.97
39	Lien Viet Bank (***Established in 2008)	0.94	0.94	0.99
40	Tien Phong Bank (***Established in 2008)	1.00	1.00	1.00
41	Vietnam Thuong Tin Bank(***Established in 2006)	0.88	0.90	0.97
42	Bao Viet Bank(****Established in 2008)	1.00	1.00	1.00
	Joint Venture Commercial Banks (5 banks)			
43	Indovina Bank	0.80	0.81	0.98
44	Shinhanvina Bank(*)	0.76	0.83	0.92
45	VID Public Bank	0.67	0.68	0.98
46	Vinasiam Bank(*)	0.85	0.86	0.98
47	Vietnam Russia Bank(**)	0.67	0.79	0.83
	Foreign Commercial Bank (1 bank)			
48	HSBC Vietnam(****Established in 2009)	1.00	1.00	1.00

Note: (*) Banks with data from 8 to 10 years; (**) Banks with data from 5 to 7 years; (***) Banks with data from 2 to 4 years; (****) Banks with data of only one year.

Table 9 Determinants of CCR and BCC efficiency ($\hat{\hat{\delta}}_{i,t}$) for the Vietnamese banking system

	Overall technical efficiency (CCR)	Pure technical efficiency (BCC)
C	-0.403*	-0.824***
	(-2.254)	(-4.418)
ROA	1.669**	1.712**
	(2.082)	(2.05)
COA	-0.467	-0.348
	(-1.794)	(-1.283)
CITY	0.156***	0.506
	(4.271)	(1.159)
LNTA	0.079***	0.164
	(6.467)	(1.129)
LNNLCL	-0.012	-0.012
	(-0.996)	(-0.928)
LNBR	-0.065***	-0.064***
	(-4.277)	(-4.012)
LNAGE	-0.096***	-0.083***
	(-3.454)	(-2.877)
Observations	379	379

*Note: The variables' coefficients and t-statistics (in brackets) are reported in the table; *** denotes significance at the 1% level, ** indicates significance at the 5% level and * represents significance at the 10% level. Sources: Financial statements of 48 Vietnamese banks in the period of 1999-2009.*