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Optimal capital adequacy ratio: An investigation of Vietnamese commercial banks using two-stage DEA

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Abstract: Over the last years the Vietnamese banking system has been struggling to restructure, reform governance, consolidate financial statements and build up merge and acquisition, in line with international standards. The Bank for International Settlements (BIS) proposed BASEL III in 2010, whereby banks must increase their minimum Capital Adequacy Ratios (CAR) year by year with a goal of 10.5% by 2019. The objective of this paper is to address the questions: (1) what are the optimal CAR levels for Vietnamese Commercial Banks (2) whether the minimum required CARs stipulated in the Basel II and III are reasonable for Vietnam banking system? The data set consists of a sample of Vietnamese commercial banks over the six-year period from 2010 to 2015. The optimal CARs of banks are calculated using the nonparametric two-stage Data Envelopment Analysis (DEA) model, with two inputs: fixed assets, employee expense and two outputs: interest income, non-interest income. The findings indicate that 92.4% of the banks have the optimal CAR higher than the minimum ratio 10.5% defined in BASEL III. Moreover, 57.98% of the

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PUBLIC INTEREST STATEMENT

This paper is a part of the research project investigating the efficiency of the Vietnamese banking system during the restructuring period. By investigating the optimal Capital Adequacy Ratio of Vietnamese commercial banks, this paper will provide a guideline for each Vietnamese commercial bank to find the trade-off between bank performance and bank risk. This paper will also help the State Bank of Vietnam regulate the banking system in line with international standards.

banks should raise their current level of CAR to reach their optimal ones. To conclude, this paper will provide a guideline for Vietnamese banks to decide their optimal CAR to reach the efficiency frontier.

Subjects: Econometrics; Banking; Investment & Securities; Risk Management

Keywords: Capital adequacy ratios; BASEL II; BASEL III; Two-stage DEA; Vietnam banking system

1. Introduction

The Basel Committee on Banking Supervision (BCBS) is a group established to regulate the banking matter worldwide, make the quality of the banking supervision at the international level better and improve the stability of international banking system. The Basel I was enforced by law in 1992 in the G-10 nations (the United State, Canada, Netherland, France, Belgium, Germany, Sweden, Italy, the United Kingdom, and Japan) or G11 (G10 plus Spain). In the Basel I, the *Capital Adequacy Ratio (CAR)* was strongly emphasized being the measurement of banks' risk and should be accepted as a global standard. With Basel I, the minimum capital requirement must be at least 8%. Because the nature of bank's financial risk varied and turned more complex, the BCBS developed the Basel II that officially carried out in 2006. According to the Basel II, the minimum CAR was still 8% and the minimum common equity required by banks to hold was 2%. Unlike the Basel I, which applied for the G-10 nations, the Basel II was regulating worldwide for the purpose to assure the nonexistence of competitive advantage inequality, unfairness among international active banks. The Great Financial Crisis in 2008 had significant impact on the international financial development and caused its weakness. As a result, Basel III was issued by the BCBS in September 2010 to enhance the ability to withstand the financial and economic stress of the banking system and improve the risk management. In the new Basel regulation, the banking industry must carry out the policies to reach the target minimum CAR of 10.5% by 2019.

On the other hand, the banking industry is developing in the direction of globalization and internationalization. Therefore, maintaining the banking stability, ensure the equality and fairness of competitive advantage between banks around the world is an important issue for financial authority. The CAR is considered as the measurement of bank's risk, regulated strictly by the Basel. The CAR can be also referred as the factor in measuring the bank solvency—the ability to perform the short term and long-term financial obligation of the banks. In general, a bank that has a quite high CAR is more likely to meet its financial obligation. In other words, according to Park and Weber (2006), Kahane (1977), a high capital adequacy ratio helps the banks take more risky activities with their great ability to finance their short term and long-term obligations. With Mester (1996), Berger (1995), and Furlong and Keeley (1989), banks will implement the diversification of risky projects which come out the result of lower risk-taking and higher income gain—more risk, more profit. Moreover, riskiness's level of risky activities has significant effects on the level of risks that the banks must face against. The interaction between minimum CAR and the bank's risk, supports the rationale of using CAR as a measurement of bank risk. The CAR is known as the financial strength of banks, the bank's ability to bear the risk of loss. For that reason, under the supervisory authority point of view, they prefer to set the minimum CAR as high as possible. Banker et al. (2010) and Berger (1995) highlight the advantage of setting a high minimum capital requirement that increases the bank's ability facing risks. But according to Mester (2008), Hughes (1999), Berger and MesTer (1997), and Hughes and Mester (1993), the high bank's capital directly affected the opportunity cost of the banks benefits from lending loan. Therefore, the bankers prefer to maintain a lower CAR, which means a lower capital's requirement. Guidara et al. (2013) and Barth et al. (2004) also pointed out the disadvantage of high CAR as it can be a source of limitation for the bank in gaining benefit from lending loans. Thus the CAR can produce both positive and negative outcomes, the CAR must be set rationally that fits the banking industry.

Therefore, the optimal CAR is very important not only for policy makers but also for banks' managers.

In Vietnam, after the global financial crisis, the banking system started to struggle. The credit growth rate was unstable, or even fell because of the decrease in demand for corporate loans. The overall ratio of non-performing loan was quite high, consequently bank performance was harmed. Acknowledging these difficulties, in October 2010, the State Bank of Vietnam issued the Circular No. 13/2010/TT-NHNN, according to which the minimum of capital adequacy ratios was regulated at 9%. Moreover, the Decision No. 254/QD-TTG in March 2012 was published by the Government with the purpose of restructuring and fostering the whole banking industry. Later, the State Bank of Vietnam issued the Circular No. 41/2016/TT-NHNN planning the new stipulated minimum capital adequacy ratio at 8% from 2020. But recently the State Bank of Vietnam issued Circular No. 22/2019/TT-NHNN, whereby the minimum capital adequacy ratio was 9% again which would be officially implemented from January 2020. This is the movement for Vietnam banking system to prepare and follow the global regulations under BASEL II and BASEL III.

To our knowledge there is lack of research about the optimal CARs for Vietnamese commercial banks. To fill this gap, this paper will investigate the optimal CARs of Vietnam commercial banks using appropriate inputs and outputs for the banking technology in the two-stage DEA model, and answer the following questions: (1) what are the optimal CARs of Vietnamese commercial banks? (2) whether the minimum required CARs stipulated in the BASEL II or BASEL III are reasonable?

The paper is organized as follows. Section 2 is devoted to the discussion of related papers worldwide and in Vietnam. Section 3 presents the methodology used in this paper. Section 4 explains the choice and definition of the outputs and inputs used for the banking technology. The results are presented and commented in Section 5. Some conclusions are drawn in Section 6.

2. Literature review

According to Fonsece and Gonzalez (2010), the main function of CAR is creating a buffer for the banks facing risks such as insolvency risk or financial crisis. In the past, reserve requirement was the main tool in maintaining the bank's strength against any risks. The reserve requirement is the amount of money that the bank must keep as reserve from the money deposited by customers, set by the Federal Reserve. In the past two decades, some regulations about the reserve requirement changed. In some countries, there is no reserve requirement at all such as Canada, New Zealand, United Kingdom, Belgium, Sweden or Denmark (Wang, 2005); or the decrease in the reserve requirement regulations like in the United State since 1990 (Chami & Cosimano, 2001) or in Germany (Sellon & Weiner, 1996). With the *BIS ratio* (minimum requirement of CAR), the banks must also hold an amount of the deposits aside the loans, it limits the amount of deposits which can be loaned out. Maintaining a minimum capital adequacy ratio as requirement will create some provision for banks to deal with any losses due to economic crisis or risks. Therefore, the importance of reserve requirement is replaced with the capital adequacy ratio gradually.

According to Chami and Cosimano (2010), banks are willing to implement the regulations referred to the capital requirement and maintain the CAR above the minimum required CAR. The banks could increase the CAR by adding more equity capital and increasing the capital, but this method causes the high cost of equity. Therefore, banks prefer to reduce the risky asset rather than increase their capital to assure the CAR greater than the minimum requirement. Moreover, in some cases such as bad financial economics, banks can raise their capital without any equity cost, but they still choose to improve the capital adequacy ratio by reducing the proportion of fund invested in the high risky asset (Hyun & Rhee, 2011). According to Mester (1996), Berger (1995), and Furlong and Keeley (1989), banks will implement the diversification of risky projects which come out the result of lower risk-taking and higher-income gain. However, to maximize and enhance the shareholder value, there are some cases that banks will allocate more funds to take large and very high-risk diversified projects, portfolio. This was already claimed in the previous research of Furlong and Keeley (1989–1990). That is the case of not well or unregulated banks. With the well-regulated banks, like stricter in the capital requirement, the higher CAR will not only help increase the bank's capacity to bear the risk, but also reduce the incentive of taking risk of the banks. Blum (1999) claimed that with the stricter the capital requirement, banks will not allocate much of their source of investment fund to high-risk asset. This will minimize the opportunity that banks would face risks. On the other hand, Kahane (1977), Koehn and Santomero (1980) stated other opinions about this relationship. They showed that with higher minimum capital requirement, and higher capital adequacy ratios regulated, bank's risk incentive would depend on the banks' risk attitude. The risk averse banks will avoid any unnecessary risks and choose the less risky investment opportunities compared to the risk neutral ones. With this point of view, stricter capital requirement or higher BIS ratio will not always make the banks safer, it can cause the banks riskier in investment. Another statement about this issue is that Calem and Rob (1999) brought out that connection as the U-shape. That means, the risk-taking incentive of banks will decrease at first when the capital requirement increases, but it would increase if the requirement goes beyond a certain point on the diagram.

However, the high BIS ratio will limit the amount of money created by banks institutions, limit the amount of deposits that can be used as source of lending fund. So, it affects the opportunity to gain benefits from loans of the banks, which has negative impact on bank's performance. However, there is no unified conclusion in this matter among studies. First, Barth et al. (2004) stated that even though banks are supervised strictly and well regulated, the probability that banks suffers from the any risks like bad economic conditions or losses will not reduce. Second, Shim (2013) indicated that the business cycle does not move in the same direction with the capital buffer, the empirical results on US banks from 1992 to 2011. On the other hand, Guidara et al. (2013) had the empirical research on Canada's banking systems in the period 1982 to 2010 and had the explanation of the well survived Canadian banks from the financial crisis in 2008 compared with other countries. It showed the positive connection between capital requirement and business performance, the well-regulated and well-capitalized banks would operate better than others. Other researchers agreed with Guidara et al. (2013) such as Kashyap and Stein (2004), Ayuso et al. (2004), and Barajas et al. (2004). They claimed that the greater rate of minimum capital adequacy defined in the Basel II would positively affect by reducing the probability of non-performing loans and loans default in the financial tsunami.

Recently Li et al. (2016) studied the optimal capital adequacy ratios of thirty-one commercial banks in Taiwan in the period from 2007 to 2009. When comparing the optimal CAR of those banks to the requirement capital adequacy ratios regulated in the BASEL II and III, the empirical results show that 93.5% and 88.2% of Taiwanese banks have the optimal capital adequacy ratios greater than the 8% stipulated in the BASEL II and 10.5% in the BASEL III, respectively.

To our knowledge there is lack of research about the optimal CARs for Vietnamese commercial banks, so we conduct this research to fill the gap.

3. Methodology

Data Envelopment Analysis (DEA) is a nonparametric method using linear programming to perform the evaluation of the relative efficiency of a set of Decision Making Units (DMUs). The efficiency will measure the DMUs ability to maximize outputs with specific deployment of input resources. In this paper, the two stages DEA approach (Chen et al., 2010) is used: the first stage is evaluating the banks operational efficiency, the second stage is measuring the bank's profitability. The optimal CAR is obtained as one intermediate measure.

According to Färe and Grosskopf (1996, 2000), production under DEA is a "black box" which is the internal structure, the transformation mechanism of inputs into outputs. With that point of view, productions are divided into several processes in which the inputs and outputs do not play a unique role in each sub-process, they will perform dual functions. The outputs of one stage can become the inputs of the next process. These products are called *intermediate products*, or *intermediates*.

Applying the decomposition of production into sub-processes, Seiford and Zhu (1999) divided the bank production into two stages. The first stage determines the banks' profitability, how well the banks earn income by utilizing their sources such as employees, asset, or equity. The second stage evaluates the operational performance of bank in terms of market value, total return to investors or earning per share. With this point of view, they choose to treat the first and the second process, the production chain independently. The main limitation coming from this approach is to ignore the interaction that may exist between two sub-processes and the production. The intermediate products are not considered.

Noticing this limitation and using a better approach, Kao and Hwang (2008) also used two stages processes but now the relationship between them is considered in examining the efficiency of DMUs (Figure 1). The efficiency of each DMU is the weighted sum of outputs over the weighted sum of inputs. The first stage generates N inputs to produce D outputs. The second stage generates D inputs to produce M outputs. The efficiency score of each stage is given as below:

$$\theta_j^1 = \frac{\sum_{d=1}^{D} w_d.z_{dj}}{\sum_{n=1}^{N} v_n.x_{nj}}$$

$$\theta_j^2 = \frac{\sum_{m=1}^{M} u_m.y_{mj}}{\sum_{d=1}^{D} w'_d.z_{dj}}$$

where θ_j^1, θ_j^2, are the efficiency scores of the first stage and the second stage of DMU j,

v_n, w_d, w'_d, u_m are the unknown nonnegative weights,

$x_{1j} \ldots x_{Nj}$ are the Ninputs of DMU j,

$z_{1j} \ldots z_{Dj}$ are the D outputs of the first stage of DMU j,

$y_{1j} \ldots y_{Mj}$ are the M outputs of the second stage of DMU j,

$\sum_{d=1}^{D} w_d.z_{dj}, \sum_{m=1}^{M} u_m.y_{mj}$: weighted sum of outputs of first stage and second stage,

$\sum_{n=1}^{N} v_n.x_{nj}, \sum_{d=1}^{D} w'_d.z_{dj}$: weighted sum of inputs of first stage and second stage.

Thus, the overall efficiency of the DMU j is the multiple of the efficiency levels of two stages:

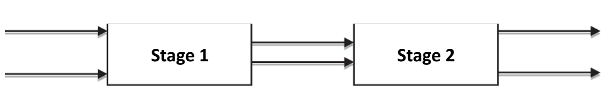
$$\theta_j = \theta_j^1.\theta_j^2$$

which can be obtained by solving the following optimization problem (P1):

$$\underset{(u_1 \ldots u_M, v_1 \ldots v_N, w_1 \ldots w_D)}{Minimize} \sum_{n=1}^{N} v_n.x_{nj}$$

$$such\ that: \sum_{m=1}^{M} u_m.y_{mj} = 1$$

Figure 1. The two-stage process for DMU j.



$$\sum_{d=1}^{D} w_d.z_{dh} - \sum_{n=1}^{N} v_n.x_{nh} \leq 0, h = 1, 2, \ldots, H$$

$$\sum_{m=1}^{M} u_m.y_{mh} - \sum_{d=1}^{D} w_d.z_{dh} \leq 0, h = 1, 2, \ldots, H$$

$$w_d \geq 0, d = 1, \ldots, D; v_n \geq 0; n = 1, \ldots, N; u_m \geq 0; m = 1, \ldots, M$$

Then, we obtain the optimal weights $u'_1 \ldots u'_M, v'_1 \ldots v'_N, w'_1 \ldots w'_D$. Moreover, the dual form of the problem (P1) is the problem (P2) as follows:

$$\underset{(\beta_j, \lambda_1, \ldots, \lambda_H, \delta_1, \ldots, \delta_H)}{Maximize} \quad \beta_j$$

such that:

$$\sum_{h=1}^{H} \lambda_h x_{nh} \leq x_{nj}, n = 1, 2, \ldots, N$$

$$\sum_{h=1}^{H} \delta_h y_{mh} \geq \beta_j y_{mj}, m = 1, 2, \ldots, M$$

$$\sum_{h=1}^{H} (\lambda_h - \delta_h) z_{dh} \geq 0, d = 1, 2, \ldots, D; \lambda_h, \delta_h \geq 0, h = 1, 2, \ldots, H$$

The result of problem (P2) is used to compute the overall efficiency of DMU j, which is the reciprocal of the optimal objective value:

$$\theta_j = 1/\beta_j.$$

Chen et al. (2010) pointed out that this conventional two-stage DEA model did not necessarily project inefficient DMUs onto the DEA frontier, and developed a new intermediate measure z'_{dj}, d = 1, 2, …, D for DMU j to establish an efficient projection. In this new model, the previous constraint $\sum_{h=1}^{H} (\lambda_h - \delta_h) z_{dh}$ is separated into two other constraints as below:

$$\sum_{h=1}^{H} \lambda_h z_{dh} \geq z'_{dj}, d = 1, 2, \ldots, D$$

$$\sum_{h=1}^{H} \delta_h z_{dh} \leq z'_{dj}, d = 1, 2, \ldots, D$$

The optimization problem (P2) now becomes the problem (P3):

$$\underset{(\beta_j, \lambda_1, \ldots, \lambda_H, \delta_1, \ldots, \delta_H, z'_{1j}, \ldots, z'_{dj})}{Maximize} \quad \beta_j$$

such that:

$$\sum_{h=1}^{H} \lambda_h x_{nh} \leq x_{nj}, n = 1, 2, \ldots, N$$

$$\sum_{h=1}^{H} \delta_h y_{mh} \geq \beta_j y_{mj}, m = 1, 2, \ldots, M$$

$$\sum_{h=1}^{H} \lambda_h z_{dh} \geq z'_{dj}, d = 1, 2, \ldots, D$$

$$\sum_{h=1}^{H} \delta_h z_{dh} \leq z'_{dj}, d = 1, 2, \ldots, D$$

$$\lambda_h, \delta_h \geq 0, h = 1, 2, \ldots, H; z'_{dj} \geq 0, d = 1, \ldots, D$$

The model (P2) is used to measure the overall efficiency of DMUs and this model considers the relationship between stages of production. It solved the problem of the previous approach, which saw each sub-process as an independent model. Moreover, besides considering the interaction between processes, the model (P3) also measures the optimal intermediate variables. This is helpful to adjust intermediate measures to achieve the efficiency frontier. Despite some differences between the two models, both models generate the same efficiency score. Therefore, this paper will apply the model (P3) to construct the two stages of evaluating bank's operational performance and bank's profitability, and determine the optimal CAR, which is one of the optimal intermediate products in the model.

4. Data definition and analysis

To achieve the objective of this study, the data set consists of all Vietnamese commercial banks with data available during the period 2010–2015. Thus, among the total of 31 existing Vietnamese commercial banks, the number of banks examined in this study is 28. The data set is collected from the audited financial statement of banks and the banks' annual reports. All variables used will be divided by equity capital to rescale them in the unit of equity, except for the CAR. The bank list in given in Appendix A.

We consider two evaluation stages in this paper: the first stage evaluates bank operation, the second stage examines bank profitability. The chosen inputs, intermediates and outputs are explained in Table 1.

The first intermediate product is *CAR—capital adequacy ratio*. According to Banker et al. (2010) and Berger (1995) the higher capital adequacy ratio will improve the bank's ability to absorb loss. However, the high CAR may cause the reduction in bank's performance, which will lead to the decrease in bank's profit. Therefore, CAR should be the output of the first process and chosen to be the input of the second process.

The second intermediate product is the *deposit*. With the production approach, there is the connection between labor, capital and the deposits. All the banks will use their employees and capital as the inputs (fixed asset and employee expenses) to increase deposit source of the banks. However, in the intermediation approach, they attract the deposits source to lend to others who need money to make their investment in business. Thus, deposit is the output variable of the first stage and treated as the input of the second stage.

The other two intermediate products are *loans and investment*. In general, loans and investment should be viewed as the outputs. The loans include performing and non-performing loans (NPLs), but the NPLs are already included in CAR: the risk-weighted assets; therefore, only performing loans or net performing loans are used in the first stage as output. Both loans and investment bear risks, and it is clear to see the relationship between loans, investment and bank's profitability. Therefore, it is sensible that loans and investment become the intermediate products due to their dual role.

Table 2 presents the descriptive statistics of eight variables of the inputs, intermediate products and the outputs used in the model with the information about 28 Vietnam domestic commercial banks in the period of six years from 2010 to 2015.

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Table 1. Variable definitions and related literature

Inputs/Outputs/ Intermediates	Variables	Definitions and related literature
Inputs (1st Stage)	Fixed Asset	Fixed Asset is the long-term property of banks such as production's equipment, real estate, etc. which are used in production and can hardly gain profit in the short-term. This variable was supported in previous studies by Chen and Zhu (2004); Hung and Lu (2008)
	Employee Expense	Employee Expense is the amount of money that the banks pay for their employees' work. It includes the basic salaries, the bonus of enhance performance, overtime wages and some other fees. This variable was supported in previous studies by Thore et al. (1996); Kozmetsky and Yue (1998); Hung and Lu (2008)
Intermediate Products (which are outputs of the first stage and inputs of the second stage)	CAR	Capital adequacy ratio
	Deposit	Deposit is the amount of money that investors send to their banks' accounts and checking account. The investors can be normal customers, other institutions, and enterprises. This variable was supported in previous studies by Sherman and Gold (1985); Camanho and Dyson (2006): *as an output of the first stage*. This variable was also supported in previous studies by Yue (1992); Miller and Noulas (1996); Weill (2004); Ray (2007); Valverde et al. (2007): *as an input of the second stage*
	Investment	Investment is the long-term investment specially with trading, investment securities of government and other firms, buying government bonds
	Performing Loans	Performing Loans account for loans that banks deliver to customers in Group 1 and 2. Performing Loans exclude sub-standard loans, doubtful and bad debts. This variable was supported in previous studies by Berger and DeYoung (1997); Park and Weber (2006); Banker et al. (2010)
Outputs (2nd Stage)Descriptive statistic of each variable	Interest Income	Interest Income is the revenues gained form the assets related to interests like interest paid by customers, financial institutions who borrow from the banks' asset, etc. This variable was supported in previous studies by Kaufman and Mote (1994); Seiford and Zhu (1999)
	Non-Interest Income	Non-Interest Income constitutes revenues earned from other activities besides the interest related ones, which consist of gain from trading securities and other service activities. This variable was supported in previous studies by Kaufman and Mote (1994); Seiford and Zhu (1999)

In general, the average CAR of commercial banks in Vietnam from 2010 to 2015 is 14.79% which is higher than the requirement of the capital adequacy ratio regulated in the BASEL II—8%. Petromimex Group Commercial Joint Stock Bank (PGB) has the smallest value of capital adequacy ratio, which is 7.55% in 2014.

In that period, the bank with the highest CAR is Ban Viet Commercial Joint Stock Bank (VietCapital), whose CAR is 54.92% in 2010.

Table 2. Descriptive statistic of each variable: inputs, intermediate variables and outputs in the model (%) (all variables are divided by the equity capital)

	Variable	Mean (Average)	Median	Standard Deviation	Minimum	Maximum
Inputs	Employee Expense	15.81%	14.87%	7.02%	4.87%	39.47%
	Fix Asset	14.59%	11.14%	9.89%	1.87%	43.42%
Intermediate Products	CAR (%)	14.79	13.33	5.92	7.55	54.92
	Deposit	828.29%	825.92%	313.91%	246.48%	1742.48%
	Investment	220.77%	206.61%	116.76%	37.28%	582.12%
	Performing Loans	548.59%	499.57%	250.38%	127.70%	1372.05%
Outputs	Interest Income	92.60%	83.80%	36.98%	27.40%	212.90%
	Non-Interest Income	13.04%	8.98%	13.64%	0.44%	82.62%

Table 3. Descriptive statistics of optimal intermediate products obtained from running the model: CAR, deposit, investment and performing loans (%) (all variables are divided by the equity capital)

	Mean	Median	Standard Deviation	Minimum	Maximum
Optimal CAR	19.03	17.84	7.90	5.73	41.52
Optimal Deposit	1255.49%	1147.20%	487.33%	394.88%	3022.62%
Optimal Investment	433.63%	398.14%	206.04%	88.62%	1178.54%
Optimal Performing Loans	684.37%	654.09%	277.45%	120.26%	1643.44%

Table 4. Optimal CARs divided into three categories

	Optimal CARs	
Range	***Number of DMUs***	***% of total DMUs***
CAR < 8%	1	0.8%
8% ≤ CAR ≤ 10.5%	8	6.7%
CAR > 10.5%	110	92.4%

5. Empirical results and discussions

Two-stage DEA model—Data Envelopment Analysis established by Kao et al. (2008) and developed by Chen et al. (2010) is implemented with the computational software MATLAB 2016. As explained in Appendix G, the linear optimization problem (P3) is solved using **linprog** solver with the chosen inputs, intermediates and outputs to obtain the overall efficiency and the optimal intermediates, which are the optimal values of the four intermediate products such as CAR, Deposit, Investment and Performing Loans. The overall efficiency scores are given in Appendix B.

The optimal values of the intermediates are given in Appendices C–F. The descriptive statistics of these obtained optimal intermediates are given in Table 3. We can see that the average optimal deposit, investment and performing loans of Vietnam commercial banks over the period from 2010 to 2015 are 1255.49%, 433.63%, and 684.37% respectively. Compared to the average of the actual proportion of deposit to equity, the investment and the performing loans to equity, which can be

Table 5. Excess CARs divided into three categories

	2015	2014	2013	2012	2011	2010	All	% of All
Less than 0	6	5	7	13	3	7	41	34.45%
Approximately 0	1	2	2	2	1	1	9	7.56%
Greater than 0	9	12	15	9	14	10	69	57.98%

seen in Table 2 that are 828.29%, 220.77%, 548.59%, the average optimal values of all variables are greater than the actual ones.

Also, the average optimal CAR of Vietnam commercial bank is 19.03%, greater than 8% and 10.5%, the BIS required in the BASEL II and in the BASEL III, respectively. The maximum optimal CAR of those banks is 41.52%, this ratio is the optimal CAR of A Chau Commercial Joint Stock Bank (ACB) in 2014. However, Tien Phong Commercial Joint Stock Bank (TPBank) in 2012 has the lowest optimal capital adequacy ratio, which is 5.73%, smaller than the required CAR in BASEL I at 8%.

Next, Table 4 states that 110 DMUs, representing 92.4% of the total number of DMUs, have the optimal CAR greater than 10.5% regulated in BASEL III. Meanwhile, 8 DMUs representing 6.7% of the total number of DMUs have the optimal CAR lying within the range from 8% to 10.5%. Only 1 DMU which is 0.8% of the total number of DMUs gets the optimal CAR less than 8%. Consequently, 99.1% of all DMUs in the period from 2010 to 2015 have the optimal CAR greater than 8% which is the BIS ratio in the BASEL II. Therefore, we can draw the conclusion that the new BIS ratios or the stricter CAR 10.5% in the requirement of capital regulated in the BASEL III will guide the Vietnam commercial banks reach their efficiency frontier, improve their operational performances. 92.4% of banks will not suffer from this new policy. In other words, the stricter required capital adequacy ratios will not have negative impacts on these banks. By obtaining the optimal CAR, they can not only satisfy the new regulated minimum CAR in the BASEL, but also help themselves to reach the efficiency frontier, develop their performances or profitability.

We also define the Excess CAR to be equal to the optimal CAR minus the actual CAR. By measuring the excess CAR, we can examine which banks should raise or reduce their present CAR to obtain the optimal CAR. According to Table 5, 41 banks which means 34.45% of the total number of banks have the excess CAR less than zero. Their actual CAR (each bank in each year) is greater than the optimal one, those banks should reduce their CAR to achieve the optimal one. In contrast, 69 banks which account for nearly 57.98% should increase their own CAR to meet the optimal CAR. The remaining 7.56% of banks have the optimal CAR approximately equal to the actual ones. In other words, the excess CARs of those banks are nearly equal to zero.

Next, we can discuss the ways the banks can use to raise their CAR. By definition, CAR is the ratio of equity capital to weighted risky assets. The equity capital holding includes Tier 1—Core Capital, Tier 2—Supplementary Capital and Tier 3 capital. The Tier 1—Core Capital can be charter capital, retained earning and some other funds; the Tier 2—Supplementary Capital can be converted bonds, added value of fix assets, revalidated securities, long-term debt instruments. In the process of increasing the CAR, the Tier I capital can be raised through issuing shares to the shareholders, paying dividend by stocks instead of cash payment, keeping the earning or profits and not paying dividends to the shareholder, or selling treasury stocks, etc. While the Tier II capital can be obtained by issuing long-term bonds. Another solution is that banks may be looking to increase foreign capital and reduce the percentage of state ownership in Vietnam commercial Joint stock banks. This solution can help reduce the pressure of government budget if these banks want to raise their capital. Moreover, the increase in the private capital will push the banks to be more careful in supervising and using their capital in running business, deciding investment projects and performing services. Because it will lessen the protection of the government for those banks, they will suffer the losses if there is any bad decision in operations with their contributed capital. The government will not be the main provision for banks if they perform poorly or inefficiently. Furthermore, with the decrease in the state ownership, the banks will be less controlled in their operational management, have more independence in making any decisions on bank activities.

6. Conclusions and recommendations

The development together with other countries in the world requires any banks in Vietnam to follow the global standards. The necessity of the minimum capital adequacy ratios is emphasized in the BASEL I, II, and III. It is stipulated to become a buffer for the banks when facing against any risks, to increase the ability of banks to absorb the losses. The minimum required CAR has increased and been controlled more strictly from BASEL I, II to BASEL III.

In this study, the two-stage Data Envelopment Analysis method developed by Chen et al. (2010) is used to measure the banks' operational efficiency and banks' profitability. Though DEA has been widely used, to our knowledge the theoretical properties of the two-stage DEA estimator have not been proved yet. For this reason, one limitation of this research is the small sample size with twenty-eight banks from the population of thirty-one banks, which is rather small to overcome the biasedness of the DEA estimator. This limitation of small sample size is commonly found in empirical research, for example, in the research work conducted by by Li et al. (2016), Chen and Zhu (2004), Kozmetsky and Yue (1998), Yue (1992), Ray (2007), Park and Weber (2006), Banker et al. (2010), and Seiford and Zhu (1999).

In this context the two-stage Data Envelopment Analysis method helps obtain the optimal values of the intermediate products including the optimal CARs. The data set used in this study includes the available information of eight variables from twenty-eight Vietnamese commercial banks in the six-year period from 2010 to 2015. The empirical results show that the mean of the optimal capital adequacy ratios of Vietnam commercial banks is 19.03% greater than 10.5%. For 92.4% of the banks, their optimal CARs are greater than 10.5%. The results of excess CAR state that 34.45% of the banks have their actual capital adequacy ratio greater than the optimal ones, those banks should reduce their CAR to achieve the optimal ones; while 57.98% banks should increase their own capital adequacy ratio. The remaining 7.56% of the banks have the optimal CAR approximately equal to the actual ones. This indicates that the minimum capital adequacy ratios regulated in the BASEL III is appropriate for Vietnam commercial banks to go towards the efficiency frontier and improve their operational performances.

There are several ways for banks to raise their CAR such as increase the Tier I capital by adding capital through issuing shares, reducing cash dividend payment or keeping the earnings; increase the Tier II capital through issuing long-term bonds, and banks can raise the CAR by reducing the rate of state ownerships in the banks' capital.

In Vietnam, the State Bank has issued Circular No. 22/2019/TT-NHNN, whereby the minimum capital adequacy ratio is 9% from 2020. Previously, in the provisions of Circular No. 41/2016/TT-NHNN, the minimum of capital adequacy ratios was regulated at 8%. The movement of increasing the minimum capital adequacy ratio from 8% to 9% by the State Bank of Vietnam is to prepare the way for the application of the Basel III standards to Vietnam banking system. Despite the difference in accounting standards to compute CAR and data unavailability of some banks, this research is useful for bank managers and regulators to help Vietnam banking system meet the global standards.

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Appendix A. Bank list

	Security Code	Stock Exchange	Bank's Name
1	STB	HOSE	Sai Gon Thuong Tin Commercial Joint Stock Bank - SacomBank
2	ACB	HOSE	A Chau Commercial Join stock bank
3	SHB	HOSE	Saigon Hanoi Commercial Joint Stock Bank
4	VCB	HOSE	Commercial Joint Stock Bank for Foreign Trade of Vietnam - VietcomBank
5	CTG	HOSE	Vietnam Joint Stock Commercial Bank for Industry and Trade - VietinBank
6	EIB	HOSE	Vietnam Commercial Joint Stock Export Import Bank - EximBank
7	Techcombank	HOSE	Vietnam Technological Commercial Joint Stock Bank
8	SCB	OTC	Saigon Commercial Joint Stock Bank
9	LPB	HOSE	LienViet Post Joint Stock Commercial Bank
10	HDBank	HOSE	Ho Chi Minh Development Joint Stock Commercial Bank
11	OCB	OTC	Orient Commercial Joint Stock Bank
12	SGB	OTC	Saigon Commercial Joint Stock Bank for Industry and Trade - Sai Gon Cong Thuong
13	ABBank	OTC	An Binh Commercial Joint Stock Bank
14	TPBank	HOSE	Tien Phong Commercial Joint Stock Bank
15	KLB	OTC	Kien Long Commercial Joint Stock Bank
16	VietABank	OTC	Vietnam Asia Commercial Joint Stock Bank
17	NVB	HNX	National Citizen Commercial Joint Stock Bank
18	NamABank	OTC	Nam A Commercial Joint Stock Bank
19	VietCapital Bank	HNX	Viet Capital Bank Commercial Joint Stock Bank
20	VPBank	HOSE	Vietnam Prosperity Joint Stock Commercial Bank
21	MBB	HOSE	Military Commercial Joint Stock Bank
22	MSB	HOSE	Vietnam Maritime Commercial Stock Bank
23	VIB	HOSE	Vietnam International Commercial Joint Stock Bank
24	BID	HOSE	JSC Bank for Investment and Development of Vietnam
25	PGB	OTC	Petrolimex Group Commercial Joint Stock Bank
26	NASB	OTC	North Asia Commercial Joint Stock Bank
27	SeaBank	OTC	Southeast Asia Commercial Joint Stock Bank
28	DongABank	OTC	Dong A Commercial Joint Stock Bank

Appendix B. Overall Efficiency

	2015	2014	2013	2012	2011	2010
STB		2.6846	2.8055	3.9231	2.5406	2.3391
ACB	2.0204	2.3859	2.5630	1.3924	1.3030	1.3870
SHB	1.2866	1.4958	2.0371	2.3192	2.1963	2.9474
VCB	1.7755	1.7966	2.0350	1.9932	1.9961	1.8043
CTG	1.8355	2.2173	2.3167	2.0137	1.8113	
EIB	1.9188	2.2064	1.9994	2.0329	1.5368	1.6278
Techcombank	1.3491	1.2594	1.1077	1.5121	1.3209	1.5084
SCB						1.4530
LPB						
HDBank	1.6254	1.4896	2.2723	1.3153	1.4600	1.5175
OCB			2.5002	2.0410		
SGB	2.0424	2.0741	2.4830	2.4283		
ABBank	2.1459	2.5353	3.1866			
TPBank				1.3823		1.5701
KLB	2.0093	2.4224	2.8553	3.0020		
VietABank						
NVB	1.8350	2.4323	3.4187	1.5327	1.2982	1.1630
NamABank	1.6085	2.4300	2.4215	2.0953	1.9094	2.4095
VietCaptal Bank	2.0284	1.8934	1.0502	1.6157	2.2169	2.3319
VPBank	1.0000	1.0000	1.0000	1.1315	1.1732	
MBB		1.2532	1.3466	1.2918		1.0401
MSB	1.0367	1.2004	1.3016	1.2399	1.0412	
VIB	1.7671	1.3730	1.6942	1.2703	1.0721	1.1090
BID			1.7789	1.3038	1.9680	1.8769
PGB		1.6101	2.4312	2.0396	2.6207	2.4303
NASB			1.0620	1.0000		
SeaBank			1.1732	1.0000	1.0080	1.1898
DongABank			2.6546	2.6172	2.2781	2.3037

Appendix C. Optimal CARs (%)

	2015	2014	2013	2012	2011	2010
STB		23.43	33.31	39.30	31.09	25.58
ACB	28.41	41.52	39.29	23.73	26.37	33.50
SHB	18.09	15.27	22.44	19.75	29.20	29.75
VCB	11.43	16.98	19.92	12.38	22.82	28.52
CTG	18.73	22.63	24.97	24.68	33.58	
EIB	18.25	13.94	19.93	17.51	16.48	13.79
Techcombank	12.33	14.63	14.03	17.81	20.98	30.62
SCB						21.12
LPB						
HDBank	15.08	19.85	18.51	10.33	21.90	22.59
OCB			21.43	13.18		
SGB	11.89	8.60	14.47	12.10		
ABBank	18.56	24.91	27.97			
TPBank				5.73		10.56
KLB	17.96	15.65	24.40	19.26		
VietABank						
NVB	21.69	19.29	28.45	10.91	10.82	17.84
NamABank	17.16	18.00	17.99	10.61	10.63	13.42
Vietcapital Bank	12.08	10.72	20.99	8.83	9.73	9.33
VPBank	12.20	11.36	12.50	16.10	16.44	
MBB		10.07	15.28	12.61		11.60
MSB	8.90	19.04	15.00	13.20	15.38	
VIB	13.78	10.89	9.99	12.44	14.48	10.88
BID			31.22	19.29	35.82	39.88
PGB		11.37	17.95	11.71	26.58	25.66
NASB			21.31	12.46		
SeaBank			14.29	15.50	13.51	13.72
DongABank			36.89	25.97	28.69	28.50

Appendix D. Optimal Deposits (%)

	2015	2014	2013	2012	2011	2010
STB		2285%	2124%	3023%	1798%	1724%
ACB	1909%	2083%	2489%	1484%	1625%	1695%
SHB	1179%	1489%	1431%	1519%	1689%	2262%
VCB	1032%	1010%	1189%	943%	1347%	1629%
CTG	1177%	1445%	1588%	1859%	2080%	
EIB	1053%	1359%	1265%	1353%	953%	815%
Techcombank	864%	939%	895%	1215%	1213%	1619%
SCB						1448%
LPB						
HDBank	1147%	834%	1044%	772%	1267%	1367%
OCB			1367%	1010%		
SGB	648%	838%	923%	931%		
ABBank	1401%	1597%	1784%			
TPBank				395%		551%
KLB	1031%	1526%	1556%	1472%		
VietABank						
NVB	1356%	1881%	1814%	759%	626%	917%
NamABank	1086%	1755%	1015%	816%	615%	1021%
Vietcapital Bank	910%	1005%	604%	678%	563%	569%
VPBank	1045%	1370%	1190%	1163%	1121%	
MBB		1011%	975%	970%		882%
MSB	644%	1029%	957%	1007%	889%	
VIB	732%	693%	840%	884%	868%	978%
BID			1979%	1483%	2072%	2123%
PGB		620%	1017%	888%	1681%	1487%
NASB			1299%	923%		
SeaBank			794%	1052%	781%	691%
DongABank			2353%	1998%	1659%	1712%

Appendix E. Optimal Investment (%)

	2015	2014	2013	2012	2011	2010
STB		847.21%	853.07%	960.57%	623.42%	482.87%
ACB	594.16%	1178.54%	999.84%	294.73%	536.19%	620.10%
SHB	366.07%	552.15%	571.50%	483.60%	585.65%	532.78%
VCB	329.17%	475.36%	467.31%	213.42%	459.62%	598.26%
CTG	376.73%	700.59%	632.44%	343.63%	683.65%	
EIB	335.30%	503.85%	500.36%	409.04%	330.58%	273.74%
Techcombank	292.78%	466.02%	355.76%	183.64%	420.68%	584.87%
SCB						398.14%
LPB						
HDBank	366.13%	417.80%	424.53%	109.55%	439.19%	483.75%
OCB			547.22%	278.72%		
SGB	211.25%	310.76%	377.09%	296.39%		
ABBank	404.70%	772.52%	716.84%			
TPBank				90.40%		199.12%
KLB	335.59%	565.85%	613.16%	456.47%		
VietABank						
NVB	419.06%	697.26%	726.74%	96.52%	217.06%	335.41%
NamABank	326.83%	650.73%	388.88%	259.91%	213.10%	240.90%
Vietcapital Bank	284.16%	410.68%	132.96%	137.52%	195.13%	183.05%
VPBank	374.16%	582.12%	488.54%	328.30%	342.24%	
MBB		378.58%	389.71%	308.17%		207.38%
MSB	186.89%	514.39%	384.66%	250.77%	308.34%	
VIB	293.01%	323.69%	336.58%	233.31%	253.17%	236.21%
BID			791.91%	431.58%	718.38%	765.41%
PGB		340.87%	413.93%	193.03%	543.66%	534.79%
NASB			526.97%	88.62%		
SeaBank			322.08%	223.20%	270.94%	259.28%
DongABank			943.93%	624.68%	575.41%	563.16%

Appendix F. Optimal Performing Loans (%)

	2015	2014	2013	2012	2011	2010
STB		1298.02%	1136.19%	1643.44%	783.70%	1001.88%
ACB	1327.39%	708.11%	1320.18%	1089.08%	729.67%	872.75%
SHB	817.84%	845.97%	765.42%	825.90%	736.22%	1370.10%
VCB	735.40%	496.26%	629.98%	581.91%	592.92%	871.81%
CTG	841.65%	630.60%	845.60%	1205.48%	935.84%	
EIB	749.08%	771.97%	679.85%	782.89%	415.57%	448.85%
Techcombank	654.09%	453.60%	478.54%	839.08%	528.84%	846.00%
SCB						846.76%
LPB						
HDBank	817.96%	402.38%	469.69%	525.61%	552.10%	743.17%
OCB			730.98%	585.02%		
SGB	471.96%	476.12%	493.68%	506.02%		
ABBank	904.12%	699.70%	954.03%			
TPBank				120.26%		288.30%
KLB	749.73%	866.95%	832.38%	811.85%		
VietABank						
NVB	936.21%	1068.29%	970.48%	533.96%	272.87%	471.87%
NamABank	730.17%	997.00%	560.35%	443.71%	267.88%	618.18%
Vietcapital Bank	634.85%	591.29%	381.72%	443.29%	245.30%	317.99%
VPBank	835.90%	838.13%	657.01%	458.33%	524.55%	
MBB		575.81%	521.26%	527.39%		534.15%
MSB	417.53%	239.53%	511.73%	603.70%	387.61%	
VIB	552.01%	378.53%	461.68%	321.13%	524.62%	606.23%
BID			1049.63%	841.75%	903.08%	1113.12%
PGB		237.72%	463.39%	553.59%	762.79%	799.88%
NASB			596.73%	660.71%		
SeaBank			346.65%	290.75%	340.60%	351.52%
DongABank			1258.31%	1097.55%	723.35%	950.10%

Appendix G. The use of MATLAB software and results

This research applies MATLAB software to solve the optimization problem (P3). Both objective function and constraints are linear, thus, the **linprog** solver is utilized in this analysis, which solves problems of the form:

$$\min_x f^T x \text{ such that } \begin{cases} A \cdot x \leq b, \\ Aeq \cdot x = beq, \\ lb \leq x \leq ub. \end{cases}$$

where

- $f^T x$ means a row vector of constants *f* multiplying a column vector of variables *x*. Then $f^T x = f(1)x(1) + f(2)x(2) + \ldots + f(n)x(n)$, where *n* is the length of the vector *f*.
- $Ax \leq b$ illustrates linear inequalities. Matrix *A* is a *k*-by-*n* matrix, where *k* is the number of inequalities and *n* is the number of variables (size of *x*). Vector *b* is a vector of length *k*.

- *Aeq x* = *beq* displays linear equalities. Matrix *Aeq* is an *m*-by-*n* matrix, where *m* is the number of equalities and *n* is the number of variables (size of *x*). Vector *beq* is a vector of length *m*.
- *lb* ≤ *x* ≤ *ub* shows that each element in the vector *x* must be greater than the lower bound *lb* and less than upper bound *ub*.

The syntax of the **linprog** solver is [*x fval*] = **linprog** (*f, A, b, Aeq, beq, lb, ub*).

An example of the results of Overall Efficiency, Optimal CAR, Optimal Deposits, Optimal Investment, Optimal Performing Loans for STB bank