Determinant of Capital Adequacy Ratio: Evidence from Commercial Banks in Vietnam

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Abstract. The Capital Adequacy Ratio (CAR) is an important measure indicating the level of safety in business operation activities. The paper is conducted to investigate the factors affecting banks' CAR in Vietnam during the period from 2008–2021. By using the sample data of 21 commercial banks with Bayesian mixed-effect regression, the results confirm that both bank-characteristic, macroeconomic factors affect bank's capital adequacy ratio. The variables that have a strong positive impact on capital adequacy ratio include the ratio of equity to total assets, deposits ratio, liquidity ratio, CPI. The variables of bank size, profitability indicator, COVID-19 pandemic have strong negative impact. The ratio of loan to total assets, loan growth rate, CPI have a weak impact on CAR From the results, the paper suggests some recommendations to increase this ratio in the future time.

Keywords: Bayesian mixed-effects · capital adequacy ratio · COVID-19

1 Introduction

The capital adequacy ratio (CAR) is an economic indicator that reflects the relationship between equity and risk-adjusted assets of commercial banks. This indicator is an important measure indicating the level of safety in business operation activities, which is built and developed by leading experts in the banking sector under the Basel Committee. In Vietnam, these days, according to circular No. 41/2016/TT-NHNN dated December 30, 2016, on prescribing the capital adequacy ratio for operations of banks and /or foreign bank branches of the Governor of the State Bank, commercial banks must maintain a capital adequacy ratio of at least 8%. Although Circular 41 is only "covered" in part by the Basel II Accord, ensuring these fairly stringent requirements necessitates significant efforts on the part of banks. According to SBV (2022), the average capital adequacy rate of banks in Vietnam is 11.59%, separately with the group of joint stock commercial banks, this rate is at the level 12.03%.[1] However, this ratio in Vietnam remains very low

[1] Access from https://www.sbv.gov.vn/webcenter/portal/vi/menu/trangchu/tk/hdchtctctd/tkmsctcb?_afrLoop=63880681920440224#%40%3F_afrLoop%3D63880681920440224%26centerWidth%3D80%2525%26leftWidth%3D20%2525%26rightWidth%3D0%2525%26showFooter%3Dfalse%26showHeader%3Dfalse%26_adf.ctrl-state%3Dwew2kbkqq_4en.

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when compared to the ASEAN + 5 countries, which range from 16% to 24%. (World Bank, 2022). As a result, the increase in capital is weighing on Vietnam's joint stock commercial banks, particularly small-scale banks. Therefore, understanding the factors affecting the CAR is essential for commercial banks to take measures to increase this ratio in the coming time.

According to the authors' knowledge regarding this topic, although several studies have been conducted in Vietnam as well as other countries, such as Vo, Nguyen & Do (2014), Pham & Nguyen (2017), Vu and Dang (2020), Aktas, Bakin & Celik (2015), El-Ansary & Hafez (2015), etc. However, these research results are not conclusive. Moreover, these studies mostly use some traditional estimation methods such as pooled OLS, FEM, REM, GMM. When applying these methods, the results are based only on data without incorporating prior information (Ngọc Thạch, 2019), thus there is a limitation that various studies mention in that the data is not enough to represent the population. In addition, these studies mainly focus on analyzing the impact of internal factors on the capital adequacy ratio without emphasizing the role of external factors.

This paper examines the determinants of the capital adequacy ratio of commercial banks in Vietnam during the period from 2008–2021. The paper makes several contributions to the existing literature. Firstly, it provides empirical evidence on the factors affecting the capital adequacy ratio with sample data of 25 commercial banks in Vietnam. Secondly, one of the limitations that previous studies usually mentioned is that data is not population, since most of them used frequentist inference. Different from these studies, in order to overcome that issue, the paper applied the Bayesian approach, this is a new point to supplement the research gap. Compare to frequentist inference, the Bayesian framework has several advantages, such as this method is based not only on research data but also on prior information, hence, with this combining, the results of Bayesian approach are more accurate as well as overcoming the limitation of data sample size. The third is, besides the bank-specific factors, this paper also implement several factors belonging to the macroeconomy, such as GDP growth, inflation and COVID-19 pandemic.

The remaining parts of this research are structured as follows. Section 2 presents the literature review, Sect. 3 describes the data, model, and methodology. Section 4 analyzes the empirical results and finally, we have some conclusions and suggest some policy implications.

2 Literature Review

Until now, there are pretty much previous studies that have explored the determinants of capital adequacy ratio. Aktas et al. (2015) analyze the impact of bank-dimensional and environmental factors on banks' capital adequacy ratio in the South Eastern European (SEE) region. Using the annual data from 71 commercial banks in 10 different countries in the SEE region in the time of 2007–2012, with a feasible GLS regression, the results show that both dimensional explanatory variables (such as bank size, ROA, leverage, liquidity, net interest margin, risk) and the environmental factors (such as economic growth rate, Eurozone stock market volatility index, deposit insurance coverage, and governance) have significant effects in determining CAR for the bank in the region.

When investigating Egyptian bank sectors, El-Ansary & Hafez (2015) use the sample data of 36 banks in the period from 2004–2013. The research results vary according to the period understudy. In 2007–2013, liquidity, management quality and size are the most significant variable. Before the financial crisis, the variables affecting the capital adequacy ratio include size, asset quality and profitability. After 2009, asset quality, size, management quality, liquidity and credit risk are the most significant variables. Also, on this topic, El-Ansary & Hafez (2015) conduct research on the banking system in Albania. Using quarterly data from Q1/2007 to Q3/2014 of 16 private banks examine the factors affecting the capital. The results find that profitability indicators (such as ROA, ROE) do not have any influence on CAR, while non-performance loan, loan to deposit ratio and equity multiplier have a negative impact, whereas the bank size has a positive impact on capital adequacy ratio. In addition to these studies, several previous also consider the factors that influence on capital adequacy ratio, for example, Yu (2000), Bateni et al (2014), Ahmet & Hasan (2011), Kleff, V., & Weber, M. (2008).

Recently, Smaoui, Salah & Diallo (2020) have researched of determinants of capital in the Islamic banking system. By using a sample data of 122 Islamic banks during 2000–2014, the paper applies the system Generalized Method of Moments (GMM) estimator. The results indicate that deposit structure, bank size, and bank competition are significantly negatively related to Islamic banks' capital ratio, thus the authors confirm the "too-big-to-fail" theory. Besides, the generous deposits insurance system leads to lower Islamic banks' capital ratio.

Regarding the data sample of Vietnamese commercial banks, so far there have been a number of studies discussing the factors affecting the capital adequacy ratio, for example, Vo, et al. (2014); Pham & Nguyen (2017), Vu and Dang (2020),… In which, Vo et al. (2014) use the data from 28 commercial banks over a five-year period from 2007 to 2012. By FGLS regression, the research results find that liquid asset, and loan loss reserves have a positive impact on the capital adequacy ratio, whereas bank size, customer deposit ratio, and return on equity have a negative influence on the bank's CAR. With the sample data of 29 commercial banks in the period from 2011–2015, Pham and Nguyen (2017) use the fixed effect model (FEM) and random effect model (REM), the research results indicate that the ratio of net interest margin and liquidity ratio have a significant positive effect on CAR. But bank size and bank leverage (represented by ratio of equity to total liabilities) do not appear to have a significant effect on CAR. Variables loan loss reserves and loan to total assets are negatively related to CAR. Vu & Dang (2020) use data from 31 commercial banks during the period from 2011–2018. The results confirm that bank leverage, loan loss reserves, and return on equity have a negative impact, return on assets has a positive impact, while bank size, deposit, loan ratio, liquidity, net interest margin and non-performing loans do not significantly influence the CAR of Vietnamese commercial banks.

In sum, the topic of the determinant of capital adequacy ratio has received the attention of many scholars. However, these research results are inconclusive. In addition, most of the previous studies mainly study the internal factors without the macroeconomic condition. That is why the research is conducted to confirm the factors affecting on capital adequacy ratio of commercial banks in Vietnam, including the bank-specific and macroeconomic factors as well as the situation of the COVID-19 pandemic. From

the research results, the paper suggests some recommendations to increase the bank's CAR in the future time.

3 Method, Model and Data

3.1 Methodology

To analyze the factors affecting on capital adequacy ratio, a multilevel model is applied. In literature, there are various sectors using multilevel approaches, from health, and social science to econometrics, for example, Simons-Morton, Simons Morton & Bunker (1988), who analyzed influencing personal and environmental conditions for community health; or Tseloni (2006), who investigated the impact of household and area on the incidence of total burglaries, property crimes, and thefts. In this paper, the authors use the multilever (mixed-effects) perspective in a Bayesian approach for several reasons as follows.

Firstly, mixed–effects models are characterized as including random effects and fixed effects. The fixed effects model indicates that the individual-specific effect is correlated to independent variables, they are estimated directly as well as similar to standard regression parameters. The random effects are not estimated directly but are summarized according to their estimated variances and covariances. Random effects might take the form of either random intercepts or random parameters, and the grouping structure of the data may consist of multiple levels of nested groups. Hence, mixed-effect models are also known as hierarchical and multilevel models. Essentially, fixed effects are defined as the predictor variables which effects you are interested in after calculating for random variability (so, fixed). Random effects are as noise in the data. These are effects that arise from uncontrollable variability within the sample. Subject level variability is often a random effect.

Secondly, these days, the Bayesian probabilistic approach is sound more popular than traditional statistics. According to Nguyen & Nguyen (2018). Nguyen et al. (2019), the Bayesian framework has several strong advantages over traditional inference. Firstly, with the frequentist inference through some traditional estimations (such as pooled-OLS, fixed effect models, random effect models), these estimators were based on the data without incorporating prior information (Ngọc Thạch, 2019). Unlike this inference, the results of the Bayesian approach are based not only on data but also on prior observations. Thank this combination, the results of Bayesian inference are more accurate and reliable as a limit is not set to the data sample size. Besides, the traditional estimators have the possibility of omitting variable that is not significant despite potentially affecting the analysis, while the Bayesian approach considers the influence of all variables.

In this study, in order to investigate the determinants of capital adequacy ratio, this research employs a Bayesian mixed-effects regression, in which both two models without and with random effects (intercepts) are estimated. The difference between commercial banks in the initial capital adequacy ratio is reflected by random intercepts. The authors use GDP, CPI and DUMMY as three control variables in the research model. A Bayes factor test and a model test will be used to choose the more appropriate model. In terms of prior information, Lemoine (2019) strongly proposes informative priors, and Block et al. (2011; 2012) recommend standard Gaussian distributions for model parameters.

3.2 Description of Variable

3.2.1 The Independent Variable: Bank Capital Adequacy Ratio (CAR)

In order to provide general principles and banking laws, the Basel Committee on Banking Supervision (BCBS) has proposed versions that commercial banks must comply with. In which, according to Basel 1, the CAR is calculated as follows:

$$CAR = \frac{Capital\ (\ Tier\ 1\ +\ Tier\ 2)}{Risk\ \ weighted\ \ assets\ (RWA)}$$

According to Basel 1, banks are required to maintain this ratio at a minimum of 8%. Basel 1 divided the bank's equity into two categories: core capital and supplementary capital. Tier 1 capital is core capital, including permanent shareholders' equity and disclosed reserves. Tier 2 capital, is supplementary capital, including undisclosed reserves, asset revaluation reserves, general loan-loss reserves, and hybrid capital instruments. Tier 3 capital including short-term subordinated debt, this capital is not taken into account when calculating the capital adequacy ratio because of its lowest reliability.

The publication of Basel 1 along with detailed regulations had great significance for the risk management of commercial banks. However, the development of banking activities in the world had made the application of Basel 1 reveal several limitations. Hence, in 2004, the BCBS published Basel 2 guidelines aiming to refine and reform the version of Basel 1. Basel 2 is divided into three pillars related to minimum capital requirements, supervisory review and market discipline. In the first pillars, the CAR is set at a minimum of 8% and is calculated as follows:

$$CAR = \frac{Capital}{RWA\ (Credit\ \ risk) + RWA\ (\text{Operational risk}) +\ \ RWA\ (Market\ \ risk)}$$

These days, in Vietnam, the State Bank issued Circular No. 41/2016/TT-NHNN. Accordingly, the commercial banks must maintain a CAR of at least 8% and the CAR is calculated by the following formula. This formula is used to measure CAR in this paper:

$$CAR = \frac{C}{RWA\ +\ 12,5\ (K_{OR} + K_{MR})} \times 100\% \quad (1)$$

In which:
C: Total equity capital
RWA: Credit risk adjusted Assets
K_{OR}: Regulatory capital for operational risk
K_{MR}: Regulatory capital for market risk

3.2.2 The Factors Affecting Capital Adequacy Ratio

Internal Factors

Bank Size

According to Pham & Nguyen (2017), the logarithm of total assets is used to measure bank size. The literature on the banking sector shows that banks with larger scales have a

better reputation as well as are more experienced (Smaoui, Salah & Diallo, 2020). Hence, larger banks are easily able to diversify their asset portfolio. At the same time, many methods of mobilization are also implemented, which increases the capital adequacy ratio and reduces the risks. When analyzing the Albanian banking system in the period from 2007–2014, Shingjergji & Hyseni (2015) indicate that the positive relationship between bank size and CAR.

However, contrary to the above view, the theory of "too big to fail" argues that large banks typically hold a diverse portfolio of deposit claims, making their deposits less risky than those of small banks (Yu, 2000). This causes large banks to tend to take on excessive risk by allocating more capital to risky assets, in order to increase expected return, leading to increased risks for their assets portfolio. Several previous empirical pieces of evidence have shown the negative relationship between bank size and capital adequacy ratio, such as those of Dreca (2013), Bateni et al (2014), El-Ansary & Hafez (2015), and Akta et al. (2015).

Bank Leverage (LEV)

In this paper, the authors measure bank leverage with the equity to total assets ratio. Hence, a high LEV denotes high equity or low leverage whereas a low LEV indicates low equity or high leverage. According to Ahmet & Hasan (2011), shareholders would discover that highly leveraged banks (lower equity to total assets ratio) are riskier than other banks. So they require a Nguyen Thi Nhu Quynh higher expected rate of return. Consequently, the high leveraged banks (lower equity to total assets ratio) may hold less equity capital and deal with difficulty in raising new equity because of the high cost of equity. So the authors suggest a positive correlation between LEV and capital adequacy ratio.

Loan Loss Provision

Loan loss provision is calculated by the ratio of loan loss provision to total loan outstanding (Vo, et al. 2014). Vu and Dang (2020) indicate that the ratio of loan loss provision is a proxy for bank risk and this indicator could demonstrate the bank's financial health. When a bank has a bad loan, it must set aside reserves, these provisions are taken from its earnings or its equity if earnings are not enough, which would reduce its capital. In addition, a higher loan loss provision ratio also indicates a higher bank risk, which would make it has more challenge to raise capital. So the paper believes that a negative link between the loan loss provision ratio and the capital adequacy ratio. In the literature term, this is consistent with several empirical evidence such as Aktas et al. (2015), Vu & Dang (2020), El-Ansary & Hafez (2015).

Deposit Ratio

The deposit ratio is measured by the ratio of the customer deposit to total assets (Vo et al. 2014). According to Kleff & Weber (2008), comparing other sources of capital (new equity, bond financing), deposits can be the cheapest. In practical terms, customers tend to deposit at financial institutions with a good reputation and high brand, so an increase in deposits signals that banks and other financial institutions as financial intermediaries have implemented suitable capital mobilization strategies, and their brand is affirmed through the trust of a customer. The results of Masood & Ansari (2016) show a positive

relationship between deposit and capital adequacy ratio. Hence this paper is also expected to have a positive linking between deposit and CAR.

Loan Ratio

The loan ratio is calculated as the ratio of the customer loan to total assets. On the balance sheet, total loans play the most important role in generating income for the bank. However, lending has two faces. Firstly, it provides the major earning for banks, and otherwise, lending is a source of credit risk. The credit risk and earnings from lending depend on the characteristics of the loan and the level of portfolio diversification of a bank. According to Vu and Dang (2020), the more loans extended, the higher the risk. Hence, a larger amount of capital will be needed to hedge the risk, so the research demonstrates the positive association between loan ratio and capital adequacy. This relationship is consistent with Mpuga (2002), and this is a reason why the paper expected a positive relationship between loan ratio and CAR.

Liquidity Ratio

Most previous studies also agree that the relationship between liquidity ratio and CAR is positive. According to Bitar, Hassan & Hippler (2017), the banks with higher liquid assets are more able to raise debt, which could increase bank capital holdings. Angbazo (1997) states that as the proportion of funds invested in cash or cash equivalents increases, a bank's liquidity risk declines, leading to a lower liquidity premium in the net interest margins. Moreover, a higher level of bank liquidity has a favorable effect on the capital ratio by altering the required rate of return on bank shares (Mehranfar, 2013). When the bank ensures the input and output cash flow, it means ensuring liquidity, thereby helping the bank increase profits and capital sources. The CAR improves as a result of this. Hence, the authors suggest a positive associate between liquidity ratio and CAR in commercial banks in Vietnam.

Profitability

According to the pecking order theory, firms in general and commercial banks, in particular, prefer internal over external financing (Rahman, 2019), internal capital can be mentioned as retained earnings. The reason is external financing emits various negative signals (Belkhir, Maghyereh & Awartani, 2016). Hence, when banks make a profit, they tend to use this profit to increase capital with the goal of making more earnings in the future. Several empirical pieces of evidence, such as El-Ansary & Hafez (2015), Keqa (2021) find a positive relationship between profitability and the capital adequacy ratio. As a result, the predicted sign of the profitability variable's coefficient is positive. There is a different proxy for profitability, similar to Vo et al. (2014), in this paper, the authors use an indicator of ROE to represent profitability.

Loan Growth Rate

Banks are financial intermediaries, having the role of moving the capital from places of excess to places of shortage capital. Therefore, if loans increase, this could result in an increase in capital requirement (Ayuso, Pezer & Saurina, 2004). Thus, the relationship between loan growth rate and capital adequacy ratio is expected to be positive.

Besides internal factors, several external factors also influence capital adequacy ratios, such as gross domestic growth, inflation, or the COVID-19 pandemic situation. The next part of this paper will discuss these factors.

External Factors

Gross Domestic Product

When the economy has a good growth rate, investment activities, as well as the production and business of enterprises, are promoted. As a result, the bank's lending increases and encourages it to raise bank capital holdings. Moreover, according to Vithessonthi (2014), during economic booms, banks may increase their capital holding because of the rapid expansion of credit growth. So the predicted sign of this variable's coefficient can be positive.

Inflation

According to Bitar et al. (2017), when the inflation of the economy is high, central banks will take some necessary measures to deal with this situation such as increasing interest rates, and increasing the required reserve,… Thereby inducing firms and banks to borrow less, which favors the use of equity financing, so the paper expects a positive association between inflation and capital adequacy ratio.

COVID-19

According to Özlem Dursun-de Neef & Alexander Schandlbauer (2022), during the COVID-19 pandemic, individuals and households were not able to spend money on relaxation activities because of mobility restrictions. As a result, they can accumulate savings in their deposit accounts. Hence, banks can increase deposits, and they also use additional funds to issue more real estate loans. This leads to an increase the bank capital holding, this is a reason why the paper suggests the positive link between COVID-19 pandemic and the capital adequacy ratio.

3.2.3 Specific Model

To examine the factors affecting on capital adequacy ratio in Vietnamese joint stock commercial banks, according to Smaoui et al. (2020), Vu & Dang (2020), Aktas. Bakin & Celik (2015), Vo et al. (2014), Ho & Hsu (2010) the study estimates a regression equation as follows:

$$\begin{aligned} \boldsymbol{CAR}_{i,t} =& \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1 BANKSIZE}_{i,t} + \boldsymbol{\alpha_2 LEV}_{i,t} + \boldsymbol{\alpha_3 LLR}_{i,t} + \boldsymbol{\alpha_4 DEP}_{i,t} + \boldsymbol{\alpha_5 LTA}_{i,t} \\ &+ \boldsymbol{\alpha_6 LIQ}_{i,t} + \boldsymbol{\alpha_7 ROE}_{i,t} + \boldsymbol{\alpha_8 LGR}_{i,t} + \boldsymbol{\alpha_9 GDP}_{t} \\ &+ \boldsymbol{\alpha_{10} CPI}_{t} + \boldsymbol{\alpha_{11} DUMMY}_{t} + \boldsymbol{\mu}_i + \boldsymbol{\epsilon}_{i,t} \end{aligned} \quad (2)$$

where i and t refer to bank and year, respectively; α_0 is the constant, μ_i and $\varepsilon_{i,t}$ are banks and time fixed effect.

Table 1 presents definition and the measurement and expected signs of the regression coefficients of the variable in research model.

Table 1. Definition and variables measurement in research model

Notation	Name of variables	Measure/Data source	Sign of expectation	Researches
Dependent variable				
CAR	Capital adequacy ratio	$CAR = \frac{C}{RWA + 12{,}5\,(K_{OR}+K_{MR})}$		Vu and Dang (2020), Nguyen & Pham (2017), Shingjergji & Hyseni (2015), Vo et al. (2014)
BANKSIZE	Bank size	Logarithm (Total asset)	±	Smaoui et al. (2020), Dreca (2013), Bateni et al (2014), El-Ansary & Hafez (2015), Akta et al. (2015), Shingjergji & Hyseni (2015)
LEV	Bank leverage	$\frac{\text{Equity}}{\text{Total assets}}$	+	Smaoui et al. (2020), Ahmet & Hasan (2011), Vo et al. (2014), Vu and Dang (2020)
LLR	Loan loss provision	$\frac{\text{Loan loss provision}}{\text{Total loan outstanding}}$	−	Vo et al. (2014), Vu and Dang (2020), Aktas et al.(2015), El-Ansary &Hafez (2015)
DEP	Deposit ratio	$\frac{\text{Customer deposit}}{\text{Total assets}}$	−	Vo et al. (2014), Kleff & Weber (2008), Masood & Ansari (2016)
LTA	Loan ratio	$\frac{\text{Customer loans}}{\text{Total assets}}$	+	Vu and Dang (2020), Nguyen & Pham (2017)

(*continued*)

Table 1. (*continued*)

Notation	Name of variables	Measure/Data source	Sign of expectation	Researches
Dependent variable				
LIQ	Liquidity ratio	$\frac{Cash\ and\ Cash\ Equivalents}{Total\ assets}$	+	Aspal & Nazneen (2014); El-Ansary & Hafez (2015), Akta et al. (2015),
ROE	Profitability	$\text{ROE} = \frac{Net\ income}{Equity}$	+	El-Ansary & Hafez (2015), Keqa (2021)
LGR	Loan growth rate	$\frac{Cash\ and\ Cash\ Equivalents}{Total\ assets}$	+	Vo et al. (2014), Smaoui et al. (2021)
GDP	Growth domestic product	$\frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}$	+	Akta et al. (2015), Smaoui et al. (2021)
CPI	Inflation	$\frac{CPI_t - CPI_{t-1}}{CPI_{t-1}}$	+	Smaoui et al. (2021)
DUMMY	COVID-19	Dummy variable with a value of in year of the COVID-19 pandemic and 0 for the remaining years	+	Suggested by the authors

Source: Various authors

3.3 Data Description

This paper uses data from 25 commercial banks in Vietnam during the period from 2008–2021. According to the State Bank of Vietnam (SBV) (2022), there are 31 Vietnamese joint stock commercial banks, but some of them are data omissions. This is the reason why our database includes 25 commercial banks. To examine the factors affecting on capital adequacy ratio, the authors use both bank-level and country-level data. In which, the bank-level data is taken from the audited financial statement or annual report whereas the country-level data is derived from the database of the World Bank. Regarding the COVID-19 variable (DUMMY), it has a value of 1 in the years of the COVID-19 pandemic (2020 and 2021) and 0 for the remaining years.

Table 2. Descriptive statistics of variables

Variable	Obs	Mean	Std. Dev	Min	Max
CAR	329	0.136	0.050	0.066	0.459
BANKSIZE	329	8.015	0.539	6.470	9.250
LEV	329	0.096	0.045	0.041	0.356
LLR	329	0.013	0.006	0.000	0.040
DEP	329	0.638	0.122	0.292	0.894
LTA	329	0.560	0.130	0.194	0.852
LIQ	329	0.013	0.015	0.002	0.124
ROE	329	0.114	0.076	0.000	0.315
LGR	329	0.246	0.252	-0.313	1.650
GDP	329	0.059	0.014	0.026	0.072
CPI	329	0.065	0.059	0.006	0.231
DUMMY	329	0.140	0.347	0.000	1.000

Source: The authors' calculations

The results of descriptive statistics of variables in research models are summarized in Table 2 with unbalanced panel data. The observations for each of the variables are 329. The average CAR is 13.6%, which is higher than the minimum ratio prescribed by the Basel committee and SBV. The lowest CAR is 6.62%, which is to the Bank for Investment and Development of Vietnam (BIDV) in 2009. The highest value is 45.89%, which belongs to Eximbank in 2009. Regarding independent variables, the mean value of bank size is 8.015 with the highest and the lowest bank sizes at 6.47 and 9.25, respectively. This indicates that the commercial banks in Vietnam are diverse in scale. The average LEV is 9.6%, which shows that the bank's assets mainly come from liabilities. The average LLR is 1.3%, which signals the proportion is quite low. The mean values of DEP and LTA are 63.8% and 56.0%. Respectively. These indicate that customer deposits are important financing for banks. At the same time, customer loans are mainly banks' assets. The LIQ variables have an average value of 1.3%, showing that the ratio of cash reserves for commercial banks is quite low, which creates motivation to increase earnings. The mean value of the loan growth rate is 24.6%, showing that the loan growth rate for customers of Vietnamese commercial banks is at an average level. In the period from 2008–2021, the mean value of CPI is higher than GDP, which indicates that for several years the economy is not efficient due to the impact of the financial crisis as well as the COVID-19 pandemic.

4 Bayesian Simulation Results

4.1 MCMC Convergence Diagnostics

In order to test the validity of Bayesian inference, we need to check the MCMC convergence, efficiency, and acceptance rate. In which, the mixing properties of MCMC are indicated by efficiency rate. Efficiency indicates the mixing properties of MCMC sequences. High-efficiency rate shows that MCMC sequences mix well, whereas low efficiency implies bad mixing in the simulated MCMC sample. In model research, the acceptance rate obtains 0.81 (the required rate is 0.1), The min, average and max of efficiency rates are 0.92; 0.98 and 1, respectively (the required rate is 0.01). Thus, regarding the acceptance rate and efficiency rate, these rates are satisfied for Bayesian inference.

Concerning the test for chain convergence. The results of chain convergence are presented in Fig. 1. From Fig. 1, the chain convergence, including traces, autocorrelation, cusum and histogram plots show no convergence issue. In particular, the trace plots traverse quickly through the posterior domain, exhibiting no trends; the autocorrelations have no lags; the cusum plots are jagged, intercepting the X axis; the histogram plots resemble the shape of the posterior distributions of the model parameters. To summarize, we can conclude that the parameters of our model have converged to reasonable values.

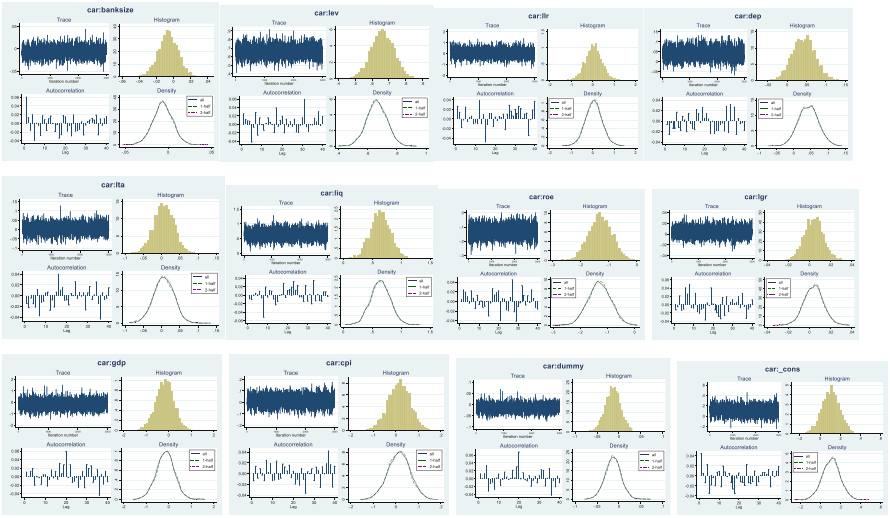

Fig. 1. Convergence diagnostics for the model parameters. *Source: The authors' calculations*

Table 3 denotes that all the parameters of the model have an efficiency of more than 0.91, while the warning level is 0.1. Furthermore, all the correlation times are relatively small.

Thus, from the results of chain convergence, the acceptance and efficiency rates as well as Effective sample size, we can conclude that MCMC sequences have converged to the desired distribution and we can proceed to inference.

Table 3. Effective sample size

	ESS	Corr. time	Efficiency
CAR			
BANKSIZE	2785.45	1.08	0.9285
LEV	2796.79	1.07	0.9323
LLR	2869.24	1.05	0.9564
DEP	3000.00	1.00	1.0000
LTA	3000.00	1.00	1.0000
LIQ	3000.00	1.00	1.0000
ROE	3000.00	1.00	1.0000
LGR	3000.00	1.00	1.0000
GDP	2938.64	1.02	0.9795
CPI	2999.22	1.00	0.9997
DUMMY	2930.67	1.02	0.9769
_cons	2754.99	1.09	0.9183
sigma2	2927.19	1.02	0.9757

Source: The authors' calculations

4.2 Interpretation of Empirical Results

All the model parameters are summarized in Table 4. From Table 4, Monte Carlo chain standard error (MCSE) estimates are close to zero, which indicates that the MCMC algorithm is reasonable. In general, the estimate will have a higher accuracy when the MCMC is lower. Unlike frequentist inference, in Bayesian inference, 95% credible intervals indicate which range the true value of a certain parameter belongs to, e.g., the mean value of variable BANKSZE lies in an interval between −0.0294 and 0.0163 with a 95% probability, and so on.

In view of probability, variables that have a positive effect on capital adequacy ratio include bank leverage (LEV), loan loss provision (LLP), customer deposit ratio (DEP), loan to total assets ratio, liquidity ratio (LIQ), loan growth rate (LGR) and inflation (CPI). In which, the variables of bank leverage (LEV), customer deposit ratio (DEP), liquidity ratio (LIQ) strongly positively contributes to the capital adequacy ratio. The variables of bank size (BANKSIZE), profitability (ROE), growth domestic product (GDP) and COVID-19 pandemic (DUMMY) have a strong negative impact on CAR.

Based on the empirical results, the paper has the following discussion.

Firstly, the regression coefficient of variable BANKSIZE is negative with 71.07% probability. That means the larger the bank size, the lower the capital adequacy ratio, this result is similar to Usman, Lestari & Puspa (2017) when they use the data sample for the banking sector in Indonesia, or Bateni, Vakilifard, & Asghari (2014) when they applied sample data for Iranian banks. According to Usman et al. (2017), a larger size bank usually has a smaller risk, as a reason, the capital adequacy ratio is not as high

Table 4. Posterior model summary

	Mean	Std. Dev.	MCSE	Median	Probability of coefficient mean > 0	Equal-tailed [95% Cred. Interval]
CAR						
BANKSIZE	−0.0062	0.0116	0.0002	−0.0063	0.2893	[−0.0294, 0.0163]
LEV	0.6626	0.0687	0.0013	0.6625	1.0000	[0.5274, 0.7970]
LLR	0.0435	0.3839	0.0072	0.0399	0.5447	[−0.7084, 0.8161]
DEP	0.0427	0.0293	0.0005	0.0430	0.9323	[−0.0136, 0.1012]
LTA	0.0060	0.0275	0.0005	0.0062	0.5873	[−0.0489, 0.0579]
LIQ	0.6392	0.1662	0.0030	0.6386	1.0000	[0.3235, 0.9639]
ROE	−0.1299	0.0418	0.0008	−0.1305	0.0007	[−0.2101, −0.0489]
LGR	0.0040	0.0091	0.0002	0.0041	0.6633	[−0.0139, 0.0223]
GDP	−0.1516	0.4030	0.0074	−0.1450	0.3543	[−0.9564, 0.6314]
CPI	0.0145	0.0486	0.0009	0.0154	0.6230	[−0.0826, 0.1083]
DUMMY	−0.0136	0.0181	0.0003	−0.0134	0.2147	[−0.0497, 0.0215]
_cons	0.1066	0.0904	0.0017	0.1090	0.8827	[−0.0730, 0.2817]
sigma2	0.0012	0.0004	0.0000	0.0011		[0.0007, 0.0022]

Source: The authors' calculations

as a bank with a smaller scale. In practical terms, large banks usually have a high level of security, because they have large enough capital to bear any risky assets. Hence, the capital adequacy ratio has a negative impact on bank size.

Secondly, bank leverage (represented by the ratio of equity to total assets) has a strong positive on the capital adequacy ratio. This result is consistent with initial expectations as well as several previous studies, such as Usman et al. (2017), Ho & Hsu (2010). And this is also completely consistent with the fact that banks with high equity ratios will hold more equity capital, so they will easily raise capital. As a result, the LEV has a strong positive association with the capital adequacy ratio.

Thirdly, the regression coefficient of variable LLR is positive with 54.47% probability, showing that the loan loss provision has an ambiguous impact on the capital adequacy ratio. In fact, loan loss provisions are cash reserves set aside by a bank in anticipation of potential losses from lending (Vu & Dang, 2020). So, the ratio of loan loss provision to total loan is a proxy for bank risk. Therefore, on the one hand, the larger the provision, the more negative impact on the bank's earnings. However, on the other hand, the more provisioning, the more banks are lending. This creates an incentive to increase the bank's earnings, thereby leading to an increase in equity and capital adequacy ratio. So, the ambiguous link between loan loss provision and capital adequacy ratio is also acceptable.

Four is both deposits and loans to total assets have a positive effect on the capital adequacy ratio. In which, the variable of deposit ratio has a very strong impact while the variable of loan to total assets has a relatively weak impact. This is reflected in the reality of the business activities of commercial banks in Vietnam. In reality, customer deposits are the cheapest financing, which is the premise for the bank to perform other business operations and generate bank profit. Whereas lending activities have two opposite sides, on the one hand, lending activities will promote generating the main bank's income; on the other hand, in the case the banks have poor loan management efficiency, it will negatively affect loan quality, thereby increasing non-performing loans. As a result, the bank's profit would reduce. Therefore, customer deposit has a strong positive while the loan to total assets has a weak positive effect on the capital adequacy ratio.

Fifth, the results show that bank liquidity affects a very strong positive on the capital adequacy ratio (the regression coefficient is positive with 100 probability). This result is similar to initial expectations and most previous studies, such as Angbazo (1997), Aspal & Nazneen (2014), El-Ansary & Hafez (2015), Akta et al. (2015). Literally, when the ratio of cash or cash equivalents increases, the bank's liquidity is higher. As a result, the capital adequacy ratio also increases. So the link between liquidity ratio and CAR is a very strong positive.

Sixth, the regression coefficient of ROE (a proxy for profitability indicator) is negative with a probability of approximately 100%. Although this result contradicts the initial expectation as well as some research by Gropp & Heider (2007). However, this result is similar to Vo et al. (2014) when they analyze commercial banks in Vietnam or Jim Wong, Ka-fai Choi & Tom Fong (2005) with their database of banks in Hong Kong. This finding indicates that commercial banks usually try to achieve the goals of shareholder wealth maximization by deciding to invest as much as possible in profitable assets withholding capital from internal financing such as retained earnings. Then, the banks tend to invest in riskier portfolios and loans, which leads to increase bank risks and thus CAR decrease.

Seventh, the positive regression coefficient between the loan growth rate and the capital adequacy ratio with a probability of 66.33% signals the ambiguous relationship between the loan growth rate and CAR. This finding is consistent with the low-level study's sign expectation. The reason is that in Vietnam, commercial banks are not allowed to grow credit freely. Instead, they have to follow the control of the State Bank to match the macroeconomic situation.

Finally, the economic condition also affects the capital adequacy ratio. In which, GDP is negative whereas the inflation rate (CPI) is a positive effect. These harmonize perfectly with practicals in Vietnam. When the economy has a good growth rate, enterprises, and individuals tend to borrow to invest. At the same time, commercial banks also tend to use idle capital to make profitable investments, which leads to increase bank risk and reduced capital adequacy ratio. On contrary, when the economy has high inflation, State Bank has various measures to deal with the situation (Bitar et al., 2017). As a result, firms and individuals borrow less, which increases the bank holding capital, thereby increasing the capital adequacy ratio. Finally, the COVID-19 pandemic (represented by the DUMMY variable) has a negative influence on the capital adequacy ratio. Although this result is not consistent with the expectation of research, however, it reflects the actual situation in Vietnam. During the COVID-19 pandemic (the year 2020, 2021), due to the impact of social distancing, enterprises, households, and individuals reduced borrowing. But at the same time, a relatively large amount of capital was withdrawn from banks to invest in the stock market channel. This leads to reducing the holding capital of the banks, thus, their CAR is reduced.

In sum, among of variables, bank size, profitability indicators, and the COVID-19 pandemic have a strong negative impact, whereas bank leverage (represented by the ratio of equity to total assets), deposits ratio, liquidity ratio, and CPI are motivating factors for a bank to increase the CAR. The variables, ratio of loan to total assets, loan growth rate, and CPI have ambiguous influences on the dependent variable. From these findings, the next section of the paper suggests some recommendations to increase the capital adequacy ratio.

5 Conclusion

This research investigates the determinants of the capital adequacy ratio of commercial banks in Vietnam in the time of 2008–2021. By Bayesian mixed-effects regression with the sample data of 25 commercial banks, the results show that both external factors and internal factors affect CAR. In which, the variables that have a strong positive impact on the capital adequacy ratio include the ratio of equity to total assets, deposits ratio, liquidity ratio and CPI. Whereas, the variables of bank size, profitability indicator and COVID-19 pandemic have strong negative. The ratio of loan to total assets, loan growth rate and CPI have a weak impact on CAR. These findings are consistent with various previous studies such as Vo et al. (2014), Akta et al. (2015), Nguyen & Pham (2017). Thus, the paper has achieved its state objective, by using a Bayesian mixed-effect estimator and has overcome the limitation of previous studies as the sample data is not representative of the population.

From the above results, the paper suggests several important recommendations as follows: (1) the results indicate that bank expansion reduces the bank's capital adequacy ratio. Hence, the State Bank should control and supervise the process of expanding the bank's scale. In addition, State Bank should be flexible in requesting an increased CAR to avoid increasing the bank's risks; (2) increasing the ratio of equity to total assets increases the capital adequacy ratio, so the banks should consider distribution policy by increasing retained earnings to increase the bank's equity. Besides, in order

to increase equity in the future, commercial banks should increase the investment of strategic shareholders; (3) the results find that the customer deposits would promote the increase of capital adequacy ratio, so the commercial banks should have various preferential policies to encourage the customer to deposit, as well as increase advertising and marketing strategies; (4) in order to increase the capital adequacy ratio, one of the important implications is that commercial banks should increase assets with high liquidity by actively developing a framework policy on liquidity risk management; (5) regarding profitability indicator, the research results show that the return on equity has a strong negative effect on capital adequacy ratio. Hence, banks need to ensure that the implementation of increasing profitability must always be closely combined with the regulations on risk control in a reasonable and specific way; (6) in the context of a rapidly growing economy, commercial banks need to be alert in the process of building lending and investment strategies to avoid risks for banks; (7) And finally, the results indicate that during the CPVID-19 pandemic, the bank's capital adequacy ratio decreases. Although in this period, enterprises, households, and individuals all borrowed less, the bank's capital flows tended to flow out into other investment channels. For this reason, the State Bank and commercial banks should consider solutions such as marketing or increasing deposit interest rate to ensure a capital adequacy ratio.

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