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The effect of credit risk and banks' specific drivers on banks' performance in light of COVID-19 pandemic: evidence from commercial banks in the UAE

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Abstract: The COVID-19 pandemic has induced a series of credit risk problems for most commercial banks in the Gulf Cooperation Council region. The study aims to examine the impact of both credit risk and bank-specific drivers on commercial banks' financial performance in the UAE using panel data with a fixed effect model on a sample of ten commercial banks over ten years from 2012–2021. The findings revealed a negative association between credit risk and financial performance while COVID-19 negatively affects financial performance. The management efficiency and banks' liquidity, which measures banks' specific drivers, are found to have a negative relationship with financial performance while capital adequacy and bank size are found to have a positive relationship with financial performance. This study contributes to the knowledge gaps on credit risk and banks' performance during the financial crisis nexus and provides valuable information to regulators and bankers.

Keywords: COVID-19; credit risk; bank-specific drivers commercial banks; financial performance; UAE.

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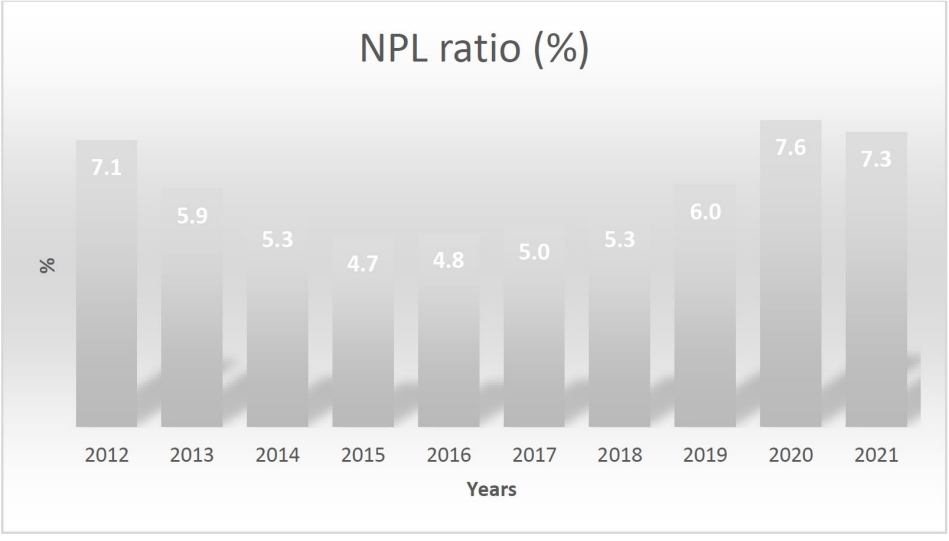
Biographical notes: Zawadi Ally received his BCom (Marketing) and MBA (Finance) from the University of Dar es Salaam, Tanzania in 1998 and 2005, respectively. He was awarded CPA(T) by the National Board of Accountants and Auditors (NBAA) in 2005. Furthermore, He received his MSc in Finance from the University of Strathclyde in the UK in 2008 and PhD from Mohanlal Sukhadia University in India in 2016. He joined the Institute of Finance Management in 2004 as an Assistant Lecturer since then he was promoted to Lecturer and then Senior Lecturer. He held various administrative posts, including head of the weekend college and campus manager. He is a member of various government and academic bodies, and external examiners of various universities. He is currently a Senior Lecturer at the institute. He has published more than 25 articles in the area of banking, accounting and finance. His main areas of research interest are banking, financial institutions' performance, financial management and project management.

1 Introduction

Around the world, the financial sector performs an essential task in bringing economic growth and financial stability by mobilising funds from surplus units across the world (Accornero et al., 2018). In the financial sector, banks play an important role by mobilising the surplus funds from surplus units (i.e., savers) and lending funds in the form of loans to the deficit units (i.e., borrowers), in return for net income in terms of a net interest margin (Ghosh, 2015; Khan et al., 2021). Commercial banks improve their performance in terms of profitability through net interest margin by issuing various types of loans to the borrowers while playing their crucial intermediary function. During this process of intermediary role, commercial banks are exposed to credit risk. According to the nature of banking activities, one of the significant commercial banks' risks is credit risk. Through an effective framework, strategies on credit risk management exposure commercial banks not only support banks' performance and stability but also assist in the efficient allocation of funds in the economic activities of a country (Psillaki et al., 2010). Accornero et al. (2018) found that the main reason for the banking sector's failure and collapse was due to high credit risk. The credit risk problem in the banks in the country contributes to the failure of the financial system as a whole (Siddique et al., 2021). The strength of the banking system is an essential prerequisite to ensuring the growth and stability of the country's economy (Halling and Hayden, 2006). Thus, the assessment of the financial performance of the banking system is a fundamental goal for banks' management and regulators. Several empirical studies on bank failure in different countries and the significant role which is played by credit risk in the bank's failure have been carried out around the world. The study carried out by Hasan et al. (2014) found that high credit risk in the banking industry was the main reason for bank failure in both developed and developing countries. The banking industry crisis in the US and some European nations was contributed by credit risk management inefficient practices which led to an increase in interest in credit risk studies in the banking industry (Juta and Ingrịda, 2009). In UAE, the primary regulator of banking institutions is the Central Bank of the UAE (CBUAE, 2021). The CBUAE is formulating and implementing banking monetary policies and credit across the UAE. There are two major groups of commercial banks in the UAE's financial systems, the first locally incorporated banks are public shareholding companies licensed by Wibynion Law No. (10) of 1980, and the second branches of foreign banks are those commercial banks that have obtained a license from the Central Bank to operate banking services in the country (CBUAE, 2021) The banking industry in UAE is largely dominated by domestic-owned banks due to licensing restrictions and entry barriers for foreign banks. The major components of the UAE commercial banks' assets are loans and overdrafts. The evidence has shown that during the COVID-19 pandemic banking industry in UAE was faced with the problem of credit risk due to the economic activities contraction which increased the overall non-performing loans for the banking industry (CBUAE, 2020). The level of NPL ratios was shown on a downtrend from 7.1% in 2012 to 4.7% in 2015. However, the ratios started to increase from 5.0% in 2017 to 5.3% in 2018, and then the NPL ratios were shown an upward trend from 6.0% in 2019 to 7.3% in 2021 (CBUAE, 2022). The soaring of NPLs causes a major burden on commercial banks' performance. The high ratio of NPLs caused a slowdown in financial market activities and the banking sector intermediary process. Recent statistics indicate that the ratios of NPLs were relatively

high compared with the world average in 2020 based on 102 countries was 5.86% (IMF, 2021). The average trends of NPL ratios for the banking sector in UAE during the period of 2012–2021 are shown in Figure 1.

Figure 1 NPL ratios of UAE banking industry 2012–2021



Source: CBUAE (2022)

An increase in the level of NPLs in the banking sector in UAE poses a great risk to banks and the financial sector at large. In the same manner, failure to manage down NPLs over a long period gradually affects the performance of banks. This implies that the performance of banks in the UAE is low due to huge credit risk exposure. This trend of high NPLs for the banking industry in the UAE poses a great problem not only for the financial sector but also for the economy at large. Therefore, by considering the importance of credit risk in the banking sector and the severe economic impact on banking sector performance, it is extremely important to conduct a comprehensive study to find out how credit risk is impacted the banks' performance in the UAE and to what extent. Credit risk empirical studies and their impact on the banking sector's performance in well-developed economies are widely presented in the banking industry performance literature. Such as the works of Altman and Saunders (1998), Weber et al. (2010), Acharya and Nada (2013) and Rampini et al. (2014) who conducted studies on credit risk's impact on banks' performance in developed economies. The scarcity of empirical studies that examined the impact of credit risk and bank-specific drivers on commercial banks' performance in GCC countries, and UAE, in particular, during the COVID-19 pandemic. Most of the previous empirical studies used only credit risk as the driver of banks' financial performance, however, bank-specific drivers' effect on banks' performance and stability was not emphasised much in previous studies. Thus, the UAE was selected due to the following reasons. First credit risk ratios have been more volatile in the region during the study period, raising concern about the financial system stability. Secondly, the UAE's banking sector attracts investors and bankers from across the world. The position strategically makes the UAE region more competitive in the financial

services sector. Thirdly, the UAE is facing various changes and challenges such as commercial banks competing and operating with Islamic banks' counterparts and the opening-up market to foreign banks' competition. Therefore, it is important to conduct this kind of study in the UAE region. This paper intended to fill the theoretical gaps in the literature by studying both bank-specific drivers and credit risk's impact on banks' performance in the UAE covering the period of 2012–2021. The aim is to answer the following questions. What is the effect of credit risk on banks' profitability in the UAE? What is the relationship between banks' profitability and bank-specific divers in UAE and to what extent? Finally, what is the impact of COVID-19 on the financial performance of commercial banks in the UAE? The empirical findings of the study will provide information to banks' regulators and management on strategies for managing the credit risks and significant drivers influencing banks' performance towards achieving banking sector stability.

In this context the paper is structured as follows: Section 2 consists of a literature review on the effect of credit risk and bank-specific drivers on banks' financial performance, Section 3 consists of data and methodology, Section 4 presents empirical results and discussion and Section 5 discusses the conclusion.

2 Empirical literature review and hypotheses development

The banking industry is highly exposed to credit risk problems during the process of intermediary roles, thus credit risk forms one of the significant risks of banks by the nature of their traditional activities. This section briefly discusses empirically how credit risks and bank-specific factors affect banks' financial performance.

2.1 The credit risk and banks' financial performance

In banking operations, the identified key is credit risk which influences commercial banks' performance in terms of profitability, liquidity and stability. Better banks' performance is evidence of effective credit management (Oduro et al., 2019). The banking industry is facing main three categories of risks while it is operating its banking activities which include financial, operational and environmental risks.

The income-generation of banks is obtained by issuing loans to their borrowers, however, in this process of lending credits to the borrowers, banks are exposed to credit risk (Siddique et al., 2021). There is a growing empirical study on credit risks' impact on the banking sector's performance. Evidence indicates that lending activities are the major indicator of credit risk reported across the world that affects the banks' performance and stability (Siddique et al., 2021). The UK, the USA, Japan, Sweden and other emerging countries like East Asia and Latin America have recently experienced several crises associated with credit risks as a result of lending activities due to non-performing loans (Ferreti, 2017). Dwyer and Russell (2010) examined the effect of credit measures on banks' performance and found that credit measures and fair-value spreads were the powerful tools that risk managers can employ to extend the coverage of credit risk measures to enhance the assessment of default risk. Al-Khouri (2011) examined the impact of credit risk on the financial performance of banks in the GCC countries for the period from 1998 to 2008 using the fixed effect regression. Dwyer (2013) examined the

link between sustainability, political risk and sovereign credit ratings in Nigeria and found that sustainability issues were important in assessing the country's risk in emerging markets. The findings showed that credit, liquidity and capital risk significantly affected the banks' profitability. Apanga et al. (2016) examined the effect of credit risk on the performance of financial institutions in Ghana for the period from 2007 to 2014 and found that the overall credit risk affects the performance of financial institutions; in addition, the findings revealed that the listed banks in Ghana were exposed to credit risk. Kishori and Sheeba (2017) examined the effect of credit risk on banks' performance and found loan to deposit ratio as a measure of credit risk had a significant effect on banks' performance. Ekinci and Poyraz (2019) conducted a study on the credit risk effect on banks' profitability in Turkey by using 26 commercial banks from 2005 to 2017, the credit risk was measured by NPL ratios while profitability was measured by ROA. The study found that credit risk had a negative and significant relationship with ROA. Oduro et al. (2019) evaluated the effects of bank credit risk on banks' corporate financial performance using financial data from banks on the Ghana Stock Exchange from 2003 to 2017. The findings revealed that profitability was inversely related to credit risk. Olobo et al. (2021) also investigated the effect of credit risk on banks' performance in South Sudan, the study used a cross-sectional survey design with 124 respondents and found a strong positive correlation between risk management practices and banks' financial performance. Hapsari (2018) conducted a study on the credit risk effect on commercial banks' financial performance using the NPL ratio and loan-to-deposit ratio (LDR) as a proxy of credit risks and ROA as a measure of financial performance and found that LDR has a positive effect on ROA while NPLs has a negative effect on ROA. Abbas et al. (2019) in their study of credit risk effect on 174 Asian countries' commercial banks' profitability for the period from 2011 to 2017, the results indicated that credit risk had a negatively significant on profitability. Recently Siddique et al. (2021) investigated credit risk effects on the performance of South Asia commercial banks using NPLs as a measure of credit risk and ROA to measure financial performance. The findings revealed that NPLs had a negative and significant relation to the ROA of South Asian commercial banks. Harb et al. (2022) evaluated the impact of credit risk by using the regression technique of a sample of commercial banks in the MENA region for the period from 2010 to 2018 and found no relationship between banks' performance and credit risk. Al Zaidanin and Al Zaidanin (2021) examined the effect of credit risk on the UAE commercial banks' financial performance for the period from 2013 to 2019 and found that the NPLs and cost-income ratio had a negative and significant effect on banks' profitability while liquidity and capital adequacy ratios found to have a weak positive relationship with banks' profitability. In reviewing of empirical literature discussed above found the mixing results from different authors. Based on the above-mentioned arguments, the study developed the following hypothesis

H_1 Credit risk negatively influences a bank's financial performance.

2.2 Banks-specific drivers and banks' performance

Bank-specific drivers are those factors that influence the day-to-day operation of the banks and are within the scope of management to control and they differ from bank to bank. Diversification of credit risk in the banking sector is associated with bank-specific drivers and the credit risk can be minimised by efficient management. The better

performance of a particular bank depends upon the proper management of these bank-specific drivers (Louzis et al., 2012; Siddique et al., 2021). In the banks' literature CAMEL framework is normally used by scholars to proxy the bank-specific internal factors. CAMEL stands for capital adequacy, asset quality, management efficiency, earnings ability and liquidity (Muriuki et al., 2019). Different authors conducted studies on bank-specific factors against banks' performance. Such as Hasanov et al. (2018) examined the effect of bank-specific drivers on banks' performance in Azerbaijan by using the GMM and findings showed that size and capital adequacy had a positive and significant relation with banks' profitability while liquidity and deposits had a negative and significant effect. The studies conducted by Chimkono et al. (2016) and Ghosh (2015) in their study evaluated the effect of management efficiency on banks' financial performance. The findings revealed a negative and significant between banks' performance and management efficiency. Alemu (2016) investigated the factors affecting the financial performance of banks in Ethiopia and found that capital adequacy and bank size had a positive and significant effect on banks' profitability while liquidity risk and operational efficiency, funding costs were found to have a negative and significant with banks' profitability. Aspal et al. (2019) in their study bank-specific factors to examine its effect on banks' financial performance in India by using the data of 20 banks from 2008–2014. The results revealed that all bank's specific drivers significantly affect the financial performance except capital adequacy and liquidity risk. Based on the above-mentioned arguments, the study developed the following hypothesis

H_2 Bank-specific drivers influence bank financial performance.

2.3 Banks' macroeconomic drivers

Although banks' specific drivers are very important factors in determining the financial performance of banks, however, some macroeconomic factors are still important in explaining the performance of banking the industry (Harb et al., 2022). Macroeconomic factors are external drivers beyond the management control of the banks influencing the banks' performance including gross domestic product (GDP), interest rates and inflation (Vong and Chan, 2009). There are various previous studies on the impact of macroeconomic factors on banks' financial performance. Bilal et al. (2013) examined the impact of real GDP on banks' financial performance in Pakistan and found that ROE was positively affected by real GDP. Van Ommeren (2011) found that real GDP growth had a positive significant effect on the ROA of 12 Western European countries' banks. Pasiouras and Kosmidou (2007) in their study found that inflation has a negative significant on foreign banks' profitability while domestic banks found it to have a small positive effect on profitability. Chowdhury (2015) in his study on Islamic banks, the inflation rate found to have a positive significant effect on ROA. Aslam et al. (2016) and Abdullah et al. (2014) on Pakistan and Bangladesh banks respectively found that the inflation rate and GDP growth rate have a negative effect on ROA. Therefore, two macroeconomic variables namely the real GDP rate and inflation rate (IR) were included in this study.

3 Data and methodology

The data sample included only the top domestic-owned commercial banks listed in the UAE market from 2012 to 2021. The reason behind this selection was that domestic-owned commercial banks largely dominated the UAE banking industry and accounted for more than 60% of the total banking assets (CBUAE, 2020). The sample selection was based on the following criteria, first, the bank selected had been in operation during the period of the study from 2012 to 2021, second, the banks that have reported full data in the whole period of the study and third the bank is among the top commercial banks in the UAE market. After filtering the sample using the above criteria, a total of ten commercial banks out of 16 domestic-owned commercial banks were selected. The study used panel data techniques. The data of the study were collected from financial reports of selected banks, the UCBUAE's published reports, the IMF's published reports and previous relevant studies. Table 1 presents the selected number of commercial banks and total assets in billion US dollars in each bank

Table 1 Sample size of selected banks in the UAE

S/N	*Name of bank*	*Total assets (in billions $)*
1	First Abu Dhabi Bank	250.18
2	Emirates National Bank Dubai	190.03
3	Abu Dhabi Commercial Bank	111.92
4	Dubai Islamic Bank	78.82
5	Mashreq	43.15
6	Abu Dhabi Islamic Bank	34.79
7	Commercial Bank of Dubai	26.5
8	Sharjah Islamic Bank	14.59
9	RAK BANK	14.37
10	National Bank of Fujairah	10.85

Source: CBUAE

3.1 Operational variables definition

Bank internal drivers are those banks' specific factors within the management's control (Chimkono et al., 2016; Siddique et al., 2021). The study used both accounting and market performance to improve the results and robustness check. In this, the dependent variable was bank financial performance which was proxied using accounting and market performance. More specifically, the average return on asset (ROA), an average return on equity (ROE) (Saleh and Afifa, 2020) as a measure of bank accounting financial performance and Tobit Q as a measure of bank market financial performance (Abdallah and Ismail, 2017). Non-performing loans are loans rendered to borrowers and become unpaid loans when the duration of the loans has expired (Hamza, 2017; Siddique et al., 2021). The study used a total loan to total customers' deposits to measure a bank's liquidity. Asset quality, the trends of non-performing loans, specific risks exposure and the health and profitability of the borrowers of the banks will determine the quality of the assets which a bank has. Studies have shown that bank failure is mainly attributed to asset

quality and low level of liquidity such as Chimkono et al. (2016) and Siddique et al. (2021). In literature, the total non-performing loans divided by total gross loans are used as the asset quality ratio of a bank and the expected relationship with the bank's financial performance is negative since more profitable banks have a better-quality portfolio (Chimkono et al., 2016; Siddique et al., 2021). In banks' performance, literature management quality represents all controllable costs assessing the management efficiency. Thus, the ratio of non-interest expenses to the average earning assets is frequently employed to measure management efficiency (Kosmidou et al., 2006). Liquidity management is an ongoing process to ensure that the funds required can be met at a reasonable cost to maintain the required level of reserves to meet the expected and contingent requirements.

Table 2 presents the descriptions of the variables of the study.

Table 2 Descriptions of variables

		Name of variable	*Symbol*	*Measurement*	*Sign*
Dependent variable	Financial performance	Return on assets	ROA	Net income/ total assets	N/A
		Return on equity	ROE	Net income/ total common equity	
		Tobit Q	Tobit Q	Firm market capitalisation over book value of total assets of a it	
Explanatory variable	Credit risk	Non-performing Loans	NPLs	Total non-performing loans/total loans	–
		Loans loss provision	LLP	Loans loss provision/ total loans	–
	Bank specific drivers	Bank asset quality	AQ	Total non-performing loans/total loans	–
		Mgt. efficiency	CER	Total operating costs/ total revenue	–
		Bank liquidity	LR	Total loans/total deposits	+
	Control variables	Capital adequacy	CAR	Tier 1 + Tier 2/ risk weighted assets	
		Bank size	Log A	Log of total assets	
		Age of bank	Age	Number of the years since the bank started	
		Gross domestic product	GDP	Real GDP growth rate	
		Inflation	IR	Annual inflation rate	
	Dummy variable	COVID-19 Pandemic	COV-19	1 for the years during the COVID-19 and 0 for the years before the COVID-19	

Source: Authors

3.2 Model specification

The paper examined the impact of credit risk and bank-specific drivers on the financial performance of commercial banks in the UAE. The panel data fixed effect (FE)

regression model was employed in this study. This model is an alternative way to remove unmeasured heterogeneity and focuses on within-unit comparisons: changes in y_{it} and x_{it} relative to their within-group means. First, note that taking the average of the y's overtime for a given unit as presented below:

$$Y_i = \frac{1}{T}\sum\nolimits_{t=1}^{T}\left\lfloor x_{it}'\beta + a_i + \mu_{it}\right\rfloor \tag{1}$$

$$= \frac{1}{T}\sum\nolimits_{t=1}^{T}(x_{it}')\beta + \frac{1}{T}\sum\nolimits_{t-1}^{T}a_i + \frac{1}{T}\sum\nolimits_{t=1}^{T}u_{it} \tag{2}$$

$$= x_i'\beta + a_i + u_{it} \tag{3}$$

The panel data regression model is shown in the following form:

$$Y_{it} = \beta_0 + \beta_i X_{1,it} + \ldots + \beta_k X_{k,it} + \gamma_2 E_2 + \ldots + \gamma_n E_n + \mu_{it} \tag{4}$$

where Y_{it} represents the dependent variable, i is firm, and t is time: X_k, it represents the explanatory variable: β_k represents the coefficient for the explanatory variable: u_{it} is the error term: E_n is the firm n. Since they are binary (dummies) it has $n - 1$ firms included in the model: γ_2 is the coefficient for the binary repressors.

The time effects could be added to the entity effects model to have a time and the entity fixed regression model as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \ldots + \beta_k X_{k,it} + \gamma_2 E_2 + \ldots + V_n E_n + \delta_2 T_2 + \ldots + \delta_t T_t + \mu_{it} \tag{5}$$

where Y_{it} represents the dependent variable, i is firm, and t represents time. X_k is the explanatory variable: β_k represents the coefficient for the explanatory variable: u_{it} is the error term: E_n is the firm n. Since they are binary (dummies) it has $n - 1$ firms included in the model: γ_2 represents the coefficient for the binary regressors; T_t is time as a binary variable (dummy); hence, $t - 1$ time periods: δ_t is the coefficient for the binary time regressors. Therefore, by substituting the variables in the model, the following equations become the econometric models which were used to estimate the influence of credit risk and bank-specific drivers on the financial perforce (ROA and ROE) of the commercial banks. The equations are illustrated as shown in equations (6) and (7) for ROA and ROE, respectively and Tobit Q as dependent variables.

$$\begin{aligned} ROA_{it} = {} & \beta_0 + \beta_1 NPL_{1,it} + \beta_2 LLP_{2,it} + \beta_3 AQ_{3,it} + \beta_4 CER_{4,it} + \beta_5 LR_{5,it} + \beta_6 CAR_{6,it} \\ & + \beta_7 LogA_{7,it} + \beta_8 AGE_{8,it} + \beta_9 GDP_{9,it} + \beta_{10} INR_{10,it} + \beta_{11} COV19_{11,it} + \mu_{it} \end{aligned} \tag{6}$$

$$\begin{aligned} ROE_{it} = {} & \beta_0 + \beta_1 NPL_{1,it} + \beta_2 LLP_{2,it} + \beta_3 AQ_{3,it} + \beta_4 CER_{4,it} + \beta_5 LR_{5,it} + \beta_6 CAR_{6,it} \\ & + \beta_7 LogA_{7,it} + \beta_8 AGE_{8,it} + \beta_9 GDP_{9,it} + \beta_{10} INR_{10,it} + \beta_{11} COV19_{11,it} + \mu_{it} \end{aligned} \tag{7}$$

$$\begin{aligned} Tobit\ Q_{it} = {} & \beta_0 + \beta_1 NPL_{1,it} + \beta_2 LLP_{2,it} + \beta_3 AQ_{3,it} + \beta_4 CER_{4,it} + \beta_5 LR_{5,it} \\ & + \beta_6 CAR_{6,it} + \beta_7 LogA_{7,it} + \beta_8 AGE_{8,it} + \beta_9 GDP_{9,it} + \beta_{10} INR_{10,it} \\ & + \beta_{11} COV19_{11,it} + \mu_{it} \end{aligned} \tag{8}$$

where β_1–β_{11} represent the estimated coefficient of control and explanatory variables and u_{it} is the error term the study used a dummy variable with 1 for the years during the COVID-19 pandemic and 0 for the years before the COVID-19 pandemic.

3.4 Selection of regression model

A linear regression analysis model established that the credit risk was measured by the NPL ratio and LLP ratio while bank-specific factors were measured by asset quality, management efficiency, bank liquidity, and control variables. For the panel data analysis, either a random effect or a fixed effect is used for the analysis, to specify the appropriate model to be used in this study, the Hausman test was applied to compare the two models' estimates of coefficients. Therefore, the study conducted the null and alternative hypotheses as follows.

H_o Random-effect model (REM) model is appropriate.

H_a Fixed-effects model (FEM) is appropriate.

The summary of the hypothesis of the Hausman test correlated results is presented in Table 3. The results indicate that the null hypothesis was not rejected since the chi-sq. statistic was 3.684 and the prob. value was 0.002 (P-value < 0.05), which was statistically significant. Thus, the null hypothesis was rejected and the fixed-effects model (FEM) was preferred.

Table 3 The Hausman test

Test	*χ^2-statistics*	*χ^2-df*	*Prob > χ^2*
Cross-section	3.684	10	0.002

Source: Authors

The study used White's test to test for homoscedasticity, and the Wooldridge test (2002) for autocorrelation because the study consisted of panel data. The summary results of homoscedasticity and autocorrelation are shown in Table 4. The findings revealed that the p-value was 0.568 thus the null hypothesis was accepted at a 5% level of significance, hence there was homoscedasticity no further corrections were needed for the sample. The findings on autocorrelation showed the p-value was 0.368, the null hypothesis was accepted, and the findings concluded that no presence of autocorrelation errors.

Table 4 Heteroscedasticity and autocorrelation testing

Prob > χ^2	*Prob.*
0.948	0.568
H_o: homoscedasticity	*H_a: unrestricted heteroscedasticity*
0.954	0.368
H_o: no first-order autocorrelation	

Source: Authors

4 Findings and discussion

The current paper presents the impact of bank-specific drivers and credit risk on the financial performance of commercial banks in the UAE throughout the study from 2012 to 2021. The big picture of the data first was analysed by using descriptive statistical analysis in Table 5 presents all variables employed in this paper, an indicator of credit

risk (NPLs and LLP), bank-specific drivers (AQ ratio, CER and LR), control variables (CAR, bank size, age, GDP and INR), Dummy variable (COV-19) and the measure commercial bank financial performance (ROA, ROE and Tobit Q), then correlation and regression analysis were presented in Tables 6 and 7.

Table 5 Descriptive statistics of variables

Variable	*Obs.*	*Mean*	*Std. dev.*	*Minimum*	*Maximum*
ROA	100	1.73	0.91	0.57	5.15
ROE	100	11.21	2.65	5.0	14.00
Tobit Q	100	2.93	1.85	1.22	6.97
NPLs	100	6.58	1.88	4.70	7.61
LLP	100	6.28	1.68	3.12	6.78
AQ	100	6.24	1.16	5.01	7.62
CER	100	32.68	8.38	26.48	33.38
LR	100	19.51	4.16	34.00	6.00
CAR	100	17.28	2.58	9.84	29.62
Log A	100	4.86	1.42	2.26	6.82
AGE	100	35.10	16.62	7.00	54.00
GDP	10	3.77	1.35	1.19	5.40
INR	10	1.11	1.99	-2.08	4.07

Source: Author's calculations

4.1 Descriptive statistics results

Table 5 presents the summary of the descriptive statistics results of the study's variables: The summary results report the financial performance ratio which is ROA, ROE and Tobit Q, two credit risk indicators, three bank-specific drivers, and five control variables. the results of the descriptive statistics revealed that the average value of ROA, ROE and Tobit Q was 1.73%, 11.21% and 2.93% with a standard deviation of 0.91%, 2.65% and 1.85% which indicates commercial banks in UAE are competing among them for making profits however the standard deviations evident that the profit-making capacity among commercial is divergent from each other. This implies that banks in UAE efficiently utilise assets to generate more revenue, which is also evidenced by high market capitalisation. The mean value of credit risk which was measured by the NPLs ratio and LLP ratio was 6.48% and 6.28% respectively with the standard deviation of 1.88 and 1.68. A high credit risk ratio level indicated inefficient credit risk management. The NPLs ratio and LLP ratio, among the banks in UAE, varied from 4.70–7.61% and 3.12–6.78% respectively indicating high volatility existed in the commercial banks' ability in managing their credit risk. The CER mean value was 32.68%, and the ratio increased slightly and reached the maximum value of 33.38% in 2020 compared to 31.1% in 2019. The bank liquidity which was measured by total loans to total deposits (LR), the ratio among the banks varied from 6.0% to 34.0% with the mean value and recorded standard deviation of 19.51% and 4.16% respectively which indicated that the bank liquidity ratio differs among the banks. Bank size and CAR showed lower standard deviation values of 2.54% and 1.42% which indicated that the sample's dataset was much

spread from the average values. However, the CAR position of UAE banks remained stable during the period of study and CAR stood at 17.28% which is higher than the regulatory requirement of 10% which is evidence of the compliance of commercial banks regarding Basel II requirements. The GDP and INR as the measure of macroeconomic factors remain stable during the period of study.

Table 6 presents the summary results which compare the relationship between credit risk measured by NPLs and bank performance measured by ROA, ROE and Tobit Q during the period of the study which consists of the period before COVID-19 and during the COVID-19 era. The results indicate NPL increased and reached 6.80% comparing the period before the COVID-19 period which recorded 4.76%. The results also indicate that ROA, ROE, and Tobit Q significantly declined to 1.05%, 9.35% and 1.27% respectively during the COVID-19 era compared to the prior COVID-19 period which was recorded to 1.88%, 12.27% and 4.51% respectively.

Table 6 ROA, ROE, Tobit Q, and NPLs before and during the COVID-19 pandemic for commercial banks

Variables	*Whole study period*	*Prior COVID 19 period*	*During COVID 19 period*
ROA	1.73	1.88	1.05
ROE	11.21	12.27	9.35
Tobit Q	3.23	4.51	1.27
NPL	5.90	4.76	6.80

Source: Author's calculations

4.2 Correlation matrix results

The summary results of the correlation analysis are shown in Table 7. The results indicated that the highest correlation was 0.458 which was the correction between LLP and ROA. The results indicate a negative relation between NPLs and all bank performance measures, i.e., ROA, ROE and Tobit Q. NPLs and CER were correlated negatively with other explanatory variables. The negative correlation of NPLs with ROA is 0.404. At the same time, two bank internal factors, NPL and CER were negatively correlated while LR was positively correlated with other variables. The multicollinearity problem exists if the correlation coefficient reaches ±0.8 or ±0.9 (Vitolla et al., 2020). However, most of the associated values used are comparatively minor less than 0.5, which proposes that there is no significant existence of multicollinearity. In addition, the variance inflation factor was used to test if multicollinearity exists and assumes that the value for the variance inflation factor is above ten multicollinearities exists (Gujarati, 2007).

In regression, analysis multicollinearity exists when two or more of the independent variables demonstrate a linear relationship between them. if multicollinearity exists, the regression coefficients are still consistent but are no longer reliable since the standard errors are inflated. This paper used the variance inflation factor (VIF) to detect whether multicollinearity exists in a regression model. The summary results of the multicollinearity analysis are shown in Table 8. The values of VIF for the explanatory variables are being less than 10. These indicated that there was no multicollinearity among the variables.

Table 7 Correlation matrix figures

Variable	*ROA*	*ROE*	*Tobit Q*	*NPL*	*LLP*	*AQ*	*CER*	*LR*	*CAR*	*LogA*	*AGE*	*GDP*	*INR*
ROA	1												
ROE	0.34*	1											
Tobit Q	0,22*	0.33	1										
NPL	–0.33	–0.42	–0.34**	1									
LLP	–0.46	–0.28	–0.28**	0.14	1								
AQ	–0.34	–0.42	–0.48**	0.24	0.22	1							
CER	–0.36	0.43	–.0.36	0.18	0.24	–0.05*	1						
LR	0.03*	0.03	0.32**	0.41	0.42	0.23*	0.31*	1					
CAR	0.02*	0.24	0.26**	0.034	0.224	0.49*	0.42*	0.44	1				
Log A	0.42*	0.22	0.38**	0.08	0.438	0.01*	0.02*	0.03	0.34	1			
AGE	0.25*	0.02	0.45	0.27	0.04	0.399	0.24*	0.18	0.27	0.18**	1		
GDP	0.38*	0.34	0.32**	0.31	0.21	0.22*	0.32*	0.23	0.23	0.04**	0.32*	1	
INR	0.24	–0.23	–0.28**	0.42	0.22	0.03*	0.22	0.26	0.38	0.23**	0.42*	0.08	1

Notes: ** represents statistically significant at 1% level.
* represents significance at 5% level.

Table 8 Results of multicollinearity (VIF)

Variable	*VIF*	*1/VIF*
NPL	1.82	0.549
LLP	1.62	0.617
DR	1.01	0.990
NPL	1.32	0.758
CER	1.28	0.781
LR	1.32	0.758
CAR	1.42	0.704
Log A	1.28	0.781
AGE	1.38	0.725
GDP	1.48	0.676
INR	1.26	0.793
Mean VIF	1.38	

Source: Authors

4.3 Empirical findings and discussion

Tables 9, 10 and 11 present the regression results summary for ROA, ROE and Tobit Q respectively using the OLS model and equation using the fixed-effects model for both time and company fixed effect. The t-statistics and standard errors were corrected for heteroscedasticity. Besides the fixed-effect model (FEM) as the main estimation model, the study also tests the results' robustness by using the simple ordinal least square (OLS). Accordingly, the results are shown in Tables 9, 10 and 11. OLS and FEM indicate similar results; both OLS and FEM reveal a negative and significant effect of credit risk, asset quality, management efficiency, and dummy variable on the financial performance of banks at a 5% significant level and an insignificant relationship between macro-economic factors and financial performance. Generally, the evidence of having a similar pattern of results in all estimation models implies the existence of strong persistency of the results that cannot be affected by the change of models. Therefore, the results are appropriate for making statistical inferences. The chi-squared values of both tests are statistically significant at a 5% level implying the explanatory variables considered are significant to predict the models. The F-statistic value in the models indicates that the variables are jointly significant at 1% and 5% significance levels. The R-squared is 68.1%, 6,2,.4%, and 61.8% for ROA, ROE and Tobit Q models respectively. The implication is that variations of ROA, ROE, and Tobit Q are explained by the variables included in the model by 68.1%, 62.4%, and 61.8%. As expected the relationship between credit risk (NPLs and LLP) and financial performance measured by ROA, ROE and Tobit Q is found a negative and significant in both models and sound credit risk management is a precondition for ensuring the financial performance of the commercial bank, the finding supports study hypothesis. The negative significance of ROA, ROE and Tobit Q indicated that high NPLs and LLP ratios adversely affect the financial performance of commercial banks. The findings are similar to those of Siddique et al. (2021), Masood and Ashraf (2012), Rasa (2021) and Abbas et al. (2019) who found a significant negative

relationship. Therefore, high credit risk hinders commercial banks' financial performance in the UAE. Thus, NPLs and LLP adversely affected the financial sector in the UAE. The implication is that if more profits as a buffer as loan loss reserve are employed, the lower will be the banks' profitability (Rasa, 2021). The banks' management needs to have sound and effective credit risk strategies as a precondition to minimise the LLP. Tables 9, 10 and 11 indicate similar results for both models. The finding showed that the asset quality is found to be negative and significant with all financial performance measures, the banks' ROA, ROE and Tobit Q. The findings support the proposed hypothesis study. This implies that the lower asset quality of the banks leads to a lower financial performance of the banks measured by return on equity, return on assets and Tobit Q. The findings are consistent with Kadioglu et al. (2017) who found a significant and negative relationship between asset quality and bank profitability which was measured by ROE and ROA. While CER, which measures banks' management efficiency, was found to have a negative and significant relationship with ROA, ROE and Tobit Q in all models. The findings are consistent with Siddique et al. (2021), Elshaday et al. (2018) and Francis et al. (2015). This indicates that an increase in CER has been associated with a decrease in banks' financial performance. These findings imply that banks with managerial inefficiencies are exposed more to lower performance in terms of profitability. Therefore, commercial banks in UAE need to adopt better strategies to manage their asset quality and control operating costs to improve their financial performance. In contrast, LR has a significantly negative relationship with financial performance. These findings imply that the more liquidity the bank has and maintained, the lower the profitability bank earns. The findings are in line with Rajkumar and Hanitha (2015), Elshaday et al. (2018), Saleh and Afifa (2020) and Siddique et al. (2021) who found similar results. The results from all models show that CAR and SIZE affect, ROA, ROE and Tobit Q positively and significantly except for AGE which is found insignificant. The implication of this is that the size of the bank determines its financial performance of the banks. The findings support the theory of firm economies of scale where large banks benefit from increasing return to scale due to bank expansion, confirmed by Pasiouras and Kosmidou (2007) and Athanasoglou et al. (2006). The findings of the paper are matched with Siddique et al. (2021) and Pervan et al. (2015) proving that total asset increments are proportional directly to the financial performance of the bank. The macro-economic variables incorporated into the models, only the changes in GDP significantly positively affect the financial performance of the commercial banks. Inflation is found to have a negative effect on financial performance, however, the inflation rate turns insignificant. The study examined the effect of the COVID-19 pandemic on the ROA, ROE and Tobit Q of the UAE commercial banks used as a dummy variable. The findings indicate that COVID-19 has a negative effect on all measures of financial performance in models. The dummy variable appears to be highly significant implying that the bank's financial performance is significantly affected by the financial crisis. The findings are matching with Ahmed et al. (2022) who found higher NPLs and lower ROA and ROE during the COVID-19 era compared to the prior COVID-19 period. The results indicate that during the COVID-19 era commercial banks in UAE have weak risk management practices which led to high NPLs. These weak risk management practices have a more detrimental effect on banks' financial performance during a crisis.

Table 9 Regression results: dependent variable: ROA

Pooled OLS		*Static panel data analysis (fixed effect)*		
Variable	*Simple*	*Time effect*	*Company*	*Company-time*
NPL	–0.681	–1.72	–1.62	–1.84
	(–3.73)**	(–3.86)**	(–3.48)**	(–3.62)**
LLP	–0.762	–0.88	–0.724	–0.684
	(–3.28)	(–4.84)**	(–4.58)**	(–4.86)**
AQ	–1.862	–2.68	–2.52	–2.88
	(–3.64)	(–4.78)**	(–3.88)**	(–4.89)**
CER	–0.964	–1.482	–1.482	–1.482
	(–4.98)**	(–5.86)**	(–4.98)**	(–4.89)**
LR	–0.782	–0.836	–0.836	–0.836
	(–5.75)**	(–6.88)**	(–5.76)**	(–6.72)**
CAR	1.21	1.38	1.44	1.88
	(3.21)*	(3.68)*	(4.37)*	(3.97)*
Log A	0.981	1.38	1.46	1.84
	(2.32)*	(3.46)*	(3.95)*	(3.86)*
AGE	0.012	0.072	0.068	0.074
	(2.93)*	(2.64)*	(2.88)*	(2.96)*
GDP	0.967	0.842	0.632	0.78
	(2.45)	(2.88)**	(2.98)**	(3.58)**
INR	–0.001	–0.022	–0.032	–0.012
	(–0.78)	(0.874)*	(0.982)*	(0.974)*
COV-19	–0.786	–0.862	–0.862	–0.862
	(–4.24)**	(–4.88)**	(–3.98)**	(–3.88)**
Cons	–2.382	–3.88	–3.58	–4.88
	(–2.34)**	(–3.26)**	(–3.98)**	(–3.82)**
R-squared	0.582	0.681	0.623	0.614
Prob. χ^2	0.000	0.000	0.000	0.000
Obs.	100	100	100	100

Notes: The table reports regression coefficients and t-statistics are corrected for heteroscedasticity and reported in brackets.
* represents statistically significant at 1% level.
** represents significance at 5% level.

Table 10 Regression results: dependent variable: ROE

Pooled OLS		*Static panel data analysis (fixed effect)*		
Variable	*Simple*	*Time effect*	*Company*	*Company-time*
NPL	–0.982	–2.22	–2.38	–2.68
	(–4.23)**	(–4.88)**	(–4.26)**	(–3.98)**
LLP	–0.982	–1.262	–1.823	–1.668
	(–3.76)	(–3.96)**	(–3.682)**	(–3.98)**
AQ	–1.382	–2.988	–2.872	–2.986
	(–3.864)	(–3.984)**	(–3.762)**	(–3.986)**
CER	–1.266	–1.886	–1.668	–1.892
	(–4.862)**	(–5.782)**	(–3.986)**	(–4.682)**
LR	–0.884	–0.878	–0.984	–0.884
	(–5.75)**	(–6.88)**	(–5.76)**	(–6.72)**
CAR	1.682	1.768	1.582	1.996
	(3.21)*	(3.68)*	(4.37)*	(3.97)*
Log A	1.284	1.886	1.584	1.986
	(2.842)*	(3.874)*	(3.862)*	(3.982)*
AGE	0.026	0.084	0.096	0.088
	(2.862)*	(2.784)*	(2.784)*	(2.866)*
GDP	0.566	0.648	0.764	0.868
	(2.946)	(2.678)**	(2.841)**	(3.696)**
INR	–0.032	–0.056	–0.086	–0.086
	(–0.688)	(0.764)*	(0.798)*	(0.846)*
COV-19	–1.482	–1.668	–1.886	–1.722
	(–4.24)**	(–4.88)**	(–3.98)**	(–3.88)**
Cons	–2.382	–3.88	–3.58	–4.88
	(–2.34)**	(–3.26)**	(–3.98)**	(–3.82)**
R-squared	0.596	0.624	0.642	0.636
Prob. χ^2	0.001	0.000	0.000	0.002
Obs.	100	100	100	100

Notes: The table reports regression coefficients and t-statistics are corrected for heteroscedasticity and reported in brackets.
* represents statistically significant at 1% level.
** represents significance at 5% level.

Table 11 Regression results: dependent variable: Tobit Q

Pooled OLS		*Static panel data analysis (fixed effect)*		
Variable	*Simple*	*Time effect*	*Company*	*Company-time*
NPL	–1.461	–1.462	–0.362	–0.642
	(–3.84)**	(–4.386)**	(–3.962)**	(–4.386)**
LLP	–1.286	–1.842	–1.624	–1.468
	(–3.842)	(–3.462)**	(–3.986)**	(–3.653)**
AQ	–0.986	–0.886	–0.874	–1.384
	(–3.586)	(–3.982)**	(–3.876)**	(–3.864)**
CER	–0.988	–1.764	–1.878	–1.968
	(–3.964)**	(–4.883)**	(–3.696)**	(–3.674)**
LR	–0.964	–0.854	–0.962	–0.878
	(–4.852)**	(–4.642)**	(–3.854)**	(–5.843)**
CAR	0.668	1.328	0.684	0.846
	(3.562)*	(3.968)*	(4.886)*	(3.674)*
Log A	0.856	0.786	0.984	0.886
	(2.864)*	(3.648)*	(3.964)*	(3.864)*
AGE	0.012	0.024	0.046	0.068
	(2.964)*	(2.856)*	(2.856)*	(2.764)*
GDP	0.467	0.786	0.846	0.654
	(3.842)	(3.876)**	(4.824)**	(3.884)**
INR	–0.012	–0.044	–0.032	–0.024
	(–0.768)	(0.886)*	(0.658)*	(0.856)*
COV-19	–1.882	–1.926	–1.894	–1.864
	(–3.262)**	(–4.543)**	(–4.846)**	(–3.964)**
Cons	–2.464	–3.964	–3.423	–3.642
	(–3.362)**	(–4.342)**	(–4.286)**	(–4.782)**
R-squared	0.568	0.618	0.6282	0.6423
Prob. χ^2	0.001	0.002	0.003	0.009
Obs.	100	100	100	100

Notes: The table reports regression coefficients and t-statistics are corrected for heteroscedasticity and reported in brackets.
* represents statistically significant at 1% level.
** represents significance at 5% level.

Table 12 Robustness results summary

Variable	*OLS*			*FEM*		
	ROA	*ROE*	*Tobit Q*	*ROA*	*ROE*	*Tobit Q*
NPL	–0.521	–0.886	–1.568	–1.822	–3.882	–1.882
	(–3.68)**	(–4.642)**	(–3.682)**	(–3.682)**	(–4.786)**	(–4.268)**
LLP	–0.682	–0.882	–1.386	–0.884	–1.884	–1.746
	(–3.36)	(–3.842)	(–3.685)	(–4.776)**	(–3.886)**	(–3.328)**
AQ	–1.784	–1.528	–0.886	–2.864	–2.786	–0.768
	(–3.864)	(–3.482)	(–3.784)	(–4.886)**	(–3.785)**	(–3.683)**
CER	–0.886	–1.842	–0.874	–1.692	–1.768	–1.683
	(–4.642)**	(–4.672)**	(–3.824)**	(–5.658)**	(–4.864)**	(–4.784)**
LR	–0.883	–0.784	–0.8563	–0.768	–0.967	–0.468
	(–5.682)**	(–5.882)**	(–4.784)**	(–5.887)**	(–5.764)**	(–3.282)**
CAR	1.342	1.782	0.784	1.864	1.678	1.288
	(3.884)*	(3.886)*	(3.684)*	(4.828)*	(3.546)*	(3.682)*
Log. A	0.869	1.362	0.684	1.462	1.664	0.682
	(2.432)*	(2.678)*	(2.782)*	(3.684)*	(3.764)*	(3.782)*
AGE	0.0162	0.032	0.021	0.0834	0.046	0.012
	(2.256)*	(2.652)*	(2.856)*	(2.886)*	(2.638)*	(2.681)*
GDP	0.768	0.764	0.682	0.7862	0.784	0.682
	(2.685)	(2.853)	(3.674)	(2.774)**	(2.653)**	(3.7832)**
INR	–0.012	–0.021	–0.031	–0.0432	–0.032	–0.032
	(–0.882)	(–0.542)	(–0.658)	(0.674)*	(0.688)*	(0.776)*
COV-19	–0.678	–1.853	–1.768	–0.768	–1.784	–1.782
	(–4.86)**	(–4.868)**	(–3.348)**	(–4.668)**	(–4.758)**	(–3.993)**
Cons	–2.568	–2.845	–2.568	–4.653	–3.563	–3.764
	(–2.586)**	(–2.854)**	(–3.468)**	(–3.653)**	(–3.682)**	(–3.868)**
R-squared	0.562	0.587	0.663	0.626	0.632	0.602
Prob. χ^2	0.002	0.000	0.001	0.002	0.000	0.001
Obs.	100	100	100	100	100	100

Notes: The table reports regression coefficients and t-statistics are corrected for heteroscedasticity and reported in brackets.
* represents statistically significant at 1% level.
** represents significance at 5% level.

4.4 Robustness check analysis

To increase the reliability of the above-presented findings of the study, the robustness check analysis has been performed and presented in Table 12. The summary results in Table 12 indicate that the coefficients of credit risk, asset quality, liquidity risk, and dummy variables still produce a negative correlation with banks' financial performance at a 1% and 5% significance level, while the coefficients of banks' size and capital adequacy still produce a positive correlation with banks' performance. Based on the robustness results summary in Table 10 the results support a negative significant impact of credit risk measured by NPLs and LLP on banks' financial performance in both models of ROA and ROE for the whole sample. The results show that during the COVID-19 pandemic era, the financial performance of commercial banks was negatively affected because the dummy variable shows a negative significant effect on both ROA and ROE. The significant negative relationship between banks' financial performance and credit risk shows that to some extent commercial banks were less restricted, particularly during the crisis.

5 Concluding remarks

The COVID-19 pandemic has induced a series of credit risk and liquidity problems for most businesses and financial institutions, particularly commercial banks where lending is the main business activity. The drastic consequences of the COVID-19 pandemic crisis called attention to the banks' importance of managing credit risk and other banks' internal drivers. The present paper evaluated the impact of bank-specific drivers and bank credit risks on commercial banks' financial performance in the UAE over the period 2012–2021 by using the fixed-effect regression model. The findings revealed a robust significant negative relationship between credit risks measured by (NPL ratio and LLP ratio) and financial performance measured by ROA, ROE and Tobit Q, the findings support the proposed hypothesis. However, the NPLs ratio is recorded with a high negative coefficient. Thus, the effect of the NPLs on banking financial performance in UAE banks is significant. The results show that the dummy variable (COVID-19) is significant in influencing the financial performance of banks during the crisis period. Asset quality, management efficiency, and banks' liquidity which represent banks' specific factors were found to have a negative and significant effect on banks' financial performance while capital adequacy and banks' size the results showed that to have a positive and significant effect on financial performance. Macroeconomic variables incorporated into the models, only the changes in the real gross domestic product significantly positively affect the financial performance of the commercial banks while inflation is found to have an insignificant negative effect on both ROA, ROE and Tobit Q. Based on the findings the paper offers the following policy implications, the negative coefficient of credit risk ratios with banks' performance shows that there is a high level of loan loss provision charged against banks' profitability and eventually leads to poor financial performance. Therefore, UAE commercial banks should strictly follow Basel II Accord and prevailing CBUAE directives on credit risk management as a sound approach to tackling credit risk problems. During the financial crisis, banks should change their credit policies to minimise credit risk which has an impact on financial performance. For better credit risk management managers should guarantee credit

policies for providing loans and timely prompt loan instalment repayment from the borrowers and monitor the liquidity situation. To minimise loan default, the management should carefully evaluate and assess borrowers' references during the credit analysis. Hence banks must implement an efficient and effective credit information system that helps in managing and filling information gaps and increasing trustworthy, accurate, and complete borrower data. Hence, the banks need to remain prudent in managing their credit risk, restructuring practices, and identifying and resolving credit quality deteriorations within their lending portfolios once the loan repayment was expired. In addition, banks can offer expert opinions to borrowers on the viability of their projects. Banks should adopt the best strategies to manage and control bank-specific drivers to improve their financial performance. The study recommends that the credit granting activities should conform to the established and implemented strategies and procedures and that loan approval and review responsibilities are properly assigned. During a pandemic such as COVID-19, the regulators should implement an early warning indicator to monitor and control the accumulation of non-performing loans to avoid the financial crisis of the banks triggered by the existence of NPLs. Also, the findings can give policymakers and regulators better insight into the efficiency and stability of the banking industry and its behaviour in credit risk management and give policy support to loan deferment programs managed to prevent large-scale loan defaulters.

While these findings have important practical implications for bankers and academics as well as the regulator's perspective, the paper's scope is limited only to UAE's commercial banks with two credit risks, six bank-specific factors, and two macroeconomic factors. Future researchers can also apply other variables of credit risk. In addition, the dataset of the study can be increased by adding a greater number of banks and increasing the time frame.

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