CREDIT RISK MANAGEMENT THROUGH STRESS TESTING DURING THE COVID-19 CRISIS: CASE OF BANQUE EXTERIEURE D'ALGERIE

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Abstract
This article examines the impact of stress tests on the financial stability of BEA-Banque, with the primary objective of assessing the bank's resilience to macroeconomic and microeconomic shocks. The methodology relies on ordinary least squares (OLS) estimation to establish a long-term relationship between non-performing loans (NPL) and several macroeconomic variables, including inflation, exchange rates, and gross domestic product (GDP), as well as bank-specific variables such as size, ROA, and total credits. The results show that inflation and exchange rates significantly affect the level of NPLs. An increase in inflation is correlated with a rise in NPLs, while an appreciation of the exchange rate has an inverse impact. In terms of microeconomic indicators, ROA negatively influences NPLs, whereas total credits have a positive effect. The applied stress tests indicate that the quality of BEA-Banque's loan portfolio deteriorates under extreme scenarios, particularly when inflation rises simultaneously with a depreciation of the currency. Nevertheless, the bank's solvency ratio remains above the regulatory threshold set by the Central Bank of Algeria (9.5%), attesting to its financial strength.

Keywords
Stress testing, Credit risk, Loss, Risky credits, Model

JEL Classification
C14, G21.

Introduction

A financial deregulation movement in the late 1970s allowed banks to form international conglomerates, and we have witnessed a proliferation of financial crises, most of which remain difficult to anticipate.

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However, it is widely recognized that macroeconomic factors play a predominant role in triggering these crises. Generally, this often results from a simple sequence: excessive borrowing by economic agents (households and businesses) due to increased bank lending. This leads to a series of bankruptcies in the productive sector, a significant increase in non-performing loans, and ultimately, the failure of banking institutions.
Thus, the turbulence caused by these crises underscores the importance of developing a macroeconomic analysis of the banking system and its interactions with financial stability in general. Regulators, especially central banks, must ensure that banks have a solid financial foundation due to the potential consequences of the eventual failure of a banking institution on the stability of the entire financial system, or even the economy as a whole.
In this context, it is crucial to consider the policies and institutional mechanisms to be put in place to anticipate and better cope with market uncertainties. Stress tests, initially developed to assess the resilience of emerging countries mainly to currency crises, have become a common practice within the International Monetary Fund (IMF).
The IMF has also expanded them to the banking sector as part of the Financial Sector Assessment Program (FSAP), aiming to determine the ability of a banking and financial system to withstand unlikely "catastrophic" scenarios. This concern has also been integrated into Basel II, where stress tests are part of the second pillar dedicated to banking system supervision. Thus, bank stress tests play a prominent role among the tools available to supervisors. Their objective is to assess the resilience capacity of a banking institution or, more generally, the financial sector to an "extreme but plausible" crisis scenario, as formulated by the Basel Committee.
Bank stress tests thus allow for the evaluation of banks' capital needs in response to a given shock, while also serving as a strategic management tool for the bank's various portfolios.
In Algeria, stress tests focus on different stress scenarios that reflect the risks that the banking system might be exposed to. This includes macroeconomic stress scenarios such as economic shocks, interest rate variations, and exchange rate fluctuations, as well as specific scenarios related to credit, liquidity, and operational risks. For conducting stress tests, the Bank of Algeria uses an Excel-based application called FPM "Financial Projection Model," which was developed by the World Bank and adapted by the Bank of Algeria to reflect the realities of the Algerian banking system. In light of these aspects related to stress tests and credit risks, this paper aims to delve deeper into these concepts by addressing the following central issue: **"Is the stress test considered as a good tool for managing bank credit risk?"**
Therefore, the objective of this study is to analyze the key concepts related to stress tests and credit risk management, examine the different methodologies and approaches used in stress tests to assess banks' credit risk and evaluate the impact of economic stress scenarios on banks' credit portfolios and their ability to absorb losses.

1. Review of the scientific literature

In this part of the study, we will present several studies that analyze the credit risk of banks using different methods. The article of (Jacobs, 2018) proposes a challenger approach in the class of machine learning models, widely used in the academic

literature, but little used in practice: the multivariate adaptive regression spline (MARS) model. The study empirically tests these models using Fed Y-9 filings and macroeconomic data released by regulators for CCAR purposes. The Champion MARS model is validated through rigorous comparison with the VAR model and exhibits greater accuracy and superior out-of-sample performance across various metrics across all modeling segments. The MARS model also produces more reasonable forecasts in terms of quality and conservatism.

Ben Youssef (2018) proposed, in his work, a model aiming to improve the assessment of credit risk in the Tunisian banking sector by conducting a macro stress test on a sample of ten Tunisian commercial banks. The results of the credit risk stress tests indicate that under an unfavourable scenario of economic slowdown, each bank is affected differently. The results of all scenario analyses indicate that the banks' capital is sufficient to cover credit risk losses in the event of applied stress, but the Tunisian banking supervisor should question whether this is sufficient to overcome a prolonged crisis period. TARI Mohamed Larbi (2018) applied credit stress tests to an Algerian bank to examine its financial soundness if a crisis were to hit its loan portfolio. The shocks to be applied to the parameters of stress in credit stress scenarios may originate from degradation of one of the following micro parameters (endogenous to the bank): Probability of Default (PD), Loss Given Default (LGD) and Concentration Risk. The results show that Bank (x) will experience a decrease in its solvency ratio in the first test (testing the bank's ability to withstand a moderate shock of a default probability of 5% overall projection periods) and the third test by (downgrading the loans granted to the bank's top 3 largest clients to category 3 (very risky assets)) a significant amount; this decrease directly affects the loan portfolio, which represents on average 60% of the balance sheet. Although Bank (x) achieved a ratio of 13.96%, it remains insufficient, as the difference between this ratio and the required regulation (9.5%) is equal to 4.46%, and through the safety cushion, which is equal to 2.5% (according to regulation 14-01); it can be observed that this margin is equal to 1.96%.

The article by Arestis and Jia (2019) examines the vulnerability of commercial banks in China to changes in macroeconomic conditions using a macroeconomic stress test. It focuses particularly on how changes in real estate market variables and the size of the shadow banking system influence credit risks across the entire Chinese banking system. Based on the results of a vector autoregression model, the study analyzes five scenarios. The main finding is that the shadow banking system has the capacity to absorb the credit risks of commercial banks rather than create a contagion effect, according to data from the first quarter of 2005 to the second quarter of 2016. Additionally, mortgage lending was found to be risky for commercial banks during this period. Moreover, the scenario analysis suggests that the Chinese banking system is relatively stable and that the People's Bank of China is capable of monitoring commercial bank credit risks through appropriate credit policies.

In the study by Mohammed and Onour (2019), the authors investigate the relationship between non-performing loans and macroeconomic and bank-specific variables to assess the exposure of Islamic banks to credit risks. They then design stress test scenarios to evaluate the resilience of the banking system to adverse shocks. The results suggest that the credit risk exposure of Islamic banks in Sudan is mainly affected by

bank-specific variables, including changes in total assets, total deposits, and total loans, all of which have a significant negative impact on the probability of loan defaults. The study also indicates that macroeconomic variables, including GDP growth, exchange rate premium variation, and money supply variation, have positive but insignificant effects on the probability of loan defaults. The study concludes by highlighting that the Islamic banking system in Sudan is more vulnerable to bank-specific risk exposures than to macroeconomic indicators.

For (Grundke and al, 2020), they discuss in their article the stress testing for credit risk and shows how leveraging discretion when defining and implementing a model can determine the results of a quantitative stress test for credit risk probabilities. default. To this end, we use several variations of a CreditPortfolioView-like model using US data from 2004 to 2016. We show that seemingly slightly different specifications can lead to entirely different stress test results, in relative and absolute terms. That said, our results reveal that the conversion of a shock (i.e., stress event) increases the probability of default (excluding stress) by 20-80%, depending on the stress test model selected. Additionally, the risk horizon over which stress default probabilities are forecast and whether one considers average stress default probabilities or quantiles appear to play only a minor role in the dispersion between results. of the different model specifications.

The main objective of the study by Abdolshah et al. (2021) is to estimate potential credit losses in the Iranian banking sector due to macroeconomic shocks and to assess minimum economic capital requirements under baseline and crisis scenarios. The paper also compares the application of linear and nonlinear models to estimate credit losses. It employs a multi-step approach to derive the distribution of portfolio losses for banks. First, the dynamic relationship between selected macroeconomic variables is estimated using a VAR model to generate stress scenarios. Second, default probabilities are estimated using a quantile regression model, with results compared to those from conventional linear models. Finally, default probabilities are simulated over a one-year horizon using the Monte Carlo method, and the portfolio loss distribution is calculated for hypothetical portfolios. Expected loss includes the loss given default for loans randomly and uniformly distributed and exposed to defaults when loans are assigned a fixed value. The results indicate that the loss distributions in all scenarios are right-skewed, with linear model results being quite similar to those of the quantile model at the 50% quantile, but very different at the 10% and 90% quantiles. Specifically, the quantile model at the 90% quantile (10%) generates minimum economic capital estimates that are significantly higher (lower) than those using the linear model.

In their study, (Merika et al, 2021) show that to correctly test credit risk, they must first deduce the default correlation between assets or companies. Then, a risk measure must be applied to the distribution of stressed default rates to obtain the default rates attached to the most negative scenarios. They find that the application of both stressed default correlation and risk measurement results in considerable deviations from the conventional approach. To illustrate this approach, they use 192 publicly traded maritime companies over the period 2000-2016 and show that conventional stress testing tools may underestimate losses under certain conditions. Furthermore, they demonstrate that the assumption of independence in the Vasicek (1987) model between

the systemic factor and default correlation may not hold in some cases. This assumption could, in fact, be the cause of the likelihood of underestimating capital requirements for credit risk as applied in the context of the Basel approach based on internal ratings (IRB). The study by (Mohamed, 2023) aimed to apply stress tests to measure financial stress to predict credit risks in banks. The research was based on the main hypothesis that the application of crisis scenario tests allows for the prediction of credit risks. The study used descriptive and analytical methods to test the hypothesis. The population studied was the Iraqi banking sector, with a deliberate sample taken from Ashur International Investment Bank. In its key findings, the study concluded that stress test scenarios help predict credit risks. Finally, the study recommends placing greater emphasis on diversified investments that generate higher returns.

The study by Pilar et al. (2023) examines whether the results of stress tests conducted between 2009 and 2019 in the United States and the EU have reduced the opacity of information on banks' credit risk. The study investigates changes in the opacity of the banking sector around the disclosure of stress test results using a panel data framework. Opacity is measured by the differences between bank credit ratings issued by various agencies. The results indicate a lower level of opacity after the disclosure of U.S. stress test results. The most significant reduction is observed for systemic banks with higher leverage that fail the test. The European testing program has specific disclosure characteristics that may explain why the effect of stress test result disclosure is more subdued for EU banks. Some indirect evidence suggests that differences in stress testing programs and banking sector structure between the two regions could explain this outcome.

For our part, we will analyze the credit risk of the Banque Extérieure d'Algérie (BEA) before and after the COVID-19 pandemic, as it has recorded disasters across various sectors.

2. Research methodology

To effectively conduct our study, we selected the Banque Extérieure d'Algérie (BEA) as the sample. This choice was made considering that BEA holds the largest client portfolio in Algeria and finances external operations with a significant percentage, resulting in a very large credit volume. The data used in our study includes annual observations from 2010 to 2022, providing 13 years of study to ensure the model is significant. We used the bank's financial statements (Balance Sheet, Income Statement, and Annual Reports). Regarding the variables, we selected two types: macroeconomic and bank-specific variables, to accurately model non-performing loans. The identification of these variables is based on a comprehensive literature review of empirical studies on the subject. For the dependent variable, we used non-performing loans (represented by classified loans). As for the explanatory variables, we chose GDP, the inflation rate, and the exchange rate as macroeconomic variables, and the bank's size, loans granted by the bank, and the bank's profitability (ROA) as bank-specific variables.

Gross Domestic Product (GDP): The growth rate of gross domestic product (GDP) is often used as a crucial indicator to assess the economic health of a nation and to

understand the impact of the macroeconomic environment on various phenomena, including non-performing loans (NPL).

Studies conducted by Nkusu (2011), Beck et al. (2015), and Klein (2013) have highlighted the significant impact of real GDP growth on the levels of non-performing loans (NPL) in the banking sector. Therefore, we formulate the following hypothesis:

H01: There is a positive impact between GDP and NPL.

Inflation Rate: The direct relationship between the inflation rate and credit risk is not well defined in the literature. Klein (2013), Alhassan et al. (2014), and Nkusu (2011) find that an increase in the inflation rate reduces real income and borrowers' debt-servicing capacity, thus increasing the risk of loan defaults.

H02: There is a positive impact between the inflation rate and NPL.

Exchange Rate: The literature presents two relationships between the exchange rate and NPL. One is negative, meaning that an appreciation of the national currency leads to a decrease in exports, which reduces the debt repayment capacity of companies in export-oriented sectors, thereby increasing the risk of loan defaults. This result is supported by studies such as Khemraj and Pacha (2009) and Beck et al. (2013). The other relationship is positive; Bock and Demyanets (2012) find that a depreciation of the national currency leads to a higher level of credit risk, due to companies borrowing in foreign currencies.

H03: There is a positive impact between the exchange rate and NPL.

Bank Profitability (ROA): Return on Assets (ROA) measures the profit generated by a bank relative to its total assets. This measure of bank profitability has been used by several researchers, such as Ghosh (2015) and Messai (2013), who argue that highly profitable banks are less inclined to engage in high-risk activities. This negative relationship is also supported by the "bad management" hypothesis originally proposed by Berger, which explains that unprofitable banks generate more NPL and are more exposed to the risk of failure. Therefore, we anticipate a negative impact of bank profitability on credit risk.

H04: There is a negative impact between ROA and NPL.

Bank Size (Total Assets): Bank size is measured by the total assets of a bank. Empirical literature does not provide a clear relationship between bank size and credit risk. Abid et al. (2015) and Alhassan et al. (2014) report a negative impact of bank size on NPL.

H05: There is a positive impact between bank size and NPL.

Loans Granted: For this variable, we did not find studies that use it to explain the variation in NPLs. However, since it is a crucial element in the calculation of NPLs, we have decided to examine its impact on NPLs.

H06: There is a positive impact between loans granted and NPL.

Regarding the methodology, we divided the study into two stages. The first stage involves identifying the factors influencing credit risk (NPL) and the explanatory variables for its variation using the Ordinary Least Squares (OLS) method, which is a commonly used econometric model and presents the linear relationship between variables. The second stage involves applying scenarios to the selected variables and assessing the bank's resilience in terms of shocks. For the first part of the estimation, we provided a descriptive analysis of the study variables, then presented the basic

assumptions underlying the OLS method, and finally performed the model estimation. For the second stage of stress testing, we applied two different magnitudes of shocks (3 times the standard deviation and 6 times the standard deviation) to the selected variables after estimation, considering the relationship between NPLs and these variables in the OLS model. We then calculated the post-test value of each variable, determined the values of other variables for the same period using the OLS model, and subsequently predicted the values of NPLs. After determining the post-test level of NPLs, we will calculate the solvency ratio. For this, we will assume that regulatory capital remains unchanged, and only the risk-weighted assets will be adjusted.

3. Results and discussions

3.1 Determinants of Credit Risk

This first part is crucial for the remainder of our work. Through this section, we have identified the most significant determinants of credit risk using an OLS modelling approach, which will be used in subsequent stress tests. However, before estimating the relationship between the variables, it is necessary to apply some preliminary tests that correspond to the assumptions of regression analysis.

3.1.1 Descriptive Analysis of the Sample

Before proceeding to the estimation of our econometric model, it is essential to review some preliminary characteristics of the data, as revealed by the descriptive analysis. The descriptive analysis of all the variables is summarized in the following table:

Table no.1. Descriptive Statistics of the Studied Series

	NPL	INF	ROA	Size	TC	TXchange	GDP
Mean	996.2499	4.694615	1.851538	2992.177	1798.561	103.5044	17471.04
Median	1057.174	4.500000	1.760000	2636.706	1959.319	109.4654	17228.60
Maximum	1440.673	8.500000	3.130000	4713.000	2431.668	142.0032	22079.28
Minimum	140.8296	2.000000	0.930000	2111.443	191.6571	72.85370	11991.56
Std. Dev.	296.9009	1.079607	0.606271	753.1394	567.8123	24.35295	2664.229
Skewness	-1.733119	0.593081	0.514095	1.071645	-1.735092	0.066751	-0.185807
Kurtosis	6.712946	2.465428	2.706014	3.299826	6.090578	1.605848	2.851380

Source: Compiled by us with tests conducted using EVIEWS 12 software

According to the results displayed in the table above, there is a variation between the minimum and maximum values for all the variables considered in this study. However, the largest variations are observed in the values for size, NPL, GDP, and total credits. Another observation is that the mean and median values of these four variables are quite close in magnitude. Additionally, it is noted that the variables studied exhibit fluctuations over time. The variables have significant standard deviations, with size being the highest. The table also shows that the Skewness and Kurtosis statistics are

different from 0 and 3, respectively, indicating a lack of normality and thus a volatile behaviour of the series.

3.1.2 Econometric Tests on Residuals

- **Normality Test of the Errors**

This test checks whether the errors follow a normal distribution and is based on the following hypotheses:

H0: The errors follow a normal distribution.
H01: The errors do not follow a normal distribution.
The results of the test are presented below:

Test of Jarque-Bera	Statistic = 1.258919
	P-value = 0.532880

Based on the results in the table above, the residuals are indeed distributed as a normal distribution. The Jarque-Bera test accepts the null hypothesis of normality (the p-value of the test is well above the 5% threshold).

- **Heteroscedasticity Test**

This test allows us to check for heteroscedasticity in the residuals and is based on the following hypotheses:

H0 : Homoscedasticity of the model's residuals.
H01 : Heteroscedasticity of the model's residuals.
The results of the test are presented below:

Test of Breusch-Pagan-Godfrey	Statistic = 0.418189
	P-value = 0.8436

Based on the results in the table above, the Breusch-Pagan-Godfrey test accepts the null hypothesis of homoscedasticity and rejects the alternative hypothesis of heteroscedasticity (the p-value of the test is well above the 5% threshold).

- **Correlation Test**

This test allows us to check for correlation in the residuals and is based on the following hypotheses:

H0: No correlation of the model's residuals.
H01: Correlation of the model's residuals.
The results of the test are presented below:

Correlation LM test	Statistic = 1.690638
	P-value = 0.2937

The Ljung-Box test reveals that the residuals are not correlated.

3.1.3 Estimation of the Model Relationship

We first estimate the long-term relationship of the model using OLS, which can be expressed as follows:

$$NPL = \alpha_0 + \alpha_1 INFL + \alpha_2 ROA + \alpha_3 TC + \alpha_4 TXCHANGE + \alpha_5 SIZE + \alpha_6 GDP + \varepsilon_t$$

Where:

NPL - Non-performing loans.
INF - Inflation.
GDP - Gross Domestic Product.
TC - Total loans.
ROA - Return on assets.
TXCHANGE - Exchange rate.
Size - Total assets.

The table below presents the results of the OLS estimation of the static relationship between the different variables:

Table no. 2. Estimation of the Model Relationship

Variable	Coefficient	Std.Error	t-Statistic	Prob.
INFL	23.76281	7.114391	3.340104	0.0156
GDP	0.008243	0.009611	0.857662	0.4240
ROA	-115.7116	33.72260	-3.431278	0.0139
Size	-0.049938	0.042483	-1.175483	0.2843
TC	0.678965	0.036426	18.63956	0.0000
TXCHANGE	-6.893756	0.757607	-5.090286	0.0022
C	596.7228	110.3544	5.407330	0.0017
R^2: 0.839504	Adj R^2 :0.989137	DW : 2.684318	F-Statistic : 0.000013	

Source: Compiled by us with tests conducted using EVIEWS 12 software

Thus, the model relationship takes the following form:

$$NPL = 596.7228 + 23.76281\ INFL - 115.7116\ ROA + 0.678965\ TC - 6.893756\ TXCHANGE + \varepsilon_t \quad (1)$$

Observing the results of our preferred models, we first note that all variables are significant at the 5% and 10% levels. The R^2 of 0.98 and the probability of the F-statistic (0.00013) indicate that the model appears to be of good quality and that 98% of the variation in NPLs is explained by the chosen variables.

- **Macroeconomic Factors**

In the following, we interpret the results obtained from the estimation of macroeconomic factors:

- **Inflation**

The results of the study show a significant and positive relationship between inflation and NPLs. In Algeria, inflation is closely linked to fluctuations in oil prices, a key resource for the country's economy. Indeed, changes in oil prices directly influence the state budget, as clearly demonstrated during the oil shocks of 2014 and March 2020, the latter being exacerbated by the COVID-19 pandemic. When inflation rises, it exerts negative pressure on households' purchasing power by reducing their real income due to higher prices. Additionally, it affects businesses by reducing their profitability and their ability to generate sufficient revenue to meet their financial obligations. This dynamic impacts the banking sector with an increase in non-performing loans (NPLs), as borrowers, whether households or businesses, face more difficulties in repaying their debts. The studies by Klein (2013), Alhassan et al. (2014), and Nkusu (2011) confirm this positive correlation between inflation and the level of NPLs, suggesting a direct link

between the macroeconomic environment, oil price fluctuations, and the financial health of the Algerian banking system.

- **Exchange Rate**

The results of the study show an inverse relationship between the exchange rate and NPLs. In Algeria, the negative relationship between the exchange rate and NPLs can be explained by the fact that an appreciation of the currency (or a stable exchange rate) improves the overall economic situation by reducing import costs, which can lower the costs for businesses that rely on imported goods and services. When these costs decrease, businesses see improved margins, enhancing their ability to repay their loans. This leads to a reduction in NPLs. Additionally, an increase in households' purchasing power facilitates debt repayment for borrowers, resulting in a decrease in NPLs. A stable and strong exchange rate promotes macroeconomic stability, attracts foreign investors, and supports economic growth. This improves the financial situation of businesses and households, reducing the risk of default. Conversely, a depreciation of the exchange rate creates inflationary pressures, increases import costs, and makes debt repayment more difficult, leading to an increase in NPLs. This result aligns with the study by Yuttadur and Celiktas (2019).

- **GDP**

Finally, for the macroeconomic factors, our model shows no relationship between NPLs and GDP. This result contradicts the findings of several researchers, including Nkusu (2011), Beck et al. (2015), and Klein (2013). Economically, an improvement in GDP generally leads to higher employment and real income levels, which enhances the financial situation of borrowers and thus their ability to repay their loans, resulting in a lower level of non-performing loans.

- **Bank-Specific Factors**

In this section, we interpret the results obtained from the estimation of the bank-specific factors:

- **Size**

The relationship between bank size and non-performing loans (NPLs) is a complex topic that depends on various factors, such as risk management, regulation, and the economic environment. Generally, several studies show mixed results, such as those by Klein (2013) and Louzis, Vouldis & Metaxas (2012). In our study, we observe no relationship between the two variables. This finding contradicts the economic reality where large public banks tend to have fewer NPLs compared to smaller private banks, due to their state support, prudent credit issuance practices, risk diversification capacity, better risk management, and more cautious credit policies.

- **LOANS**

For the variable **LOANS**, we observe a significant positive relationship with non-performing loans (NPLs). This relationship is explained by the increase in the volume of loans. When Algerian banks expand their loan portfolios, they expose themselves more to the risk of default. By granting more loans, they often lend to borrowers with varying risk profiles. In Algeria, a significant portion of bank loans is concentrated in specific

sectors of the economy, such as hydrocarbons, construction, and public enterprises. These sectors are particularly vulnerable to economic shocks, such as fluctuations in oil prices or global economic crises. When these sectors face disruptions, the companies and households that depend on them struggle to repay their loans, resulting in an increase in NPLs. An increase in loans, especially in a fragile or unstable economic context, exposes banks to a higher risk of defaults, leading to a rise in NPLs.

- **Return on Assets (ROA)**

The model shows a significant negative relationship between ROA and NPLs. ROA is a key indicator of bank profitability, measuring the profit generated per unit of assets. When the level of NPLs increases, it indicates that a larger proportion of the loans extended by the bank are not generating revenue due to borrowers' inability to repay their debts. Consequently, the interest income received by the bank decreases, directly reducing profitability and, thus, ROA. Due to the increase in NPLs, banks are required to make provisions to cover potential losses related to these loans. These provisions reduce the bank's net income, as they represent a charge against earnings. The higher the level of NPLs, the larger the provisions needed, which decreases profits and negatively affects ROA. In Algeria, where economic fluctuations (especially related to hydrocarbons) make businesses and households vulnerable, banks may be forced to set aside significant provisions, impacting their profitability. This result aligns with the findings of Ghosh (2015) and Messai (2013).

3.2 Stress Testing Application

Now we move to the second stage of our study where we will apply shocks to the significant variables and observe their impact on the bank's stability.

3.2.1 BEA Bank's Situation Before the Shocks

Before discussing the shocks to be applied and the variables involved, it is important to present BEA Bank's initial situation, which is essential for the rest of the work. The various figures are displayed in the table below:

Table no. 3. BEA Bank's Situation in 2022

Indicator	Amount in millions of DZD
Regulatory Capital	**495**
Total Loans	**2181,145886**
Total Classified Loans	**1061,127474**
Risk-Weighted Assets (RWA)	**1670,04**
Solvency Ratio	**29.64%**

Source: Prepared by the authors

In light of the table, we observe that the bank has a solvency ratio of 29.64%, which is above the regulatory threshold required by the Algerian central bank of 9.5%.

3.2.2 Choice of Variables to Stress

The selection of variables is based on the results from the model discussed in the first part, which identified the determinants of non-performing loans (NPLs) and thus the

credit risk determinants for BEA. The results of our model highlight that the exchange rate, inflation, and return on assets (ROA) are key determinants of non-performing loans (NPLs) in Algeria, offering a detailed perspective on the economic pressures and vulnerabilities faced by the banking sector. On the one hand, the exchange rate directly influences import costs for businesses and purchasing power for households; stabilizing the dinar thus lowers expenses for companies dependent on imported goods and services, improves their profit margins, and enhances their loan repayment capacity. Moreover, a stable currency supports household purchasing power, thereby reducing the likelihood of defaults. On the other hand, inflation, closely tied to fluctuations in hydrocarbon prices, exerts negative pressure on borrowers' repayment abilities at both the household and business levels. Rising prices erode purchasing power and diminish business profitability by increasing operational costs, making them more susceptible to default risk. Finally, ROA, a key indicator of bank profitability, demonstrates the importance of financial performance in absorbing credit risks. A high ROA indicates that banks have sufficient margins to cover potential losses from NPLs, thereby strengthening their resilience and ability to withstand economic downturns. Consequently, by stabilizing the dinar, controlling inflation, and supporting bank profitability, authorities can mitigate financial risks within the banking sector. These three variables thus prove crucial for a rigorous and reliable NPL risk assessment in stress testing, underscoring their central role in the economic resilience and stability of Algeria's banking sector.

3.2.3 Application of Stress Tests

In this section, we apply shocks to the variables and interpret the results:

- **Shocks on Exchange Rate**

The shocks used are inspired by the study of Gabriel Jiménez and Javier Mencía (2009). We have chosen to apply two shocks to each variable. These shocks will be 6 times the standard deviation of the variable in question and 3 times the standard deviation. Indeed, a shock that includes a six-standard-deviation variation, for example, is considered a large-scale shock, as the variation around the mean in a normal context is approximately one standard deviation.

Starting with the exchange rate, as previously mentioned, the model indicates a negative relationship between NPLs and the exchange rate. Therefore, the shocks applied will be in the direction of a decrease in the exchange rate. In other words, we will subtract from the exchange rate value for the year 2022 the value calculated as six times and three times the standard deviation to obtain the adjusted values for 2022. The following table presents the necessary elements for applying the shocks to the exchange reserves:

Table no. 4. Scenarios Applied to the Exchange Rate

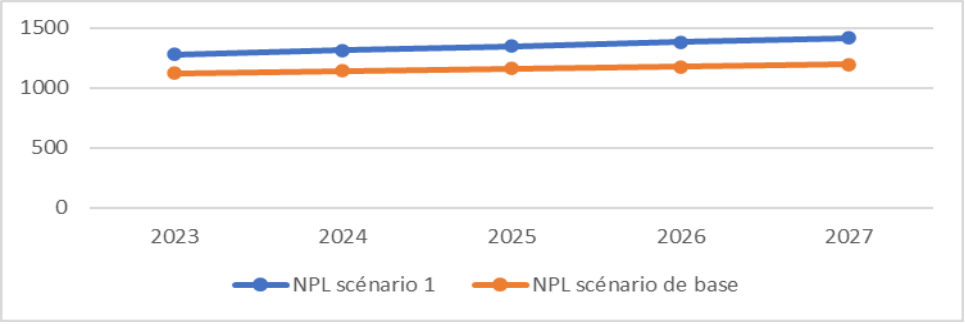
	Exchange rate
Standard deviation (σ)	24.35295
Scenario 1: decrease by an amount of 3*σ	73.05885
Scenario 2: decrease by an amount of 6*σ	146.1177

Value in 2022	142.0032
Scenario 1: value in 2023 after shock	68.94435
Scenario 2: value in 2023 after shock	(negative amount)

Source: Prepared by the authors

We observe that the post-test exchange rate value for the year 2022 is positive in the first scenario and negative in the second scenario. Therefore, we will proceed with only one scenario. Next, we will predict the NPL values for the remaining period using the forecast function in Excel, with the forecast results presented in the following graph:

Figure no. 1: NPLs After Stress Tests on the Exchange Rate



Source: Compiled by us with tests conducted using EVIEWS 12 software

Based on the test results, we observe that the quality of the bank's credit portfolio is deteriorating. In fact, the level of NPLs post-test increases over the period 2024-2027, reaching 1,418.16293 billion DA in 2027. This level of NPLs is concerning because non-performing loans consume capital on one hand and weaken management capacity on the other. This result is similar to the findings of Opoumba & Eyinga (2021).

- **Effect on the Solvency Ratio**

The solvency ratio is a very important metric, as it allows banks to assess their financial strength, in other words, their ability to withstand potential risks. It is essential to remember that the solvency ratio is calculated through the ratio of regulatory capital to risk-weighted assets (RWA).

In the following, we will calculate the solvency ratio as of all the periode, 2023 -2027, for each scenario. To do this, we will assume that the regulatory capital remains stable, and only the risk-weighted assets (RWA) will change.

We used the model equation to calculate the NPLs according to each scenario. The following table shows the amount of non-performing loans in each scenario, along with the additional risk:

Table no. 5. additional risk after the exchange rate shocks 2023

	Baseline scenario	Scenario 1
NPL	**1356,708135**	**1511,677533**
additional risk		**301,211289**

We will use this additional risk to calculate the value of the risk-weighted assets (RWA) after the shock, which will then be used to calculate the solvency ratio. The table below summarizes the calculation of the solvency ratio for the two scenarios:

Table no.06. the solvency ratio after the exchange rate shocks 2023

	Baseline scenario	Scenario 1
Regulatory Capital	**495**	**495**
RWA	**1670,04**	**1825,0094**
Solvency ratio	**29,64%**	**27,12 %**

The solvency ratio is a very important metric that allows banks to measure their financial strength, in other words, their ability to withstand potential risks. The table below shows the solvency ratio scenario 1 (The same calculation method is used for the remainder of the periode):

Table no. 7. The Solvency Ratio After Exchange Rate Shocks

	2023	2024	2025	2026	2027
Scenario 1	**27.12%**	**24.79%**	**22.65%**	**20.71%**	**18.95%**

Source: Prepared by the authors using EXCEL software

The table shows that throughout the entire period, the post-shock solvency ratio remains above the regulatory threshold required by the Bank of Algeria, which is 9.5%. These results demonstrate BEA's ability to withstand deteriorations in its loan portfolio. Therefore, the shock applied to the exchange rate negatively impacts the loan portfolio. It is worth noting that despite this impact, the bank demonstrates its strength and ability to handle a macroeconomic shock, particularly the drop in oil prices.

- **Shock on Inflation**

The relationship between NPLs and inflation is positive according to the model. Therefore, the shocks to be applied will be in the direction of increasing inflation. In other words, we will add to the inflation value for the year 2022 the value calculated from the standard deviation multiplied by three and six to obtain the inflation value for 2023. The following table presents the necessary elements for applying the shocks on inflation (The same calculation method is used for the remainder of the work):

Table no. 8. Scenarios Applied on Inflation

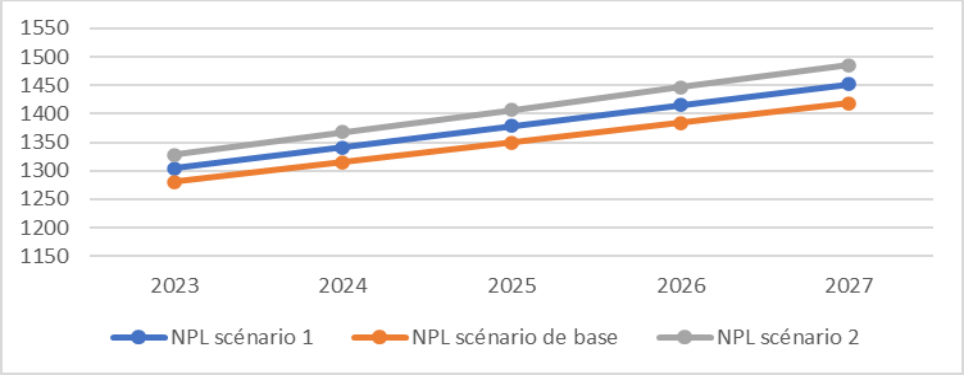
	Inflation
Standard deviation (σ)	1.079607
Scenario 1: decrease by an amount of 3*σ	3.238821
Scenario 2: decrease by an amount of 6*σ	6.477642

Value in 2022	7.9
Scenario 1: value in 2023 after shock	11.138821
Scenario 2: value in 2023 after shock	14.377642

Source: Prepared by the authors

After calculating the inflation values for the two scenarios for the year 2023, we will determine the values of the other variables for the same period using the model. Next, we will predict the values of the NPLs for the remainder of the period, and the results of the forecast are presented in the following graph:

Figure no. 2: NPLs After Stress Tests on the Inflation



Source: Prepared by the authors using EXCEL software

It is clear that positive shocks to inflation have a positive impact on the bank's credit portfolio. In other words, a higher level of inflation leads to a higher level of NPLs. According to the results of the first scenario, we observe that non-performing loans reach 43.15% in 2027. Meanwhile, the second scenario reveals a value of 44.34% in 2027. This result is similar to the findings of (Hamdi, Hakimi, & Zaghdoudi, 2017).

- **Effect on the Solvency Ratio**

The table below shows the solvency ratio for both scenarios:

Table no. 9. The Solvency Ratio After Inflation Shocks

	2023	2024	2025	2026	2027
Scenario 1	29,37%	29,09%	28,78%	28,45%	28,11%
Scenario 2	28,96%	28,26%	27,52%	26,76%	25,98%

Source: Prepared by the authors using EXCEL software

According to the table above, there is a deterioration in the solvency ratio each time the severity of the test increases over the entire period. However, the increase in non-performing loans, which results in a degradation of the bank's credit portfolio, negatively affects the solvency ratio within the CNEP. Nevertheless, it remains above the regulatory threshold of 9.5%.

- **Shock on ROA**

The relationship between NPLs and ROA is negative according to the model. Therefore, the shocks that will be applied will be in the direction of a decrease in ROA. The

following table presents the necessary elements for applying shocks to the ROA ratio (The same calculation method is used for the remainder of the work):

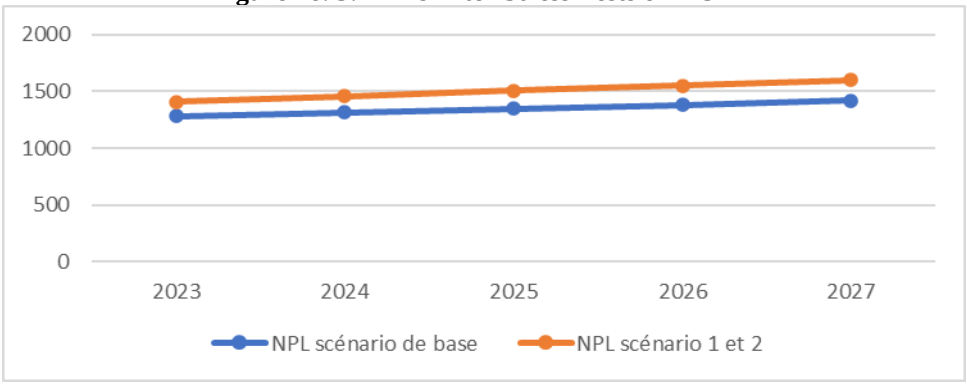
Table no.10. Scenarios Applied to ROA ratio

	ROA
Standard deviation (σ)	0.606271
Scenario 1: decrease by an amount of 3*σ	1.80813
Scenario 2: decrease by an amount of 6*σ	3.61626
Value in 2022	0.93
Scenario 1: value in 2023 after shock	0 (montant négatif)
Scenario 2: value in 2023 after shock	0 (montant négatif)

Source: Prepared by the authors

After calculating the ROA values for the two scenarios in 2023, we will determine the values of other variables for the same period using the model. Then, we will predict the NPL values for the remainder of the period, and the forecast results are presented in the following graph:

Figure no. 3: NPLs After Stress Tests on ROA



Source: Prepared by the authors using EXCEL software

Through the results of the test, we observe that the quality of the bank's credit portfolio is deteriorating. Indeed, the level of NPLs is increasing over the entire period. However, this level of NPLs is concerning because it can weigh on the bank's equity and thus threaten its solvency. This result is similar to the findings of (Gouiaa, & Ouedraogo, 2022).

- **Effect on the Solvency Ratio**

The table below shows the solvency ratio for both scenarios:

Table no. 11. The Solvency Ratio After ROA Shocks

	2023	**2024**	**2025**	**2026**	**2027**
Scenario 1	28,68%	27,69%	26,68%	25,66%	24,65%

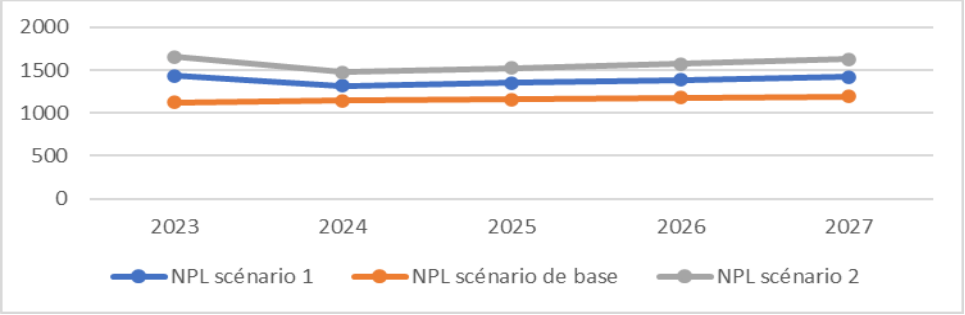
Source: Prepared by the authors using EXCEL software

The table shows that throughout the period, the post-shock solvency ratio remains above the regulatory threshold required by the Central Bank of Algeria, which is 9.5%. This stress test confirms the solvency of BEA-Bank and its ability to withstand a shock on provisions. In fact, these shocks demonstrate that the bank is sufficiently capitalized and does not need to strengthen its equity.

- **Shocks on Exchange Rate and Inflation Simultaneously**

We will take the same scenarios previously applied to each variable separately (three times the standard deviation and six times the standard deviation) and apply them simultaneously to observe the impact on the bank's credit portfolio. The shocks applied will reflect an increase in inflation and a decrease in Exchange rate. We will then predict the values of NPLs for the remainder of the period, and the results of the forecast are presented in the following graph (The same calculation method is used for the remainder of the work):

Figure no. 3: NPLs after the simultaneous shock on the exchange rate and inflation



Source: Prepared by the authors using EXCEL software

The application of stress tests on the two macroeconomic variables leads to a significant deterioration in the bank's credit portfolio, especially in the second scenario. This could threaten the bank's solvency. This result is similar to the findings of (Hamdi, Hakimi, & Zaghdoudi, 2017).

- **Effect on the Solvency Ratio**

The table below shows the solvency ratio for both scenarios:

Table no. 12. The Solvency Ratio After inflation and exchange rate Shocks

	2023	2024	2025	2026	2027
Scénario 1	25,01%	23,01%	21,16%	19,46%	17,90%
Scénario 2	22,47%	19,52%	17,06%	15,00%	13,27%

Source: Prepared by the authors using EXCEL software

The table shows that throughout the period, the post-shock solvency ratio remains above the regulatory threshold required by the Bank of Algeria (9.5%). This stress test confirms the solvency of BEA-Bank and its ability to withstand shocks related to provisions. Indeed, these shocks indicate that the bank is sufficiently capitalized and does not require an increase in its equity. For both scenarios, the solvency ratio gradually decreases, but it still exceeds the threshold set by regulations (9.5%),

indicating that the bank's capital structure is robust enough to withstand such shocks with this level of severity. Therefore, we conclude that CNEP-Bank can withstand individual shocks regardless of their severity, but if it faces a macroeconomic shock exceeding our scenarios, it risks losing its stability.

Conclusions

This research has thoroughly examined the determinants of non-performing loans (NPLs) within the context of BEA Bank in Algeria, introducing stress testing to analyze the impact of shocks to critical variables such as the exchange rate, inflation, and return on assets (ROA).

By building on previous studies, particularly those by Opoumba & Eyinga (2021), which highlighted the effects of economic shocks on NPLs, and Hamdi, Hakimi, & Zaghdoudi (2017), which established the positive correlation between inflation and rising NPLs, this study offers a significant contribution to the existing literature.

The added value of this research lies in its dynamic methodology, which goes beyond static analyses commonly found in earlier works, allowing for a more nuanced understanding of how extreme variations in economic conditions can influence banking stability.

Furthermore, by focusing specifically on the Algerian banking sector, this study addresses a notable gap in the literature, providing insights tailored to the unique risk factors within this economy.

The findings not only reinforce established relationships but also offer practical implications for risk management, guiding policymakers and bank executives in strengthening financial resilience.

Ultimately, this research enhances the understanding of the complexities faced by Algeria's banking sector and provides essential recommendations for improving its robustness against future economic challenges.

In the context of analyzing banking vulnerabilities and stress tests applied to BEA-Bank, several strategic recommendations emerge to strengthen the bank's resilience against macroeconomic shocks.

These recommendations focus on several priority areas, enabling BEA-Bank to better anticipate future crises and mitigate their impact. Firstly, integrating the ICAAP (Internal Capital Adequacy Assessment Process) is a crucial step in enhancing the risk management framework.

By implementing this internal continuous assessment process, the bank will be able to proactively determine whether its capital is adequate to cover all the risks it faces. This framework, in addition to improving strategic capital planning, should include simulations of crises specific to identified vulnerabilities, integrated into daily risk management.

Secondly, it is recommended to establish an internal rating system for credit risk. Such a system would evaluate borrower quality by considering their financial capacity and operational profiles. In the event of default, this mechanism would help the bank estimate potential losses under both normal and crisis conditions and adapt its strategies accordingly.

The implementation of a regular stress-testing program is another key element to improve credit risk management. By conducting frequent and updated stress tests, BEA-Bank can assess its strength against various crisis scenarios, whether financial or economic. The development of these scenarios should involve collaboration among different internal teams to ensure all perspectives are considered, particularly regarding critical variables to stress and the severity of the tests applied.

Additionally, it is imperative for the bank to establish robust emergency plans in case of crises. The COVID-19 health crisis highlighted the need for financial institutions to have well-defined emergency strategies. These plans should include tailored responses to different crisis scenarios and clearly define the funding sources to be mobilized as needed. Finally, special attention must be given to sensitive sectors, particularly real estate, which is a key area for BEA-Bank.

A rigorous and detailed analysis of loans granted to this sector, as well as an optimization of the recovery process, is essential to avoid significant losses in the event of an economic downturn.

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