Measuring the Impact of Digital Banking Services on the Financial Performance of Banks: An Applied Case Study on the Banque Extérieure d'Algérie (BEA) Using Lasso and ARDL-Lasso Methods

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Received: 20/07/2025 **Accepted: 08/12/2025** **Published:20/01/2026**

Abstract:

This research paper investigates the impact of digital banking services on the financial performance of Algerian banks, explicitly framing the Banque Extérieure d'Algérie (BEA) as a case study. To achieve this, the study applied an econometric approach using Lasso regression and the ARDL-Lasso model, with Return on Assets (ROA) as the main performance indicator. The analysis included digitalization variables such as the number of active CIB card users, accounts opened via mobile apps, digital banking users, and ATM/POS transactions.

The findings show that only the number of active CIB card users had a significant positive effect on ROA, suggesting that direct and regular customer use of digital payment tools is key to improving financial performance. Within the context of this case study on BEA, the remaining digital variables showed no significant impact, implying that the presence of digital services alone is insufficient unless effectively adopted by clients.

Keywords : Digital Banking, Financial Performance, ROA, ARDL-Lasso.

I- Introduction:

The emergence of digital technologies has brought about significant transformations in the global banking sector. Today, digital banking services, such as mobile applications, internet banking, ATMs, and electronic payment cards, have become essential tools for improving operational efficiency, reducing costs, and enhancing customer satisfaction. These innovations are not only reshaping how banks operate but also influencing their financial performance.

In Algeria, the digitalization of banking services has gained momentum in recent years, especially in public banks such as the Banque Extérieure d'Algérie (BEA). This shift comes in response to growing customer expectations, increased competition, and the government's push for financial inclusion. However, the actual impact of these digital services on bank profitability and financial indicators such as Return on Assets (ROA) remains under-researched, particularly in the Algerian context where digital adoption is still evolving.

Given the financial and strategic importance of digital banking, this study aims to explore whether digital services are contributing effectively to the performance of Algerian banks, and more specifically, the BEA. The study is based on the use of modern econometric methods Lasso and ARDL-Lasso regression models, to determine the most relevant digital indicators that influence ROA.

The main research question:

To what extent do digital banking services enhance the financial performance of banks through improved asset utilization efficiency?

Hypotheses of the Study:

- There is a positive relationship between the level of digital banking adoption and the Return on Assets (ROA);
- The number of new accounts opened through digital channels contributes to improving asset utilization efficiency;
- Customer use of mobile banking applications helps reduce operational costs and enhance financial performance;
- The expansion of automated teller machine (ATM) usage and digital transactions improves the productivity of banking assets.

The importance of this study lies in:

The accelerating digital transformation in the banking industry necessitates rigorous empirical evaluation to determine whether technological investments are yielding tangible financial returns. In Algeria, assessing the effectiveness of digital banking services is particularly vital for shaping both institutional strategies and regulatory frameworks. This study provides a valuable contribution by employing advanced statistical methodologies, namely, the Lasso and ARDL-Lasso models, to investigate the impact of digital banking indicators on the financial performance of banks within a real-world context.

This study seeks to explore the extent to which digital banking services contribute to enhancing the financial performance of banks in Algeria, with a particular focus on the efficient use of assets. Specifically, it aims to identify the core digital services provided by the Banque Extérieure d'Algérie (BEA), and to evaluate the bank's financial performance

using the Return on Assets (ROA) as a key metric. By employing advanced econometric techniques, namely, the Lasso and ARDL-Lasso models, the study further aims to determine the significance and strength of the relationship between digital service indicators and financial outcomes. Ultimately, the research aspires to provide practical, data-driven recommendations that can support the strategic development of digital banking in Algeria.

1. Previous Studies:

This section presents selected studies that explore the impact of electronic banking on the performance of commercial banks, focusing on objectives, methods, and main findings.

1.1. Study (Nwankwo & Agbo, 2021):

This study aimed to investigate the influence of electronic banking services on the performance of commercial banks in Nigeria. It particularly focused on examining how ATM transactions, point-of-sale (POS) terminal transactions, and mobile banking services affect the financial outcomes of Nigerian banks. The research adopted an ex-post facto design and analyzed data covering the period from 2013 to 2017. Statistical tools available online were used to process the data and measure the relationships between these variables. The findings revealed that ATM transactions have a positive and statistically significant impact on the performance of commercial banks in Nigeria. On the other hand, both POS terminal transactions and mobile banking activities showed negative and weak effects. Based on these results, the study suggests that bank management should continue integrating such digital innovations, especially ATMs, into their operations to improve profitability and efficiency

1.2. Study (Simiyu, 2018):

The study examined the impact of electronic banking on the financial performance of commercial banks in Migori County, Kenya, within the context of Vision 2030 and growing ICT adoption. Data were collected from 56 respondents across six banks using questionnaires, supported by Central Bank reports. Using descriptive design and regression analysis via SPSS and Excel, the results showed that e-banking has improved service efficiency, accessibility, and cost-effectiveness. The findings highlight the positive role of IT innovations in enhancing the performance of banks in the region.

1.3. Study (Othman, 2019):

This research explores electronic banking as a key component of the digital economy, highlighting its growing importance within the global banking system. E-banking aims to leverage modern technologies to provide faster, more efficient, and cost-effective services while creating and managing job opportunities. Despite its benefits over traditional banking, the Arab world still faces major obstacles that hinder its development and adoption compared to developed countries. The study investigates various dimensions of electronic banks—including their emergence, objectives, types, services, advantages, and risks—while examining their current state globally and in the Arab region specifically.

2. The Conceptual Framework of the Study:

2.1. Digitization and Digital Transformation:

2.1.1. Definition of Digitalization:

The concept of "digitalization" can be understood through two main dynamics. On one hand, it reflects the evolution of digital technologies, characterized by the rise of the

Internet, social media, and the development of new platforms and software. On the other hand, it encompasses the emergence of mobile technologies that are transforming usage patterns and data management practices. (BERRAHRAH & BERREZIGA, 2021, p. 632)

In a more restricted sense, digitalization refers to everything related to digital processes, including the computerization of data and the automation of its processing. It is manifested through the dematerialization of documents and work processes. However, with the advancement of information and communication technologies, its scope of application has significantly expanded.

2.1.2. Components of Digitalization :

Digitalization is driven by emerging technological practices that evolve rapidly, reach a broad audience, including entrepreneurs, and bring significant changes across multiple levels. It can be understood through three main dimensions: portability, dematerialization, and automation.

- **Portability:** One of the core features of digital systems is mobility. Applications are designed to be compatible with a wide range of devices, from desktops to smartphones and tablets, allowing users to access services (e.g., business tools, file sharing) anytime and anywhere.
- **Dematerialization:** Many processes are fully or partially digitized, eliminating the need for paper documents and human intervention. Information is entered, stored, and processed digitally, with clients often inputting their own data, which serves as the basis for delivering services.
- **Automation:** Efficiency is enhanced through increased productivity of labor, capital, and resources. Tasks are executed automatically using management rules derived from data observation, enabling faster and more tailored process execution.

2.2. Digital Banking Services :

2.2.1. Concept of Digital Banking Services:

Digital banking services involve conducting banking operations electronically, that is, through the use of information and communication technologies. These operations may include withdrawals, payments, credit issuance, transfers, securities trading, and other banking activities. (Lajal & Qasi, 2021, p. 37)

2.2.2. Characteristics of Digital Banks:

Digital banks are distinguished from traditional banks by several key features, including: (Tarshi, Abbou, & Boufleg, 2019, p. 256)

- The elimination of paper documents in transactions, as all operations are carried out electronically between the two parties involved in the banking service;
- Enabling small banks to expand their activities globally via the Internet, without the need to open new physical branches;
- The ability to efficiently manage banking operations online from any geographical location, allowing the bank to choose optimal regions worldwide based on favorable economic systems, political stability, or more advantageous tax treatment.

2.3. Financial Performance in Banks:

2.3.1. Concept of Financial Performance in Banks :

In general, financial performance represents the narrow perspective of an institution's overall performance, as it primarily focuses on the use of financial indicators to measure the extent to which set objectives are achieved. It reflects how well an institution performs and serves as a fundamental support for the various operations it undertakes. Furthermore, financial performance contributes to the availability of financial resources and provides the institution with investment opportunities across various performance areas, helping meet stakeholder needs and achieve their objectives. (Al-Khatib, 2009, p. 45)

Financial performance is also defined as the degree to which activities contribute to value creation or the efficiency in utilizing available financial resources by achieving financial goals at minimal cost. (Al-Saeed, 2000, p. 38)

Financial performance in banks refers to the bank’s ability to effectively utilize its financial and operational resources to achieve profitability, maintain financial stability, and fulfill regulatory requirements. It is commonly assessed through key indicators such as Return on Assets (ROA), Return on Equity (ROE), Net Interest Margin (NIM), and the cost-to-income ratio. A bank’s financial performance reflects its capacity to manage risks, allocate capital efficiently, and deliver value to shareholders while ensuring trust and stability within the financial system.

2.3.2. Bank Performance Indicators:

Measuring tools for banking performance are essential for evaluating a bank's profitability, which is a key indicator of its ability to generate sufficient earnings to sustain long-term operations. Various instruments are used to assess profitability, generally categorized into:

- The intermediate management balances approach;
- The approach based on costs, returns, and margins;
- The profitability ratios approach.

Each method offers a unique analytical perspective on a bank's financial performance, helping identify both strengths and weaknesses. When used in combination, these tools provide banks with a comprehensive understanding of their profitability and support well-informed decision-making aimed at improving performance.

a) Return on Equity (ROE):

ROE measures the return on shareholders' equity, assessing the bank's ability to generate profits from shareholders' investments. It is calculated as follows:

ROE = Net Income / Total Shareholders' Equity

This ratio reflects how efficiently a bank utilizes the invested capital to produce earnings.

b) Return on Assets (ROA):

ROA indicates the profitability of a bank's assets. It shows how well the bank uses its assets to generate income, particularly by attracting deposits at reasonable cost and investing them profitably. It is computed as:

ROA = Net Income / Total Assets

c) Financial Leverage Ratio:

The financial leverage ratio is a critical indicator used to analyze a bank's financial structure by comparing total assets to average shareholders' equity. It is influenced by provisions for non-performing loans and plays a crucial role in assessing both profitability potential and risk exposure. A lower leverage ratio suggests stronger equity and builds depositor confidence.

Financial Leverage = Average Total Assets / Average Shareholders' Equity

d) Solvency Ratios:

Solvency ratios are based on risk-weighted commitments, with a regulatory minimum threshold of 10%. This ratio reflects the bank's ability to manage risk-weighted obligations, which range from 0% to 100% depending on the client profile. It ensures depositor protection by safeguarding client funds relative to risk-weighted assets.

Solvency Ratio = Shareholders' Equity / Risk-Weighted Commitments > 10%

e) Banking Margin Ratio:

The banking margin ratio is defined as the gross national product (GNP) divided by average total assets. It indicates the net banking income generated per unit of assets, including both interest and non-interest income. A growing GNP suggests strong performance.

Banking Margin = Net Banking Income (GNP) / Average Total Assets > 10%

f) Profit Margin:

The profit margin measures the profitability of a bank's operations by comparing net income to net banking income. A high margin indicates strong revenue generation relative to expenses, which is generally viewed as a sign of solid financial health.

Profit Margin = Net Income / Net Banking Income (GNP)

g) Operating Efficiency Ratio:

This ratio is used in the banking sector to assess operational efficiency. It represents the ratio of operating expenses to net banking income. A lower ratio is preferable, indicating that the bank incurs fewer expenses to generate each unit of income.

Operating Efficiency = Operating Expenses / Net Banking Income (GNP) ≤ 65%

3. Presentation of Study Variables:

3.1. Explanatory Variables (Digitalization Indicators):

As part of this study, the explanatory variables were selected to reflect the main aspects of banking digitalization and their potential impact on financial performance.

All digitalization-related variables (X1 to X5) were collected from the Payment Systems Department of the Banque Extérieure d'Algérie (BEA).

- **X1: Number of clients actively using CIB cards:** This variable indicates the level of adoption of electronic bank cards. It reflects clients' willingness to shift from traditional cash payments to digital solutions, marking progress in the digital transformation journey.
- **X2: Number of accounts opened via the mobile application:** This parameter captures how many bank accounts are opened through the bank's mobile app, indicating process automation and the increasing autonomy given to clients.
- **X3: Number of clients using the bank's digital services:** This indicator measures client engagement with digital services such as mobile banking, online transfers, and balance inquiries. It reflects how integrated digital tools have become in clients' banking habits.
- **X4: Number of financial transactions via ATMs (DAB/GAB):** This variable quantifies withdrawals and other banking operations conducted through ATMs, indicating the effectiveness and accessibility of digital banking infrastructure.
- **X5: Number of card transactions through POS terminals (TPE):** This indicator represents the number of purchases or payments made using bank cards at electronic point-of-sale terminals, highlighting the adoption of digital payment methods in commercial transactions.

3.2. Dependent Variable (Financial Performance Indicator):

In this study, the dependent variable was selected to reflect the bank's financial performance in relation to the impact of digitalization.

The dependent variable (Y = ROA) was calculated based on internal financial data of the Banque Extérieure d'Algérie (BEA). Required information, such as net income, total assets, and shareholders' equity, was extracted from monthly financial reports provided by the Accounting Department.

- **Y : Return on Assets (ROA):** ROA measures profitability relative to the total assets held by the bank. It assesses how efficiently the bank uses all of its resources—both equity and liabilities to generate profit.
- **Formula:**

ROA = Net Income / Total Assets

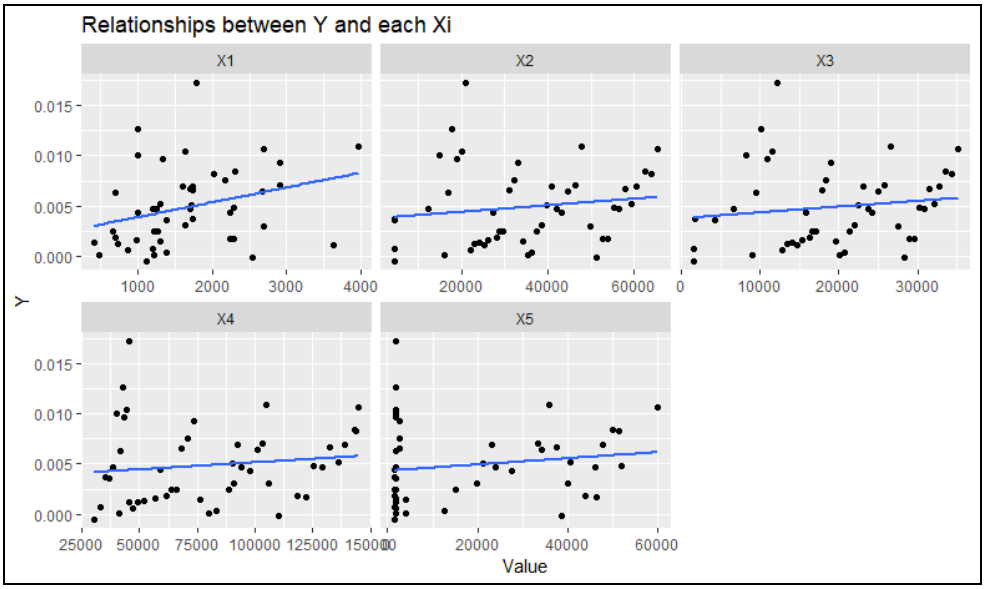
- The higher the ROA, the more efficient the bank is considered to be in managing its overall financial resources.

4. An Analytical Study of the Relationship Between Digital Banking Services and Bank Financial Performance (ROA):

As part of the study on the impact of digital banking services on bank financial performance, the relationship between Return on Assets (ROA) and five digital indicators, representing key components of digital transformation in the banking sector, was analyzed.

The following chart illustrates the relationship between the dependent variable (Y1 = ROA) and each explanatory variable separately, using scatter plots with fitted linear regression lines.

Figure (1): Relationship Between Digital Banking Indicators and Financial Performance (ROA): A Scatter Plot Analysis



Source: Prepared by the researcher based on R software

- **Number of clients actively using CIB cards (X1):** The chart shows a weak positive relationship between the number of CIB card users and ROA. Despite significant dispersion among the data points, the overall trend suggests that an increase in the number of users is associated with a slight rise in ROA. This could be explained by the growing use of electronic banking cards, which contributes to improved operational efficiency and reduced costs associated with traditional transactions.
- **Number of accounts opened via the mobile application (X2):** This variable also exhibits a weak positive relationship with ROA. A cluster of data points appears around lower ROA values, with some increases at higher X2 values. This indicates that digital account opening may slightly enhance profitability, reflecting the role of digitalization in facilitating customer access to banking services.
- **Number of clients using the bank's digital services (X3):** This relationship shows a moderate upward trend, where ROA tends to rise as the number of digital service users increases. Despite some dispersion, the overall pattern supports the hypothesis that greater client adoption of digital services translates into improved financial performance, primarily through reduced transaction costs and an expanded client base.
- **Number of financial transactions via ATMs (DAB/GAB) (X4):** This relationship appears almost flat, suggesting no clear impact of this variable on ROA. While ATMs are a key component of banks' digital strategies, their contribution to profitability may

be limited or indirect—potentially influenced by intermediary factors such as maintenance costs or underutilization.

- **Number of card transactions via POS terminals (TPE) (X5):** The chart reveals a weak positive relationship between the number of POS transactions and ROA, with a slightly upward-sloping regression line. This suggests a limited positive impact, possibly resulting from increased reliance on electronic payment methods in daily commerce, which reduces cash usage and enhances transaction flow.

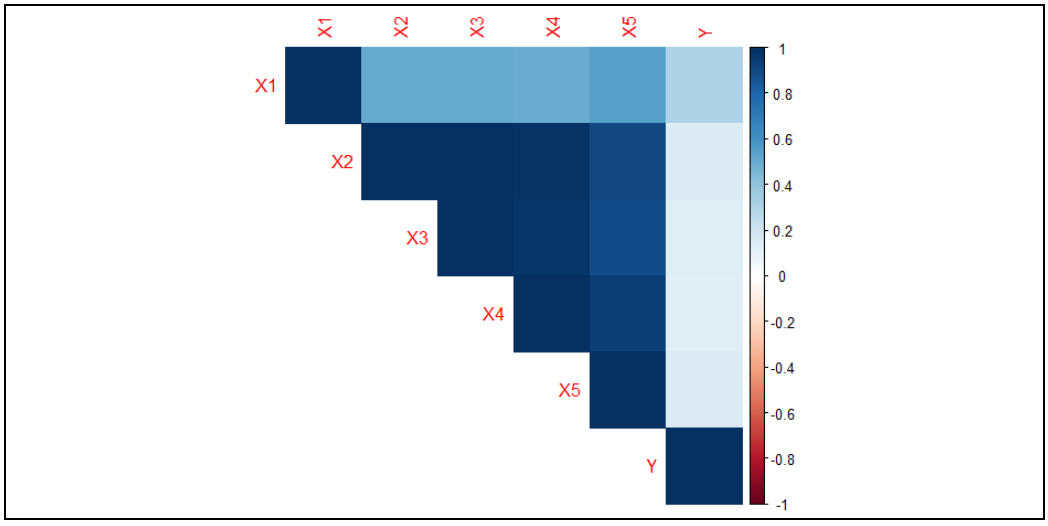
Based on this visual analysis, there are indications of a positive relationship between digital transformation and improved bank financial performance, particularly through variables X1 and X3. However, the overall impact appears to be weak to moderate, underscoring the importance of applying robust econometric models, such as Lasso and ARDL-Lasso, to accurately estimate the true effect and identify the most influential digitalization factors.

5. Correlation Matrix Analysis Between Digital Banking Services and Bank Financial Performance (ROA):

The correlation heatmap below illustrates the linear relationships between all the variables used in the study, including the financial performance variable (Y = ROA) and the explanatory variables related to digital banking services (X1 to X5). These relationships are measured using Pearson's correlation coefficient, which ranges from:

- +1: Perfect positive correlation;
- -1: Perfect negative correlation;
- 0: No correlation at all.

Figure (2): Correlation Heatmap of ROA and Digital Banking Indicators



Source: Prepared by the researcher based on R software

5.1. Relationship between explanatory variables and ROA:

All five digital banking variables (X1 to X5) show a positive correlation with ROA. This suggests that greater reliance on digital banking services is associated with improved financial performance of the bank in terms of efficient asset utilization.

X1 (number of customers actively using CIB cards) shows the highest positive correlation with ROA. This indicates that expanding the use of electronic banking cards has a significant impact on enhancing profitability. The reason lies in the fact that CIB cards

facilitate cashless transactions, help reduce operational costs, speed up transaction processes, and improve service quality all of which positively influence return on assets.

5.2. Relationships among the explanatory variables:

Strong correlations are observed between certain explanatory variables, particularly:

- X2 and X3 (number of accounts opened via the mobile app and number of users of digital banking services);
- X4 and X5 (number of transactions via ATMs and number of POS transactions using bank cards);
- These strong associations may indicate multicollinearity, which can distort the estimates and interpretations in classical statistical models like linear regression.

The correlation matrix supports the study's hypothesis that digital banking transformation contributes to enhancing the bank's financial performance. The variable X1 (CIB cards usage) emerges as a key indicator of this positive impact. However, the strong intercorrelations between some explanatory variables call for the use of advanced modeling techniques such as Lasso and ARDL-Lasso, which are better suited to handling multicollinearity and improving the robustness of the findings.

6. Econometric Study of the Impact of Digital Banking Services on Bank Financial Performance Using Lasso and ARDL-Lasso Methods:

6.1. Overview of the Lasso Regression Technique:

Lasso regression, which stands for Least Absolute Shrinkage and Selection Operator, is a statistical technique used to improve the accuracy and reliability of regression models by applying a penalty that reduces model complexity. It belongs to a family of methods known as regularization techniques, and it is specifically classified as L1 regularization.

The main idea behind Lasso is to limit the influence of variables that do not significantly contribute to explaining the dependent variable. It does this by adding a constraint to the model that penalizes large coefficient values. As a result, some coefficients are reduced to exactly zero, which effectively removes the corresponding variables from the model. This leads to a simpler, more interpretable model that focuses only on the most relevant predictors.

The concept of Lasso emerged in the 1980s, but it was formally introduced in 1996 by the statistician Robert Tibshirani, who built on earlier developments in penalized regression methods. Lasso has since become a widely used approach in both machine learning and econometrics, especially when working with datasets that include many interrelated variables.

One of the main advantages of Lasso is its ability to handle multicollinearity, which occurs when independent variables are highly correlated with each other. Multicollinearity can distort the estimation of model coefficients in traditional regression techniques like OLS. By shrinking and eliminating correlated variables, Lasso reduces this risk and ensures more stable and reliable estimates.

Another important benefit of Lasso is its effectiveness in preventing overfitting, a problem that arises when a model fits the training data too closely and fails to generalize

well to new data. Lasso reduces overfitting by discouraging the inclusion of unnecessary variables and focusing the model on the most impactful predictors.

Compared to other regularization methods, such as Ridge regression (also known as L2 regularization), Lasso has the distinct advantage of performing automatic variable selection. While Ridge only reduces the magnitude of coefficients, Lasso can completely remove irrelevant variables from the model, resulting in greater interpretability.

6.2. Justification for Using Lasso and ARDL-Lasso Methods :

Before estimating the model, it is crucial to highlight the rationale behind selecting the Lasso and ARDL-Lasso techniques, rather than relying solely on traditional estimation methods such as Ordinary Least Squares (OLS) or the standard Autoregressive Distributed Lag (ARDL) model.

The nature of the dataset used in this study, particularly the presence of relatively high correlations between some of the explanatory variables (e.g., between the number of accounts opened via the mobile application and the number of clients using digital services, or between ATM transactions and POS transactions), raises the issue of multicollinearity. This phenomenon can distort coefficient estimates in classical models, leading to:

- inflated standard errors,
- instability of estimated coefficients,
- and unreliable inference about the actual impact of each digitalization indicator on financial performance.

To overcome these limitations, the Lasso (Least Absolute Shrinkage and Selection Operator) method was employed. Lasso is a regularization technique that enhances model estimation by:

- shrinking the coefficients of less significant variables,
- and automatically eliminating those variables that do not meaningfully contribute to the dependent variable, by forcing their coefficients to exactly zero.

This feature makes Lasso particularly suitable when dealing with multicollinearity, allowing the model to retain only the most informative predictors. Additionally, it improves both the predictive accuracy and interpretability of the model.

In the context of time series analysis, where both short-term and long-term dynamics are essential, the study also adopts the ARDL-Lasso model. This hybrid approach combines the strengths of:

- the ARDL framework, which captures both immediate and lagged effects of explanatory variables on the dependent variable (ROA),
- with the variable selection capabilities of Lasso, ensuring a more robust and parsimonious model, especially when explanatory variables exhibit internal correlations.

6.3. Study Model:

In order to measure the impact of digital banking services on the financial performance of banks, we constructed an econometric model where the dependent variable is the Return on Assets (ROA), reflecting financial performance. The model includes a set of explanatory variables representing key aspects of banking digitalization. These variables are: the number of clients actively using CIB cards (X1), the number of accounts opened

via the mobile application (X2), the number of clients using digital services (X3), the number of ATM transactions (X4), and the number of transactions made through POS terminals (X5). These variables aim to capture the degree of digital transformation achieved by the bank in providing its services.

The model can be expressed as follows:

- **Y = f (X1, X2, X3, X4, X5)**

6.4. Stability Analysis of Study Variables:

To assess the time series properties of the variables used in the model, the Augmented Dickey-Fuller (ADF) unit root test was conducted. This test checks whether each variable is stationary (i.e., has a constant mean and variance over time) or contains a unit root, indicating non-stationarity.

The null hypothesis of the ADF test is that the series has a unit root (non-stationary), while the alternative hypothesis suggests stationarity. The results of the ADF tests for all variables are presented in Table 1 below:

Table (1): Results of Augmented Dickey-Fuller (ADF) Unit Root Tests

Variable	ADF Statistic p-value	Decision
Y	0.06719	Non-stationary
X1	0.03424	Stationary
X2	0.0369	Stationary
X3	0.8835	Non-stationary
X4	0.609	Non-stationary
X5	0.818	Non-stationary

Source: Prepared by the researcher based on R software

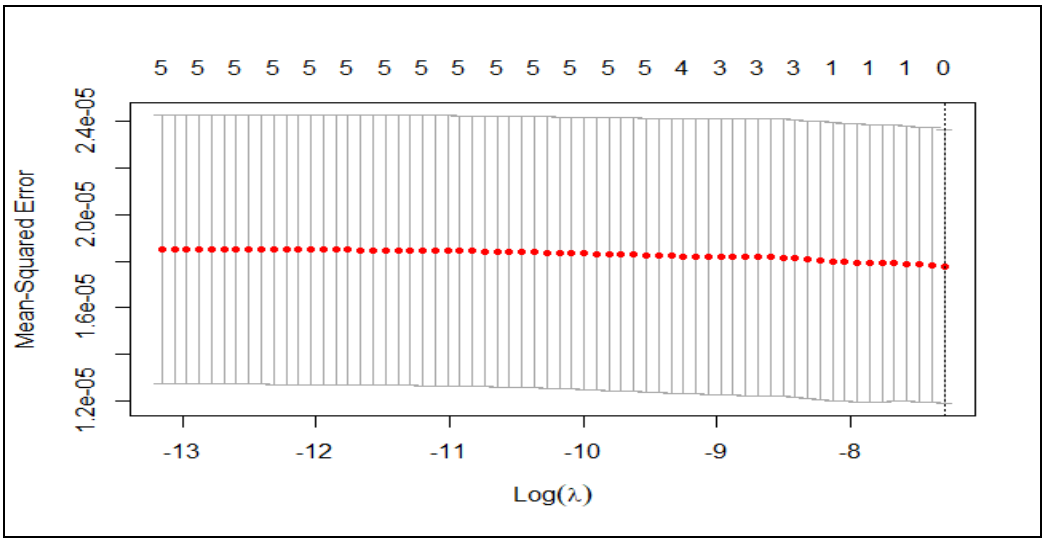
The results show that only X1 and X2 are stationary at level, as their p-values are below the conventional 5% significance level. In contrast, the dependent variable Y, along with X3, X4, and X5, exhibit non-stationarity, suggesting the presence of unit roots in these series.

Accordingly, for the standard Lasso regression, the non-stationary variables will be transformed by taking their first differences to ensure stationarity before estimation. However, in the ARDL-Lasso approach, the model can directly handle variables that are a mix of stationary and non-stationary (integrated of order zero or one), and thus the variables will be used in their level form without differencing.

6.5. Estimation Using the Standard Lasso Method:

In this study, after confirming the stationarity of the variables, first differences were applied where necessary. The standard Lasso method was then used to select the variables that significantly influence bank performance. The optimal value of λ was determined using cross-validation, with the best lambda identified as 0.000678331.

Figure (3): Cross-Validation Plot for Optimal Lambda Selection in Lasso Regression



Source: Prepared by the researcher based on R software

The figure displays the results of the cross-validation process used to select the optimal λ value. The horizontal axis represents the logarithm of λ values, while the vertical axis shows the Mean Squared Error (MSE). The red dots represent the MSE corresponding to each λ value, and the dotted vertical line indicates the optimal value that minimizes prediction error.

It is observed that the mean squared error gradually decreases as λ decreases. The value 0.000678331 is identified as the most appropriate, providing a balance between model accuracy and complexity.

Table (2): Estimated Coefficients Using the Standard Lasso Method

Dependent Variable: Y		Estimated Coefficient
Explanatory Variables	Intercept	0.0002394321
	X1	.
	X2	.
	X3	.
	X4	.
	X5	.

Source: Prepared by the researcher based on R software

The estimation results show that all explanatory variables (X1 to X5) were shrunk to zero, indicating that they are not statistically significant in the retained model. Only the intercept term was kept, with a coefficient estimated at 0.0002394. This suggests that the model does not rely on any of the included explanatory variables to explain the dependent variable.

Given that the standard Lasso estimation resulted in the exclusion of all explanatory variables (X1 to X5), with only the intercept retained, it becomes necessary to consider an alternative modeling approach. The lack of significant coefficients may be attributed to the structural limitations of the standard Lasso method, particularly in dealing with time series data that exhibit non-stationarity and dynamic interdependencies.

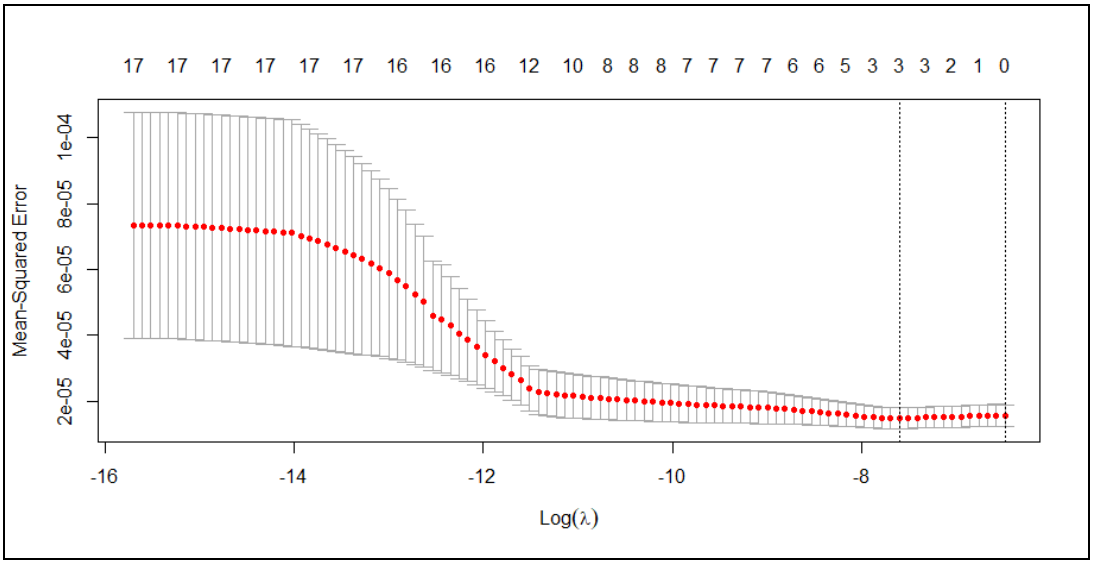
6.6. Estimation Using the Standard Lasso-ARDL Method:

Previous unit root tests revealed that several explanatory variables are non-stationary, suggesting the existence of long-run equilibrium relationships. In such cases, the Autoregressive Distributed Lag (ARDL) framework is more appropriate, as it can accommodate a mix of I(0) and I(1) variables and capture both short-run dynamics and long-run relationships.

By integrating the ARDL model with the Lasso regularization technique, the ARDL-Lasso approach enables variable selection while preserving the underlying time dynamics of the data. This provides a more flexible and robust modeling framework for assessing the impact of digital banking indicators on financial performance, especially when traditional Lasso fails to identify significant predictors.

To identify the key variables influencing bank performance, we applied the standard Lasso-ARDL estimation method. The optimal value of the regularization parameter λ was determined via cross-validation, with the best lambda identified as 0.0004984882.

Figure (4): Cross-Validation Plot for Optimal Lambda Selection in Lasso-ARDL Regression



Source: Prepared by the researcher based on R software

The figure displays the cross-validation results for selecting the optimal regularization parameter (λ) in the Lasso-ARDL model. The red dots represent the mean squared error (MSE) for each value of log(λ), with vertical bars indicating the standard error. The optimal λ (≈ 0.000498) is the one minimizing the MSE, marked by the left dashed line. This point balances model complexity and predictive accuracy, ensuring relevant variable selection while avoiding overfitting.

Table (3): Estimated Coefficients Using the Standard Lasso-ARDL Method

Dependent Variable: Y		Estimated Coefficient
Explanatory Variables	Intercept	3.252354e-03
	X1	7.307216e-07
	X2	.
	X3	.
	X4	.
	X5	.
	Y_lag1	2.594499e-01
	Y_lag2	.
	X1_lag1	.
	X1_lag2	-4.144934e-07
	X2_lag1	.
	X2_lag2	.
	X3_lag1	.
	X3_lag2	.
	X4_lag1	.
	X4_lag2	.
	X5_lag1	.
	X5_lag2	.

Source: Prepared by the researcher based on R software

From the previous table, which presents the estimated coefficients using the standard Lasso-ARDL method, we observe that this method estimates an ARDL model and automatically selects the most relevant variables using the Lasso shrinkage technique. Only the statistically significant variables were retained in the model, namely:

- X1 (Number of clients using CIB cards) in the current period;
- X1_lag2 (Number of clients using CIB cards) with a lag of two periods;
- Y_lag1 (ROA) lagged by one period.

All other variables, whether contemporaneous or lagged, were shrunk to zero, i.e., excluded from the model due to their lack of statistical significance.

6.7. Statistical Interpretation of the ARDL-Lasso Model Results:

- X1 has a positive coefficient (7.3e-07) in the current period, indicating a slight positive relationship between the use of CIB cards and the return on assets (ROA).
- X1_lag2 has a negative coefficient (-4.14e-07), which may reflect a slightly delayed negative effect of the same variable after two periods.
- Y_lag1 (0.2594): This indicates a moderate positive influence of past ROA values on the current ROA, suggesting relative dynamic stability in financial performance.

6.8. Economic Interpretation of the ARDL-Lasso Model Results:

6.8.1. Variable X1 (Number of active users of CIB cards):

6.8.1.1. Current positive coefficient for X1:

The coefficient (7.3e-07) indicates that an increase in the number of active users of CIB payment cards leads to a slight improvement in the return on assets (ROA).

Economically, this reflects that clients' consistent and repeated use of electronic payment cards directly contributes to financial performance, especially within the specific context of this case study on BEA, where card-based transactions generate fee income, reduce cash-handling costs, and increase the frequency of digital operations. This reinforces the idea that effective usage of digital tools—not merely their availability, is what drives tangible profitability gains.

6.8.1.2. Negative coefficient for X1 lagged by two periods (lag2):

The coefficient (-4.14e-07) represents a delayed negative effect.

This may suggest that, in previous periods, the expansion of card usage required additional operational or technological investments, such as upgrading ATMs, reinforcing cybersecurity systems, or maintaining the card infrastructure, which temporarily reduced profitability.

Another explanation, aligned with the realities of BEA's operating environment, is that many cardholders use CIB cards mainly for cash withdrawals rather than electronic purchases, which does not generate significant fee income and may even increase operational costs. Consequently, the lagged effect turns negative when card usage does not translate into revenue-generating transactions.

6.8.2. Lagged value of ROA (Y_lag1):

The coefficient (0.2594) indicates a positive and dynamically significant relationship between past ROA and current ROA.

Economically, this suggests that the bank's profitability follows a persistent trajectory influenced by long-term financial policies, structural characteristics, and operational stability. For BEA as a case study, this result highlights that the institution's historical performance and strategic decisions continue to shape present performance, reinforcing the importance of consistent management, sustained cost control, and stable long-term planning.

6.8.3. Why other digital variables did not show significant effects:

Within the framework of this single-bank case study (BEA), the absence of significant effects for other digital banking variables, such as mobile application account openings, general digital service users, and ATM/POS transactions, can be attributed to several economic and structural factors:

Mobile application users: Most mobile banking operations in Algeria remain limited to balance inquiries and basic non-revenue-generating services, meaning increases in user numbers do not directly enhance profitability.

ATM transactions: These are dominantly cash withdrawals, which increase logistical and maintenance costs without providing proportional fee income.

POS transactions: Despite their potential, POS usage remains limited due to low merchant adoption, customer preference for cash, and insufficient integration of electronic payments into commercial activity, making their short-term impact on ROA negligible.

Overall, these patterns show that only digital tools that generate actual transactional activity and fee income, such as active and repeated card usage, produce measurable effects on ROA at BEA.

Conclusion :

This study set out to measure the impact of digital banking services on the financial performance of banks in Algeria, using the Banque Extérieure d'Algérie (BEA) as a case study and focusing on the Return on Assets (ROA) as a key indicator of performance. Through the application of advanced econometric models, particularly the Lasso and ARDL-Lasso methods, the study produced several insightful findings that reflect the real influence of digitalization on financial efficiency.

The most prominent result is that among all the digital banking indicators included in the analysis, only the variable X1, which represents the number of actual users of CIB cards, was retained as statistically significant in the ARDL-Lasso model. This underscores a crucial reality: digitalization contributes positively to bank performance only when it is coupled with effective, customer-driven usage. In other words, it is not the mere availability of digital services that drives performance gains, but the active and routine use of these tools by clients, particularly for day-to-day banking transactions.

In contrast, other digital-related variables, such as the number of new accounts opened through mobile applications, the total number of digital service users, and the volume of operations conducted through ATMs and POS terminals (GAB/TPE), were not found to have a statistically significant impact on ROA. These findings suggest that certain digital services may not yet be sufficiently embedded in customer behavior, or they may suffer from issues such as limited geographic accessibility, low levels of digital literacy, or a lack of user trust and awareness.

From a broader perspective, this study demonstrates that digital banking can be a strategic lever for improving financial performance, but only if it is accompanied by strong adoption strategies, customer education, and targeted marketing efforts. Banks must therefore go beyond infrastructure deployment and focus on boosting actual usage and building trust in digital platforms, particularly in developing markets such as Algeria.

Ultimately, these insights offer important guidance for both banking institutions and policymakers. They emphasize the need to align digital transformation strategies with client engagement policies and to address contextual barriers that hinder full adoption. Doing so would allow the banking sector to fully capitalize on the financial benefits of digitalization, improve operational efficiency, and enhance service delivery in a sustainable and inclusive manner.

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