BAR Brazilian Administration Review

ANPAD

Research Article

The Influence of Digital Technologies on the Economic and Financial Performance of Brazilian Credit Unions

Marcelo Ibrahim Lana[1], Valéria Gama Fully Bressan[1], José Roberto de Souza Francisco[1]

[1] Universidade Federal de Minas Gerais, Faculdade de Ciências Econômicas, Belo Horizonte, MG, Brazil

How to cite: Lana, M. I., Bressan, V. G. F., & Francisco, J. R. S. (2025). The influence of digital technologies on the economic and financial performance of Brazilian credit unions. *BAR-Brazilian Administration Review, 22*(1), e230155.

DOI: https://doi.org/10.1590/1807-7692bar2025230155

Keywords:
credit union; information technology; financial performance.

JEL Code:
G23, C58

Received:
November 15, 2023.
This paper was with the authors for three revisions.

Accepted:
November 13, 2024.

Publication date:
April 04, 2025.

Funding:
Coordination for the Improvement of Higher Education Personnel (CAPES, Brazil). Financial code: 001

Conflict of Interests:
The authors have stated that there is no conflict of interest.

Corresponding author:
Marcelo Ibrahim Lana
Universidade Federal de Minas Gerais,
Faculdade de Ciências Econômicas
Av. Pres. Antônio Carlos, n. 6627, Pampulha,
CEP 31270-901, Belo Horizonte, MG, Brazil

ABSTRACT

Objective: this article aims to identify the relationship between investments in digital technologies and the performance of Brazilian credit unions, measured by return on assets (ROA), return on equity (ROE), and return on investment (ROI). **Methods:** the sample comprises active single credit unions registered with the Central Bank of Brazil during the quarters between 2012 and 2021. The study's relevance lies in understanding how credit unions can optimize investments in digital technologies to improve profitability and sustainability in a competitive financial market. The methodology adopted in this study is a dynamic panel approach using the generalized method of moments. **Results:** the results indicate that investments have positive and significant effects on performance indicators, occurring three quarters after the initial investment. **Conclusions:** this finding aligns with existing literature, suggesting that improved financial performance follows a period of investment maturation due to the need for team adaptation and training. It contributes to guiding cooperatives' investment strategies, providing a solid foundation for decision-making in an environment of constant change.

Data Availability: Lana, Marcelo; Bressan, Valéria ; Francisco, José Roberto (2025), "The influence of digital technologies on the economic and financial performance of Brazilian credit unions", Mendeley Data, V1, doi: http://doi.org/10.17632/yst8c34vd5
BAR – Brazilian Administration Review encourages data sharing but, in compliance with ethical principles, it does not demand the disclosure of any means of identifying research subjects.

Plagiarism Check: BAR maintains the practice of submitting all documents received to the plagiarism check, using specific tools, e.g.: iThenticate.

Peer review: is responsible for acknowledging an article's potential contribution to the frontiers of scholarly knowledge on business or public administration. The authors are the ultimate responsible for the consistency of the theoretical references, the accurate report of empirical data, the personal perspectives, and the use of copyrighted material. This content was evaluated using the double-blind peer review process. The disclosure of the reviewers' information on the first page is made only after concluding the evaluation process, and with the voluntary consent of the respective reviewers.

INTRODUCTION

Digital transformation refers to the process by which organizations use technology to enhance their business performance. Since the 1990s, there has been rapid growth in the transformation and computerization of processes, a trend that continues to this day (Schneider & Kokshagina, 2021). However, this scenario is constantly evolving due to the increasing use of mobile devices, which provide a new way for people to interact with technology driven by artificial intelligence. Among the sectors experiencing growth in innovations within their commercial environments, financial institutions stand out, having undergone changes in the way they interact with money, which has transitioned from being exclusively physical to virtual, relying on continuous technological advancements to maintain operations (Federação Brasileira de Bancos [Brazilian Federation of Banks, FEBRABAN], 2019). These changes have led to socioeconomic shifts and transformed the relationship between customers and financial institutions. Consequently, there has been a significant increase in the use of digital means for financial solutions such as payments, transfers, and even fund deposits (Barroso, 2019).

In this context, credit unions have shown growth in the financial market, with an increase in the volume of total assets compared to previous years (Coeli & Pires, 2022). The constant pursuit of technological improvement in banking institutions, combined with accelerated global evolution, has led these institutions to allocate part of their financial resources to keep pace with the rapid technological innovations in the sector. As a result, there is a growing use of mobile devices to perform financial services (FEBRABAN, 2023).

According to the Banking Economy Report (REB) prepared by the Central Bank of Brazil (Banco Central do Brasil [BACEN], 2022b), the National Credit Union System (SNCC) has invested financial resources in digital integration, with the main investment channels focused on technological infrastructure.

Despite being different in essence, Trindade et al. (2010) state that the economic variations between the cooperative model and traditional banks are minimal when analyzing the main variables that make up the balance sheet of these institutions. As with multiple banks, research that aims to analyze the performance of cooperatives measures their results through indicators of economic profitability, business volume, market share, and growth.

The modernization of the financial intermediation system, combined with the adoption of new information technologies, has led to cost reduction, the evolution of banking operational processes, and, consequently, greater customer satisfaction. In this way, technology has contributed to the improvement of management practices, making the financial system more robust, competitive, efficient, profitable, and less bureaucratic, which allows new companies to operate competitively with cooperatives in the financial market (Baabdullah et al., 2019; Brandt et al., 2021; Ceretta & Niederauer, 2001; Laukkanen, 2016).

Banco Central do Brasil (BACEN, 2022a) presents the operational efficiency of individual credit cooperatives for the period 2018–2022 through the analysis of the relationship between administrative expenses and revenues from the provision of services, plus financial guarantees, in comparison to the National Financial System (SFN). It can be seen that the SFN's share in the results of service provision was 67.3% in 2018, falling to 64.6% in 2022. This means that, on average, 66.0% of administrative expenses are covered by service provision revenues. In the case of credit unions, this average was 40.1% in the same period. Therefore, the SFN is ahead of credit unions in terms of the efficiency of service provision revenues. In view of this, investment in IT in credit unions becomes urgent to increase the coverage of administrative expenses in comparison to service provision revenues and financial guarantees, improving the performance obtained by the unions.

Data from Brcooperativo (2023) reinforce that investments in technology have proven to be highly necessary and effective in making unions more competitive in the market. Investments such as CashWay and Banking Service allow cooperatives to focus on customer service, improving relationships with members, reducing costs, and increasing operating results.

The digital transformation movement that has been taking place in the financial market and, consequently, in credit unions seeks to leverage better economic results for cooperatives and provide greater efficiency in offering new services to users (Schuch et al., 2023).

Based on studies carried out by FEBRABAN in partnership with Deloitte, in 2020, IT investments in Brazil reached US$38.1 billion, while worldwide they reached US$2.8 trillion. In this context, the volume of banking transactions grew in Brazil, reaching US$89.9 billion, with emphasis on operations in mobile banking, internet banking, and ATMs (FEBRABAN, 2020). Thus, it can be stated that the allocation of IT resources by credit unions provides favorable financial returns, based on the movements observed in the banking sector.

Given the importance of digital technologies, the national financial system, and the performance of credit unions, this paper seeks to answer the following research question: What is the relationship between in-

vestments in digital technologies and the profitability of Brazilian credit unions?

Considering that investment in technology is an intangible asset with a maturity period, the hypothesis is that the relationship between the growth rate of the investment in the invested period (contemporary) is negative or null, becoming positive as the new technologies affect the performance variables. To test this hypothesis, this paper uses the dynamic panel approach by the generalized method of moments (GMM), assuming simultaneity between the variables of interest. Thus, it is expected to contribute to the literature by providing evidence that investments in new technologies, measured by intangible assets, had a significant impact on the growth of performance variables (return on assets — ROA, return on equity — ROE, and return on investment — ROI) in the period from 2012 to 2021.

The database used is quarterly, and the panel is unbalanced, as not all credit unions observed in 2012 were active in 2021. The results corroborate the hypothesis that a positive variation in the growth rate of investments in digital technologies by credit unions initially leads to a reduction in performance measures, which become positive as the investment matures.

Furthermore, the relevance of this study lies in understanding how investments in digital technologies impact the profitability of Brazilian credit unions, a crucial sector of the financial market characterized by its idiosyncrasies compared to traditional banks. Given the increasing digitalization of the financial system and the importance of cooperatives in financial inclusion and socioeconomic development, this study is justified by the need to provide insights that help these institutions compete in an environment dominated by large banks. Additionally, it contributes to the academic literature and the formulation of public policies aimed at the sustainability and efficiency of the cooperative sector.

Besides this introduction, the article is divided into four more sections. The next section addresses the theoretical framework. The third section presents the methodology. The fourth section is dedicated to the results. Finally, the concluding remarks are presented.

LITERATURE REVIEW

Empirical studies on performance in financial institutions

Despite the constant use of the internet as a transaction channel, there is a relative lack of empirical studies that quantitatively analyze the impact of the internet on the financial performance of banks. Hernando and Nieto (2007) studied the influence of the internet on 72 commercial banks in Spain using the generalized method of moments. The results suggest that the effect was significant after a year and a half, providing a gradual reduction in general expenses and, consequently, an improvement in profitability in terms of ROA after one and a half years and ROE from the third year onward. Finally, the authors highlighted that the internet is used as a complementary mechanism, not as a substitute for existing services.

To investigate the impact of specific determinants of the financial sector and macroeconomic factors on the return of the largest institutions in Tunisia, Rachdi (2013) analyzed two distinct periods: the first, from 2000 to 2006, without a financial crisis, and the second, from 2007 to 2010, covering the crisis period. The profitability metrics used were return on assets (ROA), return on equity (ROE), and net interest margin (NIM). Using a panel data approach with the generalized method of moments (GMM), the author concluded that Tunisian banks were little exposed to the effects of the international subprime crisis due to their low interactivity with the international financial system.

To verify the moderating effect of capital structure on the performance of Kenyan banks, Ongore and Kusa (2013) used a data sample from 2001 to 2010 with a total of 37 commercial banks. Using multiple linear regression models for panel data, the results indicated that ownership determinants affect bank performance. However, the analysis of macroeconomic factors was not conclusive, suggesting that the performance of Kenyan banks is mainly influenced by internal management factors, with little relevance from external factors.

Rodrigues et al. (2013) conducted a study to analyze the determinants of bank performance and profitability based on a sample of fifty banks between 2000 and 2009. Using the panel data model with the generalized method of moments approach, they verified how the determinants of profitability (ROA and ROE) behaved in relation to economic, accounting, and operational factors. The results showed that macroeconomic factors, such as interest rates and inflation, modify the performance of institutions.

The study of the importance of the banking sector in Central and Eastern Europe during the financial crisis experienced in that region from 2009 to 2018 led Horobet et al. (2021) to use macroeconomic factors, such as the inflation rate, to assess the determinants of ROA and ROE. Based on the generalized method of moments, the study concluded that the inflation rate, the loan default rate, non-governmental credit, and unemployment negatively affected bank profitability in Europe.

The study by Lu and Swisher (2020) compared the growth rates of traditional banks and credit unions during the financial crisis, observing differences in the

average rates of asset growth, growth in deposit capture, and the number of loans made. The study showed that, while traditional financial institutions grew faster in normal times, credit unions outperformed banks during financial crises.

A study developed by Kumar et al. (2020) sought to understand how macroeconomic factors and monetary policies influence the profitability of New Zealand banks between 2006 and 2018. Using a sample of 19 banks and GMM, the authors verified the determinants of ROE and ROA. As a result, they inferred that, in addition to macroeconomic factors, other indicators, such as loan defaults, were decisive for the profitability of institutions.

To understand the factors that influenced the profitability of banks in India and China, Kumar et al. (2022) used a sample of 230 banks composed of 58 Indian banks and 172 Chinese banks, totaling 2,834 observations. The variable used to analyze financial performance was return on total assets (ROA), and the macroeconomic variables included the inflation rate, interest rate, and gross domestic product. The results indicate that the size of the bank, operating costs, and the volume of credit offered are the main factors driving profitability.

The study by Kwan et al. (2020) points out that financial institutions that invested in information technology (IT) achieved higher volumes of credit operations, such as loans and card usage, even during periods of recession. This demonstrates that technology can streamline credit processes and provide a differentiated experience for customers, which is crucial for credit unions to increase their competitiveness and improve their financial performance.

Additionally, the literature reinforces that, although the return on investment in IT is not immediate, it is potentially significant in the long term, as it requires a period of learning and organizational and structural adjustments (Bharadwaj et al., 1999; Halili, 2014; Rai et al., 1997; Ugwuanyi & Ugwuanyi, 2013; Winarno et al., 2021). These processes are essential for credit unions to maximize the benefits of using digital technologies, thus improving their overall performance.

Therefore, this study hypothesizes that "investments in digital technologies can positively influence the performance of credit unions," as they can allow for greater efficiency in credit operations, strengthen relationships with customers, and, in the long term, provide significant structural and financial gains.

Digital financial technologies

The so-called financial technologies (fintechs) are considered technological and digital innovations in the financial market. The use of mobile devices, such as cell phones, and fixed devices, such as microcomputers, has enabled customers to access the financial system remotely, without the need to visit physical branches to use the services (Brandl & Hornuf, 2017; Mokyr, 2018).

Among the banking services offered, mobile banking stands out, which can be understood as the set of financial solutions made available through mobile devices, involving the use of technologies connected to the telecommunications network (Cernev et al., 2010). This phenomenon of digital banks can be analyzed from two perspectives. The first, highlighted in the studies by Simpson (2007) and Laukkanen and Kiviniemi (2010), sees mobile banking as a complement to the channels already existing in the market. On the other hand, Shen et al. (2010) understand that these services can be developed and implemented as a strong instrument of financial inclusion for audiences with little access to banking services.

The advancement of computing and telecommunications technologies and the spread of the internet have created a universe of opportunities for all companies, especially banks, enabling the remote marketing of products and services with lower operating costs. The Federal Reserve defines mobile banking as the use of mobile devices to access banking services and personal accounts (Merry, 2018). According to Miklos and Soares (2016), carrying out financial transactions through mobile channels reduces costs by 50% to 70%, making them more accessible to a larger portion of the population.

The emergence of financial technologies in the market marks a new reality for banks and cooperatives, representing a major challenge not only for academia but also for managers in the financial sector (McKillop et al., 2020; Milian et al., 2019). In short, these new technologies and the reduction of traditional bureaucracy allow the relationship between financial institutions and their customers to be more dynamic, providing a better experience for both parties, with cost reduction and, consequently, a greater competitive advantage in the market, focusing on the efficiency of the services provided and long-term financial sustainability (Ceretta & Niederauer, 2001; Vilela et al., 2007; Wheelock & Wilson, 2013).

The introduction of artificial intelligence changes the operational paradigms of financial institutions, requiring the reorganization of bank strategies to ensure sustainable operational dynamics. The main contribution of using artificial intelligence software is that it allows institutions to use available data to generate disruptive solutions, boosting operational efficiency with more accurate information in shorter time frames, in addition to facilitating greater virtual interaction with their customers (FEBRABAN, 2019).

METHODOLOGY

Description of the sample used

According to data from the Central Bank of Brazil for the year 2021, the National Credit Union System (SNCC) comprised 880 credit unions, ending the year with 853. Of this total, 849 individual cooperatives were active throughout 2021; however, by December of the same year, only 818 were still in operation (BACEN, 2022a).

Despite these fluctuations, the sample covers all credit unions with active CNPJs registered with the Central Bank during the 10-year period from 2012 to 2021. This time period was chosen because the accounting records of digital information began in 2012 (FEBRABAN, 2019). Additionally, according to Technical Pronouncement CPC 04 (R1) — Intangible Assets, financial resources related to digital technology must be recorded in the intangible category. Law no. 11,941 (2009), mandated the transition of records from the deferred category to intangible in the financial statements.

Of the credit unions listed in the BACEN database, those classified as 'Central' and 'Confederation' were excluded from the sample. Details on the composition of the sample can be found in Table 1.

Table 1. Descriptive statistics of the variables used in the research.

Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total CNPJ Active at BACEN	1276	1233	1174	1133	1097	1053	1003	958	906	880
Confederations with ITI	1	1	2	2	2	2	2	2	2	2
Centrals with ITI	31	32	32	30	31	30	30	28	28	29
Confederations without ITI	0	1	0	0	0	0	0	0	0	0
Centrals without ITI	6	5	6	5	4	5	5	7	6	5
Total cooperatives singles — GMM sample	1238	1194	1134	1096	1060	1016	966	921	870	844
Confederation cooperatives										
Central and singular without investment in ITI	654	590	542	468	428	419	379	349	282	263
Individual cooperatives with investment in ITI	590	610	598	633	636	602	592	579	594	586

Note. Developed by the authors based on research data. ITI = investment in information technology.

Each year, as new credit unions emerge or mergers occur, resulting in the exclusion of certain CNPJs from the Central Bank, the number of credit unions varies, leading to an unbalanced panel. Additionally, the inclusion or exclusion of cooperatives that began to register in the Intangible Assets category (25000009) also influences this dynamic.

In the sample for the GMM analysis, all individual credit unions that presented at least one registered quarter over the years under analysis were included. These cooperatives were excluded only when there were no accounting records for the four quarters of the reference year, regardless of the reason.

Econometric modeling — Generalized method of moments

In this study, the need to use a dynamic panel econometric approach arises due to the simultaneity evidenced by the performance proxies (Dietrich & Wanzenried, 2011). The use of the GMM model employs instruments obtained from the lags of the sampled regressors themselves (Baltagi, 2005). In this sense, the GMM corresponds to an econometric model capable of addressing the endogeneity problem (Baltagi, 2005).

The econometric literature highlights two possible approaches in relation to the GMM: the GMM in differences and the systemic GMM (Roodman, 2009). The GMM in differences corresponds to a method of estimating the parameters of the proposed model that uses lags of the original regressors as instrumental variables (Roodman, 2009). However, the GMM in differences methodology highlights the problem that, when used to estimate the parameters for finite samples and regressors that exhibit behaviors close to random walks, the instruments generated are weak, resulting in bias and inefficiency of the estimated parameters. Another unfavorable aspect of using GMM in differences is the marked imbalance of the panel under analysis evidenced by the use of transformations in difference (Roodman, 2009).

In view of the problems related to GMM in differences, there is a need to improve this approach. Thus, the systemic GMM emerges, which is based on the increase in the number of instruments used in comparison to GMM in differences, resulting in greater efficiency in the estimation of the parameters of interest (Roodman, 2009).

The validation of the GMM model is done based on specific tests that assess the adjustment required by the aforementioned approach. In this sense, the adjustment of the GMM to the data under analysis is verified based on the following statistical tests: Phillips–Perron (PP) unit root test; Arellano and Bond autocorrelation test; Sargan/Hansen test for overidentification restrictions;

and Hansen difference test (DIF-Hansen) (Roodman, 2009). The Phillips–Perron (PP) unit root test is used to verify the stationarity of the model's regressors, as required by GMM. The null hypothesis of the Phillips–Perron test assumes that the series contains a unit root, while the alternative hypothesis assumes the stationarity of the series (Baum, 2006).

The Arellano and Bond autocorrelation test is suitable for verifying the existence of first- and second-order autocorrelation of the differenced residuals. The assumption is that there is significant negative first-order autocorrelation, accompanied by non-significant second-order autocorrelation. The null hypothesis of this test assumes the absence of autocorrelation between the differenced residuals (Baum, 2006). The Hansen/Sargan test is used to verify the adequacy of the instruments used in the modeling. The null hypothesis of this test is based on the premise that the instruments proposed by the model are valid (Baltagi, 2005). Finally, the Hansen difference test (DIF-Hansen) verifies the validity of the number of instruments used by the systemic GMM compared to the GMM in differences. The null hypothesis of the test considers that the instruments from the systemic GMM are adequate to treat the analyzed data (Roodman, 2009).

In this context, the present study aims to estimate the following GMM model to address the proposed objectives:

$$Performance_{i,t} = \alpha_1 Performance_{i,t-1} + \sum_{i=0}^{3} \delta_i \, ITI\_TX\_CRES_{i,t-i} + \beta_1 RPLA_{i,t} + \beta_2 REA_{i,t} + \beta_3 TA_{i,t} + \beta_4 PLD_{i,t} + \beta_5 DR_{i,t} + \beta_6 ITI\_TX\_CRES_{i,t} + c_i + \varepsilon_{i,t} \quad (1)$$

Where performance represents the financial performance proxies; ROA is return on assets; ROE is return on equity; and ROI is return on investment.

The coefficients α_1, δ_i, and β_1 to β_6 represent, respectively, the lag effect of the dependent variable; the effects of the growth rate of investment in information technology (ITI_TX_CRES) in the current period (t-0) and its three lags (t-1, t-2, and t-3); the effect of RPLA (net equity and total assets); the effect of REA (ratio between bank loans and total assets); the effect of the size of credit unions (TA); the effect of PLD (provision for doubtful accounts); and the effect of the recession period (DR) on performance. Finally, ci is the unobserved heterogeneity; εit is the usual error of the model; i represents credit unions; and **t** represents the period corresponding to the quarters between January 2012 and December 2021.

Description of the variables used in the research

The four variables used as performance proxies, as well as the COSIF accounts that comprise them, are described below:

Return on assets (ROA): ROA measures the institution's ability to add value to its own capital with its available resources. This metric is used in the specialized literature on the subject to measure the performance of financial institutions (Freitas & Kirch, 2019; Hernando & Nieto, 2007; Laureto & Oreiro, 2011; Mendes, 2015; Pessanha et al., 2012; Ponce, 2013; Rahman et al., 2015; Wijayanti et al., 2021). The formula for obtaining ROA is expressed below:

$$ROA = \frac{Surplus}{Total\ Assets} = \frac{(7.0.0.00.00-9)+(8.0.0.00.00-6)}{[(1.0.0.00.00-7)+(2.0.0.00.00-4)]} \quad (2)$$

Return on equity (ROE): ROE is a profitability measure that aims to identify the remuneration of banks' equity (Freitas & Kirch, 2019; Furst et al., 2002; Hernando & Nieto, 2007; Laureto & Oreiro, 2011; Pessanha et al., 2012; Rahman et al., 2015). The equation for obtaining ROE is expressed as follows:

$$ROE = \frac{Surplus}{Net\ Worth} = \frac{(7.0.0.00.00-9)+(8.0.0.00.00-6)}{(6.0.0.00.00-2)} \quad (3)$$

Return on investment (ROI): ROI is an indicator used by companies and investors to show that the profitability of the business depends on the capital invested in the activity (Hernando & Nieto, 2007). The formula for calculating ROI is given by:

$$\text{ROI} = \frac{\text{Operating Revenue}}{\text{Investiment}}$$

$$ROI = \frac{(7.1.0.00.00-8)+(8.1.0.00.00-5)}{[(4.1.4.00.00-9)+(4.1.5.00.00-2)+(4.1.6.00.00-5)+(6.1.1.00.00-4)]Average} \quad (4)$$

According to Beccalli (2007), information on investments in information technology in the hardware and software parts of financial institutions is obtained through intangibles recorded in the assets of the balance sheet. Thus, to achieve the objective of this research, the analysis will consider the growth rate of the intangible entry. This growth rate is given by the following formula:

$$\text{ITI\_TX\_CRES} = \left[\frac{(2.5.0.00.00-9)t-(2.5.0.00.00-9)\,t-1}{(2.5.0.00.00-9)\,t-1}\right] \quad (5)$$

As control variables, and the respective COSIF accounts, we have:

Ratio between net equity and total assets (RPLA): Dividing net equity by the institution's total assets allows us to assess the amount of equity that financial institutions are using in relation to their total assets (Dietrich & Wanzenried, 2011). According to Krakah and Ameyaw (2010), the best performance of financial institutions is directly related to a high level of net equity. Thus, the authors argue that there is a positive relationship between RPLA and the performance of financial institutions. The equation for obtaining RPLA is given below:

$$\text{RPLA} = \frac{Net\ Worth}{Total\ Assets} = \frac{(6.0.0.00.00-2)}{(1.0.0.00.00-7)+(2.0.0.00.00-4)} \quad (6)$$

Ratio between bank loans and total assets (REA): The main way for financial institutions to obtain profits is through the interest charged on loan operations. The interest rate charged in these cases makes up the main source of revenue for banks and is therefore the main component of assets. Thus, a positive relationship is expected between REA and the performance of financial institutions (Dantas et al., 2011). Higher levels of REA may indicate that a given financial institution adopts strategies focused on centralizing services. In this sense, given the relevance of credit operations for financial institutions, specialization in these operations contributes to higher performance (Barry & Tacneng, 2014). The formula for obtaining REA is given below:

$$REA = \frac{Total\ Loans}{Total\ Assets} = \frac{(1.6.0.00.00-1)+(1.6.9.00.00-8)}{(1.0.0.00.00-7)+(2.0.0.00.00-4)} \quad (7)$$

Logarithm of size (TA): The size of financial institutions can be measured in several ways. In this study, the natural logarithm of the asset is used to measure it. According to Naceur (2003), Sathye (2005), Hernando and Nieto (2007), Perera et al. (2013), Guillén et al. (2014), Petria et al. (2015), Mendes (2015), and Freitas and Kirch (2019), the size of the financial institution has a positive relationship with profitability, since larger organizations tend to have a greater degree of service diversification compared to smaller institutions.

Provisioning (PLD): The provisioning indicator is the ratio between the provision for doubtful debts and the volume of credit operations. It allows us to verify the percentage of credit with late payment or default. Studies by Sathye (2005) and Gonçalves and Braga (2008) indicate a negative relationship between provisioning and the profitability of financial institutions since the greater the amount of doubtful debts, the greater the risk, signaling that the bank has carried out operations that present low liquidity and, as a consequence, there is a reduction in profitability. The equation for calculating the proportion of doubtful debts is expressed below:

$$Provisioning = \frac{Provisions\ for\ doubtful\ debts}{Credit\ operations}$$

$$Provisioning = \frac{(1.6.9.00.00-8)}{(1.6.0.00.00-1)} \quad (8)$$

Recession dummy (DR): In the 10-year period of analysis, the dichotomous variable assumes the value zero for periods of absence of financial crisis (2010 to 2014 and 2017 to 2019) and one for the years in which an economic recession is noted (2015 to 2016 and 2020 to 2021). Regarding the influence of the crisis on the performance of financial institutions, recessionary periods can determine the decrease in the revenues of financial institutions through a decrease in resources derived from financial intermediation, which ends up mitigating the performance of these entities (Cordeiro et al., 2018; Khrawish & Al-Sa'di, 2011).

$$DR = \begin{cases} 1\ if\ year\ 2005\ to\ 2016\ and\ 2020\ to\ 2021 \\ 0\ otherwise \end{cases} \quad (9)$$

Income from services rendered (RPS): Income from the provision of services is relevant for analyzing the financial performance of financial institutions. It is responsible for a large part of the resources that the cooperative receives in the fiscal year. Income from service provision is important in calculating the performance of cooperatives since the greater the relationship between service provision and administrative expenses, the greater the institution's performance (Bressan et al., 2010). Its equation is given by the following formula:

$$\text{RPS} = \ln (7.1.7.00.00\text{-}9) \quad (10)$$

Instrumentalization of variables

The choice of instruments for the estimated models was made considering that the instruments should be correlated with the endogenous variables but should not be correlated with the error term of the explanatory equation. Thus, the instruments should only have an effect on the outcome variable through the endogenous variable; otherwise, it would result in the same endogeneity problem. That said, in both the GMM-Sis (systemic)

and the GMM-Dif (differences), it is possible to define the standard instruments (also known as instrumental variables — IV) and the GMM-type instruments, as described by Holtz-Eakin et al. (1988) and Arellano and Bond (1991). Therefore, in all models (1 to 6, in Table 4), the GMM-type instrumental variables consider the fourth and fifth lags of the first three lags of Tax_Cres_ITI and the contemporary Tax_Cres_ITI. Regarding the instrumental variables — IV instruments, the models were instrumented as follows: the first three differences of Tax_Cres_ITI and the contemporary Tax_Cres_ITI. Finally, some models did not include contemporary instruments in the analysis. These are Models 3 and 4, where the IV-type instruments are the first three differences of Tax_Cres_ITI.

The option to use the lags (for the GMM type) and differences (for the IV type) of the variables of interest themselves occurs because these variables meet both the statistical criteria and the assumptions. This is because investment in technology is a historical issue; that is, past investment can only explain returns (ROA, ROE, and ROI) through present investment (variable of interest), which is endogenous.

Therefore, past investment is the best instrument to explain contemporary investment, since technology promotes dependence on firms, which, if they do not follow market trends, will become outdated and have higher costs. Thus, this is the assumption for considering the differences and lags of the variables of interest as type IV and GMM instruments, respectively.

RESULTS AND DISCUSSIONS

This section presents the descriptive statistics of the variables used in the research, the econometric models estimated via GMM, considering the performance proxies used (ROA, ROE, and ROI) as dependent variables, while the main focus is on the ITI growth rate.

Table 2 provides the descriptive statistics of the variables to be analyzed. It is noted that the standard deviations of the performance variables (ROA, ROE, and ROI) exceed their means and medians, highlighting the high variability of the data. This relationship is also evident in the ITI growth rate, being absent in the other control variables (RPLA, REA, TA, PLD, and RPS).

Table 2. Descriptive statistics of the variables used in the research.

	Obs.	Mean	Median	Standard deviation	Minimum	Maximum
ROA	59,816	0.007	0.006	0.014	-0.224	0.175
ROE	59,816	0.028	0.029	0.066	-1.054	0.735
ROI	59,816	0.013	0.011	0.022	-0.299	0.313
ITI TX CRES	59,816	-0.000	-0.018	0.164	-0.721	2.305
RPLA	59,816	0.260	0.186	0.202	-0.888	1.093
REA	59,816	0.582	0.594	0.164	0.005	1.838
TA	59,816	18.316	18.449	1.773	10.963	22.970
PLD	59,816	2.670	2.688	0.147	1.410	2.988
DR	59,816	0.347	0.000	0.476	0.000	1.000
RPS	59,816	12.844	13.122	2.341	0.215	18.461

Note. Prepared by the author based on research data. ROA — return on total assets; ROE — return on equity; ROI — return on total investments; CPLA — adjusted equity growth; ITI — investment in IT; RPLA — ratio between equity and total assets; REA — ratio between credit operations and total assets; TA — size; PLD — provision for doubtful accounts; RPS — income from services rendered.

The averages of the performance proxies show positive values, indicating that, on average, the cooperatives presented positive financial results in the period from 2012 to 2021. However, it is observable, through the minimum values (as per Table 2), that some cooperatives operated with a deficit.

Regarding the stationarity test, several tests were conducted, including the Fisher-type unit root test based on the Phillips–Perron method. This test was chosen due to its robustness and its ability to deal with less strictly balanced data sets, as is the case with the data used in this study. Furthermore, this test combines p-values using the inverse of the chi-squared distribution, inverse-normal analysis, inverse-logit transformation, and a modified version that considers the inverse of the chi-squared distribution, as proposed by Choi (2001), which is reported when the number of observations tends to infinity.

Table 3 presents these test combinations, considering that the null hypothesis indicates that all panels have a unit root, versus the alternative hypothesis that at least one panel is stationary.

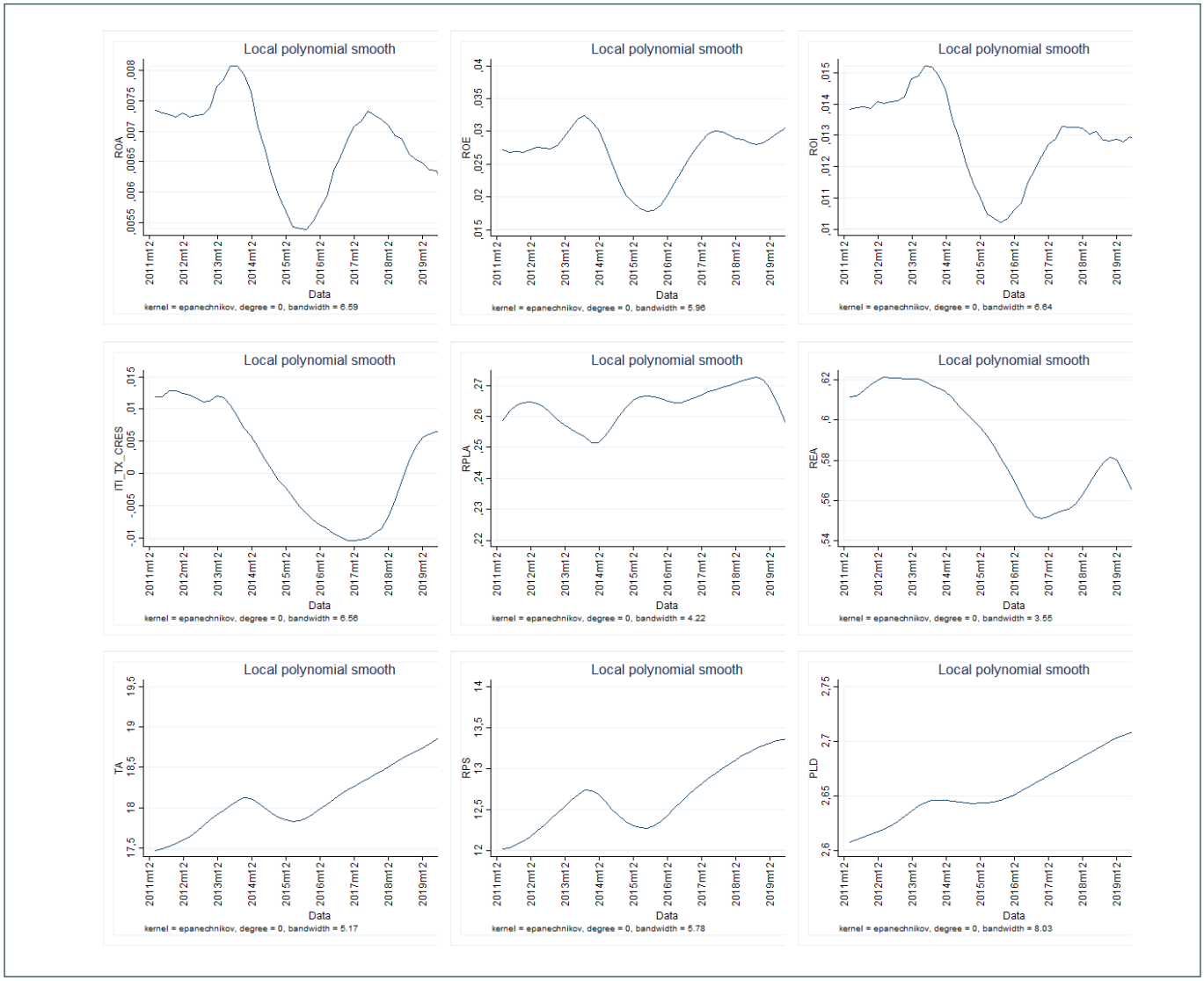
Table 3. Unit root tests.

Test/Variables	Panels	Mean Period	Inverse Chi² p	Inverse Normal z	Inverse Logit L	Mod. Inv. Chi² P_m
ROA	1,042	57.40	15,296.20***	-89.960***	-140.700***	230.000***
ROE	1,042	57.40	15,066.40***	-88.960***	-138.600***	226.100***
ROI	1,042	57.40	14,984.50***	-89.420***	-137.800***	224.700***
ITI TX CRES	1,042	57.40	37,768.40***	-177.300***	-413.200***	611.100***
RPLA	1,042	57.40	3,211.30***	-13.670***	-17.040***	24.990***
REA	1,042	57.40	2,138.60***	-0.520	-1.398***	6.795***
TA	1,042	57.40	1,579.10***	24.430***	23.700***	-2.695***
PLD	1,042	57.40	2,123.00***	3.164***	0.765***	6.530***
RPS	1,042	57.40	16,383.90***	-102.800***	-153.800***	248.400***

Note. Research data. ROA — return on total assets; ROE — return on equity; ROI — return on total investment; ITI TX CRES is the growth rate of intangible assets, which is the proxy for IT investment (ITI); RPLA — ratio between equity and total assets; REA — ratio between bank loans and total assets; TA — size; PLD — provision for doubtful accounts. Period of occurrence of crises: economic crisis for the years 2015 and 2016; COVID-19 health crisis for the years 2020 and 2021. Significance level: * 0.10, ** 0.05, *** 0.001. Null hypothesis: All panels contain a unit root. Alternative hypothesis: At least one panel is stationary. Only one lag was used. The trend was not considered in this analysis.

In general, it is noted that the panel is unbalanced, as the average of the periods is fractional. Additionally, the null hypothesis is rejected for most variables, with the only exception being REA. However, since this discrepancy only occurred with the inverse normal (z), it is considered that the null hypothesis is weakly rejected. This is because statistical significance was found in the other statistical tests.

When dealing with time series, an important point to observe is whether the variables that make up the model present similar trends (they are cointegrated) or whether they are random walks. This relationship can be better visualized in Figure 1.



Source: Research results. Note: ROA — return on assets; ROE — return on equity; ROI — return on total investments; ITI_TX_CRES is the ITI growth rate; RPLA — ratio between equity and total assets; REA — ratio between bank loans and total assets; TA — size; PLD — provision for doubtful accounts.

Figure 1. Behavior of the variables used in the study.

Evaluating the images of the variables plotted in the graphs in Figure 1, a visual 'cointegration' between the performance variables and the ITI growth rate is noticeable, but this relationship is not trivial when comparing the performance variables with the control variables (RPLA, REA, TA, PLD, and RPS). In this case, since the variables are not cointegrated, that is, they do not have a stable long-term relationship between them, traditional estimation techniques can lead to inconsistent or biased results.

Therefore, the methods adopted in this research solve this problem by incorporating information from previous periods, transforming the original variables into differences in relation to the previous period. This helps control the correlations between the errors and the independent variables, even when there is no cointegration present.

Therefore, the next step concerns the validation of the GMM to be estimated. In this case, the Arellano–Bond tests were performed for AR(1) and AR(2), the Sargan and Hansen tests to assess the adequacy of the instruments, the Dif-Hansen test to assess the difference between the GMM-systemic and the GMM-differences, and the same tests for the standard instrumental variables. These tests are presented in the lower part of Table 4, where the estimated results are also presented:

Table 4. Dynamic panel GMM models — Effect of growth rate on performance variables (ROA, ROE, and ROI).

Type of GMM	GMM Sis	GMM Dif	GMM Sis	GMM Dif	GMM Sis	GMM Dif
Proxies ITI	ROA	ROA	ROE	ROE	ROI	ROI
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (t-1)	**0.715*** (2.87)**	**0.574*** (12.83)**	-0.0889 (-0.72)	**0.465*** (2.66)**	**0.589*** (3.87)**	**0.528*** (12.52)**
Growth Rate ITI	-1.28e-5 (-0.00)	-1.26e-5 (-1.38)	3.99e-5 (0.01)	-6.71e-6 (-0.21)	-1.64e-5 (-0.02)	-1.71e-5 (-1.48)
Growth Rate ITI (t-1)	9.42e-6 (0.01)	6.99e-6 (1.29)	5.11e-5 (0.07)	8.24e-5 (1.27)	9.97e-6 (0.06)	7.04e-6 (1.21)
Growth Rate ITI (t-2)	-1.26e-6 (-0.00)	-2.50e-6 (-0.62)	1.00e-5 (0.02)	1.43e-4 (0.91)	-2.08e-6 (-0.03)	-3.11e-6 (-0.56)
Growth Rate ITI (t-3)	3.40e-8 (0.30)	**4.18e-8*** (7.05)**	5.77e-7 (1.51)	**1.65e-7*** (2.68)**	6.08e-8 (1.13)	**6.29e-8*** (7.57)**
RPLA	0.00457 (0.27)	0.00577 (1.16)	-0.272 (-0.83)	0.0122 (0.41)	0.0172 (1.29)	**0.0173** (2.17)**
REA	0.00309 (0.02)	0.00382 (1.10)	**-0.186* (-1.91)**	-0.0152 (-0.39)	0.00763 (1.22)	0.00613 (1.10)
TA	0.00339 (0.08)	**0.00367*** (2.93)**	0.0235 (1.02)	0.0116 (1.03)	0.00577 (0.65)	**0.00556*** (3.21)**
PLD	-0.0774 (-0.46)	**-0.0666*** (-4.53)**	-0.272 (-0.40)	-0.142 (-0.92)	**-0.143* (-1.93)**	**-0.114*** (-5.00)**
DR	-0.00073 (-0.18)	-0.0006 (-0.79)	-0.020 (-0.57)	-0.0034 (-0.31)	-0.00073 (-0.38)	-0.00066 (-0.55)
RPS	0.00325 (0.97)	**0.00228*** (4.40)**	0.00178 (0.13)	**0.0116*** (2.84)**	**0.00716*** (6.42)**	**0.00509*** (4.81)**
Constant	0.101 (0.24)	**0.0800*** (4.39)**	0.468 (0.29)	0.0271 (0.12)	**0.180*** (3.58)**	**0.136*** (4.39)**
Observation — Quantity — Instruments	49.370 1.013	49.370 623	49.370 1.013	49.370 623	49.370 1.013	49.370 623
AR1 (p-value)	0.061	0.017	0.328	0.316	0.192	0.165
AR2 (p-value)	0.448	0.417	0.539	0.343	0.353	0.336
Sargan (p-value)	1.000	1.000	1.000	1.000	1.000	1.000
Hansen-J (p-value)	1.000	0.999	1.000	0.986	1.000	0.999
GMM-Hansen (p-value)	0.743	0.999	0.821	0.982	0.827	0.999
GMM-Difference (p-value)	1.000	0.264	1.000	0.945	1.000	0.328
VI-Test Hansen (p-value)	1.000	.	1.000	.	1.000	.
VI-Difference (p-value)	1.000	.	1.000	.	1.000	.

Note. Research results. The term 'Sis' refers to the model that uses the first difference of the lags and the lag as instrumental variables. The term 'Dif' refers to the model that uses only the lags as instrumental variables. ROA — return on total assets; ROE — return on equity; ROI — return on investment; RPLA — ratio between equity and total assets; REA — ratio between bank loans and total assets; TA — size; PLD — provision for doubtful accounts; DR is the dummy variable with 1 for periods of crisis and 0 for typical periods; RPS refers to income from services rendered. ITI is the intangible. * 0.10, ** 0.05, *** 0.01 (significant results are in bold). T-statistics in parentheses.

When evaluating the results contained in Table 4, it can be observed, in the lower part of the table, that all models were validated, as the null hypothesis of the AR2 (second-order regression in terms of lags) and Hansen-J tests, which is the minimized value of the two-stage GMM criterion function (this being preferable to the Sargan p-value, since robust variances and covariances were used in the model), was not rejected. When performing the Hansen test, excluding groups of instruments (GMM-difference and VI-difference),

the null hypothesis was also not rejected, that is, the Hansen-J and the Hansen test with exclusion of instruments (GMM and VI for GMM-Sis or only GMM for Dif) are statistically different. Thus, the test results meet the necessary requirements for estimating both GMM-Dif and GMM-Sis.

Given these considerations, there is no statistical significance between the current ITI growth rate and ROA (calculated considering surpluses in relation to total assets). This means that nothing can be said about the (contemporary) investment made by cooperatives on top of the (contemporary) ROA. However, it can be seen that the investment made four quarters ago has a positive and statistically significant effect at the 1% level of significance in Model 2. In other words, taking the results into consideration, it can be said that a positive variation of, for example, 10% in the ITI growth rate has a positive effect of 0.00004% on the ROA of credit cooperatives after four quarters. Given that ROA is calculated as the proportion of surpluses in relation to total assets, small variations in technology investments do not immediately translate into large increases in cooperative surpluses. It is understood that technology plays an indirect role, improving efficiency, reducing operating costs, or increasing the capacity to generate revenue over time, and thus generating an incremental increase in the profitability of cooperatives.

This positive effect is also followed by the size of credit cooperatives (TA variable) and by the records of service provision income (RPS variable), both variables presenting significant and positive effects on ROA. On the other hand, PLD presents a negative effect on performance, indicating that a positive variation in provisions for doubtful loans negatively affects the performance measured by ROA (Model 2). This result is in line with the literature on the subject, which finds that larger cooperatives tend to present better financial and social performance. This may be related to the possibility of economies of scale practices and the fact that such cooperatives have a greater amount of resources, personnel, customers, and credit (Wijesiri et al., 2017).

When analyzing PLD, we have a negative relationship with ROA in Model 4, which indicates a negative relationship with performance, largely because it represents doubtful securities. This result is in line with the research by Muriithi et al. (2016), Poudel (2012), Kolapo et al. (2012), and Hosna et al. (2009), who found that credit risk negatively affects the performance of the institutions analyzed.

Regarding the ITI growth rate, the positive effect is also seen when analyzing Models 3 and 4, being statistically significant only in Model 4. As with the effect on ROA (Model 2), an increase in ROE (Model 4) was also noted. For example, a positive variation of 10% in the ITI growth rate has a positive effect of 0.00017% on the ROE performance of credit unions after four quarters. Hernando and Nieto (2007) show that financial institutions obtained a positive impact on their financial return a year and a half after making the investment. Therefore, the findings corroborate the data from Brcooperativo (2023), indicating that after legislative changes, the scope of services provided by cooperatives expanded, consequently increasing investments/technologies and leveraging operating results. However, the results found in this study indicate that these are marginal but positive performance improvements, as it is understood that a longer grace period for IT investment to be reflected in ROE is justified by the long-term nature of technological benefits, the time required for operational adaptation, and the maturation of investments.

However, there is a negative effect of loans in relation to total assets (REA) on ROE (surplus on equity) in Model 3 and a lack of statistical significance in Model 4. A possible explanation for this result is that these variables were analyzed contemporaneously, as the positive results of loans are obtained quarters ahead. However, this is not the specific objective of this work and was not analyzed. Finally, in Model 4, a significant positive relationship is observed for income from services provided (RPS), showing that the services provided by credit unions positively affect the return on equity.

The results for the performance that assesses returns on investments (ROI, Models 5 and 6) are similar to those presented in Models 1 and 2 (referring to ROA), both in terms of signs and statistical inference. A positive relationship is observed between the growth rate of investments in ITI in the third quarter of the past and the return on contemporary investment. In Model 6, a positive variation of 10% in the ITI growth rate has a positive effect of 0.00017% on the ROI performance of credit unions after four quarters. As with ROA and ROE, investments in IT have an incremental effect on financial performance. ROI, which measures the return generated in relation to the amount invested, tends to capture the direct benefits of investments in technology over time. However, these effects are gradual.

Regarding the other variables, service income (RPS) and cooperative size (TA) positively influence the performance indicator (ROI, Model 6 for TA and Models 5 and 6 for RPS), suggesting that larger cooperatives tend to present higher levels of financial performance. This finding is in line with Naceur (2003), Sathye (2005), Hernando and Nieto (2007), Perera et al. (2013), Guillén et al. (2014), Petria et al. (2015), Mendes (2015), and

Freitas and Kirch (2019), who state that larger credit cooperatives tend to obtain better financial performance compared to smaller credit cooperatives. This is because larger cooperatives can offer broader services at more favorable rates to borrowers and lenders and are therefore better positioned to capture a larger market compared to smaller credit unions (Goddard et al., 2008).

Finally, it is worth highlighting the lack of statistical significance of the control for periods of recession (DR) in all estimated models. That is, the financial crises experienced during the period did not cause significant structural changes in the performance variables analyzed (ROA, ROI, and ROE) for the periods 2015 to 2016 and 2020 to 2021. A possible explanation can be found in Figure 1, where the behavior of the credit union size variable shows a constant and increasing slope that begins in mid-2014. Therefore, other factors (including those analyzed in the models in Table 4) probably influenced the results, softening the economic crises experienced, which makes the DR dummy insignificant.

FINAL CONSIDERATIONS

Given the relevance of credit unions in the National Financial System and their impact on Brazilian economic development by granting credit to segments excluded from the traditional financial system, it is crucial to investigate mechanisms that can improve the management of these entities, aiming at greater financial performance and strengthening the credit union sector in Brazil.

The financial performance of credit unions is a fundamental factor in a market characterized by constant changes, competitiveness, and macroeconomic influences that can affect their continuity. In this context, it is pertinent to explore instruments capable of improving the performance of cooperatives in a competitive and uncertain scenario.

Investment in information technology (IT) has proven to be a relevant factor in improving the performance indicators of financial institutions. Therefore, this article aimed to evaluate the influence of the growth rate of IT investment on the performance of credit unions over the quarters from 2012 to 2021, measured by the ROA, ROE, and ROI indicators.

The results reveal that IT investments do not have positive and statistically significant effects on performance indicators in the current (contemporary) period. However, this research demonstrated that the maturation of IT investments, covering the investment base, training, adaptation, and economic returns, was significant in a period of three quarters subsequent to the initial IT investment. This finding is in line with existing literature, suggesting that the improvement in financial performance occurs in the long term, due to the need for staff adaptation and training.

In addition, the study could not infer the performance of cooperatives during periods of economic instability. It was also observed that larger cooperatives with higher revenue from services exhibit better performance indexes. On the other hand, cooperatives with riskier loan portfolios present less development.

A limitation of the study is the lack of analysis on the corporate reorganization process of cooperatives in relation to IT investments. Mergers may increase the size of cooperatives, but IT investment may not accompany this expansion, impacting financial performance in the long term.

Future research should consider incorporating credit unions into IT investments, as well as investigating the determining characteristics that drive greater IT investments in credit unions. In addition, it is suggested to analyze the persistence of the effects of the pandemic over time on the performance of credit unions and how this was related to IT investments. It would also be interesting to expand the time horizon of the study and include other variables that may impact the performance of Brazilian credit unions.

REFERENCES

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies, 58*(2), 277–297. http://www.jstor.org/stable/2297968 .%0D

Baabdullah, A. M., Alalwan, A. A., Rana, N. P., Kizgin, H., & Patil, P. (2019). Consumer use of mobile banking (M-Banking) in Saudi Arabia: Towards an integrated model. *International Journal of Information Management, 44*, 38-52. https://doi.org/10.1016/j.ijinfomgt.2018.09.002

Baltagi, B. H. (2005). *Econometric analysis of panel data* [3rd Edition]. JW

Banco Central do Brasil. (2022a). *Panorama of the National Cooperative Credit System*, https://www.bcb.gov.br/estabilidadefinanceira/coopcredpanorama.

Banco Central do Brasil. (2022b). *REB-Banking Stability Report*. https://www.bcb.gov.br/publicacoes/relatorioeconomiabancaria

Barroso, L. C. (2019). Febraban survey of banking technology: Analysis 2011 to 2018. https://www.bnb.gov.br/s482-dspace/bitstream/123456789/876/1/2019_INET_04.pdf

Barry, T. A., & Tacneng, R. (2014). The impact of governance and institutional quality on MFI outreach and financial performance in Sub-Saharan Africa. *World Development, 58*, 1-20. https://doi.org/10.1016/j.worlddev.2013.12.006

Baum, C. F. (2006). *An introduction to modern econometrics using Stata*. Stata

Beccalli, E. (2007). Does IT investment improve bank performance? Evidence from Europe. *Journal of Banking & Finance, 31*(7), 2205-2230. https://doi.org/10.1016/j.jbankfin.2006.10.022

Bharadwaj, A. S., Bharadwaj, S. G., & Konsynski, B. R. (1999). Information technology effects on firm performance as measured by Tobin's q. *Management Science, 45*(7), 1008-1024. https://doi.org/10.1287/mnsc.45.7.1008

Brandl, B., & Hornuf, L., (2017). Where did FinTechs come from, and where do they go? The transformation of the financial industry in Germany after digitalization, Working paper, University of Jena and University of Bremen.

Brandt, V. A., Zambon, A. R., & Pereira, K. L. (2021). Credit unions–efficiency analysis based on data envelopment analysis based on financial and social statements. *Brazilian Journal of Development, 7*(2), 12647-12667. https://doi.org/10.34117/bjdv7n2-062

Brcooperativo, (2023). Credit unions invest in technology to serve remote members. (Sep. 05). https://brcooperativo.com.br/2023/09/cooperativas-de-credito-investem-em-tecnologia-para-atender-associados-remotos/

Bressan, V. G. F., Braga, M. J., Bressan, A. A., & Resende, Filho, M. A. (2010). A proposal for accounting indicators applied to Brazilian credit unions. *Revista de Contabilidade e Controladoria*, *2*(3), 58-80. https://doi.org/10.5380/rcc.v2i3.19625

Ceretta, P. S., & Niederauer, C. A. P. (2001). Profitability and efficiency in the Brazilian banking sector. *Contemporary Management Journal*, *5*(3), 7-26.

Cernev, A., Diniz, E., & Jayo, M. (2010). The emergence of the fifth wave of banking innovation. In *Proceedings of the Americas Conference on Information Systems* (AMCIS). https://dx.doi.org/10.2139/ssrn.2924727

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance, 20*, 249-272. http://doi.org/10.1016/S0261-5606(00)00048-6

Coelli, C. M., & Pires, V. M. (2022). Desempenho dos maiores bancos brasileiros: Um estudo sobre o impacto da crise subprime. *Revista Ambiente Contábil, 14*(1), 245-271. https://doi.org/10.21680/2176-9036.2022v14n1ID22176

Cordeiro, F. A., Lamounier, W. M., & Barros, L. A. B. C. (2018). Economic recessionand the performance of Brazilian credit unions. *Recent Transformations in Brazilian Agriculture: Challenges in Management, Innovation, Sustainability andSocial Inclusion*. http://icongresso.itarget.com.br/tra/arquivos/ser.8/1/8763.pdf

Dantas, J. A., Medeiros, O. R. D., & Paulo, E. (2011). Relação entre concentração e rentabilidade no setor bancário Brasileiro. *Accounting & Finance Journal, 22*(55), 5-28. https://doi.org/10.1590/S1519-70772011000100002

Dietrich, A., & Wanzenried, G. (2011). Determinants of bank profitability before and during the crisis: Evidence from Switzerland. *Journal of International Financial Markets, Institutions and Money*, *21*(3), 307-327. https://doi.org/10.1016/j.intfin.2010.11.002

Federação Brasileira de Bancos. (2019). *Pesquisa Febraban de Tecnologia Bancária 2019: Base Year 2018* (1st published version). Deloitte. https://cmsarquivos.febraban.org.br/Arquivos/documentos/PDF/Pesquisa-FEBRABAN-Tecnologia-Bancaria-2019.pdf

Federação Brasileira de Bancos. (2020). *Pesquisa Febraban de Tecnologia Bancária 2020*. Deloitte Brasil, 2020. https://www2.deloitte.com/br/pt/pages/financial-services/articles/pesquisa-febraban-tecnologia-bancaria.html

Federação Brasileira de Bancos. (2023). *Pesquisa Febraban de Tecnologia bancária 2013*. Deloitte. https://cmsarquivos.febraban.org.br/Arquivos/documentos/PDF/Pesquisa%20FEBRABAN%20de%20Tecnologia%20Bancaria_2013.pdf

Freitas, O. D., & Kirch, G. (2019). Performance of Brazilian banks in the context of digitalization. *Brazilian Review of Finance, 17*(2), 38-55. https://doi.org/10.12660/rbfin.v17n2.2019.79189

Furst, K., Lang, W. W., & Nolle, D. E. (2002). Internet banking. *Journal of Financial Services Research*, *22*(1), 95-117. https://doi.org/10.1023/A:1016012703620

Goddard, J., McKillop, D., & Wilson, J. O. (2008). What drives the performance of cooperative financial institutions? Evidence for US credit unions. *Applied Financial Economics*, *18*(11), 879-893. https://doi.org/10.1080/09603100701262818

Gonçalves, R. M. L., & Braga, M. J. (2008). Analysis of the liquidity risk in credit unions: A logit multinomial approach. *Revista de Administração Contemporânea*, *12*(4), 1019-1041. https://doi.org/10.1590/S1415-65552008000400007

Guillén, J., Rengifo, E. W., & Ozsoz, E. (2014). Relative power and efficiency as a main determinant of banks' profitability in Latin America. *Borsa Istanbul Review*, *14*(2), 119-125. https://doi.org/10.1016/j.bir.2014.02.003

Halili, R. B. (2014). The impact of Online Banking on Bank [Master's thesis, Charles University of Prague]. https://dspace.cuni.cz/bitstream/handle/20.500.11956/64090/DPTX_2011_2_11230_0_365193_0_125299.pdf?sequence=1

Hernando, I., & Nieto, M. J. (2007). Is the Internet delivery channel changing banks' performance? The case of Spanish banks. *Journal of Banking & Finance*, *31*(4), 1083-1099. https://doi.org/10.1016/j.jbankfin.2006.10.011

Holtz-Eakin, D., Newey, W., & Rosen, H. S. (1988). Estimating vector autoregressions with panel data. *Econometrica*, *56*, 1371-1395. http://doi.org/10.2307/1913103

Hosna, A., Manzura, B., & Juanjuan, S. (2009). Credit risk management and profitability in commercial banks in Sweden [Master's thesis, Gothenburg University Library]. https://gupea.ub.gu.se/handle/2077/20857

Horobet, A., Radulescu, M., Belascu, L., & Dita, S. M. (2021). Determinants of bank profitability in CEE countries: Evidence from GMM panel data estimates. *Journal of Risk and Financial Management*, *14*(7), 307. https://doi.org/10.3390/jrfm14070307

Khrawish, H. A., & Al-Sa'di, N. M. (2011). The impact of e-banking on bank profitability: Evidence from Jordan. *Middle Eastern Finance and Economics*, *13*(1), 142-158.

Kolapo, T. F., Ayeni, R. K., & Oke, M. O. (2012). Credit risk and commercial banks performance in Nigeria: a panel model approach. *Australian Journal of Business and Management Research*, *2*(2), 31-38. http://doi.org/10.52283/NSWRCA.AJBMR.20120202A04

Krakah, A. K., & Ameyaw, A. (2010). The determinants of bank's profifitability in Ghana, The Case of Merchant Bank Ghana Limited (MBG) and Ghana Commercial Bank (GCB). https://www.semanticscholar.org/paper/The-Determinants-of-Bank%27s-Profitability-in-Ghana%2C-Krakah-Ameyaw/2aa1d801cf80b10c5fbf9230cbead43aa66f7985

Kumar, A., Dhingra, S., Batra, V., & Purohit, H. (2020). A framework of mobile banking adoption in India. *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(2), 40. https://doi.org/10.3390/joitmc6020040

Kumar, S., Thambiraja, T. S., Karuppanan, K., & Subramaniam, G. (2022). Omicron and Delta variant of SARS-CoV-2: a comparative computational study of spike protein. *Journal of Medical Virology*, *94*(4), 1641-1649. https://doi.org/10.1002/jmv.27526

Kwan, A., Lin, C., Pursiainen, V., & Tai, M. (2020). *Stress testing banks' digital capabilities: Evidence from the COVID-19 pandemic*. https://doi.org/10.2139/ssrn.3694288

Laukkanen, T. (2016). Consumer adoption versus rejection decisions in seemingly similar service innovations: The case of the Internet and mobile banking. *Journal of Business Research*, *69*(7), 2432-2439. https://doi.org/10.1016/j.jbusres.2016.01.013

Laukkanen, T., & Kiviniemi, V. (2010). The role of information in mobile banking resistance. *International Journal of Banking Marketing, 28*(5), 372-388. https://doi.org/10.1108/02652321011064890

Laureto, C., & Oreiro, J. L. (2011). Profitability and concentration of the Brazilian banking sector in the period. https://www.anpec.org.br/encontro2010/inscricao/arquivos/219-ee5a1c7b7cde383b5205f519d0b34361.pdf

Law no 11,941 from May 27, 2009. D.O.U de 27/05/2009, pág. nº 3. https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l11941.htm

Lu, W., & Swisher, J. (2020). A comparison of bank and credit union growth around the financial crisis. *American Journal of Business, 35*(1), 25-44. https://doi.org/10.1108/AJB-03-2019-0017

McKillop, D., French, D., Quinn, B., Sobiech, A. L., & Wilson, J. O. (2020). Cooperative financial institutions: A review of the literature. *International Review of Financial Analysis*, *71*, 101520. https://doi.org/10.1016/j.irfa.2020.101520

Mendes, V. V. C. (2015). The banking system of Cape Verde: The performance of commercial banks and the determinants of profitability [Master's thesis, University of Évora].

Merry, E. (2018). Mobile Banking: A closer look at survey measures. https://www.federalreserve.gov/econres/notes/feds-notes/mobile-banking-a-closer-look-at-survey-measures-20180327.htm

Miklos, L., & Soares, L. D. S. T. (2016). Sobre simulacros: A (im)potencialidade arquetípica do imaginário tecnológico-numinoso da tecnologia da comunicação. *Revista Mediação*, *18*(22), 11-28. https://revista.fumec.br/index.php/mediacao/article/view/3608

Milian, E. Z., Spinola, M. D. M., & Carvalho, M. M. (2019). Fintechs: A literature review and research agenda. *Electronic Commerce Research and Applications*, *34*, 100833. https://doi.org/10.1016/j.elerap.2019.100833

Mokyr, J. (2018). The past and the future of innovation: Some lessons from economic history. *Explorations in Economic History*, *69*, 13-26. https://doi.org/10.1016/j.eeh.2018.03.003

Muriithi, J. G., Waweru, K. M., & Muturi, W. M. (2016). Effect of credit risk on financial performance of commercial banks Kenya, *IOSR Journal of Economics and Finance, 7*(4), 72-83. http://doi.org/10.9790/5933-0704017283

Naceur, S. B. (2003). *The determinants of the Tunisian banking industry profitability: Panel evidence* [Working Papers, 10, 2003]. Universite Libre de Tunis

Ongore, V. O., & Kusa, G. B. (2013). Determinants of financial performance of commercial banks in Kenya. *International Journal of Economics and Financial Issues*, *3*(1), 237-252. https://dergipark.org.tr/en/pub/ijefi/issue/31956/351900

Perera, S., Skully, M., & Chaudhry, Z. (2013). Determinants of commercial bank profitability: South Asian evidence. *Asian Journal of Finance & Accounting*, *5*(1), 365-380. https://doi.org/10.5296/ajfa.v5i1.3012

Pessanha, G. R. G., Calegario, C. L. L., Safadi, T., & Ázara, L. N. D. (2012). Impactos das estratégias de fusão e aquisição na rentabilidade dos bancos adquirentes: uma aplicação dos modelos de intervenção no setor bancário brasileiro. *Revista de Administração Mackenzie*, *13*(5), 101-134. https://doi.org/10.1590/S1678-69712012000500005

Petria, N., Capraru, B., & Ihnatov, I. (2015). Determinants of banks' profitability: Evidence from EU 27 banking systems. *Procedia Economics and Finance*, *20*, 518-524. https://doi.org/10.1016/S2212-5671(15)00104-5

Ponce, A. (2013). What determines the profitability of banks? Evidence from Spain. *Accounting & Finance*, *53*(2), 561-586. https://doi.org/10.1111/j.1467-629X.2011.00466.x

Poudel, R. P. S. (2012). The impact of credit risk management on financial performance of commercial banks in Nepal. *International Journal of Arts and Commerce*, *1*(5), 9-15.

Rahman, M. M., Hamid, M. K., & Khan, M. A. M. (2015). Determinants of bank profitability: Empirical evidence from Bangladesh. *International Journal of Business and Management*, *10*(8), 135-150.

Rachdi, H. (2013). What determines the profitability of banks during and before the international financial crisis? Evidence from Tunisia. *International Journal of Economics, Finance and Management*, *2*(4), 330-377. https://www.ejournalofbusiness.org/Download_Jun-July_pdf_8.html

Rai, A., Patnayakuni, R., & Patnayakuni, N. (1997). Technology investment and business performance. *Communications of the ACM*, *40*(7), 89-97. https://doi.org/10.1145/256175.256191

Rodrigues, U. R., Primo., Dantas, J. A., Medeiros, O. R., & Capelletto, L. R. (2013). Determinantes da rentabilidade bancária no Brasil. *BASE--Revista de Administração e Contabilidade da Unisinos*, *10*(4), 308-323. https://revistas.unisinos.br/index.php/base/article/view/base.2013.104.02

Roodman, D. (2009). How to do Xtabond2: An introduction to difference and system GMM in Stata. *Stata Journal*, *9*(1), 86-136. https://doi.org/10.1177/1536867X0900900106

Sathye, M. (2005). The impact of internet banking on performance and risk profile: Evidence from Australian credit unions. *Journal of Banking Regulation*, *6*(2), 163-174. https://doi.org/10.1057/palgrave.jbr.2340189

Schneider, S., & Kokshagina, O. (2021). Digital transformation: What we have learned (thus far) and what is next. *Creativity and Innovation Management*, *30*(2), 384-411. https://doi.org/10.1111/caim.12414

Shen, Y.-C., Huang, C.-Y., Chu, C.-H., & Hsu, C.-T. (2010). A benefit–cost perspective of the consumer adoption of the mobile banking system. *Behaviour & Information Technology*, *29*(5), 497-511. https://doi.org/10.1080/01449290903490658

Simpson, J. (2007). Expert political risk opinions and banking system returns: A revised banking market model. https://scholar.google.com.br/scholar?q=-Simpson,+J.+(2007).+Expert+political+risk+opinions+and+banking+system+returns:+A+revised+banking+market+model.&hl=pt-BR&as_sdt=0&as_vis=1&oi=scholart

Schuch, Z., Milan, G.S., Kieling, R.I. Eberle, L., Freitas, Jr., J. C. S. (2023). The digital transformation in a credit cooperative. *Development in Question Journal*, *14*(12), 1-24. https://doi.org/10.21527/2237-6453.2023.59.14192

Trindade, M. T., Ferreira, F. D. A., Filho., & Bialoskorski, S., Neto. (2010). Brazilian credit co-operatives and financial banks: A ten-year performance comparison. *Journal of Co-operative Studies*, *43*(1), 14-22. https://www.ukscs.coop/resources/journal-of-co-operative-studies-vol-43-no-1

Vilela, D. L., Nagano, M. S., & Merlo, E. M. (2007). Aplicação da análise envoltória de dados em cooperativas de crédito rural. *Revista de Administração Contemporânea*, *11*(SPE2), 99-120. https://doi.org/10.1590/S1415-65552007000600006

Ugwuanyi, W., & Ugwuanyi, G. O. (2013). Evaluation of Information Technology (IT) investments on bank returns: Evidence from Nigerian banks. *Research Journal of Finance and Accounting*, *4*(4), 155-165.

Wheelock, D. C., & Wilson, P. W. (2013). The evolution of cost-productivity and efficiency among US credit unions. *Journal of Banking & Finance*, *37*(1), 75-88. https://doi.org/10.1016/j.jbankfin.2012.08.003

Wijayanti, R. P., Al Azizah, U. S., Daulay, Y., & Nugroho, A. W. (2021). The effect of digital banking innovation on the performance of conventional commercial banks in Indonesia. *International Journal Economic and Business Applied*, *2*(2), 1-14. https://simakip.uhamka.ac.id/download?type=jurnal&id=2293

Wijesiri, M., Yaron, J., & Meoli, M. (2017). Assessing the financial and outreach efficiency of microfinance institutions: do age and size matter?. *Journal of Multinational Financial Management*, *40*, 63-76. https://doi.org/10.1016/j.mulfin.2017.05.004

Winarno, W. A., Tjahjadi, B., & Irwanto, A. (2021). Time lag effects of IT Investment on firm performance: Evidence from Indonesia. *Jurnal Ekonomi Malaysia*, *55*(3), 89-101. https://doi.org/10.17576/JEM-2021-5503-06

Authors

Marcelo Ibrahim Lana

Universidade Federal de Minas Gerais, Faculdade de Ciências Econômicas

Av. Presidente Antônio Carlos, n. 6627, Pampulha, CEP 31270-901, Belo Horizonte, MG, Brazil

marcelo.lana21@gmail.com

Valéria Gama Fully Bressan

Universidade Federal de Minas Gerais, Faculdade de Ciências Econômicas

Av. Presidente Antônio Carlos, n. 6627, Pampulha, CEP 31270-901, Belo Horizonte, MG, Brazil

valeria.fully@gmail.com

José Roberto de Souza Francisco

Universidade Federal de Minas Gerais, Faculdade de Ciências Econômicas

Av. Presidente Antônio Carlos, n. 6627, Pampulha, CEP 31270-901, Belo Horizonte, MG, Brazil

jroberto@face.ufmg.br

Authors' contributions

1st author: data curation (lead), formal analysis (lead), funding acquisition (equal), investigation (equal), methodology (lead), project administration (equal), resources (equal), software (equal), supervision (equal), validation (equal), visualization (equal), writing - original draft (lead), writing - review & editing (lead).

2nd author: conceptualization (equal), data curation (equal), supervision (equal), validation (equal), visualization (equal), writing - original draft (equal), writing - review & editing (equal).

3rd author: conceptualization (equal), validation (equal), writing – original draft, writing – review & editing.