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Applying engineering principles to financial inclusion in Ecuador: A VEC model analysis of economic growth trends

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ABSTRACT

Financial inclusion is currently considered an important strategy to strengthen the economic growth of countries, especially developing ones. This study seeks to examine the impact that financial inclusion variables have had on the economic growth of Ecuador using quarterly time series information that corresponds to the period between 2020 and 2023. An error correction model was used, taking the Product Gross Domestic as a dependent variable and having as financial inclusion variables the credit granted by financial institutions with respect to GDP and the relationship credit granted by financial institutions with deposits; Other control variables were also used, such as liquidity in the broad sense (M2) in relation to GDP and the liquidity of banks and cooperatives. The study concluded that financial inclusion has a positive and significant impact on economic growth in Ecuador through the Credit variable; Additionally, in the short term all variables are related to each other, although in the long term only the variables M2/GDP and Credits/deposits influence the behavior of GDP.

Keywords: Financial inclusion, Economic growth, Quantitative data analysis, System dynamics modeling

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1. Introduction

Financial inclusion is one of the most important aspects of the government and international organizations because they consider it a fundamental tool in reducing poverty through access to financial resources. The World Bank estimates that financial inclusion is a key element to achieving 7 of the 17 Sustainable Development Goals, because it allows reducing extreme poverty and promoting shared prosperity, because access to financial services helps families and companies plan. in the long term and allows us to face unexpected emergencies; access to a savings account is a fundamental element for financial inclusion since through them, people begin to use additional financial services [1].

The Global Findex Database provides data on global access to financial services. According to this source, the percentage of adults with a savings account in a regulated financial institution rose from 51% in 2011 to 76% in 2021 worldwide. In developing economies, this figure is 71%. Additionally, the proportion of adults globally engaging in digital payments, either sending or receiving, increased from 35% in 2014 to 57% in 2021. This rate is notably higher in high-income economies at 95% and 83% in developing economies, with approximately 40% of adults using their accounts for saving and formal borrowing. By 2021, 18% of adults in developing economies paid utility bills directly from an account, while 20% (excluding China) made a digital commercial payment. Furthermore, 39% of adults in developing economies opened their first account specifically to receive

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salary payments or government transfers, and 20% of adults received salary payments or unexpected fees into an account [2].

In 2021, adults with an account in a financial institution represent 71% and that they use it to receive a salary or payment from the government are 39% [3]. Regarding particular characteristics regarding ownership of a savings account, only 69.3% of women have it, as do 67.1% of adults in the poorest 40% of households and 64. 3% of unemployed adults, as well as 66% of young people between 15 and 24 years old. As for adults who made or received digital payments in the last year, they were 65.1% and of these, 23.8% received a payment from the government and 15.3% received a salary from the private sector; Additionally, the people who sent or received a national remittance payment using an account were 18.2%. Regarding savings, 19.3% of adults saved money using an account and 30.5% borrowed formally (including using a credit card).

These elements allow us to specify the fact that, as stated by Velazquez, financial inclusion is considered an important tool in the fight against poverty and economic development and that with significant geographic penetration and investment in infrastructure, better products can be offered and financial services with greater efficiency and quality [4].

The research aims to analyze the influence of financial inclusion on economic growth in Ecuador by examining the short- and long-term relationship between Gross Domestic Product (GDP) and variables representing access to financial services, such as bank deposits and credits, the liquidity of financial institutions, and factors related to the financial system that influence economic growth, such as the volume of money in the economy.

The relevance of this study lies in the presentation of new information about the relationship between these two variables, given the scarcity of studies on this topic specific to Ecuador. This information can assist policymakers and researchers by providing new evidence that allows for a deeper understanding of data and information on such a critical issue for the growth of a country as access to financial services.

1.1. Literature review

Financial inclusion is defined as a process that enables individuals to access the formal financial system with a focus on transparency, opportunity, efficiency, and sustainability, supported by financial education processes. This allows these services to be used in a conscious and informed manner, according to the United States Agency for International Development [5]. Additionally, financial inclusion refers to the appropriate access to financial products for individuals and businesses that previously did not have it, allowing them to improve their incomes, secure financing for business growth, and save for future events and achieve personal goals.[6]. Moreover, with the support of savings mobilization, financial inclusion fosters growth and helps reduce poverty and inequality by enabling households and businesses to access resources to finance consumption and investment. It also aids in the formalization of labor and businesses, which allows the government to generate higher revenues and strengthen social safety nets. [7].

Complementarily, financial inclusion, in addition to providing access, helps people better manage their resources and develop financial capabilities, helps improve the effectiveness of transfers from the government to the social safety net; On the other hand, financial innovation can reduce transaction costs, achieving greater participation of the private sector in international development [8].

Regarding the way financial inclusion is measured, Cipoletta and Matos [9] consider that it is multidimensional in terms of access, use and quality; access is to use or easily access the services and products of the institutions of the formal financial system; use implies the effective, regular and frequent use of financial products; quality means the characteristics of access and use (quality and effectiveness). Financial inclusion is measured through four dimensions: access, use, quality and well-being; these dimensions imply the ability to access and use financial products, the main use given to them, the different products that are used and the relationship that the attributes of the products have with the needs of the people who obtain them [10].

In any case, financial inclusion must contribute to ensuring that access to financial services is efficient, taking into consideration facts such as that the products and services offered must be varied and adapted to the needs of clients, costs must be controlled and regularized, as well as the activities carried out by financial institutions.

There is numerous research that analyzes the relationship between financial inclusion and economic growth, with diverse results for different parts of the world.

In a study conducted in Mexico, a fixed effects panel data approach was utilized, with the Quarterly State Economic Activity Index (ITAEE) as the dependent variable and the increase in technological infrastructure as the independent variable [11]. The findings indicate a positive correlation between enhanced financial inclusion and the growth of technological access points. Consequently, it can be inferred that the adoption of digital devices plays a crucial role in promoting both financial inclusion and economic growth. Reference [12] reviews the theoretical and empirical literature regarding the link between financial inclusion and economic growth. The results show that most studies identify a positive relationship between financial inclusion and economic growth, mainly through improved financial intermediation, which offers greater access to financial products and services, ultimately driving economic growth. Common empirical methods in this body of literature include causality tests, cointegration techniques, and regression analysis. In contrast, Hidayatinnisa, Fauziah, Trivena, and Aini conducted a panel data regression analysis in Indonesia over two periods, 2016 and 2019, and found that neither education nor financial inclusion significantly influences economic growth, either individually or collectively [13].

These studies reflect varying perspectives and methodologies in assessing the relationship between financial inclusion, education, and economic growth across different contexts. In a study carried out by Ain, Sabir and Asghar [14] for 33 developing countries during the period 2004-2016, using the Generalized Method of Moments (GMM), they obtained the results that financial inclusion has a positive effect on economic growth. On the contrary, entrepreneurship has a negative but significant effect; Institutional variables such as rule of law and political stability have negative effects, while control of corruption and government effectiveness have positive effects on economic growth. A multidimensional index of financial inclusion in emerging markets is constructed that is used in a panel data model for emerging economies and which shows as results the fact that there is a positive relationship between inclusion financial and economic growth, being stronger in low-income countries and having a relatively lower degree of influence of financial inclusion in higher-income countries [15]. In the descriptive study for Mexico, statistical data taken from secondary sources were analyzed, seeking to analyze the importance of financial inclusion in reducing poverty and as a driver of economic growth [4]. In Mexico, they concluded that the inhabitants of the Lower-income sectors settled in geographic areas that are difficult to access are those who do not use financial services, specifically due to ignorance or lack of access, which would minimize their possibilities for economic growth and development; Additionally, it was established that in Mexico 90% of the population still uses cash as a means of payment, which implies insignificant use of electronic channels. Using the ARDL model and the error correction model (ECM) for the period 1985-2017, find that in Pakistan, financial inclusion and economic growth are cointegrated and that inclusion financial positively impacts economic growth in the short term with a delay of one year [16].

In a study conducted from 2004 to 2010 across 31 countries, both developed and developing, Sethi and Acharya utilized panel data models along with various causality tests [17]. Their results reveal a positive long-term relationship and bidirectional causality between financial inclusion and economic growth. Similarly, Kim, Yu, and Hassan [18] analyzed 55 countries from the Organization of Islamic Cooperation (OIC) using a dynamic panel, panel VAR, impulse response functions (IRFs), and Granger causality tests. Their findings suggest that financial inclusion positively impacts economic growth and that there is mutual causality between the two variables. Additionally, a theoretical and empirical review indicates that clear empirical evidence on the impact of financial inclusion on economic growth is still lacking [19]. Some studies show positive effects related to access to financial services, like the expansion of bank branches, while others point to negative contributions due to the weaknesses in the financial system and its limited accessibility. Analyzing time series data from 1990

to 2014, a study employing the Error Correction Model and various financial deepening variables—such as broad money, private sector credit, rural credit deposits, and the liquidity ratio of commercial banks—concluded that financial inclusion significantly and positively affects economic growth in Nigeria. The author recommends that regulators focus on ensuring that all financial inclusion efforts are designed to enhance economic activity, leading to inclusive economic growth [20].

For India, a study by Lenka and Sharma [21] conducted between 1980 and 2014 utilized Principal Component Analysis (PCA) to develop a financial inclusion index based on annual time series data. They applied an Autoregressive Distributed Lag (ARDL) model and an Error Correction Model (ECM), discovering a positive impact and a unidirectional relationship from financial inclusion to economic growth in both the long and short term. Similarly, Tega, Adegoke, and Dare examined panel data from 2006 to 2015 across three selected African countries using a log-linear model. Their findings suggested that the number of active ATMs, bank branches, and government spending were the most significant predictors of how financial inclusion contributes to poverty reduction in developing economies [22].

In a separate study examining Nigeria from 1986 to 2015, Okoye, Adetiloye, and Modebe used ordinary least squares to show that financial inclusion has played a role in alleviating poverty by providing rural credit. They suggested that monetary authorities should intensify their efforts to improve financial inclusion by increasing credit access for the private sector and enhancing the regulatory framework to ensure better resource allocation and utilization [23].

Through a VAR model, Saab [24] investigates the impact of financial inclusion on economic growth in the MENA region, demonstrating that financial intermediaries significantly influence growth. The study found bidirectional causality between the use of credit cards, mobile accounts, and Gross National Income. In a similar vein, Sharma applied a vector autoregression (VAR) model along with a Granger causality test to analyze the Indian economy from 2004 to 2013. He concluded that financial inclusion is vital for developing a strong and efficient financial infrastructure, thereby fostering economic growth [25]. The analysis revealed bidirectional causality between geographic coverage and economic development, as well as unidirectional causality from the number of deposit and credit accounts to GDP [26].

In another study utilizing secondary data and an ordinary least squares model, financial inclusion was identified as a key factor in increasing total production. Kodan and Chhikara developed a financial inclusion index that considered depth, availability, and usage for all countries as well as for Indian states, revealing that the depth index was the primary contributor. Their log-linear regression analysis showed that a 1% rise in financial inclusion was associated with an average 0.142% increase in the Human Development Index globally, while for Indian states, the increase was 0.139%. Additionally, the study found that the ratios of depth, availability, and usage were inversely related to poverty [27]..

1.1.1. Financial inclusion in Ecuador

Financial inclusion can be analyzed from the demand and supply sides.

On the demand side and according to Global Findex, financial inclusion processes have improved in Ecuador, although there is still much to do to reach efficient indicators. The data for those over 15 years of age are:

- Ownership of an account in a financial institution has been growing, going from 37% in 2014 to 64% of the total in 2021, although 16% keep it inactive.
- Regarding the use of accounts in a financial institution, for the year 2021, 53% have made deposits, 51% made a withdrawal and only 23% of all those over 15 made this withdrawal 2 or more times a month. years. Additionally, 13% saved money in the account and made a loan, 23%.
- Account ownership in a financial institution, for those people with primary education or less, increased their participation between 2011 and 2021, going from 23% to 60%. People with an account and who have a high school education or more improved between the two years, going from 41% to 67%. By

income level, the poorest 40% went from 23% with account ownership to 59%. Those who correspond to the richest 60% of income improved from 46% to 68% between 2022 and 2021. Regarding people who are outside the labor force, those who have an account went from 29% in 2014 to 48% in 2021 and, people who are in the workforce improved since 2023, by only 14 points, reaching 69% in 2021.

- Regarding the sending and receiving of remittances, 21% have received them and only 2% have received them through a money transfer service; Likewise, those who have received remittances in an account are barely 10%. Domestic remittances sent through a money transfer service have been sent by 3% and through an account by 8%. By gender, women over 15 years of age who have an account in a financial institution have increased from 33% in 2011 to 58% in 2021. On the other hand, men with an account increased from 40% to 71 %, between the years 2011 and 2021. By age, young people (between 15 and 24 years old) who maintain an account, increased from 26% in 2011 to 55% in 2021 and people over 25 years old improved the ownership of an account by going from 41% to 68% between 2011 and 2021.
- Only 15% of all people have a credit card in 2021 and only 10% use it. As for the debit card, 38% have it and only 16% use it.
- Regarding the ownership of a credit card, women who have one went from 8% to just 9%, while among men from 13% to 20% between 2011 and 2021. Card holders with 15 and 24 years old, they are 7% for 2021 and, for those over 25 years old, 18%. Those with primary education or less represent 13%, while those with secondary education or more are 16%. In terms of income level, 10% of the poorest 40% own a credit card and, on the contrary, 18% of those in the richest 60% income range have a credit card. 11% of people who are out of the labor force maintain a credit card compared to 16% of those who are in the labor force.
- The percentage of women over 15 years of age who handle debit cards represents 30% of the total, while the percentage of men is higher, 47%; As for young people, 32% have it and those over 25 years of age this percentage is 41%. For those with primary education or less, only 30% use the debit card and 44% for those with more than secondary education. Additionally, people in the range of the poorest 40% are 29% of the total and those with income from the richest 60% are 44%. Finally, of people who are outside the labor force, only 24% have a debit card and those who are in the labor force correspond to a value of 42%.
- The percentage of people who have access to the Internet was 70% for the year 2021 and ownership of a mobile phone was 89%. Of these people, the percentage that uses the mobile phone or the Internet to make payments, buy things, or send or receive money, through an account at a financial institution, is 26%.

On the supply side, the Superintendency of Banks of Ecuador publishes information on indicators of access and use of financial services and products. For September 2023, the following information was obtained at the national level [28].

- The number of service points decreased by -14.7% compared to 2022, reaching a total of 181,572. Of this grand total, 1,385 correspond to Offices (0.8%), 4,885 to ATMs (2.7%), 39,058 are correspondents (21.5%) and 136,244 represent dataphones and ATMs (75%), the latter being those with the greatest decrease (-20.6%) in relation to the previous year.
- The number of care points per 10,000 adults is 138.8, which shows a decrease of -15.94% between 2022 and 2023. By type of care point, the data shows that for every 10,000 adults there are 11 offices, 3.7 ATMs, 29.9 correspondents, 96.1 dataphones and 8.2 tills. It is the savings banks that have lost the greatest presence, since they decreased by -81.3%; On the contrary, the presence of correspondents has been strengthened, increasing by 9.1% between the two years.

- The number of service points per 1,000 km2 corresponds to: 4.9 for offices, 17.2 for ATMs, 137.7 for correspondents, 442.9 for dataphones and 37.60 for tills. In this indicator, it is the offices that have lost presence geographically, decreasing by -81% between September 2022 and September 2023.
- Most of the ATMs are located outside the offices of financial institutions, 56.4%, of which the majority are found in supermarkets (18.7%), health and related businesses (13%) and gas stations (12.3%).
- Bank correspondents, the highest percentage are located in factories (21.8%), stores (18.5%) and health and related businesses (11.5%).
- Regarding the number of credit operations per 10,000 adults, for consumption there were 1,011 and for microcredit, 377. The value per 10,000 adults was 2.86 million and 1.46 million for consumption and microcredit, respectively. Regarding the average amount of credit, it was 2,829 UDS for consumption and 3,871 for microcredit.
- Transactions for financial services were 3,055 million dollars between January and September 2023, with an increase of 1.9% compared to the previous year; Of this total amount, 73.5% was made through electronic channels, which showed an increase of 1.7%. There is a 17.2% annual increase in mobile banking transactions, while those carried out in electronic banking have decreased by -20.7%.

Both the financial inclusion data on the supply and demand sides show that the financial inclusion variables in Ecuador continue to improve in most aspects, but these processes must continue to be strengthened by private institutions, but with the support and backing of the authorities.

2. Methodology

In this research, to find the causal relationship of financial inclusion on economic growth in Ecuador, an error correction model will be used, which allows obtaining the relationship between variables in both the short and long term.

2.1. Cointegration

Cointegration as a concept was initially developed by Granger and Newbold [29], [30], Engle and Granger [31] and means that sometimes two or more time series with stochastic trends can show the same trend component, which implies that they evolve together long-term with a common trend Stock and Watson [32]. In short, cointegration implies a relationship between variables that is strong in the long term, with the same trend.

According to [32] (p. 468), referencing [31], if Xt_and Yt are both integrated of order one, and the difference Yt−Xt is integrated of order zero for some coefficient, then Xt_and Yt are considered to be cointegrated. This coefficient is referred to as the cointegration coefficient. When Xt and Yt are cointegrated, they share a common stochastic trend, and taking the difference Yt−Xt removes this shared trend. In essence, testing for cointegration between two I(1) variables is equivalent to testing for the stationarity of their relationship.

2.1.1. Error correction model specification

According to the Granger representation theorem, when variables are cointegrated, there must also be an error. Gujarati and Porter [33] state that taking into account the (linear) trend between two variables and if they are cointegrated, a long-term equilibrium relationship between the two is verified, although in the short term there may be disequilibrium and the error term the "equilibrium error", which also allows us to relate the short-term behavior of the dependent variable with its long-term value. According to Wooldridge, if yt and xt are I(1) processes and are not cointegrated, a dynamic model can be estimated in first differences, considering the following equation [34]

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \Upsilon_0 \Delta x_t + \Upsilon_1 \Delta x_{t-1} + u_t \quad (2)$$

Where ut has mean zero given $\Delta x_t \Delta y_{t-1}$, Δx_{t-1} y additional delays. y_t and x_t are cointegrated with the parameter β, so we have additional I (0) variables that can be included in equation 2. Let $s_t = y_t - \beta x_t$ so that st is I (0) and with mean zero. Now, lags of st can be included, such as a single lag:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \Upsilon_0 \Delta x_t + \Upsilon_1 \Delta x_{t-1} + \delta_1 \Delta s_{t-1} + u_t \quad (3)$$

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \Upsilon_0 \Delta x_t + \Upsilon_1 \Delta x_{t-1} + \delta_1 (y_{t-1} - \beta x_{t-1}) + ut \quad (4)$$

where E(ut|It-1) = 0 and It-1 contains information about Δxt and all passed values of x and y. The term $\delta_1(y_{t-1} - \beta x_{t-1})$ is called the error correction term.

This study takes into consideration the Private Sector Credit to GDP ratio (IF1) and the loan/deposit ratio (IF2) as variables to determine financial inclusion. Control variables are used such as the relationship between broad money/GDP and the liquidity index of commercial banks since this would allow the institutions of the financial system to be able to deliver greater resources to the population. Regarding the sources of financial inclusion data, the Monthly Financial Bulletins published by the for information on public banks, private banks and financial companies were used, as well as the Financial Situation statements issued by the Superintendency of Popular and Solidarity Economy for savings and credit cooperatives and mutual societies. The information on the variable money in the broad sense (M2) and Gross Domestic Product (GDP) was obtained from the monthly statistical bulletins and the Quarterly National Accounts of the Central Bank of Ecuador [33]. The data are quarterly from March 2010 to June 2023, due to the periodicity of the information provided by the ECB.

The model developed to measure the impact of financial inclusion on economic growth in Ecuador is the following.

$$PIB = \beta_0 + \beta_1 DP + \beta_2 IF_1 + \beta_3 IF_2 + \beta_4 PD + \beta_5 LB + \beta_6 LC + \mu_t \quad (5)$$

Where,

PIB = country's gross domestic product
DP = Relationship between broad money and GDP (M2/GDP)
IF_1 = Relationship between Credit to the Private Sector and GDP (CSP/GDP)
IF_2 = Loan to deposit ratio
LB = Liquidity index of commercial banks.
LC = Cooperative liquidity index
β_i = Parameters to find.
μ_t = estimated error

2.2. Quantitative analysis flow chart

Figure 1 illustrates the flowchart of the analytical techniques employed in this study to assess the impact of financial inclusion on Ecuador's economic growth.

2.3. Data

This methodology was employed to identify the long-term relationship between the two variables, as it is anticipated that the processes of financial inclusion, similar to the broader trends of financial development, will stimulate economic growth in Ecuador. This presumed positive relationship has already been examined in numerous studies.

To assess the impact of financial inclusion on GDP, the analysis utilized variables such as the credit extended by financial institutions relative to GDP, and the ratio of credit to deposits. Additional control variables included broad liquidity (M2) in relation to GDP and the liquidity of banks and cooperatives. The data, which encompasses quarterly time series from the Central Bank of Ecuador for GDP and broad liquidity (M2), as well as credit, deposits, and liquidity data from the Superintendence of Banks and the Superintendency of Popular and Solidarity Economy [36][37][38], covers the period from the first quarter of 2010 to the second quarter of 2023, resulting in a total of 54 observations for each variable. To account for the variability in observations, the GDP variable was transformed into logarithms.

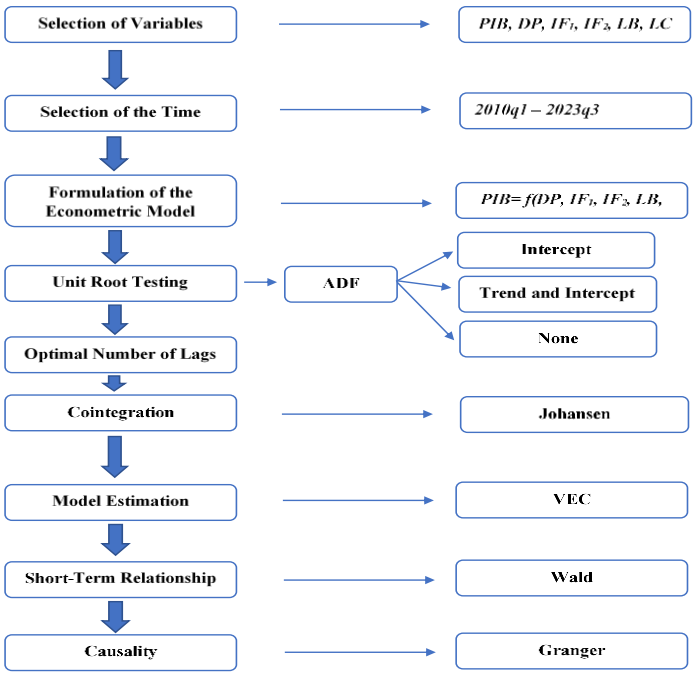

Figure 1. Flow chart of the techniques used in quantitative analysis

3. Results and discussion

3.1. Behavior of the Model Variables

The general pattern of the variables LNPIB, CREDITODEPOSITOS, and CREDITOPIB indicates a consistent and linear growth, which might suggest a situation where these variables are closely related and positively influence each other. It is likely that the system or phenomenon being analyzed is in a phase of expansion or sustained development.

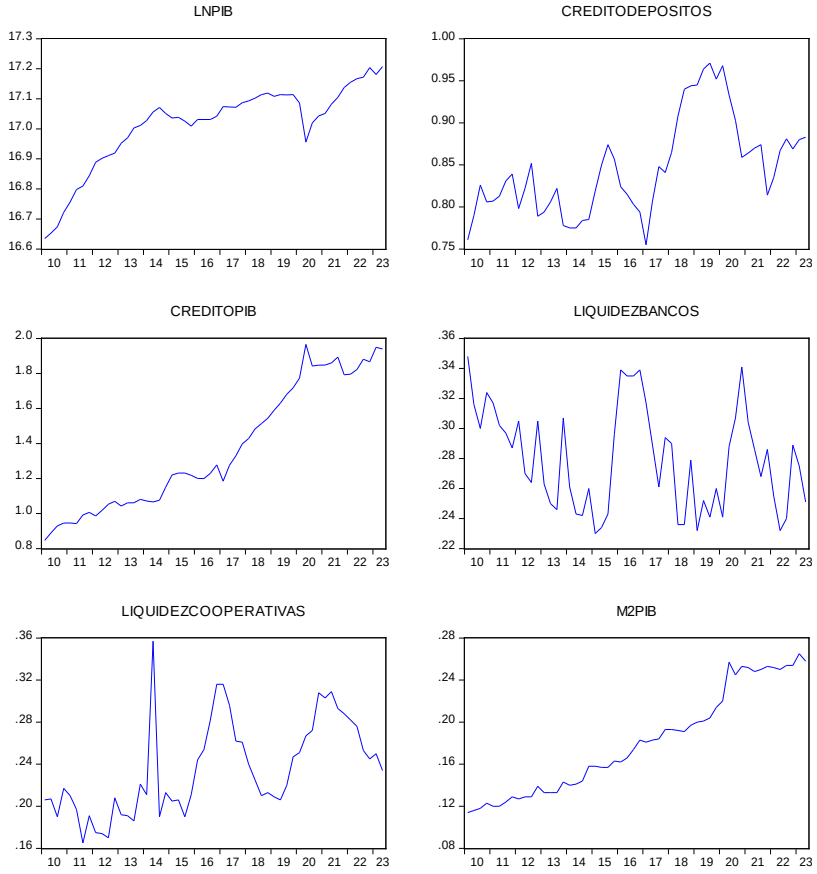

Figure 2. Evolution of the variables

When analyzing the time series of the variables "CREDIT/DEPOSITS," "LIQUIDITY/BANKS," and a third correlated variable, a general growth trend is observed throughout the period from 2010 to 2023. In the initial years, "Credit/Deposits" and "Liquidity/Banks" show moderate growth with some fluctuations. However, starting in 2016, a more pronounced increase in "Credit/Deposits" is evident, which could be related to changes in monetary policy or credit demand.

Meanwhile, "Liquidity/Banks" also experiences growth, but at a more stable and controlled pace. The third variable, possibly a risk or interest index, seems to exhibit more pronounced fluctuations, potentially reflecting uncertainty or volatility in financial markets. Together, these trends suggest a strengthening of the financial system, albeit with moments of tension and adjustments, as reflected in the peaks and troughs of the analyzed variables.

3.2. Unit root contrasts

n the context of the Vector Error Correction (VEC) model, the stationarity of the time series is assessed by examining the probability values associated with the t-statistic from the Augmented Dickey-Fuller (ADF) test. These probabilities determine whether to accept or reject the null hypothesis, as shown in Table 1, which indicates that all series exhibit stationarity in first differences, supported by the statistical significance of the probabilities. Consequently, the null hypothesis is rejected, supporting the alternative hypothesis that indicates the absence of a unit root, confirming the stationarity of the variables in first differences.

This aspect is crucial because a key condition for applying the VEC model is that the series must be non-stationary in levels, meaning their properties—such as mean, variance, and covariance—exhibit temporal variability. Verifying this requirement is essential to ensure the validity and reliability of the results obtained from the VEC model.

Table 1. Unit root contrasts

Variable	ADF in Levels			ADF in First Difference		
	Intercept	Trend and	None	Intercept	Trend and	None
LnPIB	-2.87**	-2.65	2.87	-6.49***	-6.74***	-5.77***
M2/PIB	-0.20	-2.81	3.40	-9.31***	-9.25***	-7.78***
Credit/PIB	-0.26	-2.07	2.95	-8.25***	-8.19***	-6.98***
Credit/Deposits	-2.01	-2.17	0.50	-6.58***	-6.52***	-6.62***
Liquidity/Banks	-	-3.64**	-0.86	-8.10***	-8.01***	-8.16***
Liquidity/Cooperatives	-2.03	-3.90**	-0.15	-	-11.13***	-

Note. The values correspond to the t statistic; *prob.<0.1; **prob.<0.05; ***prob.<0.01.

Table 2 presents the results regarding the optimal number of lags in the model, indicating that three information criteria—the Final Prediction Error (FPE), the Schwarz Criterion (SC), and the Hannan-Quinn Criterion (HQ)—consistently recommend using one lag. This is supported by the significant results found in the row corresponding to the use of a lag across all three criteria. Furthermore, the agreement among these multiple criteria in selecting a single lag suggests strong reliability in model identification.

This reliability enhances confidence in the chosen temporal structure, laying a solid groundwork for interpretation and further analysis..

Table 2. Optimal Number of Delays

Lag	LogL	LR	FPE	AIC	SC	HQ
0	558,2113	NA	1,03e-17	-22,08845	-21,85901	-22,00108
1	841,0107	486,4149	5,37e-22*	-31,96043	-30,35433*	-31,34882*
2	877,5891	54,13602*	5,58e-22	-31,98356	-29,00081	-30,84771
3	909,0875	39,05802	7,90e-22	-31,80350	-27,44409	-30,14341
4	954,8682	45,78075	7,59e-22	-32,19473*	-26,45866	-30,01040

3.3. Johansen cointegration analysis

The Johansen cointegration test is performed with 1 lag as the optimal number of lags was determined before, which leads to the following results. The interpretation of Johansen cointegration plays an important role in the empirical determination that the Vector Error Correction (VEC) model is the most appropriate choice to analyze the collected data. In this context, attention is directed toward the probabilities associated with the cointegration test, specifically the results labeled "None" in the Trace and Maximum Eigenvalue statistics.

Table 3. Unrestricted Cointegration Rank Test (Trace)

Hypothesis about the number of cointegration vectors	Own value	Trace statistician	Critical value
None *	0.560040	111.7244	95.75366
At least 1	0.453091	69.02865	69.81889
At least 2	0.299197	37.64806	47.85613
At least 3	0.181901	19.16059	29.79707
At least 4	0.086595	8.720418	15.49471
At least 5 *	0.074226	4.010499	3.841466

Table 4. Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesis about the number of cointegration vectors	Own value	Trace statistician	Critical value
None *	0.560040	42.69572	40.07757
At least 1	0.453091	31.38059	33.87687
At least 2	0.299197	18.48747	27.58434
At least 3	0.181901	10.44017	21.13162
At least 4	0.086595	4.709919	14.26460
At least 5 *	0.074226	4.010499	3.841466

Two hypotheses are proposed in this analysis. The null hypothesis suggests the absence of a cointegration vector, which would advocate the use of a VAR model. In contrast, the alternative hypothesis postulates the existence of a cointegration vector, thus favoring the use of a VEC model. The probabilities obtained reveal their significance, being lower than the critical level of 5%, both in the "None" category for Trace and for Maximum Eigenvalue. The consequence of these significant probabilities is the rejection of the null hypothesis. Therefore, the presence of a cointegration vector is inferred, supporting the suitability of the VEC model for the research in question. The strength of this empirical evidence reinforces the choice of the VEC model as the most appropriate framework for the exploration and analysis of the underlying patterns in the data.

3.4. VEC estimation

The cointegration vector meets the characteristics of being negative and significant (even at 1%), which, taking its absolute value, means that the speed of adjustment in the long term is 3.97%, that is, the adjustment will be made in a very short time.

When examining the variables included in the VEC model, it is evident that only the variables "M2/GDP" and "CREDIT/DEPOSITS" exhibit a significant error correction vector. This finding suggests that, in long-run equilibrium, substantial dynamic adjustments occur specifically in these two variables to counteract previous imbalances. That is, the error correction coefficient for the M2GDP variable is 0.02. This implies that, in case

there is an imbalance in the long-term relationship between "M2/GDP" and the response variable "LNPIB", approximately 2% of that imbalance is corrected in the next period or quarter.

On the other hand, the error correction coefficient for the variable "CREDITDEPOSITS" is -0.08. This indicates that, in case of an imbalance between "CREDITDEPOSITS" and the response variable "LNGDP", approximately 8.4% of that imbalance is adjusted in the following period or quarter.

Regarding the "M2/GDP (-1)" variable, a value of -33.23 indicates that a one-unit increase in the money supply relative to GDP from the previous period is associated with a decrease of approximately 33.23 in "LNPIB" in the current period. Similarly, the "CREDITOGDP (-1)" variable has a coefficient of 4.68, suggesting that in the long-term equilibrium, a unit increase in credits relative to GDP from the previous quarter is linked to an increase of about 4.68 in "LNPIB" in the current quarter. The "CREDITDEPOSITS (-1)" variable shows a coefficient of -3.55, meaning that in long-term equilibrium, a unit increase in the "CREDIT/DEPOSITS" ratio from the previous quarter is associated with a decrease of approximately 3.55 in "LNPIB" in the current quarter.

The "BANK LIQUIDITY (-1)" variable has a positive coefficient, indicating that an increase in bank liquidity in the previous period correlates with a significant rise in the logarithm of GDP in the current period. Lastly, the "COOPERATIVE LIQUIDITY (-1)" variable suggests that an increase in the liquidity of cooperatives in the previous period is also associated with a significant increase in the logarithm of GDP in the current period..

Table 5. VEC Approach: Financial inclusion and economic growth: (2010-2023).

Dependent variable: Y (growth)

	Coefficient	**Error Std.**	**t statistician**	**Prob.**
LNPIB(C1)	-0,039756	0,037323	-1,065,175	0,2878
M2/PIB(C9)	0,020106	0,008854	2,270,805	0,0240
CREDIT/PIB(C17)	-0,020435	0,065004	-0,314362	0,7535
CREDIT/DEPOSITS(C25)	-0,084024	0,035737	-2,351,153	0,0195
LIQUIDITY/BANKS(C33)	-0,027633	0,036160	-0,764193	0,4454
LIQUIDITY/COOPERATIVES(C41)	0,059313	0,044255	1,340,243	0,1813
R-squared	0.148890			
Adj. R-squared	0.013486			
sum squares residuals	0.032570			
Sum of errors equation	0.027207			
F-statistic	1.099597			
Registration probability	117.9809			
Akaike AIC	-4.230035			
Black SC	-3.929844			
Dependent on the mean	0.010654			
S.D. dependent	0.027392			

3.5. Short-term relationship

The results indicate that the independent variables—M2/GDP, Credit to the Private Sector relative to GDP, the loan-to-deposit ratio, the liquidity index of commercial banks, and the liquidity index of cooperatives—exert a short-term effect on GDP. This is evidenced by the significant short-term adjustment coefficients at conventional levels of significance. Therefore, there is support for the alternative hypothesis, suggesting that a relationship exists between these variables in the short term..

Table 6. Wald test

Statistical test	**Valor**	**df**	**Probability**
Chi-squared	47.92459	31	0.0268

3.6. Causality

According to the Granger causality test, there are only two relationships: the CREDITODEPOSITOS variable causes the M2GDP variable in the Granger sense and the CREDITOGDP variable also causes LIQUIDEZCOOPERATIVAS, at less than 5%.

It is then interpreted that the Credit/Deposits variable statistically precedes the Broad Money/GDP variable, that is, the lagged values of said variable have a significant impact on the M2/GDP variable, which means that Credit/Deposits can be used to predict the M2/GDP variable better than would be done if the antecedents of the latter were simply used. The same interpretation would be given for the Credit/GDP variable, which implies that this variable would be used to greatly predict the cooperative's Liquidity variable.

In conclusion, Credit/Deposits and Credit/GDP have significant effects on Broad Money/GDP and Liquidity of cooperatives, respectively.

The VEC model obtained allowed us to find that the variables Broad money (M2)/GDP, Credit/GDP, credits/deposit, Liquidity index of commercial banks and Liquidity index of cooperatives have a short-term effect on the GDP, that is, in the short term there is a relationship between the variables used in the model.

In the long term, in the VEC model it is evident that only the variables "M2/GDP" and Credit/GDP exhibit a significant error correction vector, a finding that suggests that, in long-term equilibrium, substantial dynamic adjustments occur specifically in these two variables to counteract previous imbalances. The model determined that the error correction coefficient for the variable M2/GDP is 0.02, this implies that, in case there is an imbalance in the long-term relationship between M2/GDP and the response variable LNPIB, approximately 2 % of that imbalance is corrected in the next period or quarter. Similarly, the error correction coefficient for the CREDIT/DEPOSITS variable is -0.08. This indicates that, in case of an imbalance between CREDITDEPOSITS and the response variable "LNPIB", approximately 8.4% of that imbalance is adjusted in the following period or quarter.

With respect to causality, only the CREDITODEPOSITOS variable Granger causes the M2GDP variable and the CREDITOGDP variable also causes LIQUIDITYCOOPERATIVES, at less than 5%, which means that the Credit/Deposits variable can be used to predict the variable M2/GDP better than would be done if the antecedents of the latter were simply used. The same interpretation would be given for the Credit/GDP variable, which implies that this variable would be used to greatly predict the cooperative's Liquidity variable.

All this implies that, to a small extent, financial inclusion, represented by the Credit variable, influences economic growth. This reasoning aligns with results observed by several authors [39]-[44], who suggest the importance of financing in the economic growth of countries.

3.7. Discussion of Results

The empirical results of this study find that in the short term, all variables related to financial inclusion are interrelated. However, in the long term, the financial inclusion variable, Credit/GDP, impacts the response variable LNPIB both in the long and short term. This indicates that financial inclusion positively influences economic growth in Ecuador. These findings are consistent with other studies, such as Kumar Lenka & Sharma, who found that financial inclusion has a positive impact on economic growth in India, both in the long and short term [21]. Similarly, the study by Sethi & Acharya found that in MENA countries, economic growth drives financial inclusion in both the long and short term, considering the highly significant F and t statistics [17]. Complementarily, studies such as Van, Vo, Nguyen, and Vo found a positive link between financial inclusion and economic growth in Vietnam, although it is not evident that greater access to credit positively affects economic growth, which is inconsistent with the results of the present study [15]. Other studies, such as Ifediora et al, agree that deposit accounts and loans promote economic growth, albeit marginally [45]. Regarding the causality between the variables, works like those of Kumar Lenka & Sharma [21] and Sethi & Acharya [17]

found a unidirectional relationship between financial inclusion and economic growth, an aspect not found in Ecuador. In Ecuador, there were only two causal relationships: the variable CREDITODEPOSITOS with the variable M2/GDP and the variable CREDITOGDP causing LIQUIDITYCOOPERATIVES. These results are consistent with those found in [25], who identified a unidirectional causality between the number of deposit/loan accounts and the gross domestic product in India.

4. Conclusions

In the econometric analysis, a Vector Error Correction (VEC) model was used because the logarithmic series were non-stationary and exhibited cointegration with a cointegrating vector. The long-term adjustment speed is -3.97%, which is both negative and significant at the 1% level. This indicates that adjustments between the variables occur rapidly, suggesting that financial inclusion, particularly through the credit/deposit variable, has an impact on economic growth in Ecuador.

Additionally, in the short term, the independent variables—M2/GDP, Credit to the Private Sector relative to GDP, the loan-to-deposit ratio, and the liquidity indices of commercial banks and cooperatives—show a significant short-term effect on GDP.

These findings suggest that a portion of financial inclusion, represented by the credit variable, plays a role in influencing economic growth. This perspective is supported by the research of various authors [40] [44], who emphasize the importance of financing for the economic growth of countries.

Declaration of competing interest
The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Authors' contributions

Mauricio Rivera and Willman Carrillo are the principal authors of the research. Their main contributions were in the development of the idea and design of the study, data collection, and critical review of the work. The other authors contributed to data tabulation, analysis, and interpretation of the results, as well as drafting the manuscript. Mauricio Rivera edited and approved the final manuscript and accepted responsibility for the final version of the work, ensuring its accuracy and completeness.

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