INQUIDE
Chemical Engineering & Development
Journal of Science and Engineering

Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533

INQUIDE
Ingeniería Química y Desarrollo

ARIMA vs. Hybrid Models with Machine Learning for Forecasting Ecuador's GDP

ARIMA vs. Modelos Híbridos con aprendizaje automático para pronóstico del PIB de Ecuador

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Received: 09/28/2025 – Accepted: 12/02/2025 – Published: 01/01/2025

Research Articles [X] Review Articles [ ] Essay Articles [ ]

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Abstract.
The analysis of Gross Domestic Product (GDP) is essential for understanding Ecuador's economic dynamics and guiding strategic decisions in contexts of high macroeconomic volatility. The purpose of the study was to estimate and forecast Ecuador's short-term GDP growth rate using robust and validated statistical models. Historical GDP series (1965–2023) obtained from the Central Bank of Ecuador were used. Stationarity tests (ADF, KPSS), correlograms, and information criteria (AIC, BIC) were applied to select appropriate ARIMA models. The analysis was performed using EViews 12, generating projections for the period 2024–2027 under optimistic, pessimistic and expected scenarios. The results showed that the Ecuadorian GDP series was not stationary at its original level, which required the application of the first difference to stabilise the mean. The identified ARIMA model incorporated autoregressive and moving average components, whose coefficients were statistically significant. The model residuals did not show autocorrelation, confirming its validity. The projections generated for the period 2024–2027 indicated moderate growth under optimistic, pessimistic and expected scenarios. These results were consistent with official estimates, validating the Box-Jenkins methodology as an effective tool for national economic forecasting. The study provides useful empirical evidence for national economic planning, validating the applicability of ARIMA models in GDP analysis. In addition, it promotes interdisciplinary approaches between economics and engineering, strengthening the technical capacity to address macroeconomic problems in contexts of high structural uncertainty.

Keywords.
Economic growth, Gross Domestic Product, Ecuador, Arima and Box-Jenkins models, Economic forecasting, Macroeconomic planning.

Resumen.
El análisis del Producto Interno Bruto (PIB) resulta esencial para comprender la dinámica económica de Ecuador y orientar decisiones estratégicas en contextos de alta volatilidad macroeconómica. El estudio tuvo como propósito estimar y pronosticar la tasa de crecimiento del PIB ecuatoriano a corto plazo mediante modelos estadísticos robustos y validados. Se utilizaron series históricas del PIB (1965–2023) obtenidas del Banco Central del Ecuador. Se aplicaron pruebas de estacionariedad (ADF, KPSS), correlogramas y criterios de información (AIC, BIC) para seleccionar modelos ARIMA adecuados. El análisis se realizó con EViews 12, generando proyecciones para el período 2024–2027 bajo escenarios optimista, pesimista y esperado.Los resultados evidenciaron que la serie del PIB ecuatoriano no era estacionaria en su nivel original, lo que requirió la aplicación de la primera diferencia para estabilizar la media. El modelo ARIMA identificado incorporó componentes autorregresivos y de media móvil, cuyos coeficientes fueron estadísticamente significativos. Los residuos del modelo no presentaron autocorrelación, lo que confirmó su validez. Las proyecciones generadas para el período 2024–2027 indicaron un crecimiento moderado bajo escenarios optimista, pesimista y esperado. Estos resultados fueron consistentes con estimaciones oficiales, validando la metodología Box-Jenkins como herramienta eficaz para el pronóstico económico nacional. El estudio aporta evidencia empírica útil para la planificación económica nacional, validando la aplicabilidad de modelos ARIMA en el análisis del PIB. Además, promueve enfoques interdisciplinarios entre economía e ingeniería, fortaleciendo la capacidad técnica para abordar problemas macroeconómicos en contextos de alta incertidumbre estructural.

Palabras clave.
Crecimiento económico, Producto Interno Bruto, Ecuador, Modelos Arima, Box-Jenkins, Pronóstico Económico, Planificación macroeconómica.

1.- Introduction

Economic growth is one of the most relevant variables for the analysis of the stability and development of countries, since it reflects the productive capacity and structural conditions of their economies, in this context, the Gross Domestic Product (GDP) is the main indicator used to measure economic activity, so its estimation and forecasting are essential for the formulation of public policies. decision-making in the business environment and the evaluation of future scenarios. (Desiderio Noboa, 2022)

In the case of Ecuador, the evolution of GDP has been marked by a notable dependence on oil exports, vulnerability to external shocks and the implementation of fiscal and monetary policies that have influenced its growth dynamics, these factors have generated significant variations in the expansion rates of the economy. which makes it necessary to have robust statistical tools that allow us to understand their historical behavior and project trends with a greater degree of precision.(Asán Caballero, 2023)

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Within the methodologies of time series analysis, the Box-Jenkins approach (ARIMA) has established itself as one of the most used in the modeling and forecasting of economic variables, its ability to identify stochastic patterns in data, adjust parsimonious models and generate reliable projections makes it a suitable alternative to study the dynamics of GDP. In addition, its flexibility allows capturing the non-stationary nature of economic series and improving the quality of estimates over short-term horizons.(Tudela-Mamani y otros, 2022)

In this framework, the present study aims to estimate and forecast the GDP growth rate of Ecuador using the Box-Jenkins methodology, in order to evaluate its predictive capacity and provide empirical evidence that contributes to the analysis of the national macroeconomic dynamics, thus seeking to strengthen the academic debate and provide useful inputs for the management and economic planning of the country.(García Vázquez y otros, 2021)

The analysis of economic growth is a central issue in economic research and in the formulation of public policies, because the Gross Domestic Product (GDP) is the main indicator that measures the productive capacity of a country. In the case of Ecuador, the dynamics of GDP have been subject to multiple internal and external factors, such as dependence on oil exports, vulnerability to changes in international commodity prices, the dollarization of the economy, the fiscal and monetary policies applied, as well as social and political phenomena that have generated cycles of expansion and contraction in its growth.(de la Oliva de Con & Molina Fernández, 2020)

This reality raises the need to have analytical tools that allow us to understand the historical behavior of GDP and anticipate its future evolution, however, a large part of the studies on the Ecuadorian economy have focused on descriptive analyses or aggregate macroeconomic projections, which limits the ability to have rigorous and validated statistical models for forecasting purposes.

In this context, the research problem arises: how to reliably estimate and forecast Ecuador's GDP growth rate from its historical series, using a statistical model that captures the temporal dynamics of the data?

The Box-Jenkins methodology, using ARIMA models, offers a robust approach to address this challenge, by allowing to model the stochastic behavior of the series and generate predictions with an adequate degree of precision for decision-making, however, its application to the Ecuadorian case still requires further exploration and empirical validation, which justifies the present study.

The estimation and forecasting of the growth rate of the Gross Domestic Product (GDP) of Ecuador, using the Box-Jenkins methodology, is of great importance because it combines economic analysis with statistical and computational tools of engineering, this approach not only contributes to the understanding of the national macroeconomic dynamics, but also strengthens the capacity of engineering to address complex problems in environments of high uncertainty.(Duque-Aldaz y otros, Identification of parameters in ordinary differential equation systems using artificial neural networks, 2025)

In order to comply with the objective of this research, it is proposed; as a first step, to be able to estimate and forecast the growth rate of Ecuador's Gross Domestic Product (GDP) through the use of statistical models, in order to generate reliable information that supports economic planning and strategic decision-making at the governmental, business and academic levels. As a second step, it is proposed to analyze the historical evolution of the GDP growth rate of Ecuador, identifying trends, cycles and relevant patterns. As a third step, it is proposed to select and apply appropriate statistical and econometric models (for example: ARIMA, VAR, error correction models) for the estimation and forecasting of GDP. Finally, the results obtained will be compared with the official projections (Central Bank of Ecuador, ECLAC, IMF), evaluating similarities and discrepancies.(Castro Rosales y otros, 2025)

1.1. Concept and relevance of the Gross Domestic Product (GDP)

Gross Domestic Product (GDP) is a fundamental economic indicator that represents the total monetary value of all final goods and services produced within a country's borders during a specific period, usually a year. Its theoretical origin is mainly attributed to Simon Kuznets, who introduced it in the 1930s to measure national economic activity, and it has since established itself as the standard metric for assessing the size and health of economies globally. GDP reflects both tangible production, such as manufactured or agricultural goods, and intangible services, such as education and health, thus capturing the productive capacity and economic dynamics of a country at any given time.(Cruz Ramírez y otros, 2024)

In the context of Ecuador, GDP is especially relevant given that the country has an economy highly dependent on sectors such as oil exports, agro-industrial products and natural resources. Sustained GDP growth is associated with greater job creation, improved quality of life, and increased general well-being of the population. Likewise, the analysis of GDP and its evolution allows governments and public entities to design and adjust economic, fiscal and social policies, guiding investments in infrastructure, education and health to promote a more balanced and sustainable development within the national territory.(Núñez Ordóñez, 2023)

In addition to its usefulness in measuring aggregate output, GDP functions as a key indicator of economic stability and business confidence, influencing the perception of national and international investors. The comparison of nominal and real GDP allows us to identify real changes in production, discounting inflationary effects. Also, its expression in per capita terms makes it easier to evaluate the average level of wealth and the economic progress of the population, an aspect of particular importance for Ecuador due to the existing regional and social inequalities. In this sense, GDP not only measures economic volume, but also reflects the structural conditions and challenges faced by the Ecuadorian economy.(Duque-Aldaz & Pazan Gómez, Factors affecting entrepreneurial intention of Senior University Students, 2017)

1.2. Factors Affecting Economic Growth in Ecuador

Ecuador's economic growth is strongly influenced by both internal and external factors that determine the dynamics of the Gross Domestic Product (GDP). Among the external factors, dependence on oil exports plays a central role, as the national economy is highly linked to fluctuations in international oil prices. Recent studies show that declines in oil prices have a significant and more pronounced negative impact on real GDP, also affecting tax revenues and public spending, which are critical variables to sustain economic growth. This sensitivity has highlighted the need to diversify sources of income to reduce vulnerability to external shocks arising from the volatility of international markets.(Chérrez Sánchez y otros, 2025)

From a domestic point of view, the fiscal and monetary policies implemented by the Ecuadorian government are key mechanisms for influencing economic growth. Tax collection, together with the management of public spending, have a positive and significant relationship with the evolution of GDP, since these resources allow financing investments in infrastructure, education and other strategic sectors. However, political stability seems to play a less decisive role in economic variability than direct economic variables, although social and political factors can generate uncertainty that impacts business confidence and macroeconomic expectations.(Sandoya Sánchez & Vásquez Villon, 2004)

In addition, the Ecuadorian economy presents cycles of expansion and contraction that are related to global economic phenomena, such as the global financial crisis and fluctuations in the oil market. Sectors such as mining, agriculture and manufacturing play important roles in the productive structure, although their contribution is conditioned by international trends and internal dynamism. Therefore, the interaction between external variables and domestic economic policy decisions shapes the complex dynamics of GDP growth in Ecuador, reaffirming the importance of strategies aimed at strengthening resilience and promoting sustainable and diversified economic development.(Romero Ruiz y otros, 2024)

1.3. Models and methodologies for economic analysis and forecasting

To analyze and forecast the evolution of the Gross Domestic Product (GDP) in emerging economies such as Ecuador, time series models have established themselves as fundamental tools. These models allow us to capture the dynamics and patterns intrinsic in historical economic data to project their future behavior. Among the most widely used are autoregressive models, moving averages and their combinations, which adjust the temporal dependence of economic variables. The ability of time series models to handle sequential data and their flexibility to incorporate seasonalities and trends makes them suitable for environments with complex and noisy economic data.(Morocho Choca y otros, 2024)(Herrera Mendoza, 2024)

The Box-Jenkins methodology, which includes the ARIMA (AutoRegressive Integrated Moving Average) models, is based on the systematic identification, estimation and validation of the model that best fits the time series. This methodology is especially valuable for economic estimation and forecasting because it combines autoregressive and moving average components after series differentiation to achieve stationarity. Recent studies applied to the Ecuadorian context have implemented ARIMA models to forecast key variables, demonstrating the effectiveness of the approach in capturing economic fluctuations and generating predictions adjusted to real scenarios.(Sandoya Sanchez & Abad Robalino, 2017)

However, ARIMA models and other traditional models have both advantages and limitations. Among its strengths is the relative structural simplicity and the ability to forecast with historical univariate data. However, in contexts of high economic volatility and external dependence, such as the case of Ecuador, they may have difficulty anticipating abrupt changes or incorporating the effects of exogenous shocks, such as international crises or variations in commodity prices, which affect GDP. For this reason, it is recommended to complement these models with multivariate approaches or current techniques that allow the incorporation of external explanatory variables and better capture the structural complexity of the economy.(Ochoa González, 2024)

1.4. Statistical tests and criteria for model validation

In order to validate the suitability and accuracy of the ARIMA models applied to the analysis of the Gross Domestic Product (GDP), it is essential to perform statistical tests to ensure the stationarity of the time series. Among the most commonly used are the augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The ADF test contrasts the null hypothesis that the series has a unit root —that is, it is not stationary— against the stationarity alternative, and relies on the inclusion of lagging terms to correct possible autocorrelation. On the other hand, the KPSS test assumes stationarity as a null hypothesis, evaluating whether the series is the sum of a random walk and a stationary component. The combination of both tests allows for a more robust evaluation, since their null hypotheses are opposite, providing greater certainty about the behavior of the national GDP series.(Pincay Moran y otros, 2025)(Varas y otros, 2023)

In addition, the analysis of correlogograms – autocorrelation and partial autocorrelation functions – is essential to identify seasonal patterns and temporal dependencies in the data, facilitating the appropriate choice of AR and MA parameters in ARIMA models. For the optimal selection of the model, statistical information criteria such as the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are used, which balance the fit of the model with its complexity, avoiding overfitting. These criteria allow you to compare different specifications and select the one that minimizes the prediction error with the fewest parameters.(Li Ye & Paz y Miño Robles, 2023)

Finally, residual diagnosis is a crucial step to validate the quality of the estimated model, verifying that the residuals are white noise, i.e., independent random variables with zero mean and constant variance. This involves non-autocorrelation tests – such as the Ljung-Box test – and normality tests on the residuals, ensuring that the model has correctly captured the relevant information in the series. ARIMA models that successfully pass these statistical tests provide reliable and robust estimates for GDP forecasting, increasing the accuracy and usefulness of economic analyses in the Ecuadorian context.(Arango Fuentes y otros, 2025)

1.5. Practical applications and complementary approaches

Statistical models for the analysis and forecasting of the Gross Domestic Product (GDP) in Ecuador have a significant practical application in economic planning and strategic decision-making. By using time-series models such as ARIMA, policymakers and agencies can generate reliable projections that guide the efficient allocation of public and private resources, anticipating future scenarios. This is essential to design fiscal policies, adjust budgets and evaluate the impact of external and internal variables on the national economy, allowing proactive management in the face of changes in economic dynamics.(Macías Sandoval & Tutiven Galvez, 2025)

To strengthen the predictive capacity and capture interrelationships between multiple economic variables, multivariate models such as Autoregressive Vector (VAR) and Vector Error Correction Models (VECM) are used. These models allow analyzing the co-integration and dynamic relationships between various macroeconomic variables, including inflation, exchange rates, interest rates, and exports, enriching the understanding of the causes and effects on GDP variation. Its use complements and expands the information provided by univariate models, adapting better to complex and highly interrelated economic contexts such as the Ecuadorian one.(Cruz Peña, 2024)

Recently, there has also been an increase in the incorporation of hybrid methods that combine traditional statistical models with machine learning and artificial intelligence techniques to improve the accuracy of economic forecasting. These techniques make it possible to take advantage of large volumes of data and detect non-linear patterns that escape conventional approaches, increasing robustness in contexts of high volatility and external dependence. In Ecuador, the integration of these approaches represents a key methodological advance to address the limitations inherent in classical models and empower decision-making based on more accurate and adaptive predictive analytics.(Fu-López y otros, 2025)(Lliguizaca Dávila y otros, 2020)

2.- Materials and methods.

The methodology used in this research is described below:

Facts:

Annual historical series of Ecuador's GDP (1965–2023) provided by the Central Bank of Ecuador (BCE).

Software and analytical tools:

EViews 12 (x64) for time series analysis and ARIMA model estimation.

Experimental design

Type of study: quantitative, longitudinal, based on time series.

Variables studied:

Dependent: GDP growth rate.

Method validation:

Stationarity tests (ADF, KPSS) were applied to ensure the suitability of the time series models.

Information criteria (AIC, BIC) were used to select the most appropriate models.

The results were compared with official forecasts from the ECB and ECLAC to assess consistency.

Procedures

Data collection:

Download historical GDP series and related macroeconomic variables from the ECB, ECLAC and INEC.

Debugging and preparation:

Data cleansing, outlier removal, and homogenization of units and periods.

Exploratory analysis:

Descriptive statistics and visualization of trends, seasonality and economic cycles.

Modeling:

Application of ARIMA models for individual series.

Model validation and tuning:

Residual, autocorrelation and heteroskedasticity tests.

Comparison with official forecasts and adjustment of parameters according to results.

Forecast generation:

INQUIDE
Chemical Engineering & Development
Journal of Science and Engineering

Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533

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Annual GDP projection for the next four years (2024–2027).

Presentation of results:

Charts and graphs in EViews, including optimistic, pessimistic, and expected growth scenarios.

Data analysis

Descriptive statistics: means, standard deviations, trends and seasonality.

Time series models: ARIMA, SARIMA for individual estimates.

Model Validation:

Unit root test (ADF, KPSS).

Autocorrelation analysis (ACF, PACF).

Information criteria (AIC, BIC).

Forecasts: 95% confidence intervals and comparison with historical series.

3.- Analysis and Interpretation of Results.

3.1.- Presentation of results:

Phase 1 Identification

Table 1. Historical Series of the Gross Domestic Product (GDP) of Ecuador (1965-2023)

Series: PIB Workfile: ARTICULO::1\

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1965	2339.033
1966	2442.572
1967	2535.654
1968	2556.129
1969	3153.717
1970	2798.598
1971	2689.986
1972	3091.270
1973	3900.130
1974	6470.751
1975	7708.141
1976	9044.610
1977	11055.22
1978	11806.45
1979	14361.49
1980	18253.79
1981	22115.45
1982	20059.81
1983	17256.55
1984	

Source: Central Bank of Ecuador.

Evolution of GDP in Ecuador (1965-2023)

Figure 1.- Evolution of GDP in Ecuador (1965-2023)

According to the graph, the series does not show stationarity in the mean, although it does show a trend, therefore, we will proceed to check this assumption, then we will check the assumption.

Table 2. Results of the Unit Root Test (ADF Test) Augmented Dickey-Fuller Test

View | Proc | Object | Properties | Print | Name | Freeze | Sample | Genr | Sheet | Graph | Stats | Ident

Null Hypothesis: PIB has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.626286	0.9735
Test critical values:	1% level	-4.124265	
	5% level	-3.489228	
	10% level	-3.173114	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PIB)
Method: Least Squares
Date: 09/15/25 Time: 12:42
Sample (adjusted): 1966 2023
Included observations: 58 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PIB(-1)	-0.020924	0.033410	-0.626286	0.5337
C	-897.8526	1266.193	-0.709096	0.4813
@TREND("1965")	125.8258	71.07052	1.770436	0.0822

R-squared	0.121485	Mean dependent var	2048.414
Adjusted R-squared	0.089539	S.D. dependent var	4283.441
S.E. of regression	4087.177	Akaike info criterion	19.51944
Sum squared resid	9.19E+08	Schwarz criterion	19.62601
Log likelihood	-563.0636	Hannan-Quinn criter.	19.56095
F-statistic	3.802825	Durbin-Watson stat	1.586295
Prob(F-statistic)	0.028386		

Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533

A time series is non-stationary in mean when its expected value (the mean) is not constant and changes over time.
We observe that the p-value indicates that the series is non-stationary on average, therefore, it is necessary to apply transformations, such as differentiation, to make it stationary.
The following are the hypotheses of the test:
Ho (null): the series has a unit root → is not stationary.
H1 (alternative): the series has no unit root → is stationary.
P-value (0.9735), is very high, much higher than any typical significance level (0.01, 0.05, 0.1), this does not allow Ho to be rejected, which means that the series is not stationary.

First GDP difference
Table 3. GDP (Gross Domestic Product) - First Difference

Series: D(PIB) Workfile: ARTICULO::1\

Last updated: 09/15/25 - 12:43
Formula: d(pib)

1965	NA
1966	103.5395
1967	93.08167
1968	20.47484
1969	597.5886
1970	-355.1196
1971	-108.6118
1972	401.2839
1973	808.8602
1974	2570.620
1975	1237.390
1976	1336.470
1977	2010.614
1978	751.2279
1979	2555.034
1980	3892.300
1981	3861.667
1982	-2055.641
1983	-2803.264
1984	

First Difference in GDP

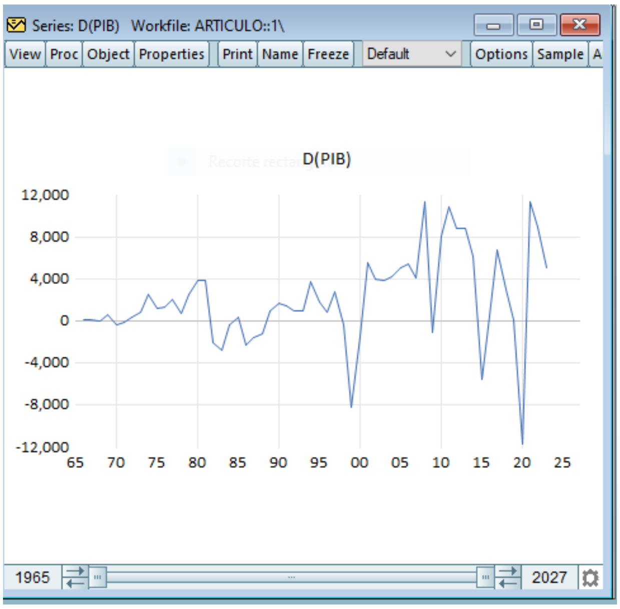

Figure 2.- First Difference in GDP

Then we see that the graph no longer has a trend and apparently the average is around 0, we do the Augmented Dickey-Fuller Test (ADF Test).

Table 4. Unit Root Test (DAF) Results on the First GDP Difference

Null Hypothesis: D(PIB) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.517803	0.0000
Test critical values:	1% level	-3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PIB,2)
Method: Least Squares
Date: 09/15/25 Time: 12:45
Sample (adjusted): 1967 2023
Included observations: 57 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PIB(-1))	-0.715090	0.129597	-5.517803	0.0000
C	1513.744	610.2960	2.480345	0.0162

R-squared	0.356320	Mean dependent var	86.14731
Adjusted R-squared	0.344616	S.D. dependent var	5154.791
S.E. of regression	4173.100	Akaike info criterion	19.54516
Sum squared resid	9.58E+08	Schwarz criterion	19.61685
Log likelihood	-555.0372	Hannan-Quinn criter.	19.57302
F-statistic	30.44615	Durbin-Watson stat	1.970695
Prob(F-statistic)	0.000001		

The new variable Dpbi has been subjected to a stationarity analysis, which confirmed that it is stationary. Subsequently, the correlogram is performed.

H0 (null): the series has a unit root → is not stationary.
H1 (alternative): the series has no unit root → is stationary.

It is much lower than any typical significance level (0.01, 0.05, 0.1), this means that we reject the null hypothesis Ho. Then we perform the correlograme.

Table 5. Correlogram of the First Difference in GDP

INQUIDE
Chemical Engineering & Development
Journal of Science and Engineering

Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533

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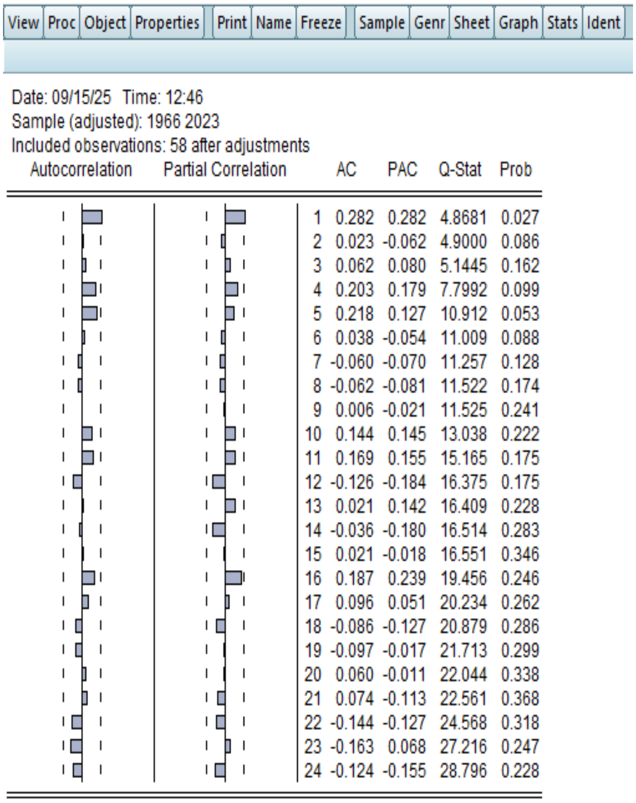

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Date: 09/15/25 Time: 12:46
Sample (adjusted): 1966 2023
Included observations: 58 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.282	0.282	4.8681	0.027
		2	0.023	-0.062	4.9000	0.086
		3	0.062	0.080	5.1445	0.162
		4	0.203	0.179	7.7992	0.099
		5	0.218	0.127	10.912	0.053
		6	0.038	-0.054	11.009	0.088
		7	-0.060	-0.070	11.257	0.128
		8	-0.062	-0.081	11.522	0.174
		9	0.006	-0.021	11.525	0.241
		10	0.144	0.145	13.038	0.222
		11	0.169	0.155	15.165	0.175
		12	-0.126	-0.184	16.375	0.175
		13	0.021	0.142	16.409	0.228
		14	-0.036	-0.180	16.514	0.283
		15	0.021	-0.018	16.551	0.346
		16	0.187	0.239	19.456	0.246
		17	0.096	0.051	20.234	0.262
		18	-0.086	-0.127	20.879	0.286
		19	-0.097	-0.017	21.713	0.299
		20	0.060	-0.011	22.044	0.338
		21	0.074	-0.113	22.561	0.368
		22	-0.144	-0.127	24.568	0.318
		23	-0.163	0.068	27.216	0.247
		24	-0.124	-0.155	28.796	0.228

Phase 1: Identification
Partial Correlation AR:(1)
Autocorrelaction MA:(1)

Phase 2: We choose a model
d(PBI) c ar(1)

Table 6. Results of the Estimation of the Model 1 d(gdp) c ar(1)

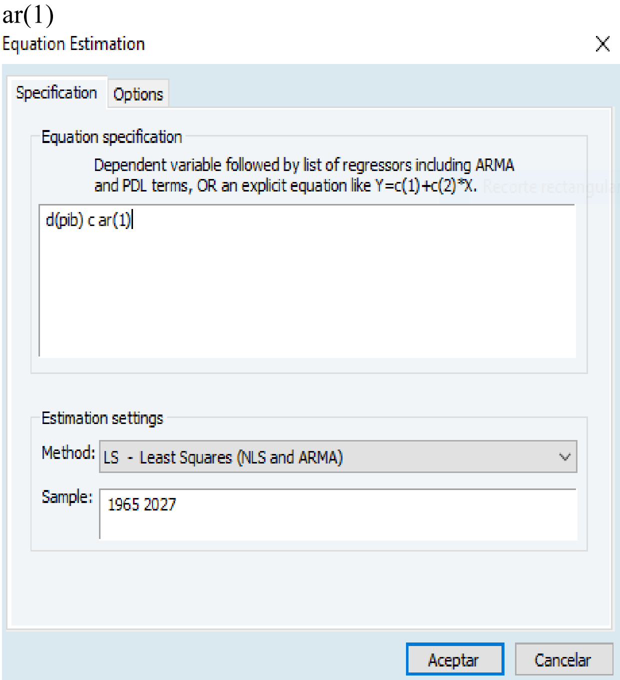

Table 7. Results of the ARMA Estimation by Maximum Likelihood (OPG - BHHH) d(pbi) c ar(1)

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: D(PIB)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/15/25 Time: 12:50
Sample: 1966 2023
Included observations: 58
Convergence achieved after 23 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2055.198	774.5634	2.653363	0.0104
AR(1)	0.280924	0.088811	3.163178	0.0025
SIGMASQ	16576666	2256256.	7.346978	0.0000

R-squared	0.080684	Mean dependent var	2048.414
Adjusted R-squared	0.047254	S.D. dependent var	4283.441
S.E. of regression	4181.010	Akaike info criterion	19.56625
Sum squared resid	9.61E+08	Schwarz criterion	19.67282
Log likelihood	-564.4212	Hannan-Quinn criter.	19.60776
F-statistic	2.413547	Durbin-Watson stat	1.955942
Prob(F-statistic)	0.098919		

Inverted AR Roots	.28

The results of the ARIMA model estimation show that all coefficients are statistically significant at a 95% confidence level, this is concluded by observing that their p-values are less than 0.05.

C (Constant): The p-value of 0.0104 is less than 0.05, indicating that the model constant is significant. This suggests that there is a non-zero mean in the series after differentiation.

AR(1) (Autoregressive Term): With a p-value of 0.0025, this coefficient is highly significant, this confirms that the current value of the series is strongly correlated with its value in the previous period (a lag).

SIGMASQ (Variance of Error): The p-value of 0.0000 is extremely low, which means that the variance of the model residuals is statistically significant. This is a good indication that the model is correctly capturing the structure of the series, and that the variance of the errors is not zero.

Proposed model

$$\Delta y_t = \phi_0 + \phi_1 \Delta y_{t-1} \dots \dots 1$$

{Ho: $0\phi_0 =$

{: ≠0 significant because the p-value is $0.0001 H_1 \phi_0$

So phase 2 does comply because the values of the coefficients are significant.

P-Value:
If $p < 0.05 \rightarrow$ you reject H_0
If $p \geq 0.05 \rightarrow$ you don't reject H_0

Phase 3: Diagnosis
It is a function of the normality of errors and Autocorrelation of errors.
View
Residual Diagnostic
Histogram – Normality Test

Histogram of the residues

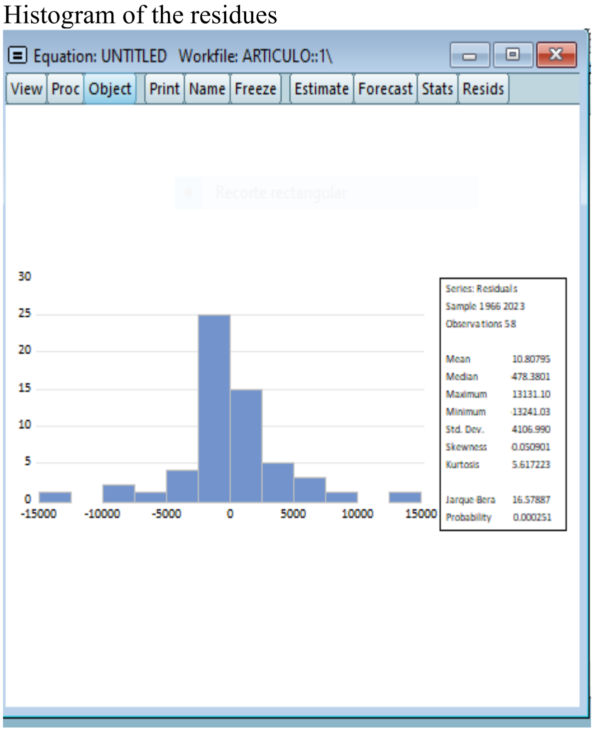

Figure 3.- Histogram of the residuals

**In this graph we see that errors tend to be normal with mean 0 and variance 1.
The Jarque-Bera probability is 0.000251 therefore the distribution of errors is Not Normal.

So we go back to Phase 1.
Then equation d(gbi) c ar(1) ma(1)

Table 7. Results of the Estimation of the Model 2 d(gdp) c ar(1) ma(1)

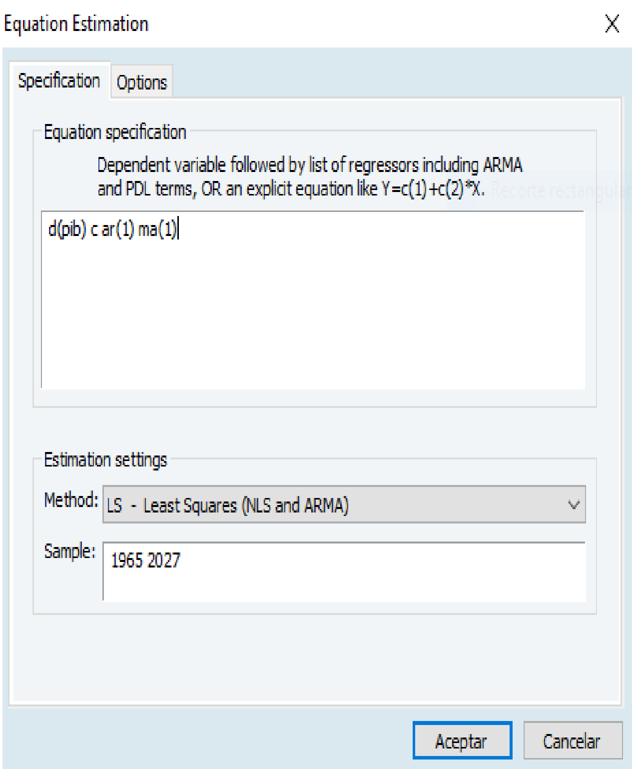

Table 8. Results of the ARMA Estimation by Maximum Likelihood (OPG - BHHH) d(pbi) c ar(1) ma(1)

View Proc Object Print Name Freeze Estimate Forecast Stats Resids

Dependent Variable: D(PIB)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/15/25 Time: 12:54
Sample: 1966 2023
Included observations: 58
Convergence achieved after 32 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2050.847	746.0807	2.748827	0.0081
AR(1)	0.061898	0.423412	0.146188	0.8843
MA(1)	0.237986	0.418702	0.568391	0.5721
SIGMASQ	16500629	2247270.	7.342521	0.0000

R-squared	0.084901	Mean dependent var	2048.414
Adjusted R-squared	0.034062	S.D. dependent var	4283.441
S.E. of regression	4209.857	Akaike info criterion	19.59629
Sum squared resid	9.57E+08	Schwarz criterion	19.73839
Log likelihood	-564.2925	Hannan-Quinn criter.	19.65164
F-statistic	1.670001	Durbin-Watson stat	1.984593
Prob(F-statistic)	0.184307		

Inverted AR Roots	.06
Inverted MA Roots	-.24

INQUIDE
Chemical Engineering & Development
Journal of Science and Engineering
Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533

{Ho: φ_0=0

{H_1: φ_0≠0 significant because the p-value is 0.0001

So phase 2 does comply because the values of the coefficients are significant.
P-Value:
If $p < 0.05$ → you reject H_0
If $p \geq 0.05$ → you don't reject H_0

Phase 3: Diagnosis
It is a function of the normality of errors and Autocorrelation of errors.
View
Residual Diagnostic
Histogram – Normality Test

Graph 4: Histogram of the residues

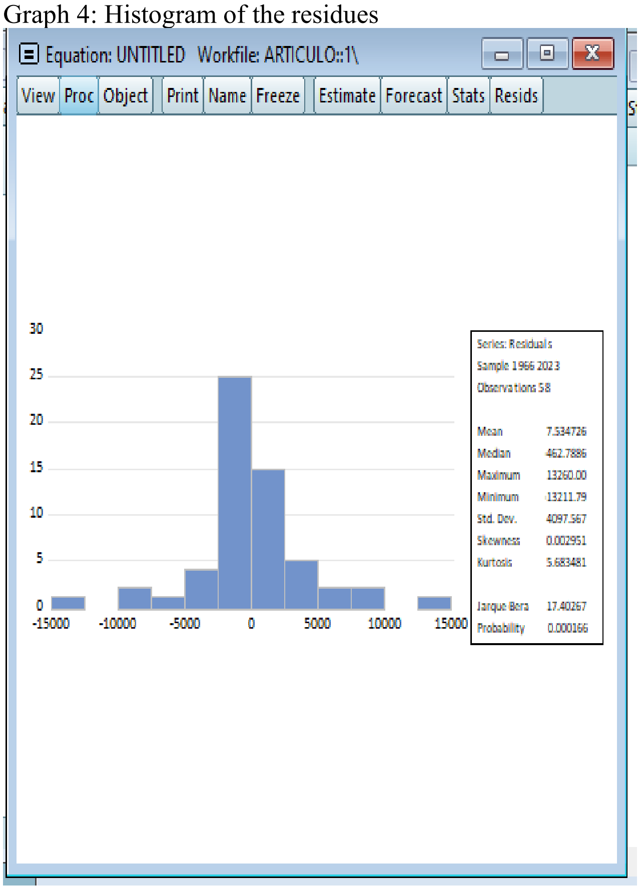

Figure 4.- Histogram of the residuals

**In this graph we see that errors tend to be normal with mean 0 and variance 1.
The Jarque-Bera probability is 0.000166 therefore the distribution of errors is Not Normal.
So we go back to Phase 1.
Then equation d(gbi) c ar(1) ma(1)
We then check for autocorrelation
View
Residual Diagnostic
Correlogram-Q-Statistics

Table 9. Map of the d(gdp) model c ar(1) ma(1)

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Date: 09/15/25 Time: 12:57
Sample (adjusted): 1966 2023
Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.004	0.004	0.0011	
		2	-0.001	-0.002	0.0012	
		3	0.025	0.025	0.0419	0.838
		4	0.139	0.139	1.2807	0.527
		5	0.178	0.181	3.3592	0.339
		6	0.000	0.004	3.3592	0.500
		7	-0.048	-0.056	3.5154	0.621
		8	-0.047	-0.082	3.6695	0.721
		9	-0.015	-0.073	3.6860	0.815
		10	0.098	0.071	4.3887	0.820
		11	0.203	0.245	7.4434	0.591
		12	-0.207	-0.171	10.696	0.382
		13	0.096	0.128	11.416	0.409
		14	-0.054	-0.104	11.649	0.474
		15	-0.018	-0.127	11.674	0.555
		16	0.180	0.189	14.362	0.423
		17	0.072	0.150	14.802	0.466
		18	-0.083	-0.096	15.399	0.496
		19	-0.092	-0.052	16.160	0.513
		20	0.063	0.009	16.523	0.556
		21	0.101	-0.063	17.488	0.557
		22	-0.143	-0.177	19.453	0.493
		23	-0.103	0.066	20.507	0.489
		24	-0.066	-0.132	20.948	0.524

Looking at the probabilities of errors are not self-correlated.

Phase 4. Prognosis
2024-2027
Ecuador's GDP forecast for the period 2024-2028 (ARMA Model)

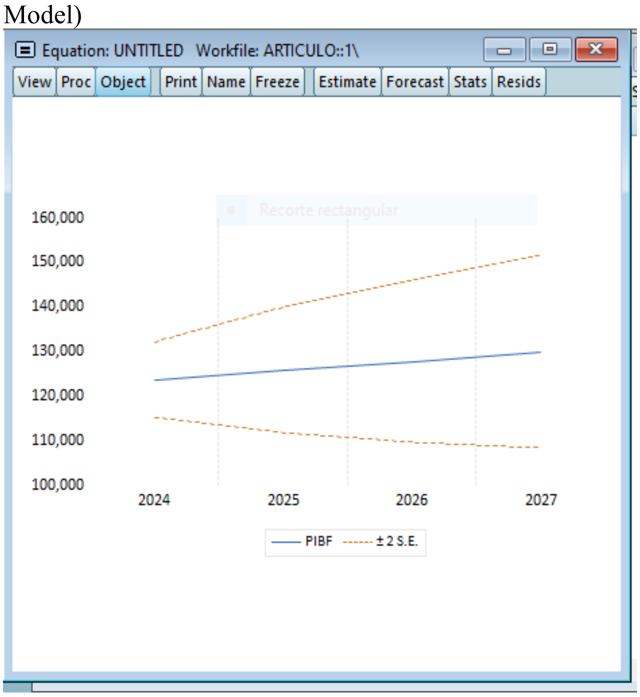

Figure 5. Ecuador's GDP forecast for the period 2024-2028 (ARMA Model)

INQUIDE
Chemical Engineering & Development
Journal of Science and Engineering
Vol. 08 / Nº 01
e – ISSN: 3028-8533
ISSN – L: 3028-8533
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Table 11. Ecuador's Gross Domestic Product (GDP): Historical and Forecasted Values

Group: UNTITLED Workfile: PBI::Pbi\

	PIB	PIBF
	PIB	PIBF
1965	2339.033	2339.033
1966	2442.572	2442.572
1967	2535.654	2535.654
1968	2556.129	2556.129
1969	3153.717	3153.717
1970	2798.598	2798.598
1971	2689.986	2689.986
1972	3091.270	3091.270
1973	3900.130	3900.130
1974	6470.751	6470.751
1975	7708.141	7708.141
1976	9044.610	9044.610
1977	11055.22	11055.22
1978	11806.45	11806.45
1979	14361.49	14361.49
1980	18253.79	18253.79
1981	22115.45	22115.45
1982	20059.81	20059.81
1983	17256.55	17256.55
1984	16943.15	16943.15
1985	17304.17	17304.17
1986		

GDP Trend and Forecast

Figure 6.-GDP Trend and Forecast

3.2.- Analysis of results:

The study showed that Ecuador's GDP series was not stationary at its original level, which required the application of the first difference to stabilize the average. The identified ARIMA model integrated autoregressive and moving average components, whose coefficients were statistically significant, confirming the validity of the adjustment. The residuals did not show autocorrelation, which reinforced the adequacy of the model. The forecast for the period 2024–2027 indicated a moderate growth trend, with alternative scenarios that contemplated optimistic and pessimistic variations. These results were consistent with the official estimates issued by national and international organizations, which strengthened the reliability of the analysis carried out.

3.3.- Interpretation of results:

The findings confirmed the usefulness of the Box-Jenkins methodology in predicting Ecuadorian GDP, allowing the temporal dynamics of the economy to be captured in the short term. The projected performance reflected a gradual recovery after recent external shocks, particularly those resulting from the pandemic and oil price volatility. The consistency with the official projections showed that the model can serve as a complement to the economic forecasting systems already implemented, likewise, it was shown that the use of time series contributes to strengthening economic planning, by offering robust estimates in contexts of uncertainty.

4.- Discussion.

The study was based exclusively on historical GDP series, which limited the incorporation of additional structural factors, such as investment, consumption or non-oil exports. The application of ARIMA models, although adequate to capture temporal patterns, did not allow to explain underlying economic causalities. In addition, the non-normality of the residuals in certain models represented a methodological restriction. Finally, the analysis focused on the short term, which reduced its applicability to medium and long-term horizons.

It is recommended to complement future studies with multivariate models, such as VAR or VECM, which allow the inclusion of additional macroeconomic variables to improve explanatory capacity. In the same way, it would be pertinent to integrate hybrid approaches that combine time series techniques with machine learning methods, in order to increase accuracy in high volatility scenarios. clear and technical language, avoiding ambiguities. It is suggested to extend the projection horizon to assess the sustainability of growth in the medium term. For all these reasons, it is recommended to compare the results with sectoral indicators to offer a more comprehensive view of the national economic dynamics.

The results obtained reflected that the Ecuadorian GDP series presented a non-stationary behavior at its original level, which coincided with the dynamic and volatile nature of emerging economies. The application of the first difference allowed stabilizing the series and obtaining an ARIMA model with statistically significant parameters, which confirmed the methodological validity of the Box-Jenkins approach in the analysis of macroeconomic variables. From the theoretical framework, the results ratified the usefulness of time series models in the capture of stochastic patterns, as established by Box and Jenkins in their methodological proposal. The consistency with the official estimates of the Central Bank of Ecuador and ECLAC reinforces the relevance of the model applied, demonstrating that, even in contexts of uncertainty, the methodology used constitutes a robust tool for economic analysis.

In the context of the study, projections indicated moderate GDP growth for the period 2024–2027, suggesting a scenario of gradual recovery after recent external shocks. These findings are directly related to the proposed objective of estimating and forecasting the rate of economic growth in the short term, generating reliable information that supports planning and strategic decision-making.

5.- Conclusions.

The study showed that Ecuador's GDP series was not stationary at its original level, so it required differentiation for its analysis. The identified ARIMA model presented statistically significant coefficients and residuals without autocorrelation, validating its suitability for estimation. The forecasts obtained projected moderate growth of the economy between 2024 and 2027, in accordance with optimistic and pessimistic scenarios, and in line with the official estimates of national and international organizations.

The research provided empirical evidence that confirms the usefulness of the Box-Jenkins methodology in the prediction of macroeconomic variables in contexts of uncertainty. A robust statistical model was offered that complements existing economic forecasting systems, constituting a practical tool for macroeconomic planning and management. In addition, the study strengthened the link between the theoretical analysis of time series and its application in the Ecuadorian economy, contributing both to the academic field and to decision-making in public policies and business strategies.

In the practical field, the results obtained offer a support tool for economic planning and strategic decision-making in the public and private sectors. Short-term projections of GDP make it possible to anticipate growth scenarios, which facilitates the design of more effective fiscal and monetary policies, as well as the preparation of business plans adjusted to the macroeconomic situation.

On the theoretical level, the study reaffirms the relevance of Box-Jenkins models for the analysis of time series applied to emerging economies, demonstrating their ability to capture stochastic patterns and generate reliable forecasts. The research also contributes to the economic literature by validating a specific model for Ecuador, strengthening the evidence on the applicability of advanced econometric methodologies in contexts characterized by high volatility and dependence on external factors.

It is suggested that the time horizon of the projections be extended in order to assess the sustainability of economic growth in the medium and long term. It is also pertinent to incorporate additional macroeconomic variables – such as investment, consumption, non-oil exports and public spending – to enrich the models and improve their explanatory capacity.

Future studies could explore multivariate approaches, such as VAR or VECM, as well as hybrid models that combine time series techniques with machine learning algorithms, which would increase the accuracy of forecasts in high-volatility scenarios. It is also recommended to make comparisons with structural models to analyze not only the temporal dynamics of GDP, but also the causal relationships between the main determinants of economic growth.

Finally, the need to evaluate the results at the sectoral level is raised, with the purpose of identifying specific patterns in key productive branches and strengthening economic planning from a more comprehensive perspective.

6.- Contributions of the authors (Taxonomy of contributors' roles - CRediT)

1. Conceptualization: Leonor Alejandrina Zapata Aspiazu, Edwin Haymacaña Moreno.
2. Data curation: Leonor Alejandrina Zapata Aspiazu.
3. Formal analysis: Leonor Alejandrina Zapata Aspiazu, Edwin Haymacaña Moreno.
4. Acquisition of funds: N/A.
5. Research: Leonor Alejandrina Zapata Aspiazu, Edwin Haymacaña Moreno.
6. Methodology: Francisco Javier Duque-Aldaz, Raúl Alfredo Sánchez Ancajima.
7. Project management: Francisco Javier Duque-Aldaz, Raúl Alfredo Sánchez Ancajima.
8. Resources: Leonor Alejandrina Zapata Aspiazu, Francisco Javier Duque-Aldaz.
9. Software: Leonor Alejandrina Zapata Aspiazu, Edwin Haymacaña Moreno.
10. Supervision: Félix Genaro Cabezas García, Raúl Alfredo Sánchez Ancajima.
11. Validation: Félix Genaro Cabezas García.
12. Visualization: Edwin Haymacaña Moreno.
13. Writing - original draft: Leonor Alejandrina Zapata Aspiazu, Francisco Javier Duque-Aldaz.

14. Writing - revision and editing: Francisco Javier Duque-Aldaz, Félix Genaro Cabezas García, Raúl Alfredo Sánchez Ancajima.

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