OPEN ACCESS

Saudi Journal of Economics and Finance
Abbreviated Key Title: Saudi J Econ Fin
ISSN 2523-9414 (Print) | ISSN 2523-6563 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://saudijournals.com

Original Research Article

Estimation of Exchange Rate Volatility in Mexico an Approach with ARCH-GARCH Models

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DOI: 10.36348/sjef.2023.v07i12.005 | **Received:** 05.11.2023 | **Accepted:** 21.12.2023 | **Published:** 30.12.2023

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Abstract

This article analyzes the behavior of the exchange rate and its volatility for the period from December 2, 2003, to November 2, 2023. The analysis conducted was of a quantitative documentary nature; the statistical tool EViews9 was used for data capture, analysis, and interpretation; therefore, it was not experimental. Data analysis was performed using the ARIMA model for exchange rate estimation and the ARCH and GARCH model families for conditional variance estimation – volatility. The results obtained allow observing the trajectory of volatility, whose behavior has been affected by the economic policy followed by the economic authority and the crises generated by subprime mortgages and the pandemic. It is recommended to incorporate other volatility models, as well as comparison with other key variables in the financial sector, particularly the price and quotation index of the Mexican Stock Exchange, to include more relevant information that can improve the behavior of the exchange rate and its volatility.

Keywords: Volatility, exchange rate, ARCH-GARCH models, Mexico.

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INTRODUCTION

The process of globalization and interconnection among different markets makes the price of financial assets more risky with significant fluctuations, causing consequential changes in volatility. This volatility has been increased in recent decades by new technologies, information technology, and communications.

The Mexican financial market exhibits significant dynamic behavior, albeit below that of developed economies. The exchange rate is a fundamental variable within the financial field, especially considering Mexico's position as one of the most open economies in the world.

Understanding the behavior of the exchange rate and its volatility is crucial for grasping one of the most important variables in the business world. Consequently, it plays a fundamental role in decision-making for organizations, primarily at an economic, financial, and investment level.

Financial liberalization established a global monetary space induced by capital movement, creating an institutional framework to favor the valorization of financial capital through price level stabilization. Thus, the autonomy of Banxico established price stability as the exclusive objective, limiting credit to the government and banks (Domínguez Blancas & Levy Orlik, 2022) [1].

In the case of Mexico, the exchange rate is affected by the discrepancy between the rates of economic growth, inflation, and interest between the North American and Mexican economies. Additionally, other variables of particular importance include expectations of economic growth, trade barriers, labor productivity, public debt levels, and the trade deficit. In other words, volatility is the result of both objective and subjective factors (Clavellina Miller, 2018) [2].

During the subprime crisis of 2008-2009, Banxico intervened by placing significant amounts of dollars to support the exchange rate with little effect on the currency. This policy incurred a high cost due to the loss of international reserves it caused and did not reduce exchange rate risk (López Herrera, Rodríguez Benavides, & Ortiz Arango, 2011) [3].

In the recent period, the increase in volatility in 2016-2017 (see Table 1) has been due to the weak growth of the Mexican economy, the decrease in oil revenues, and the rapid increase in external public debt. The change in monetary policy in the United States during the Trump administration, with an increase in the federal funds rate, also contributed to this direction.

During the Trump administration in the United States, there was no influence on the average Mexican exchange rate, although there was an impact on volatility. The transmission of the fiscal deficit to the current account deficit was not effective because the domestic interest rate did not have enough impact to appreciate the exchange rate. Consequently, the depreciation of the exchange rate was related to the shortage of financing in the twin deficits (Hernández Trillo & Luevano, 2019) [4].

Since 2020, the COVID-19 pandemic, a phenomenon with vast consequences, has generated a profound economic recession with a drastic fall in investment, production, and employment globally, manifested by business closures and a decrease in oil prices. In Mexico, the Bank of Mexico had to counteract the appreciation of the peso through currency auctions, resorting to the Exchange Commission. Additionally, it reduced the reference interest rate to stimulate economic recovery.

In the analyzed period, the most significant clusters were two external ones – the subprime crisis and the pandemic – and one national, produced by the increase in external public debt. Of the three, the least aggressive was the pandemic.

This work has a purely statistical connotation, resorting to ARIMA models and conditional heteroskedasticity for volatility analysis. However, it is important to distinguish between risk and uncertainty from a Keynesian perspective. The concept of risk is associated with the probability of an event occurring, while uncertainty is when we cannot assume whether the phenomenon will occur or not, and if so, when it will happen. An example of risk is the increase in the exchange rate due to the behavior of the economy in a stable period, and uncertainty occurs when the exchange rate increases due to the effects of the pandemic (Bendesky, 2021) [5]. This clarification is important to understand the scope and limits of the models presented, taking into account the reality of the current world.

MATERIALS, METHODS AND EMPIRICAL RESULTS

The analysis of exchange rate volatility takes into account the characteristics of the time series. Volatility is largely explained by information available to economic agents in three main areas: economic-financial, political, and natural phenomena.

According to Reyes Guzmán (2018) [6] highlights the role of conjuncture phenomena in the United States, such as the initiation of a contractionary monetary policy by the Federal Reserve, as well as the triumph of Donald Trump and his protectionist policy towards Mexico. To explain the dynamics of depreciation in the short term, Reyes Guzmán uses the basic monetary exchange rate model that instructs on the behavior of the exchange rate under a regime of flexibility and free capital movement.

Meanwhile, Benavides, G., & Capistrán, C. (2009) [7] aim to advance the understanding of the mechanisms through which monetary policy affects the economy by analyzing the volatilities of short-term interest rates and the peso-dollar exchange rate under two monetary policy instruments: the Short-Term and interest rate targets.

Data Description

The database consists of 5190 daily observations of the peso-dollar exchange rate at the closing from December 2, 2003, to November 2, 2023. It was obtained from Yahoo Finance (2023) [8] and is constructed by the daily rate of exchange rate variation.

The average and median are relatively similar. Kurtosis reveals that there are data in the tails of the sample. The skewness close to zero indicates that observations are centered around the average and median.

Table 1: Descriptive statistics exchange rate

Exchange Rate	
Sample 12/01/2003 to 11/02/2023	
Observations 5191	
Average	15.191480
Median	13.430170
Maximun	25.336200
Minimun	9.866500
Standard deviation	3.774795
Asymmetry	0.349225
Kurtosis	1.659036

Source: Yahoo Finance. Self-made in EViews.

Characteristics of ARCH and GARCH Models

The main characteristics of financial series are: leptokurtic, meaning flattened with thicker tails; non-linear relationships between gain and risk; volatility appears in clusters; and the leverage effect: volatility increases when the value of the financial asset decreases.

Currently, there are various models that allow obtaining, determining, and modeling the behavior of the conditional variance of time series. Engle developed the Autoregressive Conditional Heteroskedasticity (ARCH)

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model (Engle, 1982) [9]. The specification of the ARCH(m) model admits that the variance depends on past news or past shocks.

$$h_t=\alpha_0+\alpha_1\varepsilon_{t-1}^2+\alpha_2\varepsilon_{t-2}^2+\ldots+\alpha_m\varepsilon_{t-m}^2$$

$$\varepsilon_t\to(0,h_t)\ \ \varepsilon_t=\sqrt{h_t}v_t\ \ v_t\sim iidN(0,1)$$

In this sense, ARCH resembles a Moving Average (MA) model because conditional variance is an MA of squared residuals. Two conditions must be met in this type of model: a) variance must be positive and finite, and b) the estimation method, as the mean and variance of the series, must be estimated simultaneously.

Conditions:

1. Positive variance $\alpha_0>0$ $\alpha_j\geq0$
2. More recent news have a greater impact $\alpha_i>\alpha_j$ $para\ i>jn$
3. The ARCH process must be stationary, which is certified when $0\leq\sum_{i=1}^{m}\alpha_i\leq1$

Limitations of the ARCH(m) Model

- Compliance with parameter restrictions becomes more difficult as the order of ARCH increases.
- The variance is only explained by news, providing no additional information about the variance of returns.
- Tends to overestimate the variance of the time series.
- Does not distinguish between positive or negative shocks.

The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model is another model of conditional variance (Bollerslev, 1986) [10].

Specification of the GARCH Model

- Prospective behavior, requires adequately forecasting the volatility and risk of an asset.
- Volatility is not an observable series at time t, historical data is required to estimate volatility.
- Historical volatility is estimated with the variance of simple returns.

$$\sigma_{t+1}^2=\lambda\sigma_t^2+(1-\lambda)R_t^2$$

It states that the variance of the next period is a weighted average of the current variance and the current squared return, allowing a systematic pattern in the evolution of variance.

The generalization of the ARCH(m) model proposes that conditional variance depends on its own lags. $h_t=\alpha_0+\sum_{i=1}^{m}\alpha_i\varepsilon_{t-i}^2+\sum_{j=1}^{p}\beta_j h_{t-i}$ $\varepsilon_t\to(0,h_t)$ $\varepsilon_t=\sqrt{h_t}v_t$ $v_t\sim iidN(0,1)$

Specification of GARCH(m,p) Models

1. Estimate the conditional mean of the return series.
2. Identify the ARCH effect.
3. Identify the order of the GARCH model (m,p).

- Lagged variance $\sum_{j=1}^{p}\beta_j h_{t-i}$
- News or shocks $\sum_{i=1}^{m}\alpha_i\varepsilon_{t-i}$

Restrictions of the GARCH Model $\alpha_0>0$ $\alpha_i\geq0$ $\beta_j\geq0$
GARCH models require that conditional variance is non-negative. $\sum(\alpha_i+\beta_i)$ max $(mp)\,i<1$
Variance does not grow to infinity, describing a stationary process.

RESULTS AND DISCUSSION

The analysis of volatility is carried out considering a sequence of steps necessary in these types of models. The exchange rate series is worked on in logarithms for estimation. The graph shows the behavior of the exchange rate during the considered period.

The graph with the Hodrick-Prescott filter shows the trend behavior of the exchange rate. It has had three major shocks due to the sub-prime crisis, the high indebtedness of the public sector in the period 2015-2017 and, later, in 2020-2021 due to the pandemic. These abrupt movements are captured even in a trend analysis.

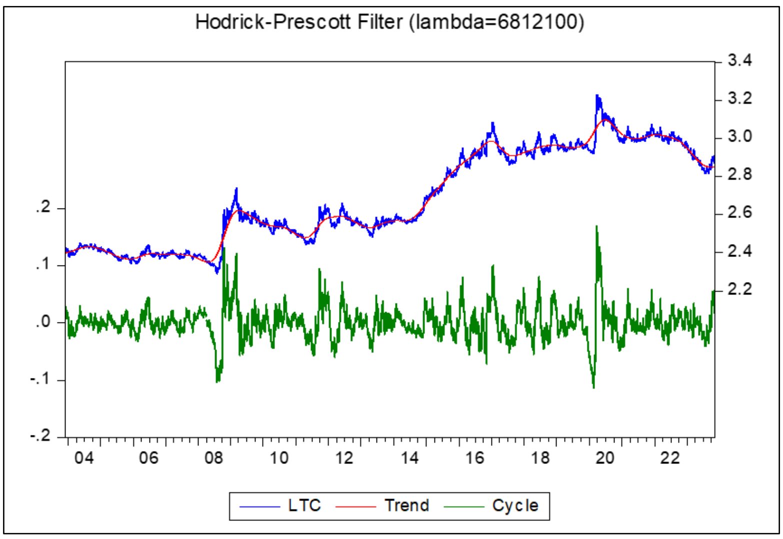

Figure 1: Exchange rate

Source: Yahoo Finance. Self-made in EViews.

The difference in the logarithm of the exchange rate shows the performance of this variable which, on the other hand, is exhibiting daily volatility.

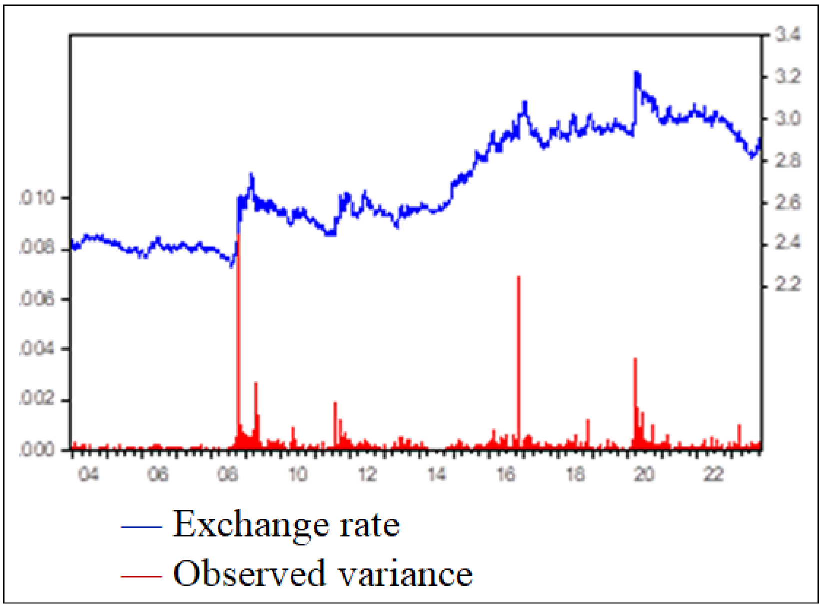

Figure 2: Exchange rate and observed variance
Source: Yahoo Finance. Self-made in EViews.

It can be observed that the exchange rate behaves similarly to any financial asset, i.e., when the return falls, volatility increases.

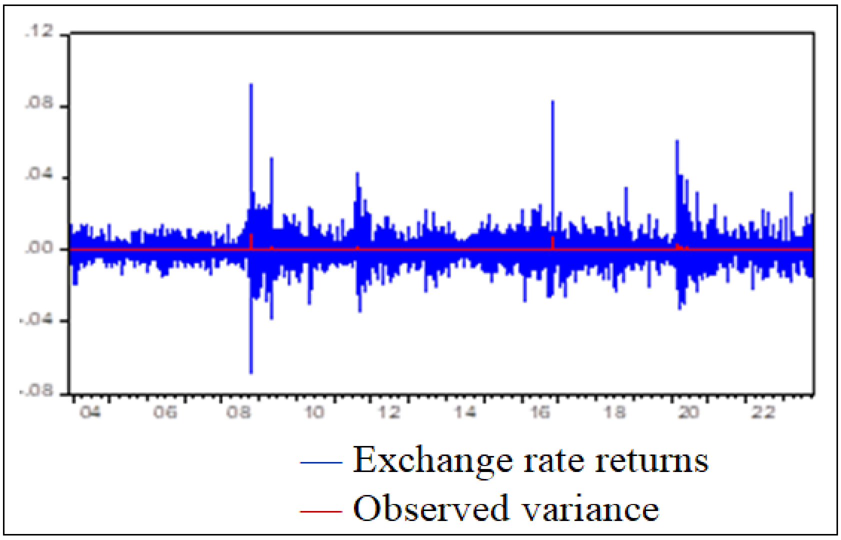

Figure 3: Exchange rate returns and observed variance
Source: Yahoo Finance. Self-made in EViews.

To estimate the exchange rate series, the Box-Jenkins methodology will be used, i.e., an Autoregressive Integrated Moving Average (ARIMA) model is employed. In this type of model, the order of integration is important, so the corresponding unit root tests are carried out (Box & Jenkins, 1978) [11].

As seen in Table 3, the unit root tests using the Augmented Dickey-Fuller indicate the presence of autocorrelation in levels. However, in first differences, this disappears; therefore, the ARIMA model is estimated in the first differences of the logarithm.

Table 2 shows the unit root tests using the Augmented Dickey-Fuller, they indicate the presence of autocorrelation in levels, however, in first differences this disappears, therefore, the ARIMA model is estimated in logarithm first differences.

Table 2: Unit Root Tests in Levels and First Differences

Unit Root Test - Augmented Dickey Fuller		
Level		
H0: Log(TC) has a unit root	t-Statistic	Prob.
Exogenus: Constant	-1.231309	0.6631
Constant, Linear Trend	-2.470407	0.3430
None	0.717808	0.87
First difference		
H0: D(Log(TC)) has a unit root	t-Statistic	Prob.
Exogenus: Constant	-75.28424	0.0001
Constant, Linear Trend	-75.27802	0.0001
None	-75.28185	0.0001

Source: Yahoo Finance. Self-made in EViews.

Calculating the model in EViews yields the following equation
Ls dlog(tc) c ma(1), c=8.48E-05 y ma(1) =-0.046929.

The conditional heteroscedasticity test is performed on this equation

Table 3: Heteroskedasticity Test: ARCH

F-statistic	218.3258	Prob. F(1,5187)	0
Obs*R-squared	209.5883	Prob. Chi-Square(1)	0

Source: Yahoo Finance. Self-made in EViews.

The hypothesis test is:

H_0: the dlog(tc) series does not support a conditional heteroscedasticity model; $p>0.05$.

H_A: dlog(tc) series supports conditional heteroscedasticity model; $p<0.05$.

As $p<0.05$, the dlog(tc) series admits a conditional heteroscedasticity model.

From the ARIMA model, eight models are tested to identify which one best estimates the conditional variance, in this way, the models ARCH0-GARCH2, ARCH2-GARCH1, ARCH1-GARCH2 y ARCH2-GARCH2 do not meet the required estimation requirements, that is, the probabilities of the coefficients are greater than 0.05 or the sum of the coefficients of the variance equation is greater than 1 or some of the variance coefficients are negative.

Models ARCH1-GARCH0, ARCH2-GARCH0, ARCH0-GARCH1, ARCH1-GARCH1 y ARCH2-GARCH1 meet the estimation requirements because the probabilities of the coefficients are less than 0.05 for both the ARIMA and the conditional variance, the sum of the conditional variance coefficients is less than 1 and all the variance coefficients are positive. The best model is ARCH1-GARCH1 because it is the one with the lowest values for the Akaike, Schwarz and Hanna Quinn criteria.

Table 4: ARCH1-GARCH1 model

GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-8.30E-05	7.48E-05	-1.10974	0.2671
MA(1)	-0.066344	0.013743	-4.82761	0
C	1.06E-06	1.41E-07	7.5619	0
RESID(-1)^2	0.109698	0.005102	21.49971	0
GARCH(-1)	0.873949	0.006714	130.1615	0
R-squared		0.001216	Mean dep. var	8.45E-05
Adjusted R-squared		0.001024	S.D. depen var	0.007762
S.E. of regression		0.007758	Akaike criterio	-7.22273
Sum squared resid		0.312211	Schwarz criteri	-7.21641
Log likelihood		18747.97	Hannan-Quinn criter.	-7.22052
Durbin-Watson stat		1.957172		

Source: Yahoo Finance. Self-made in EViews.

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The variance estimated with the ARCH1 – GARCH1 model shows a behavior similar to the observed variance.

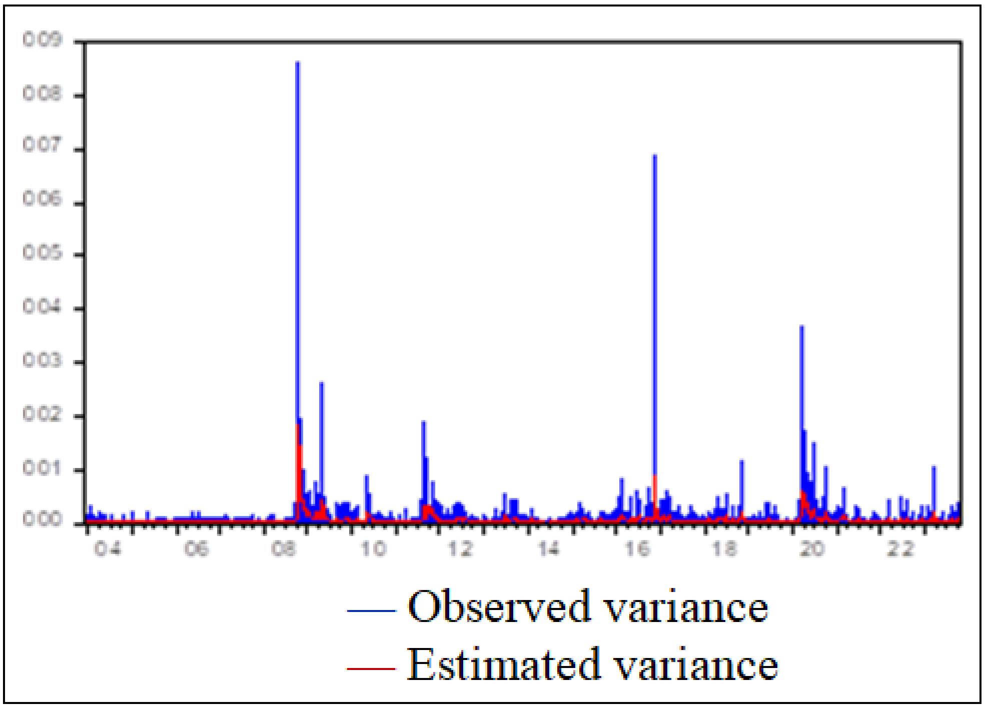

Figure 4: Observed and estimated variance
Source: Yahoo Finance. Self-made in EViews.

The relationship between the exchange rate return and the estimated standard deviation corroborates the relationship of any financial asset between return and risk, according to which when the asset's return falls, volatility increases and viceversa.

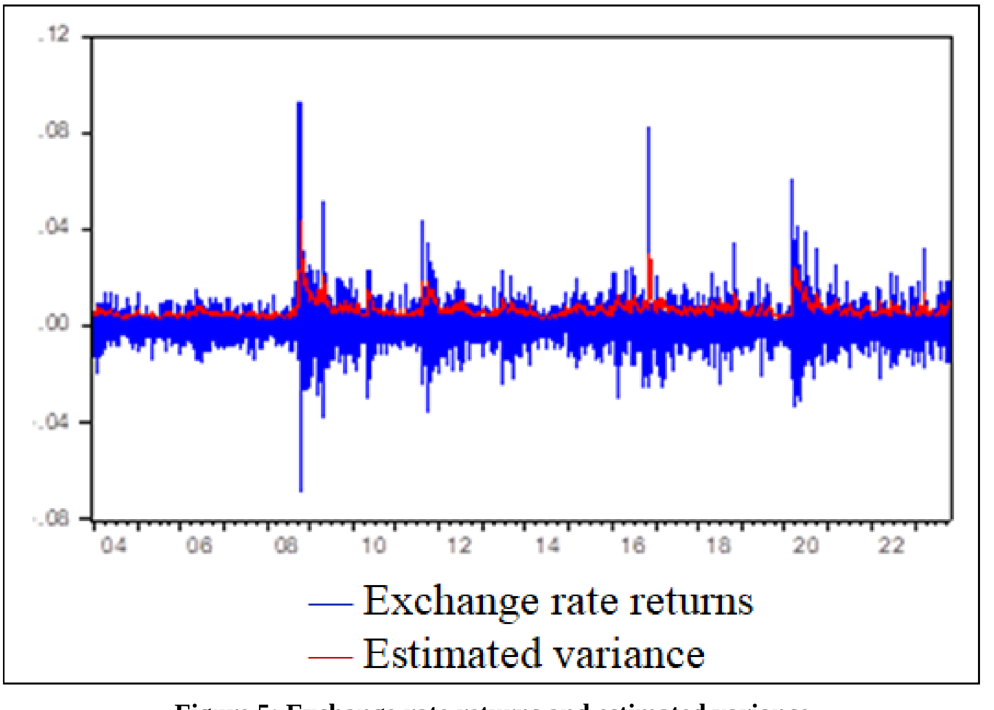

Figure 5: Exchange rate returns and estimated variance
Source: Yahoo Finance. Self-made in EViews.

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The estimation of the next day's volatility taking into account the values of the estimation coefficients obtained with the ARHC1-GARCH1 model. Thus, the expected volatility for the next day is 0.010164134.

Table 5: Forecast standard deviation next day

C	9.66E-06
RESID(-1)^2	0.086858
GARCH(-1)	0.89232
ε_{t-1}= YIELD EXCHANGE RATE	-0.02430854
h_{t-1} = VARIANCE	4.74323E-05
h_t= VARIANCE	0.00010331
STANDARD DEVIATION	0.010164134

CONCLUSION

The behavior of the exchange rate, as observed, is influenced by the economic cycle, the fluctuations in economic policy, and various shocks faced by the economy. The two significant milestones of the period that led to substantial increases in the currency's quotation were the subprime crisis of 2008-2009, the public debt in the 2015-2017 period, and the pandemic in 2020-2021, generating considerable increases in daily volatility in both cases. It is essential to note that the volatility was much stronger in the first period than in the others.

The volatility estimated through various models of the ARCH family confirmed the observed volatility's behavior. In this way, the ARCH1-GARCH1 model was identified as the best, as it better met the Akaike, Schwarz, and Hannan-Quinn criteria compared to others. Additionally, the sum of the coefficients in the conditional variance equation is less than 1, and the probabilities of these coefficients are less than 0.05, indicating the reliability of the obtained models.

Finally, it is recommended to deepen the analysis of the exchange rate and its volatility in future studies by incorporating its relationship with other important variables such as the price and quotes index of the Mexican Stock Exchange and the interest rate. This will contribute to greater precision in the research.

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