

MODELLING AND FORECASTING THE VOLATILITY OF THE INFORMAL EXCHANGE RATE IN ALGERIA (2014-2024) USING GARCH MODELS

***Oussama OULDDALI:**

National Higher School of Statistics and Applied Economics,
Email : oulddali.oussama@learning.enssea.edu.dz

Soumeya BENABDALLAH :

National Higher School of Statistics and Applied Economics,
Email : benabdallah.soumeya@learning.enssea.edu.dz

Reçu le: 26/04/2025 **Accepté le:** 18/05/2025 **Publication en ligne le:** 03/06/2025

ABSTRACT:

This research examines the volatility of the Algerian informal exchange rate by employing the *GARCH* model. The rationale behind choosing the *GARCH* model is based on empirical characteristics of the data like volatility clustering, non-normality, and large *ARCH* effects. Employing a blend of descriptive statistics, stationarity and diagnosis tests, the research confirm that exchange rate returns exhibit time-varying volatility—typical of financial time series for emerging economies. The results validate a high persistence of volatility that validates the long-term effect of shocks. A 10-day in-sample informal exchange rate prediction validates the model's predictability according to *MAE* and *RMSE* results. These results validate the relevance of the model to capture magnitude and structure of informal market movements.

Keywords : Informal exchange rate, stationarity, Volatility Clustering, Heteroscedasticity, *GARCH* model.

I. INTRODUCTION

As the informal sector has grown, Algeria is in a precarious economic situation. The parallel market has introduced an informal exchange rate whereby "40% of the monetary mass in circulation" is "controlled" by it. Such a situation creates a huge difference between the official and informal exchange rate, thus making the devaluation of the Algerian dinar easier by increasing foreign currency demand. The exchange rate prediction challenge has been a long-standing interest for economists, especially in informal markets. It is a key area of study in macroeconomics and international finance that has drawn the interest of many economists and econometricians globally. Predictive models must be accurate for policymakers and traders to make informed choices and efficiently handle economic risks.

*Oussama OULDDALI

The primary intention of this article is to explain the modelling of parallel exchange rate volatility.

Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are nowadays an established method for financial market volatility modelling and prediction. GARCH models can model time-varying volatility in addition to clustering patterns which normally occur in financial time series. They can describe the conditional variance of a series, and their predictions for future volatility are more accurate compared to traditional models. In this research, we employ a GARCH model to analyse the informal exchange rate (EUR/DZD) during the period determined. We perform an ARCH test to determine if there is conditional heteroskedasticity and our data was able to reject the homoscedastic null hypothesis since we establish that GARCH models are suitable to use in analysing this case. This positions us with the question at the ground level: **Do we have the capability of measuring volatility for the parallel exchange rate?** Alternatively, are we able to make predictions concerning the parallel exchange rate of the Algerian dinar with regard to the euro from a *GARCH* model? The research question addressed in this paper is examined through four main sections: the theoretical framework, the review of empirical studies, the presentation of data and model, and finally the results and discussion.

II. THEORETICAL FRAMEWORK:

Exchange rate volatility has been a persistent problem of particular interest to economists as well as policymakers, particularly in those economies with parallel currency markets. The Informal exchange rate or parallel market rate in Algeria plays a crucial role in reflecting the dynamics of the demand and supply of foreign currency outside the official channels. This essay gives a theoretical background on the Informal exchange rate in Algeria, the Box-Jenkins ARCH-GARCH method of volatility modelling, and a review of empirical results from earlier literature.

1. The Informal Exchange Rate in Algeria:

The Informal exchange rate is the parallel or unofficial market exchange rate at which currencies are exchanged. In Algeria, this market has been created by controls on official currency markets and foreign exchange. The Informal exchange rate is determined by economic, political, and social forces and is an important indicator of informal economic activity.

The evolution of Algeria's black-market exchange rate is a significant event in the broader context of exchange rate regimes and monetary policy in the developing world. It is characterized by a large gap between official and parallel exchange rates and has emerged as a structural feature of the Algerian economy. The foreign exchange black market reflects underlying macroeconomic imbalances, institutional rigidities, and policy inefficiencies. The purpose of this theoretical framework is to identify the major models and theories behind the

origin and evolution of parallel exchange markets, and more precisely Algeria. There have been several economic theories developed to understand the prevalence and dynamics of black-market exchange rates. The most relevant models in the Algerian context are the real trade model, the portfolio balance model, and the monetary model. The reality trade model suggests that black markets arise as a result of trade restrictions and foreign exchange controls that cause disequilibrium between the real demand and supply of foreign currency and the official exchange rate. In Algeria, several import quotas, tariffs, and tight currency controls have resulted in a persistent excess demand for foreign currency, leading to and developing a parallel exchange market [1]. The portfolio balance theory emphasizes the role of currency as an asset. As the residents lose faith in the domestic currency due to inflation, political instability, or a lack of financial opportunities, they will opt to keep foreign currencies like the euro or the US dollar. In Algeria, this has been exacerbated by inflationary forces and suspicion about the value of the Algerian dinar. Thus, the black market is a destination for asset diversification [2]. This model relates black market premia to excessive growth in money supply in the home money supply. When the monetary authorities raise money supply over the real development of the economy, inflation rises, depreciating the purchasing power of the national currency. In Algeria, easy monetary policies, especially in times of declining hydrocarbon revenues, have driven inflation and increasing reliance on the parallel exchange market [1]. The evolution of the black currency market in Algeria can be divided into significant phases:

- **Pre-1994:** It was marked by a closely regulated foreign exchange system with limited convertibility of the dinar. The difference between official allocations and actual demand led to the proliferation of unofficial channels of exchange [2].
- **Post-1994 Reforms:** Following the implementation of the Structural Adjustment Program (SAP), partial liberalization of the exchange rate regime was carried out. Nevertheless, the administratively managed official exchange rate system remained in place, and the continued existence of economic distortions maintained the black market [13].
- **2010s and Beyond:** Perpetuating economic uncertainty, inflation, and world oil price volatility accelerated the gap between the official rate and the black-market rate, which rendered the parallel market a stronger player in currency exchange [2].

Determinants of the Black-Market Exchange Rate Premium

Different studies have indicated the most significant macroeconomic determinants of the black-market exchange rate premium in Algeria:

- **Inflation Rate:** Higher inflation reduces the real value of the dinar and increases the demand for foreign currencies [2] [1].

- **Money Supply Growth:** Unchecked growth in money without related growth in output leads to depreciation [1].
- **Interest Rate Differentials:** Lower returns on domestic saving instruments force citizens to seek safer destinations for the preservation of value [2].
- **Current Account Balance:** Trade deficits and lower foreign reserves limit official currency supplies [13].

The parallel exchange market sends the Algerian economy far-reaching ripples:

- **Foreign Investment:** Uncertainty created by the discrepancy between official and black-market rates discourages foreign direct investment [13].
- **Inflation:** The black-market exchange rate acts as a reference point for pricing foreign goods, indirectly inducing inflation [2].
- **Fiscal Policy:** Difficulty in getting foreign currency at the official exchange rate weakens fiscal revenues and the efficiency of public spending [3]
- **Capital Flight:** Black markets make illegal capital flight possible, undermining the balance of payments [2].

Since the 1980s, Algeria has consistently had trouble managing its foreign exchange markets. The state's heavy reliance on hydrocarbon receipts, coupled with currency controls, has bred the growth of a robust parallel foreign exchange market. This market often gives a better reflection of the value of money than the official exchange rate. The Informal exchange rate's volatility has important economic stability implications. Businesses and consumers who utilize parallel markets for currency exchange are subject to higher uncertainty, which affects investment and consumption choices.

Empirical Studies on Volatility Modelling:

Empirical studies of black-market exchange rates have examined in detail the macroeconomic determinants and implications of parallel exchange rate markets, especially in developing and emerging economies. In the case of Algeria, increasingly empirical studies have examined the evolution of the black-market premium, the economic drivers of its volatility, and its impact on broader monetary stability and macroeconomic performance. [2] provided one of the earliest comprehensive empirical analyses of parallel currency markets in developing countries. Cross-country panel data were employed, and it was found that inflation, foreign exchange controls, and imbalances on the current account were primary causes of black-market premia. This early work emphasized the importance of structural reform as a means of curbing the extent of the parallel market.

In the case of Algeria, [6] studied the difference between the official and parallel exchange rates of Algeria. Using cointegration techniques, they presented evidence that the parallel market rate more accurately reflects economic fundamentals and should be considered by monetary authorities when adjusting the official rate. [7] studied and analyzed the impact of the parallel exchange rate on money demand in Algeria between 1980–2010. Using the *ARDL* model, the author found a long-run equilibrium relationship between the parallel rate and money demand, indicating its strong impact on monetary behavior. Focusing on countries like Nigeria, Zaire, and Ghana, [4] developed a macroeconomic model to describe the parallel exchange rate. They econometrically applied the model and found that macroeconomic imbalances, inflation, and foreign exchange market controls are major determinants of the informal exchange rate in African economies. [3], in comparing Pakistan with the North African economies, including Algeria, demonstrated empirically that volatility of the black-market exchange rate is associated with speculative activity that responds to non-coordinated fiscal and monetary policy. Their finding supported the theory of portfolio balance, which was demonstrated to exist such that the demand for foreign currency in the parallel markets mimics residents' demand for secure assets when economies are uncertain. In addition, [10], as the 2021 Country Report on Algeria, have provided empirical misalignment estimates of exchange rates and segmentation of the market. These estimates highlight dual exchange rate regime inefficiencies and recommend phased liberalization of exchange rates and institutional reforms to end illicit market dependence. In general, the empirical facts always point towards a causative link between monetary instability, inflation, and the existence of black-market exchange rates. Such studies provide very valuable evidence that is most informative into the underlying dynamics for the parallel currency market in Algeria as well as offering the argument required for ambitious policy reform aimed at exchange rate regime unification and re-establishing macroeconomic credibility.

III. DATA SOURCES AND MODEL SPECIFICATION:

Data:

The data utilized in this study are the daily readings of the nominal parallel exchange rate (EUR/DZD) between October 1, 2014, and December 31, 2024. These readings were collected through a survey conducted by the author on the parallel exchange market, specifically at Square Sofia. The sample utilized is 3745 readings, and the data analysis was done using Eviews 13 software. Daily frequency allows the intraday movements to be recorded and a more vivid description of exchange rate dynamics to be provided.

The daily time series of the parallel exchange rate is denoted by TCI_t in (EUR/DZD). The objective of this research is to model the volatility of the parallel exchange rate and attempt to explain its fluctuations. Before the estimation of a *GARCH* model, one should investigate the statistical properties of the time series under study. The following table presents the descriptive statistics for the informal exchange rate TCI_t in Algeria over the observed period.

Figure 1: Informal exchange rate graph



Table 1: Descriptive statistics

Descriptive statistics	TCI_t
Mean	204.4046
Median	210.0000
Maximum	260.0000
Minimum	155.5000
Std. Dev	23.15102
Skewness	-0.205187
Kurtosis	2.740431
Jarque-Bera	37.30666
Probability	0.00000
Sum	765495.4
Sum sq. Dev	2006671.
Observations	3745

Source: By the author using EViews 13

The median of the informal exchange rate is 210.00 DZD, while the mean is 204.40 DZD, indicating a slightly left-skewed distribution.

The exchange rate is somewhat volatile, with a standard deviation of 23.15 DZD, indicating significant variability away from the mean.

The distribution is slightly negatively skewed), suggesting lower values are slightly more common than higher ones.

The kurtosis of 2.74 is close to the normal 3, indicating a roughly normal distribution, but slightly platykurtic (i.e., thinner tails).

The JB statistic with p-value 0 indicate a rejection of the null hypothesis of normality. This also indicates the suitability of GARCH-type models, which do not assume normally distributed errors.

These observations reveal a non-normal and asymmetric distribution that is slightly and highly volatile in the off-the-books exchange rate.

These are significant motivating factors to specify conditional variance using GARCH-type models given their effectiveness in modelling fluctuations in exchange rates under such circumstances.

The model:

Asset return series in time series analysis, particularly financial econometrics, usually exhibit autocorrelation, volatility clustering, and conditional heteroskedasticity behavior. While ARMA models are well suited to model autocorrelation, they fail to model changing volatility over time. To balance this, ARMA models are typically combined with GARCH models of errors such that it is now feasible to model the mean and the conditional variance of a time series at the same time.

The ARMA model captures the linear relationship in the conditional mean of a time series. Suppose X_t is a weakly stationary time series (e.g., log returns), The ARMA(p,q) model is as follows:

$$X_t = c + \sum_{i=1}^p \phi_i \cdot X_{t-i} + \sum_{j=1}^q \theta_j \cdot \varepsilon_{t-j} + \varepsilon_t \dots (1)$$

Where:

c is the constant term,

ϕ_i are the autoregressive coefficients,

θ_j are the moving average coefficients,

ε_t is the error term (innovation), assumed to be conditionally heteroskedastic.

For ARMA models, stationarity requires that roots of the equation for characteristics to lie outside of the unit circle.

To estimate conditional heteroskedasticity and volatility clustering in financial series, error variance is represented through a GARCH process. The GARCH(a,b) model specifies the conditional variance $\sigma_t^2 = V(\varepsilon_t | I_{t-1})$.

$$\sigma_t^2 = \omega + \sum_{i=1}^a \alpha_i \cdot \varepsilon_{t-i}^2 + \sum_{j=1}^b \beta_j \cdot \sigma_{t-j}^2 \dots (2)$$

Where:

$\omega > 0, \alpha_i \geq 0$ and $\beta_j \geq 0$ to ensure non-negative variance,

α_i are ARCH terms capturing the short-run impact of shocks,

β_j are GARCH terms capturing the persistence of volatility,

To ensure the stationarity of the **GARCH(a,b)** process we must have:

$$\sum_{i=1}^a \alpha_i + \sum_{j=1}^b \beta_j < 1$$

I_{t-1} is the information set available at time $t - 1$.

The innovation term is expressed as:

$$\varepsilon_t = \sigma_t z_t$$

where z_t is an i.i.d. process with zero mean and unit variance, typically assumed to follow a standard normal or standardized Student's t-distribution.

Combining the two components, the $ARMA(p, q)$ - $GARCH(a, b)$ model is specified as:

The mean equation is :

$$X_t = c + \sum_{i=1}^p \phi_i \cdot X_{t-i} + \sum_{j=1}^q \theta_j \cdot \varepsilon_{t-j} + \varepsilon_t \dots (3)$$

$$\varepsilon_t = \sigma_t Z_t$$

z_t iid (0,1) and $\sigma_t^2 = \omega + \sum_{i=1}^a \alpha_i \cdot \varepsilon_{t-i}^2 + \sum_{j=1}^b \beta_j \cdot \sigma_{t-j}^2$ is the variance equation.

This model captures both the autocorrelation in the series level and the time-varying volatility in its variance. The parameters of the *ARMA – GARCH* model are typically estimated via maximum likelihood estimation (MLE). The estimators are consistent and asymptotically normal under regularity conditions.

GARCH models are especially well-suited to model the Algerian black-market exchange rate since they are able to capture relevant characteristics such as volatility clustering and time-varying variance, which are common in financial time-series data. They represent an improvement over the traditional approaches in that they accommodate conditional heteroskedasticity and offer better volatility forecasting.

However, their use relies on assumptions such as stationarity and normally distributed standardized residuals. Among drawbacks are sensitivity to model specification, potential data quality issues in the black-market context, and failure to account for structural breaks or asymmetric shock effects, which may require complicated variants such as *EGARCH* or *TGARCH*.

IV. RESULTS AND DISCUSSION:

In order to accurately capture and represent the volatility of Algeria's black-market exchange rate, the analysis in this paper was conducted based on the logarithmic transformation of the exchange rate series $ITCI_t$. This transformation is widely applied in financial econometrics for a variety of reasons.

ADF stationary test results:

To ensure reliable time series modelling, particularly when using *GARCH* models, it is important to verify whether the series is stationary. This analysis uses the Augmented Dickey-Fuller (ADF) test to assess the presence of a unit root in the series.

Table 2 :ADF tests

Serie	Model	Prob	Décisions	Conclusion
$lTCI_t$	3	0.3686	H_0 accepted	$lTCI_t$ is a TS/DS nonstationary process
		0.0000	H_0 rejected	
$dlTCI_t$	1	0.0001	H_0 rejected	$lTCI_t$ is stationary

Source: By the author using EViews 13

The informal exchange rate series is integrated of order 1, i.e., $I(1)$. This result justifies the use of returns or first differences of the log of the exchange rate for further modelling, such as *GARCH* estimation. The presence of stationarity in the return series also fulfils a key assumption required for the application of conditional heteroskedasticity models.

To model the dynamics of the black-market exchange rate in Algeria, we applied the Box-Jenkins methodology. This approach involves identifying, estimating, and diagnosing appropriate time series models, allowing for a rigorous selection of the best-fitting model for the data. After examining the stationarity and autocorrelation structure of the series, and conducting model selection using Akaike information criterion, we retained the most suitable *ARMA – GARCH* specification to capture both the mean and volatility behaviour of the series.

IV.1. The mean equation results:

The model estimated:

$$d\widehat{lTCI}_t = -0.186128dlTCI_{t-1} + e_t \dots (4)$$

e_t residuals.

Table 3 : AR(1) model estimated

Variable	Coefficient	Std.error	t-Statistic	Prob
AR(1)	-0.186128	0.008304	-22.41344	0.0000
AIC	(-8.119736)			

Source: By the author using EViews 13

Before estimating a *GARCH* model, it is essential to verify that the residuals of the return series meet the assumptions necessary for modelling conditional heteroskedasticity. The following tests were conducted: Ljung-Box for autocorrelation, Jarque-Bera for normality, and *ARCH* tests for conditional heteroscedasticity.

Residual’s diagnostic results:

Table 4 : Validation results

<i>Test hypothesis</i>	<i>Tests</i>	<i>Prob</i>	<i>Conclusion</i>
Autocorrelation	<i>Ljung-Box</i>	0.101	No significant autocorrelation in residuals
Normality	<i>Jarque-Bera</i>	0.000	Residuals are not normally distributed
Heteroscedasticity	<i>ARCH test order 1</i>	0.000	Presence of heteroscedasticity
	<i>ARCH test order 2</i>	0.000	
	<i>ARCH test order 3</i>	0.000	
	<i>ARCH test order 3</i>	0.000	

Source: By the author using EViews 13

The Ljung-Box test yields a p-value of 0.101, which is greater than 0.05, indicating that there is no significant autocorrelation in the residuals. This suggests that the mean dynamics of the series have been adequately captured.

The Jarque-Bera test shows a p-value of 0.000, leading to the rejection of the null hypothesis of normality. This indicates that the residuals are not normally distributed, which is common in financial time series and suggests the presence of skewness and/or excess kurtosis.

The ARCH tests at lags 1, 2, and 3 all produce p-values of 0.000, strongly rejecting the null hypothesis of homoscedasticity. This confirms the presence of conditional heteroscedasticity in the residuals an essential condition for justifying the use of GARCH type models.

IV.2. GARCH results:

$$\widehat{dITCI}_t = -0.220751dITCI_{t-1} + e_t \dots (5)$$

$$e_t = \sigma_t z_t$$

$$\sigma_t^2 = 3.49 \times 10^{-7} + 0.114074.e_{t-1}^2 + 0.87068.\sigma_{t-1}^2 \dots (6)$$

The estimated $GARCH(1,1)$ model for the informal exchange rate returns in Algeria includes an $AR(1)$ term in the mean equation and $ARCH/GARCH$ terms in the variance equation. The results are summarized in the table below:

Table 5 : GARCH model estimated

Variable	Coefficient	St. Error	z-Statistic	Prob
AR(1)	-0.220751	0.018981	-11.6300	0.0000
c	3.49E-07	1.73E-08	20.10927	0.0000
Resid^2(-1)	0.114074	0.004054	28.13921	0.0000
GARCH(-1)	0.870680	0.004094	212.6806	0.0000

Source: By the author using EVIEWS 13

To analyse and explain the fluctuations in the informal exchange rate in Algeria, we chose the $GARCH(1,1)$ model. This model is widely used in financial economics because it can capture the changing volatility often observed in financial time series. In our case, the daily exchange rate series shows signs of volatility clustering, meaning that periods of high and low volatility tend to follow each other. Traditional time series models, like ARIMA, are not designed to account for this. The $GARCH(1,1)$ model allows us to model the conditional variance of the exchange rate returns, considering both past shocks and past volatility. This makes it a suitable and efficient tool to understand and forecast the behavior of the informal exchange rate over time.

The coefficient of the $AR(1)$ term is negative and statistically significant. This indicates that today's return is slightly negatively correlated with yesterday's return, although the effect is relatively small.

The $ARCH(1)$ coefficient is positive and significant, indicating that recent shocks (past squared residuals) have a noticeable effect on today's volatility.

The $GARCH(1)$ coefficient is also positive and highly significant, suggesting that past volatility strongly influences current volatility.

The sum of the $ARCH$ and $GARCH$ coefficients ($0.1141 + 0.8707 = \mathbf{0.9848}$) is close to 1, which indicates **high persistence in volatility**. This means that shocks to the exchange rate tend to have a long-lasting effect.

These results suggest that the informal exchange rate in Algeria exhibits **volatility clustering**, where periods of high volatility are followed by high volatility, and low by low. This justifies the use of the $GARCH$ model and reflects uncertainty and instability in the informal currency market.

IV.3. Forecast results:

Table 6 : Volatillity forecast results

Step Ahead	Forecasted Variance	Forecasted Volatility (%)
1	0.000053	0.7292
2	0.000047	0.6830
3	0.000041	0.6400
4	0.000036	0.6001
5	0.000032	0.5631
6	0.000028	0.5287
7	0.000025	0.4969
8	0.000022	0.4694
9	0.000019	0.4401
10	0.000017	0.4149

Source: By the author using EViews 13

Based on the *GARCH*(1,1) estimates, the short-term forecast of the exchange rate volatility shows a high level of uncertainty in the immediate future, with a gradual decline in volatility over the forecast horizon. This confirms that shocks in the informal currency market tend to persist initially, but the market adjusts slowly over time, highlighting its dynamic nature and sensitivity to past volatility.

The informal exchange rate forecast:

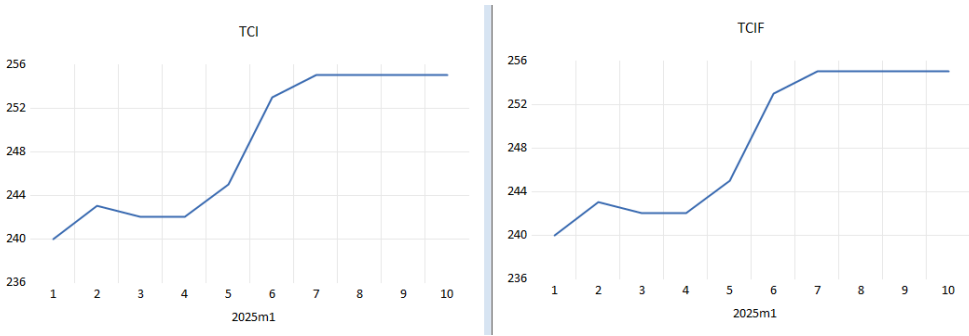
Table 7 : GARCH (1,1) Forecast results

Step Ahead	Forecasted Exchange Rate (DZD)	Actual Exchange Rate (DZD)	Actual- Forecasted	MAE
1/1/2025	240	240	0	6.4
2/1/2025	241	243	2	RMSE
3/1/2025	241	242	1	7
4/1/2025	242	242	0	
5/1/2025	243	245	2	
6/1/2025	243	253	10	
7/1/2025	245	255	10	
8/1/2025	245	255	10	

9/1/2025	245	255	10
10/1/2025	246	255	9

Source: By the author using EViews 13

Figure 2 : Informal exchange rate (forecasted vs real)



Source: By the author using EViews 13

The $GARCH(1,1)$ model provided a highly accurate 10-day forecast of the informal exchange rate in Algeria, with a MAE of 6.4 DZD and a $RMSE$ of 7.0 DZD. These results confirm that $GARCH(1,1)$ is well-suited to capture both the direction and volatility of the market, reflecting the persistent uncertainty and structural features of the Algerian parallel exchange rate environment. It also validates the model's usefulness as a forecasting tool and a lens to interpret market risk and confidence dynamics.

V. CONCLUSION:

This article set out to examine and model the behaviour of the informal exchange rate in Algeria using econometric tools tailored to financial time series, particularly the $GARCH(1,1)$ model. The choice of this model was justified by the empirical characteristics of the data, notably the presence of volatility clustering, non-normality, and significant $ARCH$ effects. Through the application of descriptive statistics, stationarity tests, and diagnostic tests (Ljung-Box, Jarque-Bera, and $ARCH$ tests), it became clear that the exchange rate returns exhibit time-varying volatility a common trait in financial and economic data, particularly in emerging or unstable markets.

The results from the $GARCH(1,1)$ model reveal that shocks to volatility are highly persistent. In other words, a volatility shock today will have long-lasting effects on the conditional variance of the exchange rate. This persistent volatility suggests that market participants react not only to new information but also to expectations based on past volatility

patterns. In an informal or parallel market, where speculative behaviors and information asymmetry are prevalent, such dynamics become even more pronounced.

From an economic perspective, the observed volatility can be interpreted as a reflection of underlying macroeconomic instability, uncertainty regarding monetary policy, limited access to foreign exchange through official channels, and geopolitical or fiscal concerns. The informal exchange market acts as a barometer for confidence in the national economy. High volatility and clustering may indicate a lack of investor confidence, inflationary expectations, or supply-demand imbalances driven by informal transactions and speculative motives.

This analysis has several important policy implications. First, reducing volatility in the informal market requires restoring credibility and transparency in official exchange rate policy, while improving access to foreign exchange through regulated channels. Second, macroeconomic stabilization through inflation control, fiscal discipline, and institutional transparency can mitigate the uncertainty that fuels speculative behavior in informal markets. Lastly, the ability to model and forecast exchange rate volatility provides useful tools for policymakers, economists, and financial analysts seeking to assess risk and plan interventions.

To test the practical application of the *GARCH* (1,1) model, a 10-day forecast of the informal exchange rate was carried out and compared with actual market data. The model performed well in tracking the upward trend in the exchange rate, with a **Mean Absolute Error (MAE) of 6.4 DZD** and a **Root Mean Squared Error (RMSE) of 7.0 DZD**. These results confirm that the *GARCH* (1,1) model not only captures volatility dynamics but also provides a reasonable approximation of real market behavior, even in an informal and unregulated environment.

In response to the central research question — *Can we measure the volatility of the parallel exchange rate?* this study provides a clear and affirmative answer. The empirical results show that *GARCH*-type models, particularly *GARCH* (1,1), are highly effective in modeling the volatility of the parallel exchange rate in Algeria. The model quantifies how past shocks affect future uncertainty and offers a structured approach to forecasting market risk. Therefore, yes, it is not only possible but also highly relevant to measure and model the volatility of the informal exchange rate using appropriate econometric tools.

Ultimately, this study contributes both theoretically and practically by providing evidence that informal financial markets, despite their complexity and opacity, can be rigorously analyzed using modern econometric techniques. The findings reinforce the importance of incorporating volatility modeling into the analysis of foreign exchange markets in developing

economies and highlight the value of *GARCH* models as decision-support tools for financial regulation and macroeconomic stability.

VI. BIBLIOGRAPHY:

- [1] ADOUKA , . L. ., CHENINI, . A. ., & BENGANA, . I. . (2015).” Peut-on modéliser la volatilité du taux de change de dinar algérien par un processus GARCH ?”. *مجلة أداء المؤسسات الجزائرية*, 3(2), 25-44.
- [2] Agenor, P. (1992). “Parallel Currency Markets in Developing Countries: Theory, Evidence, and Policy Implications” . *Princeton Studies in International Economics*, (188).
- [3] Arby, M., Hanif, N., & Jahanzeb, M. (2012). “The Size of Informal Economy in Pakistan”. *Finance Research*, 1(2), 11-18. <https://doi.org/https://mpr.ub.uni-muenchen.de/60855/>
- [4] Azam, J., & Daubrée, C. (1991). « La détermination des taux de change parallèles en Afrique : modèle macro-économique et test économétrique (Nigeria, Zaïre, Ghana) ». *Économie & Prévision*, 97, 105-115.
- [5] Baillie, R., & Bollerslev, T. (1989). “The Message in Daily Exchange Rates: A Conditional-Variance Tale”. *Journal of Business and Economics Statistics*, 7(3), 297-305.
- [6] BENBOUZIANE , . M. ., BENHABIB , . A. ., & ZIANI, . T. . (2005). « MARCHE DE CHANGE INFORMEL ET MESALIGNEMENT : LE CAS DU DINAR ALGERIEN ». *Les Cahiers Du Mecas*, 1(1), 118-131.
- [7] BENDOB, . A., & SI MOHEMMED , . K. (2014). “L’impact du taux de change parallèle sur la demande de la monnaie ; Cas de l’Algérie durant 1980-2010 : Etude économétrique”. *مجلة الباحث*, 14(14), 17-25.
- [8] Bollerslev, T. (1986). “Generalized autoregressive conditional heteroskedasticity”. *Journal of Econometrics*, 31(13), 307-327.
- [9] Dukundane, D. (2023). “Modeling and Forecasting Exchange Rate Volatility in West Africa using GARCH models”. *Journal of Statistical and Econometric Methods*, 12(14), 1-2.
- [10] Eichengreen, B., & Hausmann, R. (1999). “Exchange Rates and Financial Fragility”. *NBER Working Paper*.
- [11] Engle, R. (1982). “Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation”. *Econometrica*, 50(14), 987-1007.
- [12] Ezzebsa, A., Nedjar, S., & Zeghdoudi, H. (2023). « On GARCH Models and Applications: Foreign Exchange Rate Volatility and a Price Index” . *Thailand Statistician*, 21(14), 812-823.
- [13] IMF, C. (2023). *Algeria: selected issues*. International Monetary Fund .website: <https://www.imf.org/en/Publications/CR/Issues/2023/02/02/Algeria-Selected-Issues-529083>

- [14] Kwarah, A. (2021). “The Empirical Analysis of Exchange Rate Volatility in Emerging African Economies” . *Finance & Economics Review*, 3(12), 47-70.
- [15] Mustapha, D. (2020). “Volatility and Long Memory Modeling of Exchange Rate Case of Algerian Interbank Market”. *International Journal of Economics, Finance and Management Sciences*, 8(14).
- [16] Pagan, A., & Shwert, G. (1990). “Alternative models for conditional stock volatility”. *Journal of Econometrics*, 45, 267-290.
- [17] Siklos, P. (2008). “No Single Currency Regime is Right for All Countries or At All Times”. *European Journal of Political Economy*, 24(14), 802-816.
- [18] Yussif, A., Onifade, S., Ay, A., Canitez, M., & Bekun, F. (2022). “Modeling the volatility of exchange rate and international trade in Ghana: empirical evidence from GARCH and EGARCH”. *Journal of Economic and Administrative Sciences*, 40(12), 308-324

APPENDIX :

I. Descriptive statistics using EVIEWS :

	TCI
Mean	204.4046
Median	210.0000
Maximum	260.0000
Minimum	155.5000
Std. Dev.	23.15102
Skewness	-0.207187
Kurtosis	2.740431
Jarque-Bera	37.30666
Probability	0.000000
Sum	765495.4
Sum Sq. Dev.	2006671.
Observations	3745

II. ADF stationnary test results :

Null Hypothesis: TCI has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 1 (Automatic - based on SIC, maxlag=29)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.374898	0.3927
Test critical values: 1% level	-3.960491	
5% level	-3.411006	
10% level	-3.127317	

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

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(TCI)
 Method: Least Squares
 Date: 04/26/25 Time: 09:08
 Sample (adjusted): 10/03/2014 12/31/2024
 Included observations: 3743 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TCI(-1)	-0.003265	0.001375	-2.374898	0.0176
D(TCI(-1))	-0.168875	0.016143	-10.46096	0.0000
C	0.587020	0.232705	2.522590	0.0117
@TREND("10/01/2014")	5.70E-05	2.94E-05	1.936402	0.0529
R-squared	0.030454	Mean dependent var		0.022442
Adjusted R-squared	0.029676	S.D. dependent var		0.841149
S.E. of regression	0.828574	Akaike info criterion		2.462847
Sum squared resid	2566.954	Schwarz criterion		2.469502
Log likelihood	-4605.218	Hannan-Quinn criter.		2.465214
F-statistic	39.14816	Durbin-Watson stat		2.004142
Prob(F-statistic)	0.000000			

Modelling And Forecasting The Volatility Of The Informal Exchange Rate In Algeria (2014-2024) Using GARCH Models

Null Hypothesis: D(TCI) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=29)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-72.46673	0.0001
Test critical values: 1% level	-2.565580	
5% level	-1.940909	
10% level	-1.616643	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TCI,2)
Method: Least Squares
Date: 04/26/25 Time: 09:10
Sample (adjusted): 10/03/2014 12/31/2024
Included observations: 3743 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TCI(-1))	-1.169491	0.016138	-72.46673	0.0000
R-squared	0.583918	Mean dependent var	-0.000935	
Adjusted R-squared	0.583918	S.D. dependent var	1.285671	
S.E. of regression	0.829315	Akaike info criterion	2.463833	
Sum squared resid	2573.608	Schwarz criterion	2.465497	
Log likelihood	-4610.063	Hannan-Quinn criter.	2.464425	
Durbin-Watson stat	2.004256			

III. The Estimated mean equation and validation tests results:

The mean equation:

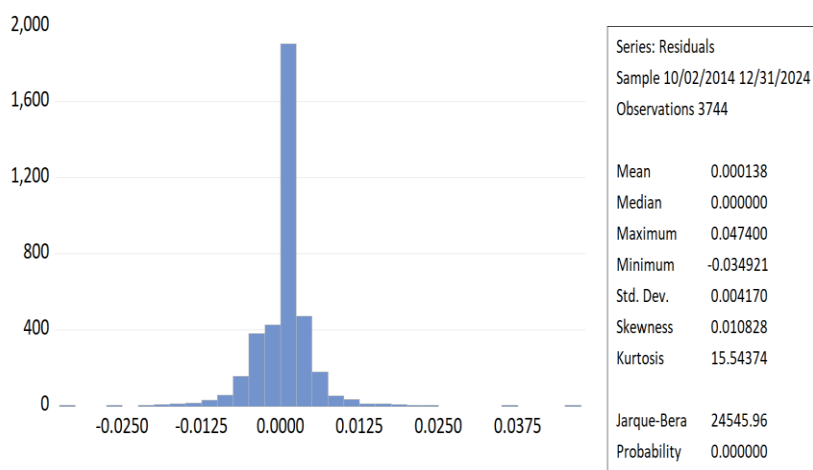
Dependent Variable: DLTCI
Method: ARMA Maximum Likelihood (BFGS)
Date: 01/02/25 Time: 21:35
Sample: 10/02/2014 12/31/2024
Included observations: 3744
Convergence achieved after 3 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	-0.186128	0.008304	-22.41344	0.0000
SIGMASQ	1.74E-05	1.50E-07	116.2682	0.0000
R-squared	0.033858	Mean dependent var	0.000116	
Adjusted R-squared	0.033600	S.D. dependent var	0.004245	
S.E. of regression	0.004173	Akaike info criterion	-8.119736	
Sum squared resid	0.065168	Schwarz criterion	-8.116409	
Log likelihood	15202.15	Hannan-Quinn criter.	-8.118553	
Durbin-Watson stat	2.009147			
Inverted AR Roots	-.19			

The validation tests :

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.008	-0.008	0.2173	
		2 -0.031	-0.031	3.7195	0.054
		3 0.021	0.021	5.4221	0.066
		4 -0.031	-0.032	9.0787	0.028
		5 0.019	0.020	10.483	0.033
		6 0.010	0.008	10.872	0.054
		7 -0.003	-0.000	10.906	0.091
		8 0.017	0.016	11.988	0.101
		9 0.011	0.012	12.457	0.132
		10 0.002	0.004	12.474	0.188
		11 -0.002	-0.003	12.496	0.253
		12 -0.015	-0.015	13.395	0.268
		13 -0.001	-0.001	13.397	0.341
		14 -0.018	-0.020	14.649	0.330
		15 0.005	0.005	14.732	0.397
		16 0.027	0.025	17.461	0.292
		17 -0.005	-0.004	17.563	0.350
		18 0.005	0.005	17.651	0.411
		19 -0.022	-0.022	19.441	0.365
		20 -0.005	-0.003	19.550	0.422
		21 0.006	0.003	19.666	0.479
		22 -0.027	-0.026	22.480	0.372
		23 0.027	0.026	25.203	0.287
		24 0.019	0.017	26.636	0.272
		25 0.007	0.010	26.809	0.313
		26 0.007	0.005	27.016	0.355
		27 -0.018	-0.015	28.294	0.344
		28 -0.017	-0.016	29.429	0.340
		29 0.018	0.016	30.660	0.332
		30 0.007	0.009	30.872	0.371
		31 0.033	0.033	35.077	0.240
		32 -0.019	-0.021	36.440	0.230
		33 -0.033	-0.031	40.501	0.144
		34 -0.010	-0.014	40.875	0.163
		35 -0.002	0.000	40.893	0.194
		36 -0.037	-0.038	46.004	0.101

Modelling And Forecasting The Volatility Of The Informal Exchange Rate In Algeria (2014-2024) Using GARCH Models



Date: 04/26/25 Time: 09:15

Sample (adjusted): 10/02/2014 12/31/2024

Included observations: 3744 after adjustments

Autocorrelation		Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.206	0.206	159.26	0.000	
		2	0.128	0.090	220.98	0.000	
		3	0.107	0.068	263.71	0.000	
		4	0.100	0.060	301.00	0.000	
		5	0.137	0.098	371.46	0.000	
		6	0.246	0.198	598.73	0.000	
		7	0.101	-0.001	636.79	0.000	
		8	0.088	0.020	665.82	0.000	
		9	0.079	0.018	689.49	0.000	

Heteroskedasticity Test: ARCH

F-statistic	166.5880	Prob. F(1,3741)	0.0000
Obs*R-squared	159.5713	Prob. Chi-Square(1)	0.0000

Heteroskedasticity Test: ARCH

F-statistic	99.36410	Prob. F(2,3739)	0.0000
Obs*R-squared	188.8502	Prob. Chi-Square(2)	0.0000

Heteroskedasticity Test: ARCH

F-statistic	72.25394	Prob. F(3,3737)	0.0000
Obs*R-squared	205.0973	Prob. Chi-Square(3)	0.0000

IV. Estimation of the GARCH model:

Dependent Variable: DLTCI

Method: ML - ARCH

Date: 01/02/25 Time: 21:38

Sample (adjusted): 10/03/2014 12/31/2024

Included observations: 3743 after adjustments

Convergence achieved after 23 iterations

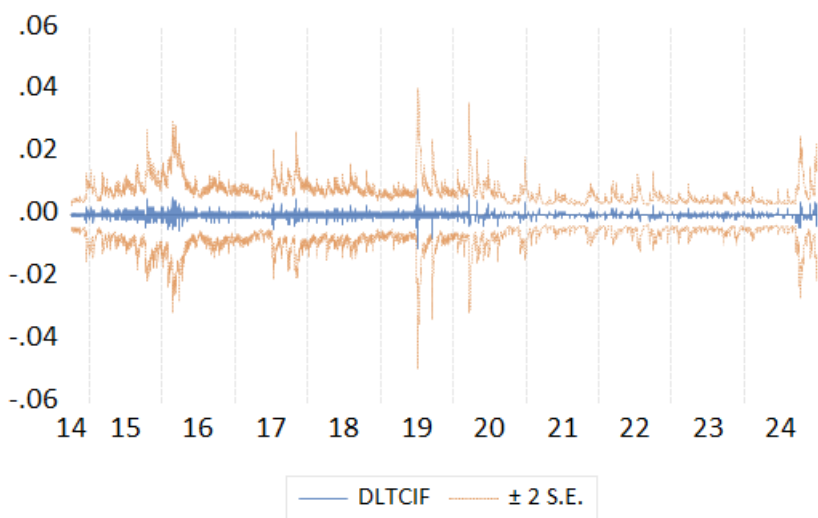
Coefficient covariance computed using outer product of gradients

Presample variance: backcast (parameter = 0.7)

GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.220751	0.018981	-11.63000	0.0000
Variance Equation				
C	3.49E-07	1.73E-08	20.10927	0.0000
RESID(-1)^2	0.114074	0.004054	28.13921	0.0000
GARCH(-1)	0.870680	0.004094	212.6806	0.0000
R-squared	0.032672	Mean dependent var		0.000115
Adjusted R-squared	0.032672	S.D. dependent var		0.004245
S.E. of regression	0.004175	Akaike info criterion		-8.516919
Sum squared resid	0.065239	Schwarz criterion		-8.510264
Log likelihood	15943.41	Hannan-Quinn criter.		-8.514552
Durbin-Watson stat	1.942980			
Inverted AR Roots	-.22			

V. Forecast results:



	TCI	TCIF	
	TCI	TCIF	
1/01/2025	240.0000	240.000	
1/02/2025	243.0000	243.000	
1/03/2025	242.0000	242.000	
1/04/2025	242.0000	242.000	
1/05/2025	245.0000	245.000	
1/06/2025	253.0000	253.000	
1/07/2025	255.0000	255.000	
1/08/2025	255.0000	255.000	
1/09/2025	255.0000	255.000	
1/10/2025	255.0000	255.000	