

## Monte Carlo Simulation Vs classic models ARIMA SARIMAX to Forecast Exchange Rate Volatility Based on historical Data from (1961 - 2024 ) to 2034

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### Summary:

In an environment of uncertainty, economic forecasts face significant complexities. Well, The In an environment of uncertainty, economic forecasts face significant complexities. This study aims to forecast the Algerian dinar's exchange rate against the US( \$ )up to 2034, based on actual data spanning from 1960 to 2023, using two models: the classical ARIMA model and the SARIMAX model enhanced with Monte Carlo simulation. External variables, generated using R software, included inflation rates, interest rates, global oil price fluctuations, trade balance, and foreign direct investment. The study found an overall upward trend in the exchange rate, indicating a decline in the dinar's value. Additional findings from the SARIMAX model suggest that increasing the interest rate leads to a decrease in the exchange rate (-8.9018), while the trade balance had a weak effect (0.0001). A slight positive impact on the exchange rate was observed from rising oil prices (0.0126), along with a limited positive effect from foreign direct investment.

**Keywords:** Exchange rate ; Algerian dinar ; Arima model ; Sarimax model.

**Jel Classification Codes :** C53 ; f31 ; G15; O53

### 1- Introduction :

In the realm of economic forecasting and future scenario analysis, accurately accounting for uncertainty is crucial. Traditional forecasting methods often analyze variables in isolation, which limits their ability to capture the complex interdependencies among macroeconomic factors. To overcome these limitations, this study compares two predictive approaches: the classical ARIMA model and an enhanced model incorporating Monte Carlo simulation techniques.

The ARIMA model is a well-established tool that forecasts time series data by extrapolating historical patterns (Jamal Fattah et al., 2018). While effective in identifying trends, ARIMA does not explicitly consider external influences or seasonal variations. In contrast, the advanced model integrates Monte Carlo simulation to generate external variables theoretically linked to the target variable. This involves a systematic process of adjusting variables based on their statistical properties and probability distributions, thereby aligning the model with real-world uncertainty (Vyom Shah et al., 2024).

Building on this, our study further enriches the analysis by employing a SARIMAX model, which extends the traditional ARIMA framework to incorporate both seasonal fluctuations and external economic variables. This comprehensive approach allows for a more nuanced understanding of exchange rate dynamics, capturing the potential impacts of fluctuations in key economic indicators under uncertain future conditions.

By comparing these models, we aim to provide deeper insights into the behavior of the Algerian dinar exchange rate. The findings will offer valuable guidance for policymakers and analysts navigating the complexities of an evolving economic landscape, enabling more robust and reliable forecasts..

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## ▪ Research Problem

Given the inherent volatility and uncertainty in economic environments, it is essential to develop analytical methods capable of accommodating diverse scenarios. This study addresses the fundamental question: How does scenario analysis based on Monte Carlo simulation differ from classical methods when applied to forecasting the Algerian dinar exchange rate under uncertainty?

### ▪ Previous Studies

**SURENDRA P. VERMA** study (2015), *Monte Carlo comparison of conventional ternary diagrams with new Log-ratio bivariate diagrams and an example of tectonic discrimination*. This study employed Monte Carlo simulation to evaluate errors in conventional ternary diagrams compared to log-ratio-based bivariate diagrams. The latter showed superior performance in distinguishing tectonic environments (oceanic arc, within-plate, mid-ocean ridges) for basaltic rocks. Statistically, the new bivariate diagrams outperformed the Zr-3Y-Ti/100 ternary diagram, with improved discrimination accuracy after applying linear discriminant analysis. The study recommended replacing ternary diagrams with log-ratio-based bivariate diagrams for enhanced accuracy.

**Vitali Bondariev et al.** 2024, *Research on the Influence of Matrix Shape on Percolation Threshold Values for Current Flow Conducted Using the Monte Carlo Simulation Method*. This study used Monte Carlo simulation to examine the effect of matrix shape on percolation thresholds by comparing square and rectangular matrices with the same number of nodes. Results indicated that percolation thresholds for square matrices were equal in both current flow directions, while in rectangular matrices, the threshold increased in the longitudinal direction and decreased in the transverse direction. The findings highlighted the necessity of considering two percolation thresholds when analyzing the electrical conductivity of thin nanocomposite films.

## 1, Dataset and Methodology

### ▪ 1.1. Dataset

The data used, is sourced from the Université de Sherbrooke's Perspective platform, which provides detailed statistical information for Algeria. The dataset includes two key economic indicators: **exports of goods and services** and **GDP growth**. This time series data spans multiple periods, offering insights into trends in exports and economic growth over time. It can be accessed via the following link: (<https://perspective.usherbrooke.ca/>) The dataset will be used to explore the relationship between Algeria's export activities and its economic growth, enabling an in-depth econometric analysis.

### ▪ 1.2. Methodology

The study combines quantitative analysis using the ARIMA model and Monte Carlo simulation to provide a comprehensive outlook on future forecasts for the Algerian dinar exchange rate. Initially, time series data on the exchange rate from 1960 will be collected.

✓ **First Level:** The ARIMA model will be applied to the exchange rate data to analyze historical patterns and generate stability-based forecasts grounded in past trends.

✓ **Second Level:** External variables such as inflation rate, capital interest, trade balance, oil prices, and foreign direct investment will be generated using Monte Carlo simulation to create multiple scenarios. This approach enables the integration of uncertainty and the interactive effects of macroeconomic variables, deriving distinctions and linking predictions to robust determinants.

### ▪ Variables of the Study

To predict the exchange rate of the Algerian Dinar against the US Dollar (%) up to 2034, the study uses actual data from 1960 to 2023, sourced from the Université de Sherbrooke's Perspective database. External variables will be simulated using the Monte Carlo method, with theoretical links to their impact on the response variable. These variables include:

- ✓ Inflation rates
- ✓ Capital interest rates
- ✓ Trade balance
- ✓ Oil prices
- ✓ Foreign direct investment

## **2.Theoretical Framework of the Study**

### ▪ **2.1. ARIMA (Auto-Regressive Integrated Moving Average) Model**

ARIMA model is a widely used statistical model for time series analysis and forecasting future values based on historical data. The ARIMA model relies on three main components:

**Auto-Regressive (AR):** This indicates that future values depend on past values in the series.

**Integration (I):** This component addresses the issue of non-stationarity in the data by calculating differences to transform the series into a stationary form.

**Moving Average (MA):** This component focuses on the relationship between the residuals from previous models.

ARIMA is widely used in fields such as economics, finance, and demand analysis. It is important to note that the selection of models generated in ARIMA is based on several criteria, including:  $\sigma^2$ , AIC, BIC, MAPE, and RMSE.

### ▪ **2.2. Monte Carlo Simulation approach**

#### ▪ **Concept of Monte Carlo Simulation**

Monte Carlo Simulation is a modern method used to analyze future scenarios under uncertainty. It relies on conducting multiple simulation experiments to derive various probabilistic outcomes based on random inputs. The goal of this simulation is to study the behavior of a system (variable) in complex and dynamic environments where it is difficult to predict the outputs accurately using traditional models. Monte Carlo Simulation allows for the imitation of different potential scenarios by repeating computational processes for a set of random variables that may influence the system under study (Raychaudhuri, 2008).

#### ▪ **Scientific Foundations of Monte Carlo Simulation**

Monte Carlo Simulation is based on using probabilities and statistical distributions within mathematical methods to address uncertainty. Random values are generated from a specific distribution for each input variable in the system. These processes are repeated across a large number of simulations, providing a broad set of potential outcomes that represent the distribution of results based on various probabilities. These outcomes can be used to derive estimates for certain outputs based on the uncertainty of the inputs (Asai, 2019).

#### ▪ **Uses of Monte Carlo Simulation**

Monte Carlo Simulation is used in various fields such as economics, finance, and engineering, where it is relied upon for risk analysis and evaluating the probabilities of future events. In this context, it can be used to analyze economic fluctuations that affect exchange rates by generating multiple scenarios based on a set of economic inputs such as inflation rate, capital interest, fiscal deficit, or even fluctuations in oil prices. In this way, Monte Carlo Simulation provides a more accurate picture of potential future conditions compared to traditional models that rely on fixed assumptions (Sutaria, 2016).

#### • **Monte Carlo Simulation as a Tool for Deepening Uncertainty Analysis**

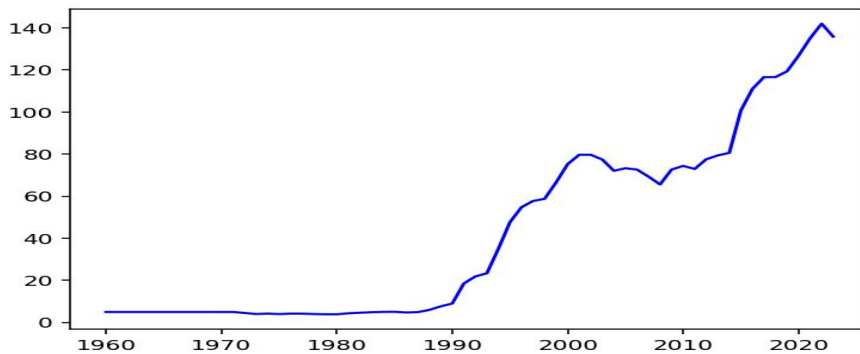
Monte Carlo Simulation is distinguished by its ability to handle uncertainty and unstable economic conditions. It allows for the analysis of the impact of these fluctuations on expected outcomes, which helps in identifying the risks associated with each scenario. Additionally, this simulation provides a foundation for understanding the probabilistic distribution of results, rather than relying solely on central forecasts or individual values. Through these methods, decision-makers in various fields can make choices based on comprehensive and accurate data that represents the complex and changing reality (Mikael, 2013).

## **3- Results and discussion :**

Building on the theoretical discussion regarding the methodology of Monte Carlo Simulation and its applications in analyzing complex economic scenarios, the practical part of this study aims to apply the theoretical foundations to analyze the future exchange rate predictions of the Algerian dinar under macroeconomic variables. In this section, the ARIMA model will be applied to analyze time series data for the exchange rate from 1960 to 2034, with the goal of understanding historical patterns and providing future predictions based on the available data. On the other hand, Monte Carlo Simulation will be used to generate multiple scenarios based on a set

of important economic variables such as the inflation rate, oil price, foreign reserves, fiscal deficit, and other variables that directly affect the exchange rate.

Figure 1: Exchange Rate of the Algerian Dinar Against the (US\$) for 1960-2023.



The Source: Prepared by the author's based on R o

The exchange rate of the Algerian dinar against the US dollar remained relatively stable until 1990, a year that followed popular protests due to worsening economic conditions, known as the October 5, 1989 events. This prompted the government at the time to implement a series of political and economic reforms. As a result, Algeria entered a new phase characterized by the introduction of political pluralism, which led to unbalanced levels of polarization due to both the state and the public lacking the proper tools to manage such events. On the economic front, the government took several economic measures, including the liquidation and privatization of several state-owned enterprises. This was considered one of the key conditions by the International Monetary Fund for facilitating loan approvals. All these events, along with other factors, can explain the reasons behind the depreciation of the Algerian dinar.

▪ **3.1. Forecasting Exchange Rate Until 2034 Using ARIMA Model**

The Auto-Regressive Integrated Moving Average (ARIMA) model is one of the leading models in time series analysis, used to predict future values of variables based on historical data. In this context, forecasting the exchange rate for the coming years until 2034 begins by converting the data into a time series, allowing for the representation of changing patterns over time. Next, the levels of integration, p and q, are determined to assess how past values influence the data, and the model parameters are fine-tuned to ensure the highest accuracy in future predictions.

Table( 1): Estimated ARIMA Model Parameters

Category	Details
Series	data_ts
Model	ARIMA(0,2,2)
Coefficients	ma1: -0.4342 (s.e. 0.1190)
	ma2: -0.4557 (s.e. 0.1223)
sigma^2	16.47
Log Likelihood	-174.54
AIC	355.07
AICc	355.49
BIC	361.45
Training Set Error Measures	
ME	0.4341555
RMSE	3.928981
MAE	2.205092
MPE	1.984176
MAPE	5.499410

<b>MASE</b>	0.7698403
<b>ACFI</b>	-0.01474299

The Source: Prepared by the author's based on R

The outputs of the ARIMA(0,2,2) model used to forecast the Algerian Dinar exchange rate against the US Dollar indicate that the model relies on the second differencing to achieve stationarity, with no autocorrelation and two moving average terms (MA1 and MA2) with coefficients of -0.4342 and -0.4557, respectively. This suggests an inverse effect of previous errors on future values. The  $\sigma^2$  value of 16.47 reflects the variance of the residual errors, while the model selection criteria, AIC (355.07) and BIC (361.45), indicate that this model performs well compared to other models.

Regarding prediction accuracy, the RMSE is 3.93 and the MAE is 2.21, suggesting acceptable deviations from actual values. The mean absolute percentage error (MAPE) is 5.5%, indicating high prediction accuracy. Additionally, the ACF1 coefficient has a value close to zero (-0.0147), showing no temporal correlation in the residual errors, which further supports the model's suitability for reliable future exchange rate forecasts.

▪ **3.2. Stationarity Testing**

Before estimating the ARIMA and SARIMAX models, it was necessary to verify whether the exchange rate series was stationary. Two complementary tests were applied: the **Augmented Dickey-Fuller (ADF)** test and the **Kwiatkowski-Phillips-Schmidt-Shin (KPSS)** test.

Table (2): Results of Unit Root and Stationarity Tests

Test	Tes	-value	L	Critical Values	ion	Decis	Con
	t Statistic		ags Used				clusion
ADF (Level)	1.2096	0.9960	1	(1%: -3.56, 5%: -2.92, 10%: -2.59)	Fail to reject $H_0$	Fail	Non-stationary
KPSS (Level)	0.2185	0.01	5	(10%: 0.119, 5%: 0.146, 1%: 0.216)	Reject $H_0$	Rejec	Non-stationary
ADF (2nd Difference)	-	-	-	-	Reject $H_0$	Rejec	Stationary
KPSS (2nd Difference)	-	-	-	-	Fail to reject $H_0$	Fail	Stationary

The Source: Prepared by the author's based on R

As reported in Table (2), the ADF test yielded a statistic of 1.2096 with a p-value of 0.9960, indicating that the null hypothesis of a unit root cannot be rejected; thus, the series is non-stationary at level. Similarly, the KPSS test produced a statistic of 0.2185 with a p-value of 0.01, leading to the rejection of the null hypothesis of stationarity. The convergence of both results confirms that the exchange rate series contains a unit root.

To address this issue, the data were differenced twice ( $d = 2$ ). After second differencing, both tests indicated stationarity, validating the transformation process and confirming that the ARIMA(0,2,2) specification is appropriate for forecasting the Algerian dinar exchange rate. These findings ensure that the subsequent ARIMA and SARIMAX estimations are statistically sound and unbiased.

Figure 2. Autocorrelation Function (ACF) for Differenced Exchange Rate

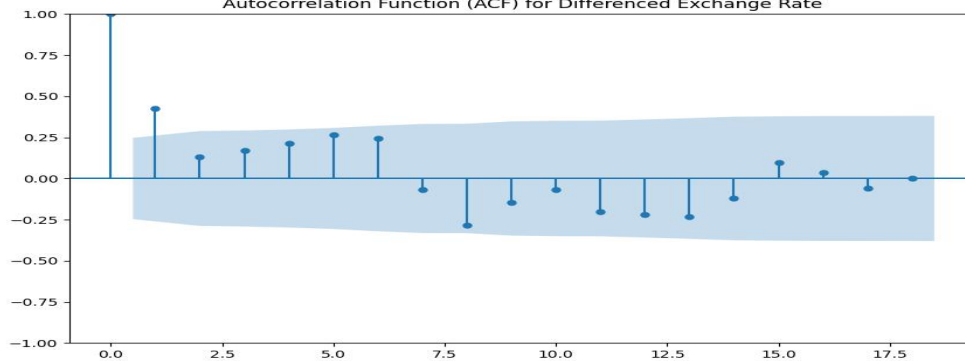
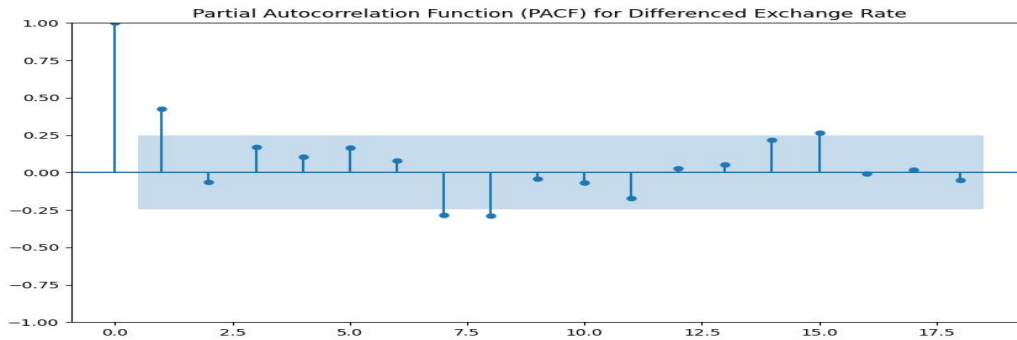


Figure 3. Partial Autocorrelation Function (PACF) for Differenced Exchange Rate



The Source: Prepared by the author's based on R

### 3.3. Diagnostic of ARIMA Model

The autoregressive integrated moving average (ARIMA) model is one of the essential tools in time series analysis, as it helps in understanding the relationship between current and previous values of economic variables. To assess the suitability and efficiency of the model, statistical criteria such as the AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) are used. These help evaluate the prediction accuracy while considering the model's complexity, alongside  $\sigma^2$ , which reflects the accuracy of the estimates. This section aims to use these indicators to select the most effective model for providing accurate forecasts, thereby contributing to the improvement of economic decision-making strategies.

The evaluation of the ARIMA model reveals several important indicators regarding the model's accuracy and performance. The value of  $\sigma^2$  (residual variance) at 16.47 indicates the degree of dispersion of the errors around the mean, serving as an indicator of how closely the forecasts align with the actual values. Additionally, the AIC (355.07) and BIC (361.45) reflect the preference for this model over other potential models, as these criteria are used to assess the model's fit and simplicity, with the relatively low values here confirming the model's efficiency. Furthermore, the MAPE of 5.5% demonstrates the average absolute percentage error compared to the actual values, reflecting a high level of accuracy in the predictions. Finally, the RMSE of 3.93 represents the mean deviation of the predicted values from the actual values, enhancing the model's reliability and confirming its suitability for future time series analysis.

### 3.4. Forecasting Future Exchange Rates Using the ARIMA Methodology

This test aims to predict future values of the exchange rate until the year 2034 using the ARIMA model. Initially, the number of forecast steps required to predict up to the desired year (2034) is determined, assuming that the data is monthly. This variable is referred to as forecast steps. Using these steps, future predictions are generated based on the current ARIMA model stored in the variable model.

Next, the preliminary forecast results are displayed using the head() function to check the predicted values. Then, a plot is created showing the historical values of the time series alongside the predicted values up to 2034. The plot includes a blue line representing the entire time series, while the red line shows the expected average, which helps in visualizing the predicted trend and clearly estimating the future exchange rate value.

Table (3): Forecast Results of Exchange Rate with Confidence Intervals.

Year	Forecast	Fore	Lo 80	80	Hi	Lo 95	95	Hi	
2024	2	133.8766	266	128.676	0770	139.97	125.92336	8299	141.
2025	2	136.9653	409	127.303	6271	146.982	122.18872	7418	151.
2026	2	140.0539	756	127.041	0661	153.968	120.15352	9543	159.
2027	2	143.1426	249	127.155	1299	159.719	118.69206	5931	167.
2028	2	146.		127.447		165.	117.50343		174.

028	2312	138	0153	757	9590
029	2 149.	127.832	170.	116.45749	182.
030	2 152.	128.265	176.	115.48547	189.
031	2 155.	128.721	182.	114.54660	196.
032	2 158.	129.180	187.	113.61492	203.
033	2 161.	129.634	193.	112.67300	210.
034	2 164.	130.072	199.	111.70870	217.

The Source: Prepared by the author's based on R

The predictive model used is the ARIMA(0,2,2) model to forecast the time series data until 2034. The general trend shows an upward direction starting from 2024, with the forecast beginning at around 133.88 and gradually increasing until reaching 164.76 by 2034. The model demonstrates moderate effectiveness, with error estimates ranging from -0.4342 to -0.4557 in the moving average coefficients (ma1 and ma2), indicating some fluctuations around the predicted estimates. This suggests that there are fluctuations in the time series. Additionally, the residual errors show significant variance during certain periods, such as 1977 and 1991, which were transformative periods coinciding with the collapse of the Soviet Union, one of the major global powers, leading to the dominance of the Western world. During this time, political parties were allowed to form, and political activity was allowed after decades of state monopoly, leading to polarization. Economically, the scene was marked by a period of openness, moving away from previous practices characterized by state control and monopoly over institutions, which could reflect the impact of external factors or instability that affected the studied time series.

The forecasts indicate that the Algerian dinar will experience a gradual depreciation against the US dollar, which can be attributed to several economic factors, primarily the growing current account deficit, possibly caused by a decline in revenues from oil and gas exports or an increase in imports. Monetary policies aimed at financing fiscal deficits by printing more money may also contribute to rising inflation and additional pressure on the exchange rate. In general, these forecasts suggest that there will be fluctuations in Algeria's overall economic situation, which heavily relies on oil and gas prices. This signals that if volatility in energy markets continues, serious issues and significant challenges may arise that need to be addressed. It is imperative to implement comprehensive economic reforms aimed at enhancing financial and monetary stability and achieving economic diversification beyond reliance on oil and gas exports.

### 3.5. Monte Carlo Simulation for New Variables

Monte Carlo simulation relies on generating new data related to the target variable (exchange rate) using appropriate probability distributions, such as the normal distribution, while considering the distribution characteristics of each variable individually. The simulation steps include: generating random data, combining variables according to needs, and creating variables that reflect direct or indirect fluctuations in the exchange rate. The researcher has the freedom to determine the number of scenarios, with 1,000 scenarios used in this study. This simulation can be implemented using the R programming language, with libraries such as MASS and ggplot2 required.

#### ▪ Simulating Economic Scenarios: A Monte Carlo Approach to Key Economic Variables

To model economic fluctuations, 1,000 possible scenarios are simulated for key economic variables using normal probability distributions derived from historical data. The inflation rate has an average of 3% with a standard deviation of 2%, reflecting moderate price changes. The capital interest rate, indicative of monetary policy stability, is set at 5%, with slight fluctuations of 1%. The trade balance shows a deficit, averaging -500 million with a standard deviation of 200, highlighting significant international trade variations. Oil prices average \$70 per barrel with a standard deviation of 10, capturing global energy market fluctuations. Lastly, foreign direct

investment averages 1,000 million with a standard deviation of 500, emphasizing its sensitivity to geopolitical dynamics. This simulation framework provides comprehensive insights into the potential impact of economic variability on the broader economy.

**3.6. Stages of Modeling According to the SARIMAX Model**

The modeling process involves three main stages. The first stage is data generation, where random techniques are used to simulate data representing various possible scenarios. These simulations are based on probabilistic distributions and are designed to model potential future changes in the variables of interest. The second stage is data integration, where the simulated data is merged with real or pre-prepared data to form a comprehensive dataset. This stage aims to create a robust model by combining historical and simulated data. The final stage is prediction, where the trained model is used to generate future forecasts based on the integrated data. This stage can be combined with the SARIMAX methodology to forecast seasonal time series. By incorporating autoregressive, moving average, and seasonal components, SARIMAX provides accurate predictions that account for trends, cycles, and seasonal effects in the data.

**3.6.1. Simulation of External Variables**

In this stage, external variables that are theoretically related to changes in exchange rates will be simulated. It is important to note that the selection of simulation variables is based on theoretical concepts and observations. In our study, we selected variables such as inflation, interest rates, oil prices, foreign trade, and foreign direct investment due to their direct or indirect link to exchange rate fluctuations.

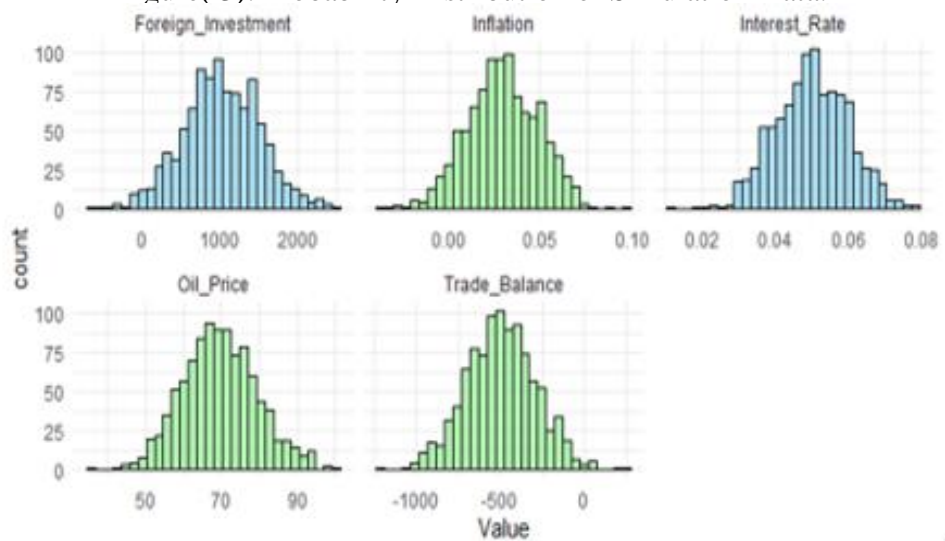
Table (4): Simulation of External Variables Using the Monte Carlo Method

Year	Inflation	Interest Rate	Trade Balance	Oil Price	Foreign Investment
024	0.0160 154379	0.0338 1963	- 397.79992	89.3 1576	2185.36261
025	0.0499 209306	0.0537 9181	- 138.40144	63.8 3525	916.59402
026	0.0161 450929	0.0690 2250	- 840.52299	64.3 7433	1463.48070
027	0.0270 933311	0.0560 8743	- 442.51055	60.1 0037	715.92413
028	0.0796 737313	0.0528 6075	- 435.88225	97.3 1228	1112.54504
029	0.0594 100030	0.0587 1081	- 575.90404	62.7 8334	1565.99295
030	0.0615 973224	0.0472 3172	- 638.87631	83.3 3505	1690.24077
031	0.0615 590490	0.0614 7490	- 538.70534	57.7 9992	883.59829
032	0.0207 629510	0.0550 4500	- 584.01776	84.0 1776	199.67834
033	0.0068 294959	0.0580 0387	- 664.41427	73.3 2223	850.81541
034	0.0062 437812	0.0684 6739	- 562.04932	61.8 1526	862.18796
035	0.0074 302201	0.0507 3368	- 415.76794	73.0 7817	984.83721
036	0.0246 319995	0.0525 0100	- 409.46847	1544 .67301	1544.67301
037	0.0401 559853	0.0504 3554	- 150.32369	79.3 2779	497.28912

The Source: Prepared by the author's based on R

The provided economic data shows clear fluctuations in several key economic indicators over the studied period. While the exchange rate remains stable at 4.937 for most periods, it experienced a slight decrease to 4.481, suggesting potential changes in monetary policy or shifts in economic conditions. On the other hand, the inflation rate fluctuates between 0.0068 and 0.0616, reflecting economic challenges that may affect the purchasing power of the local currency. The interest rate ranges from 0.0338 to 0.0690, indicating a fluctuating monetary policy aimed at controlling inflation or maintaining currency stability. As for the trade balance, it shows a continuous deficit between -397.8 and -840.5, indicating weaknesses in exports or an increase in imports, which puts pressure on financial reserves. Regarding oil prices, they range between 57.79 and 97.31, reflecting fluctuations in global oil prices that impact the economy, especially given the current situation where the country heavily depends on oil revenues. Foreign investment ranges from 199.68 to 2185.36, reflecting the volatility in investor confidence in the local economy. Overall, these data indicate that the economy faces several economic challenges, including trade deficits and inflation, and require adjustments in monetary and fiscal policies to achieve stability and sustainable growth.

Figure( 3): Probability Distribution of Simulation Data.



The Source: Prepared by the author's based on R

Each of the generated series represents a possible outcome based on a set of random or varying inputs, and when we repeat the process 1000 times, the generated shapes explain the existence of a normal distribution for all the series.

**3.6.2.Phase of Merging Changes**

In this phase, we will merge the variables by combining the actual data with the simulated data according to the following algorithm.

Table(5): Variable Merging Using the Monte Carlo Technique

Year	Exchange Rate	Inflation	Interest Rate	Trade Balance	Oil Price	Foreign Investment
024	4.937	0.016	0.033	-397.7999	9.31576	2185.362
025	4.937	0.049	0.053	-138.4014	3.83525	916.5940
026	4.937	0.016	0.069	-840.5230	4.37433	1463.480
027	4.937	0.027	0.056	-442.5102	0.10037	715.9241
028	4.937	0.042	0.067	-553.8228	7.31228	1112.545
029	4.937	0.017	0.048	-575.9049	2.78334	1565.993

030	4.937	0.031	0.047	-	8	1690.240
		697322	27132	638.8763	3.33505	8
031	4.937	0.061	0.061	-	5	883.5983
		559804	47490	538.7085	7.79992	
032	4.937	0.020	0.055	-	8	199.6783
		726925	05400	312.6212	4.01776	
033	4.937	0.006	0.058	-	7	850.8154
		829460	01037	664.4142	3.32223	
034	4.937	0.044	0.048	-	6	862.1880
		473713	64739	562.0493	1.81526	
035	4.937	0.014	0.049	-	7	984.8372
		309187	52370	415.7679	3.07817	
036	4.481	0.024	0.052	-	8	1544.673
		631999	50103	409.4687	1.33651	0

Source: Prepared by the author's based on R

### 3.6.3. Forecasting Phase

In the forecasting phase, the Seasonal Auto-Regressive Integrated Moving Average with Exogenous Variables (SARIMAX) model will be used as a standard method for predicting exchange rates, as it is most suitable for cases involving volatility and uncertainty. SARIMAX is a powerful tool for analyzing time series data that includes seasonal components, widely used to forecast future values based on historical data. It is important to note that the model is an extension of SARIMA, but it also allows for the inclusion of exogenous variables to improve predictions.

On the other hand, Monte Carlo simulation is a technique that generates multiple simulations using random values to explore the various possibilities of future outcomes. This approach provides a distribution of future predictions rather than a single value, allowing for a better analysis of risks and probabilities. The simulation is conducted through several iterations (1000 repetitions) to generate multiple time paths and then analyze the results to obtain comprehensive estimates of future predictions. This combination of tools allows for interpreting and forecasting exchange rate fluctuations under uncertainty, offering a broader view of how different variables may affect outcomes.

### 3.6.4. Presentation of Forecast Results

The forecast outputs consist of two main parts: the first relates to the training error measure, while the second pertains to the estimated model parameters.

### 3.6.5. Training Error Measures

The error measure is a key tool in forecast analysis and statistical modeling, as it helps assess the accuracy of predictions compared to actual values. The error measure is widely used in various fields that rely on statistical modeling, including economics, management, and trade. This analysis aims to evaluate forecasting models based on a set of measures that allow for the examination of model accuracy and its ability to provide correct estimates. In this context, a table will be analyzed that includes several measures used to evaluate forecast errors.

Table (6): SARIMAX Model Outputs for Simulated and Response Variables.

Category	Details
Series	combined_data_cleanExchange_Rate
Model	Regression with ARIMA(0,1,1) errors
Coefficients	0.5187 (s.e. 0.1039)
	2.0058 (s.e. 1.8906)
sigma^2	16.72
Log Likelihood	-174.56
AIC	365.13
AICc	367.79
Training Set Error Measures	
ME	0.006111905

RMSE	3.824938
MAE	2.668548
MPE	-11.15826
MAPE	16.65107
MASE	0.9316421
ACFI	0.06356008

Source: Prepared by the author's based on R

### 3.6.6. Standard Parameters of the Estimated Model in the SARIMAX Model

The standard parameters explain the overall suitability of the estimated model, and they are described as follows:

Table (7): Standard Parameters of the SARIMAX Model

Metric	alue	Interpretation
Error Variance	6.72	Measures the variance of the emors in the model. The smaller the value, the better the model fit. Likelihood Function
Likelihood Function	74.56	The value of the likelihood function, which measures how well the model fits the data. The larger the value, the better the model.
AIC	65.13	A measure used to determine the model's fit, with a smaller value indicating a better model Adjusted AIC
Adjusted AIC	67.79	A correction of the AIC criterion that also considers sample size. A lower value Indicates a better mode Model Quality
Model Quality (BIC)	82.27	Another measure of model quality. A smaller value indicates a better model

The Source: Prepared by the author's based on R

**Standard parameters** measure the overall adequacy of the estimated model, with the following recorded values:

✓ **AIC = 365.13** and **BIC = 382.27**, which reflect the evaluation of the model compared to other models that can be tested.

✓  **$\text{Sigma}^2 = 16.72$** , which represents the variance of errors in the model.

✓ **Error metrics** in the training set showed that **RMSE (3.82)** and **MAE (2.67)** indicate significant errors in the predictions, while **MAPE (16.65%)** shows that the model does not provide highly accurate results.

✓ The value of **ACF1 (0.0636)** indicates a weak relationship between errors across time periods.

Although the model requires further improvement in light of the metrics showing significant prediction errors, some variables such as inflation and oil prices exhibit significant effects.

In general, based on these metrics, it can be observed that some values indicate accurate prediction performance (such as the standard error and **MASE**), while others (such as **MAPE**) indicate significant errors in modeling. The negative values in **MPE** suggest that the predictions were lower than the actual values, requiring model improvement to ensure higher accuracy in future predictions. However, in general, the estimated model provides reasonable forecasts, as **AIC** and **BIC** reflect the quality of an acceptable model.

## 4. Estimated Parameters in SARIMAX Model

The estimation of parameters in the SARIMAX model is a critical step in understanding the underlying dynamics of the time series data. These parameters, which include the coefficients for

autoregressive (AR), moving average (MA), seasonal components, and exogenous variables, help capture the relationships within the data. Accurate estimation of these parameters ensures that the model can effectively explain past behavior and generate reliable forecasts for future periods.

Table (8): Interpretation of the Estimated Parameters of SARIMAX Model

Parameter	V alue	Interpretation
Effect of Interest Rate on Exchange Rate	-6.9016	An increase in the interest rate may lead to a decrease in the exchange rate.
Effect of Trade Balance on Exchange Rate	0.0001	The relationship between the trade balance and exchange rate is very weak
Effect of Oil Prices on Exchange Rate	0.0126	An increase in all prices may lead to an increase in the exchange rate.
Effect of Foreign Investment on Exchange Rate	0.0005	The relationship is positive, but its effect on the exchange rate is minimal

The Source: Prepared by the author's based on R

SARIMAX model used to predict exchange rates is based on ARIMA (0,1,1) with a set of explanatory variables (inflation, interest rate, trade balance, oil prices, and foreign investment) that were simulated using the Monte Carlo method. The estimation parameters show that the model includes the MA1 coefficient (0.5187), indicating a positive relationship between past errors and the exchange rate. Meanwhile, the drift (2.0058) reflects a long-term upward trend in the exchange rate.

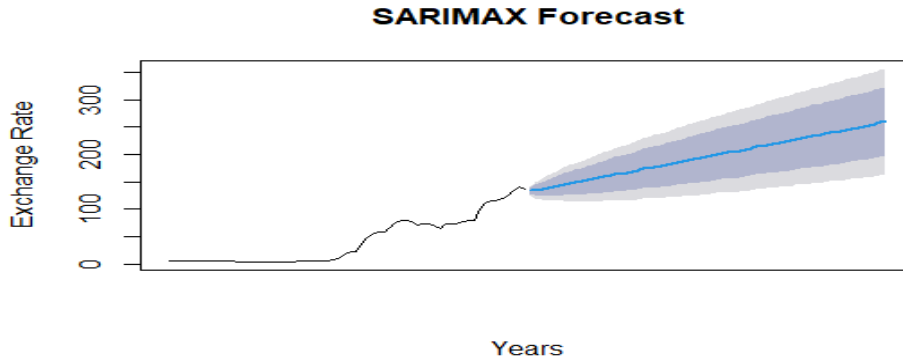
The results of the parameters indicate that inflation has a positive effect on the exchange rate (18.7488), while the interest rate has a negative effect on it (-8.9018). However, the effect of the trade balance (-0.0001) is very weak, suggesting that it does not play a significant role in explaining exchange rate fluctuations in this model.

On the other hand, oil prices show a positive relationship with the exchange rate (0.0126), reflecting the financial markets' greater sensitivity to oil price fluctuations. Foreign investment also shows a very weak effect (0.0005), indicating that it does not have a significant impact on exchange rate volatility during the studied period.

▪ **Graphical diagnostics of the estimated SARIMAX model.**

The diagnostic assessment of the estimated SARIMAX model is essential in econometric studies to ensure the validity of the model used to interpret the econometric relationship between various economic variables.

Figure( 4): Exchange Rate Trend Estimated Using the SARIMAX Methodology



The Source: Prepared by the author's based on R

The chart illustrates the SARIMAX model's exchange rate forecasts over several years. The blue line represents the expected future trend of the exchange rate based on historical data, while the shaded gray areas represent the confidence intervals, indicating the level of uncertainty in these forecasts. It is evident from the chart that there is an upward trend in the exchange rate in the long term, meaning that the forecasts suggest a continuous increase over time. However, the confidence intervals widen as time progresses, reflecting increased uncertainty about these predictions as we move further from the current period. This indicates the possibility of price variability in the future, which is typical in economic and financial forecasting, as predictions become more challenging with time.

**4.1. Residuals Diagnostic Evaluation of ARIMA and SARIMAX Models**

Residual analysis constitutes a crucial step in assessing the performance and adequacy of time-series models. It involves examining the differences between observed and predicted values to determine whether the model has successfully captured the underlying data patterns without systematic bias. The evaluation focuses on key statistical properties of the residuals—specifically, independence, normality, and homoscedasticity.

Autocorrelation tests are applied to verify the independence of residuals over time, as random, uncorrelated residuals indicate that the model captures the dynamic structure of the series effectively. Random residual behavior also supports the model's suitability for reliable forecasting.

Accordingly, residual diagnostics were conducted for both the ARIMA(2,1,2) and SARIMAX(2,1,2)(0,0,0,0) models to verify these assumptions.

The main test results assess serial independence (Ljung–Box test), normality (Jarque–Bera test), and homoscedasticity (ARCH–LM test), providing a comprehensive diagnostic evaluation of the estimated models.

Table 9. Ljung–Box Test (Residual Independence)

Model	M	-value	Decision	Interpretation
RIMA	A	.75	No autocorrelation	Residuals are uncorrelated
ARIMAX	S	.78	No autocorrelation	Residuals are uncorrelated

Both models exhibit high p-values (> 0.05), confirming that serial correlation has been effectively removed.

Table 10. Jarque–Bera and Distribution Metrics

Model	M	J B p-value	kew.	urt.	Decision
RIMA	A	0.00	.32	.33	No n-normal
ARIMAX	S	0.00	.62	.61	No n-normal

The Source: Prepared by the author's based on R

The low p-values and high skewness/kurtosis indicate non-normal, fat-tailed residuals—typical of exchange-rate series. This does not bias the mean forecasts but may affect confidence intervals.

Table 11. Heteroskedasticity and Simulation Summary

Model	M	H-Test p-value	Decision	Mean Sim.	SD Sim.	Sample Size	Interpretation
IMA	AR	0.00	Heteroskedastic	18.16	5.78	1	Stable variance
RIMAX	SA	0.00	Heteroskedastic	18.19	5.97	1	Slightly higher spread

The Source: Prepared by the author's based on R

The heteroskedasticity tests reject the null of constant variance, suggesting time-varying volatility.

Monte Carlo simulations show both models yield similar mean forecasts (~18.17) with slightly more dispersion under SARIMAX.

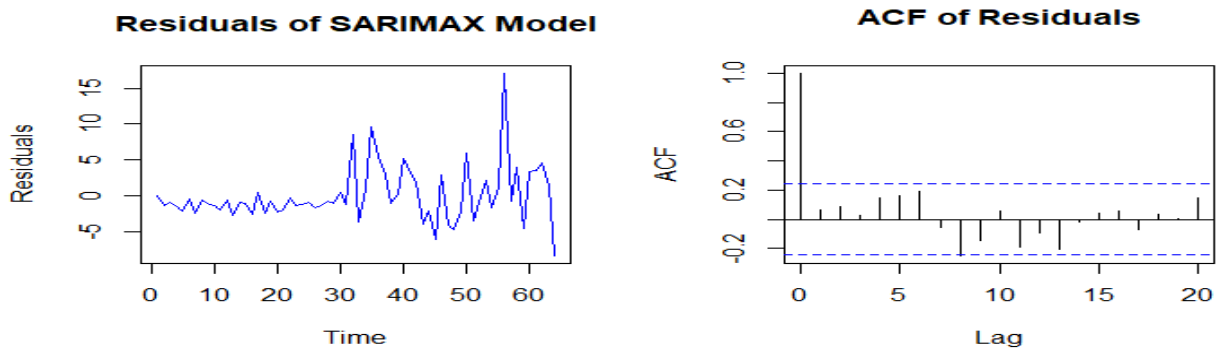
Table 12. Summary of Diagnostic Results for ARIMA and SARIMAX Models

Aspect	Diagnostic	ARIMA	SARIMAX	Verdict
Autocorrelation	None	No	No	Both models valid
Normality	Violated	Violated	Violated	Heavy tails, right skew
Homoscedasticity	Violated	Violated	Violated	Volatility clustering
Simulation stability	Stable	Slightly variable	Slightly variable	Comparable accuracy

The source: Author's computation using model residual diagnostics and Monte Carlo simulations (Python 3.13)

Both models capture the conditional mean dynamics and remove serial correlation, but residuals remain non-normal and heteroskedastic. Forecast means are reliable, yet prediction intervals may be conservative. Future work may employ **GARCH-type** or **SARIMAX-X** models to model volatility more effectively.

Fig. (5): Residual Analysis of the Estimated SARIMAX Model



Source: Prepared by the author's based on R

The graph shows the residual analysis of the estimated SARIMAX model over time (on the left) and the autocorrelations of the residuals (on the right) to assess the randomness of the residuals and the accuracy of the model. It appears that the residuals fluctuate around zero with some significant changes at specific points, indicating that there is no major bias in the predictions. However, these large fluctuations might suggest moments when the model was less accurate. On the other hand, the autocorrelation plot shows that most of the values fall within the confidence intervals, suggesting that the residuals are random and there are no strong time patterns left unaccounted for by the model. While some values exceed the confidence limits, this slight

deviation does not significantly affect the model's efficiency, indicating that the SARIMAX model is suitable for future predictions.

### **5. Conclusion:**

The analysis provides a comprehensive comparison between the traditional ARIMA model and the SARIMAX model supported by Monte Carlo simulation for forecasting exchange rates. The ARIMA (0,2,2) model predicts an upward trend in the exchange rate, with expectations of reaching 164.76 Algerian Dinars by 2034. However, its reliance solely on historical data significantly limits its interpretive capacity. While it can capture past patterns to build a future outlook for values, it fails to consider external factors, making it less effective in volatile environments. Residual analysis reveals the model's inability to account for complex external factors, such as the significant political and economic transformations that Algeria experienced during the 1980s and 1990s, which led to sharp fluctuations in the value of the Algerian Dinar. These shortcomings highlight the limitations of using the ARIMA model alone in dynamic and multidimensional economic contexts.

In contrast, the SARIMAX model supported by Monte Carlo simulation offers a more comprehensive and forward-looking approach by integrating a range of fundamental economic variables, such as inflation, oil prices, trade balance, and interest rates. Including these factors enables a multidimensional view of the determinants of exchange rate movements. The analysis shows that inflation has a significant positive impact on the currency's value, while interest rates have a negative effect, and the trade balance plays a relatively weak role. By utilizing Monte Carlo simulation, the SARIMAX model generates a range of potential future economic scenarios, taking into account uncertainty and providing a probabilistic understanding of exchange rate fluctuations.

This enhanced approach not only improves the accuracy of forecasts but also offers valuable insights into the interaction between economic variables and exchange rates. Policymakers and analysts can leverage these insights to make more informed decisions, particularly in managing monetary policy, trade strategies, and foreign investment planning. By emphasizing the importance of economic fundamentals and scenario analysis, this analysis underscores the superiority of the SARIMAX-Monte Carlo framework in addressing the complexities of exchange rate forecasting within a constantly evolving global economic environment.

### **6. Recommendations**

Based on the results obtained, the following recommendations can be made:

- ✓ It is crucial to adhere to economic measures aimed at reducing expected exchange rate fluctuations by prioritizing economic diversification.
- ✓ There should be a focus on reducing reliance on oil revenues and increasing investments in non-oil productive sectors.
- ✓ Balanced monetary policies should be adopted to control inflation and address the trade deficit, which will contribute to stabilizing the dinar's value and boosting confidence in the domestic economy.

Additionally, integrating advanced analytical techniques, such as Monte Carlo simulations, into economic forecasting models is essential for developing evidence-based policies. This approach allows policymakers to anticipate future economic challenges more effectively and design strategies that support sustainable economic growth. By combining economic reform with strong analytical tools, the recommendations aim to enhance resilience against external shocks and promote long-term stability.

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