Forecasting Foreign Exchange rates using an ARIMA Model: A case study of USD/KSH rate

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Introduction

This document serves the purpose of explaining to the reader the procedures taken to develop a model that forecasts foreign exchange rates. The data for this project has been sourced Here. The CBK uploads forex data on 21 currencies. Out of the 21 currencies, this project works with the USD/KES pair. EDA was conducted to the data to discern the possible hypothesis tests and assumptions to be made. Anomalies such as duplicates and wrongly worded characters were identified and dealt with. No missing values were reported.

The data used to build the model runs from 1st December 2016 upto 13th June 2025. It has 2114 observations made on weekdays, excluding public holidays and weekends. All rates are the equivalent value of 1 US Dollar.

Descriptive summaries

Date

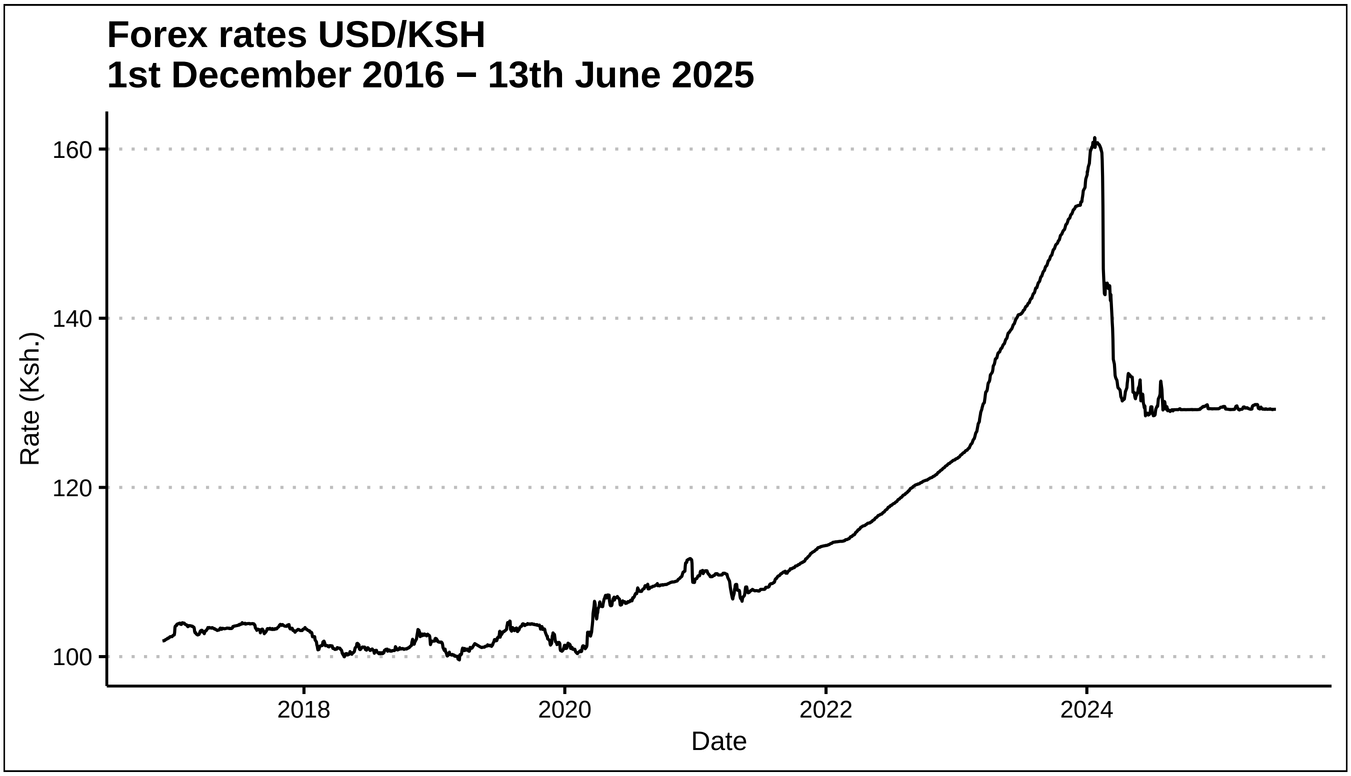
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
2016-12-01	2019-01-16	2021-03-10	2021-03-09	2023-04-25	2025-06-13

Rates

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
99.61	103.1	108.8	115.1	129.2	161.4

Data Visualization

Time plot



Methodology

An ARIMA model was chosen to forecast the Forex rates. Fortunately, the `forecast` library has a function that returns an optimal model. This accelerated the workflow and diagnostics. An ARIMA model can have an auto-regressive coefficient(s) or moving average coefficient(s) or both. In addition ,they allow for differencing if the data to be modelled is non-stationary. The optimal model chosen for this data is the `ARIMA(1,2,1)` with an auto-regressive order of `1`, a moving average order of `1` and a differencing order of `2`. Generally an ARIMA model is written as;

$$\Phi(B)(1-B)^d y_t = \Theta(B)Z_t$$

where:

- B is the backshift operator such that $B^1 y_t = y_{t-1}$
- d is the level of differencing performed
- $\Phi(B)$ is the autoregressive polynomial
- $1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$ with ϕ_i the AR coefficients for $i = 1, 2, \cdots, p$
- $\Theta(B)$ is the moving average polynomial $1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_p B^p$ with θ_i the MA coefficients for $i = 1, 2, \cdots, q$
- Z_t is the error term

The model has a single AR coefficient of `0.3198253` and a single MA coefficient of `-0.9845105`. Plugging the values to the above formula and simplifying, we end up having the model as,

$$\hat{y_t} = 2.3198 y_{t-1} - 1.6396 y_{t-2} + 0.3198 y_{t-3} + 0.9845 Z_{t-1}$$

Results and Findings

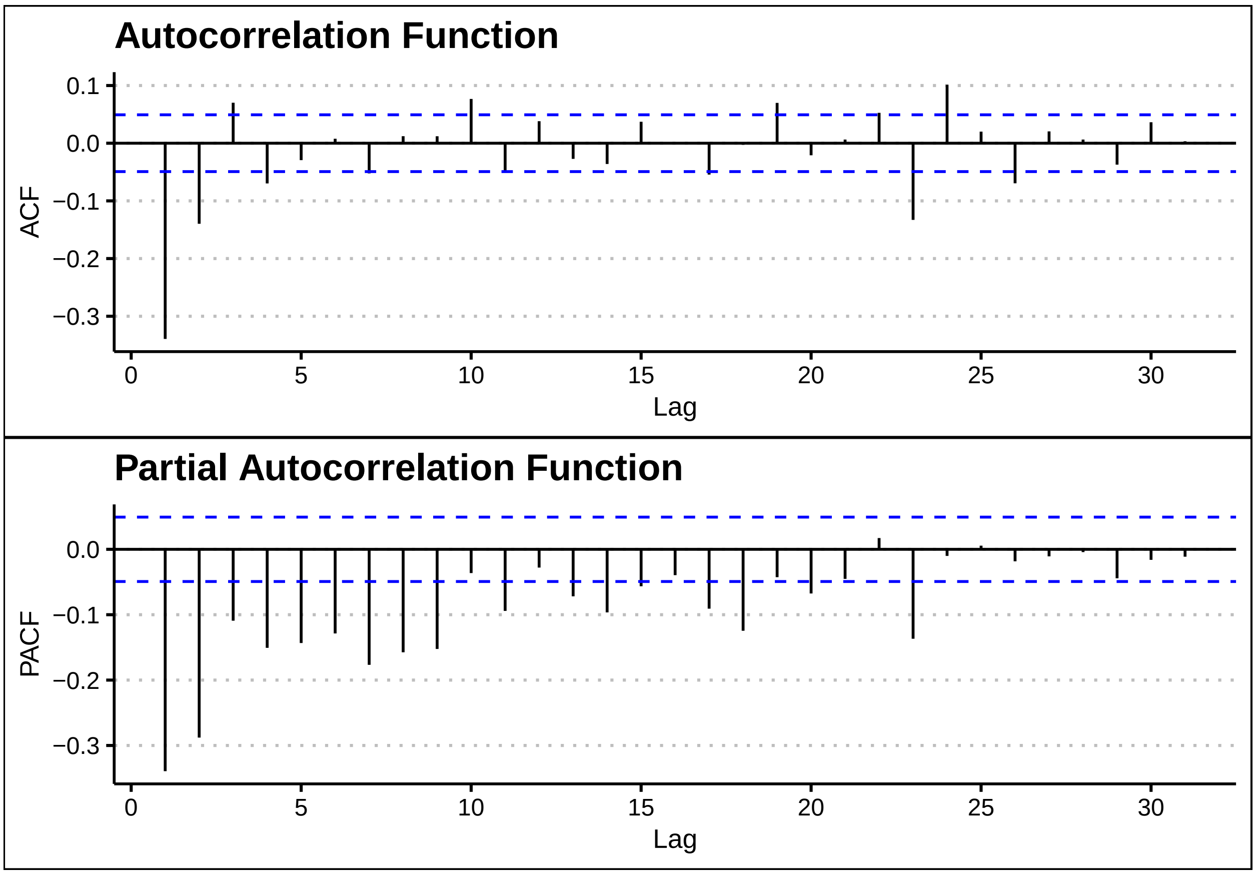
Model building

The first course of action was to split the data into a training (`75%`) and testing set (`25%`). The training set runs from 1st December 2016 upto 25th April 2023 containing `1585` observations. The testing set runs from 26th April 2023 to 13th July 2025 with `529` observations. The training set facilitated model building and diagnostic checks while the testing set was used to evaluate the model's predictive ability.

Model validation

ACF and PACF

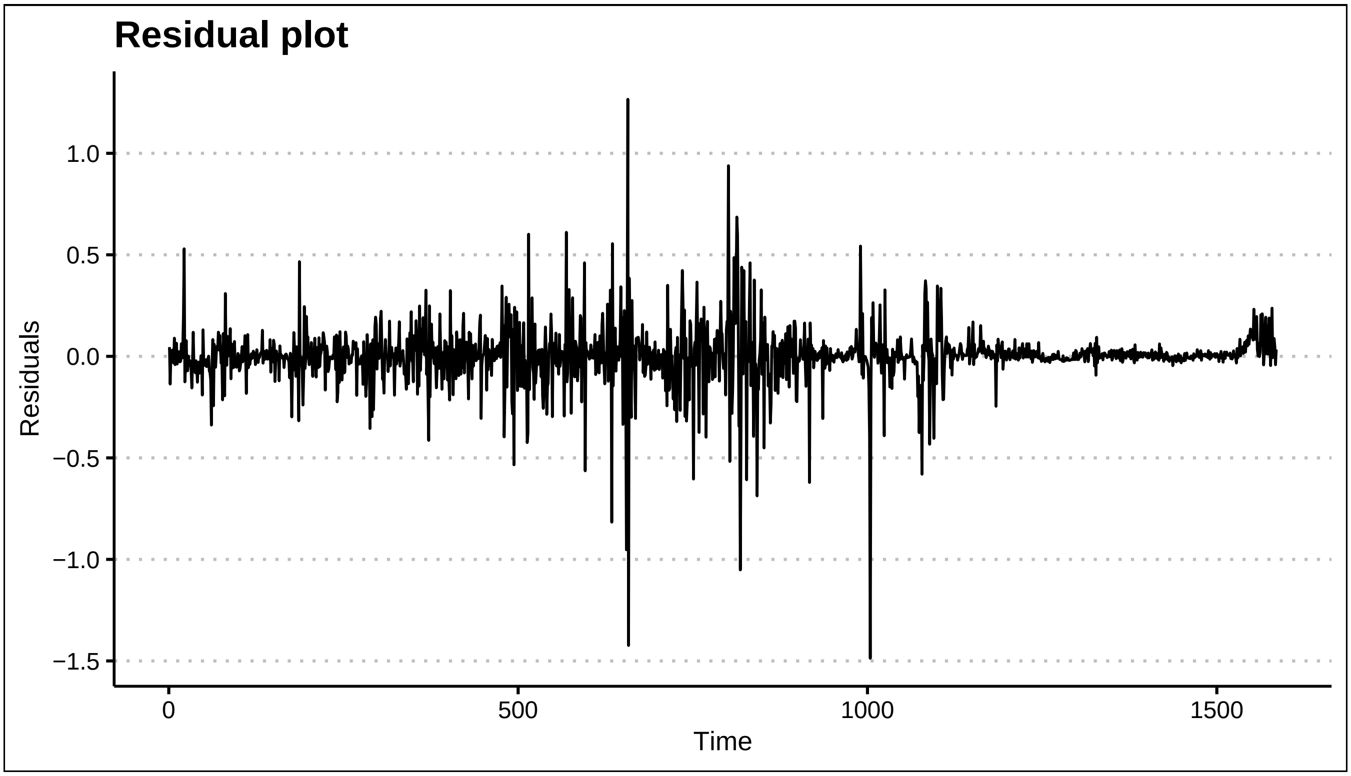
This section validates the order used under the ARIMA model `p = 1` and `q = 1`. This is made possible via autocorrelation (ACF) and partial auto-correlation plots. (PACF) The figure below shows the ACF and PACF for the training set.



Both the ACF AND PACF tail off gradually as there exists some significant spikes as the lag increases. In this case a mixed model such as an ARMA model would be of use.

Residual analysis

For an ARIMA model to hold, its residuals should have no autocorrelation (White noise). First, let us visualize the training set's residuals.



The residuals appear to be centered around `0.0` with a few extremes. Next, we use the `Ljung-Box Test` to check for independence of residuals.

Table 3: Box-Ljung test: `residuals(model)`

Test statistic	df	P value
0.0008154	1	0.9772

A p-value of `0.9772` suggests that we fail to reject the null hypothesis of residual independence.

Predictive ability

This section analyses forecast ability of our ARIMA model. The table below shows the predictive metrics for the training set;

Table 4: Table continues below

	ME	RMSE	MAE	MPE	MAPE	MASE
Training set	0.002892	0.1446	0.0782	0.00226	0.07446	0.8444

	ACF1
Training set	-0.0007166

- Summary
  - The **ME** (Mean Error) value of `0.0028921` indicates that the model has a minimal bias score.

- A **MAPE** (Mean Absolute Percentage Error) value of `0.0744629` shows that on average ,the model's fitted values deviate by about `7.4 %` from the actual values, which is an acceptable value for forecast models.

Next, we intend to make a forecast 21 days ahead *i.e* 26th April 2023 o 23rd May 2023 with weekends and Labour Day excluded. After making the forecast, we once again check the model's predictive metrics, this time, using the first 21 observations of the testing set. The metrics are shown below;

	ME	RMSE	MAE	MPE	MAPE
Test set	0.01289	0.06385	0.04479	0.01254	0.0438

- Summary
  - The **ME** is relatively close to 0 ,implying a small prediction bias.
  - The **MAPE** value of `0.04479` shows minimal deviation between fitted values and the reported values.

Below is the table consisting of the forecast values for the period 26th April 2023 upto 25th May 2023 with 95% confidence bounds;

date	actual value (Ksh.)	fitted value (Ksh.)	absolute deviation (Ksh.)	lower bound (Ksh.)	upper bound (Ksh.)
2023-04-26	135.6588	135.6311	0.0277310	135.3473	135.9148
2023-04-27	135.8324	135.7737	0.0587487	135.3003	136.2470
2023-04-28	135.9118	135.9143	0.0024871	135.2856	136.5430
2023-05-02	136.0176	136.0543	0.0367002	135.2931	136.8155
2023-05-03	136.1529	136.1941	0.0412142	135.3155	137.0727
2023-05-04	136.2618	136.3339	0.0720645	135.3486	137.3192
2023-05-05	136.3971	136.4736	0.0764945	135.3893	137.5579
2023-05-08	136.4676	136.6133	0.1457180	135.4357	137.7909
2023-05-09	136.5853	136.7530	0.1677393	135.4866	138.0194
2023-05-10	136.6765	136.8928	0.2162600	135.5412	138.2444
2023-05-11	136.7912	137.0325	0.2412805	135.5986	138.4664
2023-05-12	136.8765	137.1722	0.2957009	135.6584	138.6860
2023-05-15	136.9794	137.3119	0.3325213	135.7203	138.9035
2023-05-16	137.1029	137.4516	0.3487417	135.7839	139.1194
2023-05-18	137.3735	137.5914	0.2178621	135.8490	139.3338
2023-05-17	137.2382	137.7311	0.4928825	135.9153	139.5469

date	actual value (Ksh.)	fitted value (Ksh.)	absolute deviation (Ksh.)	lower bound (Ksh.)	upper bound (Ksh.)
2023-05-19	137.4912	137.8708	0.3796029	135.9827	139.7589
2023-05-22	137.6265	138.0105	0.3840233	136.0511	139.9700
2023-05-23	137.7618	138.1502	0.3884437	136.1202	140.1802
2023-05-24	137.9559	138.2900	0.3340640	136.1902	140.3898
2023-05-25	138.1324	138.4297	0.2972844	136.2607	140.5987

- Summary
  - All of the Actual rates fall within the 95% confidence bounds.
  - The largest deviation `0.4928825` was recorded on `2023-05-17`
  - The smallest deviation `0.0024871` was recorded on `2023-04-28`

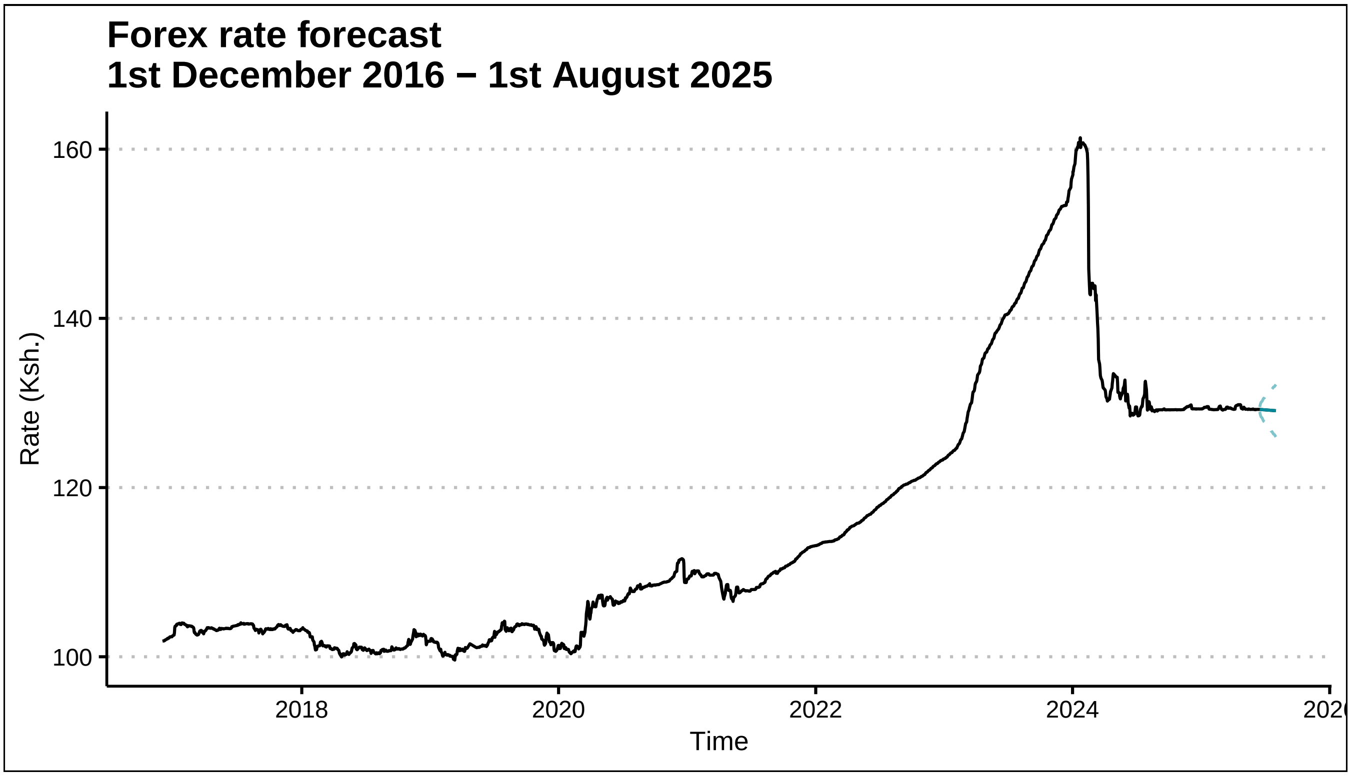
Forecasting

Now it is time to put the model into use. To do this we generate a 35-business day ahead forecast from 16th June 2025 to 1st August 2025. The forecast values are shown in the table below

Date	Predicted rate (Ksh.)	Lower bound (Ksh.)	Upper bound (Ksh.)
2025-06-16	129.2372	128.9535	129.5210
2025-06-17	129.2332	128.7598	129.7065
2025-06-18	129.2287	128.6000	129.8574
2025-06-19	129.2241	128.4629	129.9854
2025-06-20	129.2195	128.3410	130.0981
2025-06-23	129.2149	128.2296	130.2002
2025-06-24	129.2103	128.1259	130.2946
2025-06-25	129.2056	128.0280	130.3832
2025-06-26	129.2010	127.9346	130.4674
2025-06-27	129.1964	127.8448	130.5479
2025-06-30	129.1917	127.7578	130.6256
2025-07-01	129.1871	127.6733	130.7008
2025-07-02	129.1824	127.5908	130.7740
2025-07-03	129.1778	127.5101	130.8455
2025-07-04	129.1732	127.4308	130.9156
2025-07-07	129.1685	127.3527	130.9843
2025-07-08	129.1639	127.2758	131.0520
2025-07-09	129.1593	127.1998	131.1187
2025-07-10	129.1546	127.1246	131.1846
2025-07-11	129.1500	127.0502	131.2498
2025-07-14	129.1454	126.9764	131.3143
2025-07-15	129.1407	126.9032	131.3783
2025-07-16	129.1361	126.8304	131.4418
2025-07-17	129.1315	126.7581	131.5048
2025-07-18	129.1268	126.6862	131.5675
2025-07-21	129.1222	126.6145	131.6298
2025-07-22	129.1176	126.5432	131.6919
2025-07-23	129.1129	126.4722	131.7537
2025-07-24	129.1083	126.4013	131.8153

Date	Predicted rate (Ksh.)	Lower bound (Ksh.)	Upper bound (Ksh.)
2025-07-25	129.1037	126.3306	131.8767
2025-07-28	129.0990	126.2601	131.9379
2025-07-29	129.0944	126.1898	131.9990
2025-07-30	129.0898	126.1195	132.0600
2025-07-31	129.0851	126.0493	132.1209
2025-08-01	129.0805	125.9792	132.1817

The figure below captures the ARIMA forecast with 95% confidence bounds.



Conclusion & Recommendations

- Foreign exchange data is non-stationary in nature and therefore, there is need to perform a stationary check before modelling.
- ARIMA models have good predictive metrics that make them suitable for forecasting foreign exchange data.
- Other non-linear models such as GARCH and prophet can be used in place of ARIMA when it comes to forecasting forex data in order to handle their volatility.

References

- Mong T. U. (2016). Forecasting Foreign Exchange Rate by using ARIMA Model: A Case of VND/USD Exchange Rate. *Research journal of finance and accounting Vol.7(No.12)*