

An application of Box-Jenkins methodology to model the series of currency in circulation in Mozambique

Samuel G. Arone^{1,2}, Catarina S. Nunes^{2,4} and Luís M. Grilo^{3,5,6}

¹ISMU - Instituto Superior Mutasa, Maputo, Moçambique

²DCeT- Departamento de Ciências e Tecnologia, Secção de Matemática, Universidade Aberta, Portugal

³Departamento de Matemática, Universidade de Évora, Portugal

⁴LAETA / INEGI, Porto, Portugal

⁵CIMA, Universidade de Évora, Portugal

⁶NOVA Math, Universidade NOVA de Lisboa, Portugal

E-mail addresses: *sbototi@gmail.com; 1500887@estudante.uab.pt; CatarinaS.Nunes@uab.pt; luis.grilo@uevora.pt*

The use of banknotes and coins depends exclusively on the preference of the public for liquidity, and specifically, on the functionalities of various denominations put into circulation, making it difficult to determine exactly the quantity of means that the monetary authorities should put into circulation in the economy. Considering its relevance, monetary authorities must adopt models that allow describing and forecast currency in circulation. Thus, we use Box-Jenkins methodology to estimate and forecasting the series of currency in circulation in Mozambique. The main result reveals that SARIMA(1,1,0)(0,1,1)₁₂ model, is the most suitable to estimate and forecast this series.

Keywords

Box-Cox transformation, Forecast, Non-stationary, Seasonality, Trend.

Currency in circulation represents banknotes and coins issued by a monetary authority and placed into the economy to carry out day-to-day transactions. It is a more liquid and indispensable monetary aggregate for any economy. With the growing trend of digitalization, several alternative payment methods to cash are available, but the use of banknotes and coins continues to be universally accepted in many countries, including the most developed ones [3]. In the case of Mozambique, data available in the statistical database published by the Banco de Moçambique, in its website *www.bancomoc.mz*, indicate that in the last five years, the average annual growth of currency in circulation stood at around 9%. However, based on the periodic variation, from 2018 to 2023, currency in circulation grew up by 50%, a reduction compared to 76% recorded in the previous five years, a period associated with average annual growth of 12% [4]. These figures suggest the growth of currency in circulation at a decreasing rate.

Statistical analyzes carried out on the monthly series of currency in circulation in Mozambique, covering a period from January 2011 to December 2023 allowed us to conclude that this series has an increasing trend, is seasonal and is autocorrelated. Due to these specific characteristics Box-Jenkins methodology was used for its estimation and forecasting.

Box-Jenkins methodology is based on a class of stochastic processes called ARIMA (Autoregressive Integrated Moving Average) or SARIMA (Seasonal Autoregressive Integrated Moving Average) models if it includes a seasonal component. The general notation

of this class of models is SARIMA $(p,d,q)(P,D,Q)_s$, where p and P represent, respectively, non-seasonal and seasonal autoregressive parameters, q and Q represent non-seasonal and seasonal moving average parameters, d and D represent the integration levels of the series in a non-seasonal and seasonal components respectively, and s represents the seasonal amplitude. Therefore, identifying a model means discovering the integers p , d , q , P , D and Q that allow a better description of the process [1,2,5].

Based on the analysis of the correlogram of the series (autocorrelation and partial autocorrelation functions), two processes: SARIMA(1,1,0)(0,1,1)₁₂ and SARIMA(1,1,0)(1,1,0)₁₂ were identified as those that faithfully describe the series of currency in circulation in Mozambique. After identification, we moved on to estimation of models. Subsequently, using the t -ratio test, we found that the parameters estimates of the models are all statistically significant (p -values < 0.001). Regarding the diagnosis of the residuals, in both models, the Box-Pierce and Ljung-Box tests were unanimous in not rejecting the null hypothesis of absence of autocorrelation in the residuals. However, the Kolmogorov normality test did not support the hypothesis of normality of residuals at the 5% level, but it was relatively close. Therefore, the adjustments of the two models can perhaps be considered acceptable.

Once the models were adequately adjusted, and there was a need to choose the best one, models selection criteria that take into account the residuals of the estimated models were considered, specifically: Akaike Information Criterion, Bayesian Schwarz Criterion and Hannan-Quinn Information Criterion, as well as the criteria that take into account the analysis of forecast errors namely: Root Mean Square Error, Mean Absolute Error, Mean Absolute Percentage Error and U-Theil coefficient [1, 2, 5]. All models selection criteria were unanimous in suggesting that SARIMA(1,1,0)(0,1,1)₁₂ model is the most appropriate to estimate and forecast the currency in circulation in Mozambique.

References

- [1] J. Caiado. *Métodos de Previsão em Gestão com Aplicações em Excel*. Edições Sílabo, Lisboa, 2011.
- [2] C. Chatfield. *Time Series Forecasting*. Chapman Hall/CRC. New York, 2000.
- [3] FIS WorldPay. *The Global Payments Report. Payment insights that drive growth*. 8th edition, 2023.
- [4] <https://www.bancomoc.mz/pt/areas-de-actuacao/estatisticas/>.
- [5] W. Wei, *Time Series Analysis: Univariate and Multivariate Methods*. Philadelphia, 2006.