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Forecasting the Foreign Exchange Reserve of Lao PDR by ARIMA Model

Pheng HER* and Bounthong PHONPRASITH
The School of Economics, Yunnan University, China

Corresponding Author:
Pheng HER, Department of Finance and Accounting, Factulty of Economic and Tourism, Souphanouvong University, Lao PDR.
Tel:+856 20 5568 6398,
E-mail: heping_econ@yahoo.com

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Abstract

Foreign Exchange Reserve (FER) consists of foreign currency, deposits denominated in foreign currency, Monetary Gold, Special Drawing Rights (SDRs) and reserve position in the International Monetary Fund (IMF). It is one of the important macroeconomic to provide confidence, keep markets steady, etc. Autoregressive Integrated Moving Average (ARIMA) model is one of the mostly used approaches to time series forecasting was introduced by Box and Jenkins. Lao PDR is one of the least developed countries which have witnessed rapid economic growth. Since 2000, the foreign exchange reserve of Laos has rapidly increased, but the foreign currency exchange rates and inflation were increased too. Therefore, this paper aims to forecast the monthly foreign exchange reserve of Lao PDR from January 2000 to December 2020 by using ARIMA model. The estimation found that ARIMA (3,1,3) model is an appropriate model for predicting the foreign exchange reserve. The more effectiveness for predicting before 2010, after that the estimated error will be wider and high fluctuation. However, the forecasting value nearly the actual value was on March 2020, differences only 0.22.

Keyword:

ARIMA, Box-Jenkins, Foreign Exchange Reserve

1. Introduction

Foreign exchange reserves consist of foreign currency, deposits denominated in foreign currency, Monetary Gold, Special Drawing Rights (SDRs) and reserve position in the International Monetary Fund (IMF). It is held by monetary authorities to finance trade imbalances, check the impact of foreign exchange fluctuations and address other issues under the purview of the central bank. Many countries also aim to increase the level of foreign exchange reserves as much as possible which based on the following purposes: First, countries use their foreign exchange reserves to keep the value of their currencies at a fixed rate. Second, those with a floating exchange rate system use reserves to keep the value of their currency lower than the dollar. Third is to maintain liquidity in case of an economic crisis. Fourth reason is to provide confidence. The central bank assures foreign investors that it's ready to take action to protect their investments. Fifth, reserves are always needed to make sure a country will meet its external obligations. These include international payment obligations, including sovereign and commercial debts. They also include financing of imports and the ability to absorb any unexpected capital movements. Sixth, some countries use their reserves to fund sectors, such as infrastructure. Seventh, most central banks want to boost returns without compromising safety. “Foreign exchange reserves are particularly important in international trade because they facilitate international transactions and increase the speed in which trade deals are finalized. Additionally,

these reserves could contribute to the efficiency of international supply chains" (Riasi, 2015). In the 1980's the topic of foreign exchange reserves was less clear, and countries were bound to follow fixed exchange rate regimes (Frenkel & Johnson, 1978).

The main reasons for a country holding external reserves include foreign exchange market stability, exchange rate stability, exchange rate targeting, creditworthiness, transactions buffer, and emergency such as natural disasters (Archer & Halliday, 1998 & Humphries, 1990). Lao PDR is one of the least developed countries which has seen rapid economic, since 2000, the foreign exchange reserve of Laos was shapely increased but it also faced the problem of foreign currency and inflation increased too.

Based on the literature reviews found that there are many researches on the foreign exchange rate used ARIMA model to predict such as Daniya Tlegenova (2015), heanyichukwu Iwueze et al (2013) and NYONI Thabani (2019) but in the case of Lao PDR, no one has ever used such a study model. Autoregressive Integrated Moving Average (ARIMA) model is one of the mostly used approaches to time series forecasting was introduced by Box and Jenkins (1970) which let the data speak for themselves. The outcomes of this paper maybe useful for most of readers especially students whom would like to try predict the financial or economic variables. Therefore, the objective of this study is forecasting the foreign exchange reserve of Lao PDR.

2. Materials and Methods

This paper researcher used the monthly of the foreign exchange reserve of Lao PDR from January, 2000 to December, 2020 (the data derived from CEIC Data) and implied by Box and Jenkins (1970) methodology or ARIMA, they introduced four steps method for select appropriate models for estimating and forecasting univariate models, including identification, estimation, diagnostic and forecasting. The ARIMA (p,d,q) will have the equation as following:

2.1 ARIMA (p,d,q) Model

$$\Delta_d fer_t = \delta + \emptyset\Delta_d fer_{t-1} + \cdots + \emptyset\Delta_d fer_{t-p} + u_t - \theta_1 u_{t-1} - \cdots - \theta_q u_{t-q}$$

Where,

fer_t : the foreign exchange reserve in the period t

t : time

d : the differences of the time series.

p : the lag of Autoregressive

q : the lag of Moving Average

δ : Constant term

Δ_d : Difference of place d

$\emptyset_1 \ldots \emptyset_p$: Parameters of Autoregressive

$\theta_1 \ldots \theta_q$: Parameters of Moving Average

u_t : Error term

2.1 The Accuracy Analysis of the Forecast

To decide which model good fitted the researchers will use the criteria of log likelihood, Autocorrelation Function(ACF) and Partial Autocorrelation Function (PACF), written as:

1) Likelihood Function

$$L_t(y_t, x_t, \tau) = \prod_{t=1}^{T} L_t(y_t, x_t, \tau)$$

where L_t is the (exact) likelihood function for observation t

$$L_t(y_t, x_t, \tau) = f_{Y_t|X_t(y_t|x_t,\tau)\times f_{X_t}(x_t)}$$

Accordingly, the exact likelihood function is given by

$$L(y, x, \tau) = \prod_{t=1}^{T} f_{Y_t|X_t}(y_t|x_t, \tau)$$

The conditional log-likelihood function is then given by

$$L(y|x, \tau) = -\frac{T}{2}\log(\sigma^2) - \frac{T}{2}\log(2\pi) - \frac{1}{2\sigma_t^2}\sum_{t=1}^{T}(y_t - x_t'\beta)^2$$

2) Autocorrelation Function (ACF)

It is a function measuring the correlation between data at time $t(x_t)$ and data at $t-k$ (x_{t-k}) of k intervals which represented by r_k and can be written as following:

$$r_k = \frac{\sum_{t=k+1}^{n}(x_t-\bar{x})(x_{t-k}-\bar{x})}{\sum_{t=1}^{n}(x_t-\bar{x})^2}$$

And the Box-Pierce Q-Statistics

$Q = n\sum_{k=1}^{m} r^2 \sim \chi^2(m-p-q)$

3) Partial Autocorrelation Function (PACF)

Considering the relationship between the variables x_t and x_{t-k}, it is possible that correlation is the result of the correlation ship between the variables $x_{t-1}, \dots, x_{t-k+1}$ which can be written as following:

$$R_{kk} = \frac{Cov[(x_t-\widehat{x_t}),(x_{t-k}-\widehat{x_{t-k}})]}{\sqrt{Var(x_t-\widehat{x_t})}\sqrt{Var(x_{t-k}-\widehat{x_{t-k}})}}$$

Where R_{kk} : the partial autocorrelation and $\widehat{x_t} = \beta_1 x_{t-1} + \cdots + \beta_k x_{t-1+k}$

2.2 Test for Unit Root

In order to avoid the inconstant mean and variances of data at different times, the unit root testing is used to check if the data is stationary [$I(0)$; integrated of order 0] or non-stationary [$I(d); d>0$, integrated of ordered] by considering the Augmented Dickey – Fuller test statistics at the 1%, 5%, and 10% level of significance respectively. The test will examine whether the appropriate model consists of intersection and time trend by using the model without trend and intercept and will select the maximum value of lag lengths 4. For the consideration of the stationary of the data, we will analyze by comparing the Augmented Dickey-Fuller test statistic with the MacKinnon critical statistic at the significance level of 1%, 5%, and 10% respectively.

2.3 White Noise Test

The Box–Pierce portmanteau (or Q) test, developed in 1970, may be applied to a univariate time series, and is often considered to be a general test for 'white noise'. The test implemented by that command is the refinement proposed by Ljung and Box (1978), implementing a small-sample correction. The formulation for the Ljung-Box statistic is

$$Q = N(N+2)\sum_{k=1}^{h}\frac{\widehat{p_k}^2}{N-k}$$

Where, N indicates the number of the observations, the autocorrelation order of lag is denoted by $\widehat{p_k}$. The number of lags to be tested is indicated by k and h.

However, if the portmanteau test is applied to a set of regression residuals, the regressors in the model are assumed to be strictly exogenous and homoskedastic. A process a_t is called a white noise process if it is a sequence of uncorrelated random variables from a fixed distribution with constant mean,$E(a_t) = \mu_a$, usually assumed to be zero, constant variance,$Var(a_t) = \sigma_a^2$ and $\gamma k = Cov(a_t, a_{t+k}) = 0$, for all $k \neq 0$. It is denoted by $a_t \sim White\ Noise(0, \sigma_a^2)$, where WN stands for white noise . By definition, a white noise process $a_t$is stationary with autocovariance function,

$$\gamma k = \begin{cases}\sigma_a^2, k=0\\ 0\ , k\neq 0\end{cases}$$

The autocorrelation function is given as:

$$\rho_k = \begin{cases}1, k=0\\ 0, k\neq 0\end{cases}$$

while the partial autocorrelation function is

$$\varphi_{kk} = \begin{cases}1, k=0\\ 0, k\neq 0\end{cases}$$

Thus, the implication of a white noise specification is that the ACF and PACF are identically equal to zero.

Hypothesis: H_0: residuals are white noise

H_1: residuals are not white noise

If the residuals are white noise a researcher will use aroots method [Juan D'Amico,2021] to solve this problem which has the condition likes, if the ARMA process is stationary, AR and MA roots lie inside the unit circle and if the ARMA process is non-stationary, AR and MA roots lie outside the unit circle.

3. Results

3.1 Identification

Based on the theoretical before analyze the ARIMA model, the properties of our variable should be stationary mean that a series is covariance stationary therefore I have to plot the series as figure 1 below:

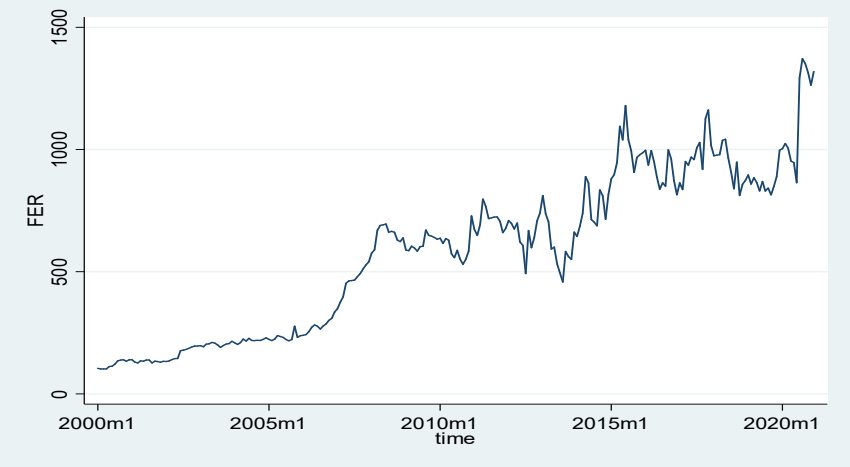

Figure 1. Monthly volatility of foreign exchange reserve of Lao PDR

The figure 1 above it is found that the series is fluctuated and has positive trend, it shapely increased from a minimum of $104.61 million in 2020 January to a maximum of $1371.73 million in 2020 August and ending at $1319.16 million. Therefore, the researchers used the Augmented Dickey Fuller (ADF) test to check and apply 1st differences to conduct the unit root test (without trend and intercept), result in MacKinnon approximate p-value was less than the 5% level of statistically, expressed that after the converted the time series data is stationary. Then investigators continue to determine the value of p,d,q by checking the correlogram of the Autocorrelation Function (ACF) and the partial Autocorrelation Function (PACF) and result in.

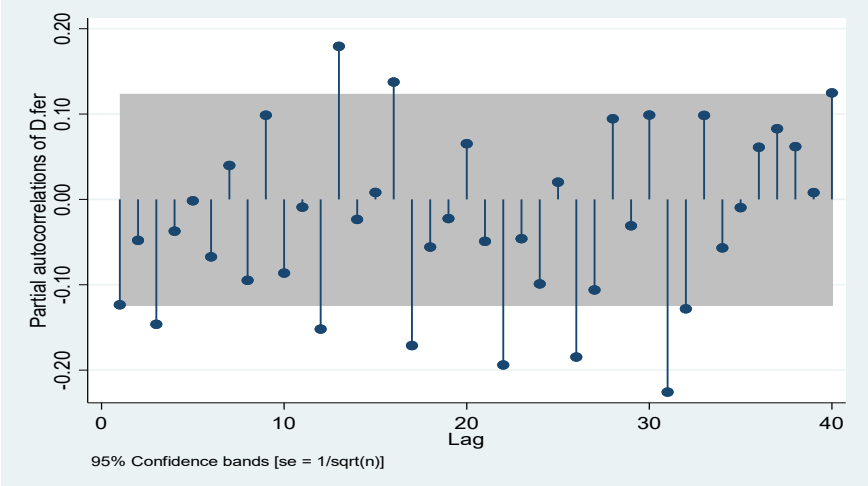

Figure 2. Partial Autocorrelation

Interval at the adjustment at a 95% confidence level. The best model as simple as possible minimizes and certain criteria, namely AIC and BIC, lowest variance, maximum likelihood. Suggesting that we should try AR (1) and AR (3) which AR (32) and AR (40) is not flat mean that some information must be captured. However, AR (12), AR (13), AR (16), AR (17), AR (22), AR (26) and AR (31) can be considered if it is insignificant.

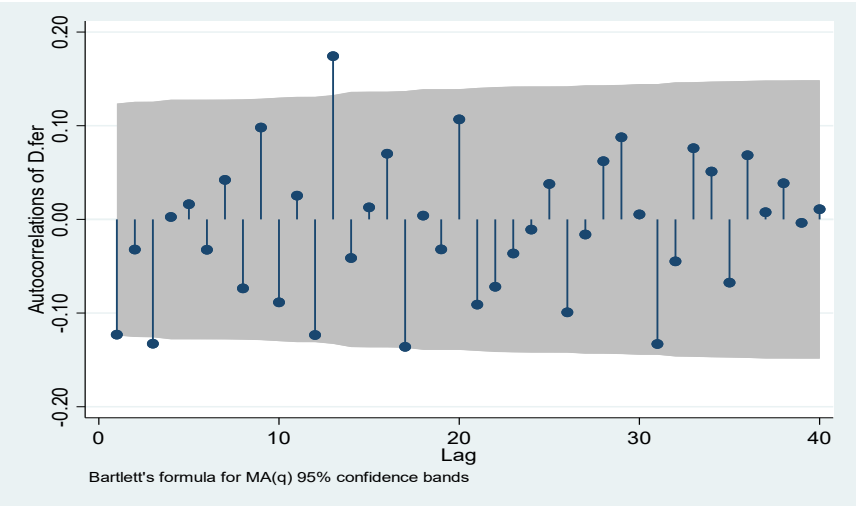

Figure 3. Autocorrelation

Suggesting that we should try including MA (1) and MA (3). Which MA (17) is a very thin line, meaning that some information must be captured so I ignored it in this case due to the concept of "Parsimony". However, MA (13) can be considered if it is insignificant.

3.2 the Estimation

The estimation of the models was expressed in the table 1 bellows

Table 1. the Model's Selection Criteria.

Criteria	Models				Concluded
	1	2	3	4	
	ARIMA(1,1,1)	ARIMA(3,1,1)	ARIMA(3,1,3)	ARIMA(1,1,3)	
C,AR&MA	2/3	1/5	4/7	1/5	3
log likelihood	-1363.905	-1365.868	-1363.508	-1365.696	3
Sigma	55.0991	55.8456	55.2502	55.8059	1
AIC	2735.81	2743.737	2743.016	2743.392	1
BIC	2749.912	2764.889	2771.219	2764.545	2

Note: Test at the Statistical 5% level.

As the results of table 1 indicated that ARIMA (1,1,1) and ARIMA (3,1,3) results are the similar but the variance of ARIMA (1,1,1) is insignificant and has only two variables significant (included constant), therefore we chose the ARIMA (3,1,3) is an appropriate model for forecasting the foreign exchange reserve of Lao PDR and can formulate this expression as follows:

$$\widehat{fer}_t = 4.6979 - 0.5041 fer_{t-1} + 0.5278 fer_{t-3} + 0.3774 u_{t-11} - 0.7311 u_{t-3}$$
$$(>0.071)^{**} \quad (<0.004)^{*} \quad (<0.001)^{*} \quad (<0.010)^{*} \quad (0.000)^{*}$$

Note: The number in the parenesis is the p-value and ** indicated it is significant at 5% and 10% level respectively.

3.3 Diagnostic Testing

To ensure above model perfect researchers tried to check the fluctuated of the residual, found that the mean equal to -0.0194 which very near to zero meaning that it is good, shown as the figure 2 below:

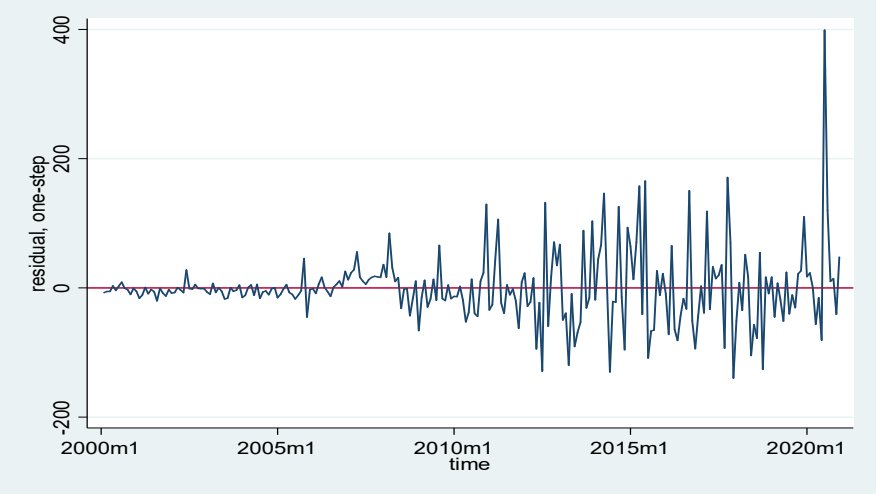

Figure 4. Residual of the Estimation

For checking the white noise problem by Box-Pierce Portmanteau test or Q-test (1978) found that the p-value= 0.4248, higher than the 5% level of statistical conclude that we cannot reject null hypothesis, meaning that the residual is white noise, therefore investigators solved this problem by AR roots and MA roots, result in.

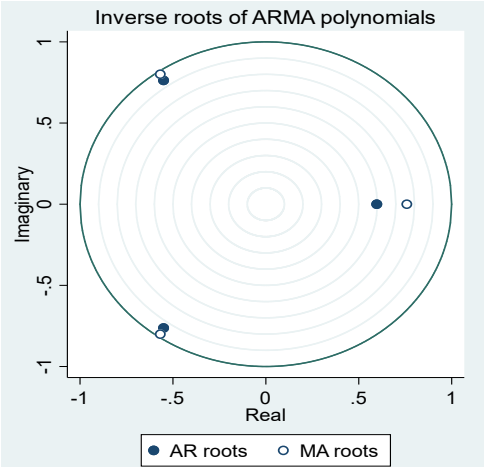

Figure 5. AR roots and MA roots

From figure 5 shown that AR roots and MA roots lie inside the unit circle, it confirms that covariance is stationary and satisfied thus we can forecast the foreign exchange reserve of Lao PDR by this model.

3.4 Forecasting

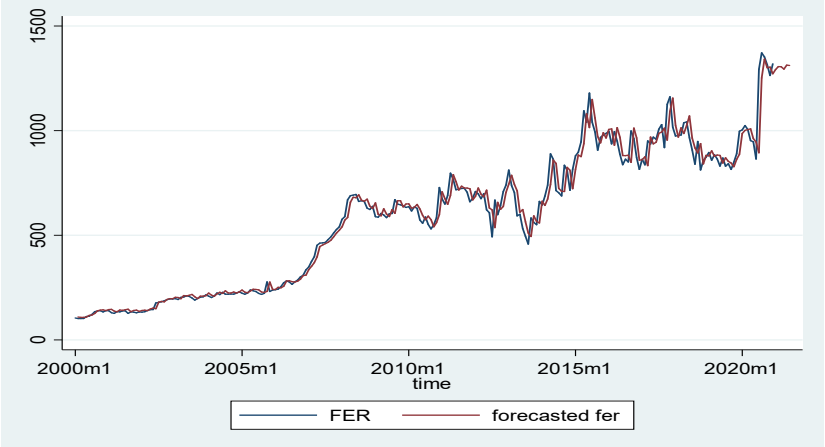

Figure 6. the Forecasted Eoreign Exchange Reserve

The figure 6 above shown that the actual value and the forecasting value are nearly which a nearest value was on March 2020 which differences from the actual value only 0.22 point) while the highest difference was on October 2010, difference from the actual value with 170.82 point. The forecasting expressed that the first month and second month of 2021 the foreign exchange will increase but two month later it will decrease and for the fifth month it increases again.

4. Discussion

According to the empirical results, found that forecasting effectiveness therefore ARIMA model useful for investor and government which aligned the study of Thabani (2019) that studies An ARIMA analysis of the Indian Rupee per USD exchange rate in India. He found that the Indian Rupee per USD exchange rate will appreciate over the period 2018-2022, after which it will depreciate slightly until 2027. Deng Xiaoyong and Yang Zhiming (2011) shows that the change in China's foreign exchange is line with the process of ARIMA (2,1,0), and by using the model to predict, it finds that, in the future, China's position for foreign exchange will continue to maintain a stable growth trend, but the speed-up will postpone compared with before. Tran Mong Uyen Ngan (2016) Forecasting Foreign Exchange Rate by using ARIMA Model: A Case of VND/USD Exchange Rate by using ARIMA model and found that ARIMA model is suitable for estimating foreign exchange rate in Vietnam only short-time period and Carina Intan Permatasari et al (2018) sales forecasting newspaper with ARIMA model, found that ARIMA model were adopted to predict the right number of newspapers for a real case study of a newspaper company in Surakarta which presents the appropriate of modeling and sales forecasting newspaper based on the output of the ARIMA models is ARIMA (1, 1, 0) due to the smallest value of the mean absolute percentage error. Otherwise, Isaac O.Ajao (2019) also found that ARIMA models is necessary in order to establish the best and the downward movement in the forecasts of Nigeria external reserve would be helpful for policy makers in Nigeria. Therefore, using ARIMA model for forecasting is effectiveness. However, Chunhua Shi et al (2011) study ARIMA and neural network prediction of foreign exchange reserves in China. They found that the predictive accuracy of neural networks outperforms ARIMA in terms of the MSE and MADE criteria.

5. Conclusion

This paper aims to forecast the monthly foreign exchange reserve of Lao PDR from January 2000 to December 2020 by using ARIMA model. The estimation indicated that a maximum of AR was lag 40 and a maximum of MA was lag 17 but in empirical analysis, the researcher found that ARIMA (3,1,3) is an appropriate model for predicting the foreign exchange reserve due to more coefficients significant, highest log likelihood, lowest volatility, lowest AIC respectively. The more effectiveness for predicting before 2010, after that the estimated error will be wider and high fluctuation. However, the forecasting value nearly the actual value was on March 2020 (differences only 0.22). ARIMA model is a more art than science. To make the forecasting more effectiveness ahead predictor should consider this problem and use another method for forecasting.

6. Conflict of Interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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