

## Predict the Parallel Market's Exchange Rate Volatility of Kip Per Dollar by ARCH Family Models

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### Abstract

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The foreign exchange rate is one of the important factors of macroeconomic. If the policymaker does not have an enough efficient tools to manage the monetary which will trigger the emergence of the black market or parallel market especially when the demand of foreign currency is higher than the supply. Therefore, forecasting the exchange rate volatility will be useful for the decision of holding the assets. To study the prediction of the parallel market's exchange rate volatility of kip per dollar by the Autoregressive Conditional Heteroscedasticity (ARCH) family models, the researchers used the daily times series data obtained between January 02, 2019 to April 2021. The empirical results expressed that ARCH (1) has the coefficient of mean equation of 1.8007 and time varying volatility in variance equation include constant and plus with the past error term. In terms of Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model especially the GARCH (1,1) model, all coefficients are positive and statistically significant at 1% level, the mean equation include constant and its past value significantly predicts the present series by 0.45 points. All coefficients of the conditional variance specification meet the stability conditions of the model, but sum of the ARCH and GARCH parameters is very small. For the Threshold GARCH or TGARCH (1,3) model, the mean equation includes constant and its past value also able to predict the present series by 0.494 points, but the asymmetric of the variance equation is negative and statistically significant 1 % level, meaning that the good news has larger effects on the volatility of the market than bad news. According to the Exponential GARCH (1,1) or EGARCH (1,1) model, the mean equation includes constant value and its past value significantly predicts current series by 0.253 points and all the coefficients of the asymmetric term of variance equation is negative and statistically significant at 1% level, indicated that bad news has larger effects on the volatility of the market than good news. However, the constant coefficient is negative and the previous volatility is insignificant at 5% level statistically so this model is not satisfied. In model's selection, we found that the AIC and SIC value of the ARCH model is lower than others therefore we conclude that ARCH (1) model is an appropriate model to predict the parallel market's exchange rate volatility in Lao PDR especially the exchange of kip per UD dollar.

**Keywords:** Exchange Rate, ARCH Model, GARCH Model, TGARCH Model, EGARCH Model.

## 1. Introduction

If the policymaker does not have enough efficient tools to manage monetary system it may lead to black market or parallel market especially when the demand of foreign currency is higher than the supply and will causes the fluctuation of the exchange rate unstable. The volatility of the exchange rate will result in the participators in the economy being affected differently in the direction of fluctuations, the exchange rate fluctuate is determined by the volume of foreign exchange transactions in the exchange rate market, inflation and interest rate. Exchange rate fluctuations are noticeable variables with a variety of results (Bauwens & Sucarrat, 2005). Exchange rates are highly volatile in the short term and can respond to political events, monetary policy and expectations,

and in the long run the exchange rate's fluctuation will be determined by the commodities price of foreign countries (Samuelson & Nordhaus, 2001). In reality, the exchange rate fluctuates on its own rather than being determined by long-term fundamental variables (Gärtner, 1993), this is because international private capital flows are now larger than trade flows, indicating that the exchange rate reflects more on financial transactions than trade, especially in the short term. According to the statistical data of the Bank of Lao PDR found that in recent months the fluctuation of exchange rate in parallel market of Laos for kip against the baht, dollar risen sharply as the figure 1 below, it increased form 8,650 kip/dollar (LAK\_USD) in January 02,2019 to 10,242.5 kip/dollar in April 30,2021 (mid-rate).

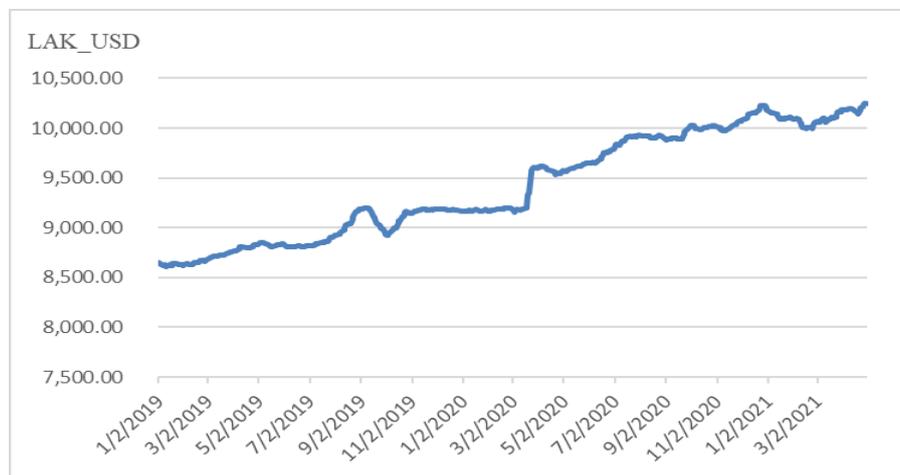


Figure 1: The Daily Parallel Market's Exchange Rate of Kip per US Dollar

Based on the literature reviews there are many approaches to predict the fluctuation of the exchange rate and the accuracy of each method is differences such ARCH family models which proposed by Robert F.Engel (1982) and Tim Bollerslev (1986). Many researchers use ARCH family model to predict the volatility in finance because in reality there is heteroscedasticity in time series. Ching Mun Lim and Siok Kun Sek (2013) applied GARCH type models in capturing the stock market volatility in Malaysia. Hongyu Pan and Zhichao Zhang (2006) also used ARCH model to forecasting the Chinese stock market. Chin Wen Cheong (2009) also used the ARCH-type models forecasting crude oil markets. In addition, Md. Zahangir Alam et al (2013) has used the ARCH model for forecasting volatility of stock indices in Bangladesh.

Although ARCH family models are popularly for many researchers but there still no one uses in

case of Lao PDR which motivated the researchers tried to imply with the technical method by using the time series data to show the best accuracy forecasting model in the evidence of Laos due to each approach has unique or specific characteristic.

Thus, the objective of this paper to construct the appropriate model for forecasting the parallel market's exchange rate of kip per dollar to support the investors or policymakers to capture the volatility.

## 2. Materials and Methods

This paper the researchers used the daily time series data of the Parallel Market's Exchange Rate of Kip per US Dollars from the Bank of Lao PDR in terms of week days since January 02, 2019 to April 30,2021 (excluded government designated holidays such as Lao New Year, National day, women's day, etc.) which equal to 587 observations. This paper, the researchers implied it by the ARCH family

models such as Autoregressive Conditional Heteroscedasticity (ARCH), Generalized Autoregressive Conditional Heteroscedasticity (GARCH), Threshold Autoregressive Conditional Heteroscedasticity (TGARCH) and Exponential Autoregressive Conditional Heteroscedasticity (EGARCH). Which has the equations as following:

### 2.1 ARCH Model

Generally, we assume that there are no heteroscedasticity in our time series but in reality some series may have the heteroscedasticity problems in the time series analysis which the residual volatility from the model will depends on its past volatility, it was introduced by Robert F.Engel (1982) and known as the Autoregressive Conditional Heteroscedasticity (ARCH) model, written as:

$$\text{Mean Equation: } y_t = c + u_t \quad (1)$$

Where  $y_t = LA\bar{K}\text{-}USD_t$ : the mean equation or parallel exchange rate of kip per dollar,

$c$ : mean,  $u_t$ : a white noise error term.

Let the error variance be time varying, that is heteroscedasticity and called  $h_t$  therefore we get the variance equation as:  $h_t = b_0 + b_1 u_t^2$  (2)

$$u_t \sim iid N(0, \sigma_t^2), h_t = \sigma_t^2 = b_0 + b_1 u_t^2$$

$$b_0 > 0, 0 \leq b_1 < 1$$

$\sigma_t^2$ : Variance,  $b_0$ : constant and  $t$  is the variance changes over time.

And the ARCH (q) model can write as:

$$h_t = b_0 + \sum_{i=1}^q b_i u_{t-i}^2 \quad (3)$$

$$\text{Forecast Variance: } h_{t+1} = b_0 + b_1 (y_t - \hat{y}_t)^2 \quad (4)$$

$$h_t = \alpha_0 + \sum_{i=1}^p \alpha_i u_{t-i}^2 + \sum_{i=1}^p \gamma_i d_{t-i} u_{t-i}^2 + \sum_{j=1}^q \beta_j h_{t-j} \quad (5)$$

$$\text{Where } d_{t-i} = \begin{cases} 1, u_{t-i} < 0 \text{ bad news symmetrically} \\ 0, u_{t-i} \geq 0 \text{ good news symmetrically} \end{cases}$$

$\gamma$ : the leverage parameter or asymmetric term. If  $\gamma > 0$  is asymmetries and significant this evidence of the leverage effect, negative shocks will have larger effects on  $h_t$  than positive shocks. If  $\gamma = 0$  is asymmetries or model collapses to the standard

$$\log h_t = \varphi + \sum_{i=1}^q \eta_i \left| \frac{u_{t-i}}{\sqrt{h_{t-i}}} \right| + \sum_{i=1}^q \lambda_i \frac{u_{t-i}}{\sqrt{h_{t-i}}} + \sum_{k=1}^p \theta_k \log(h_{t-k}) \quad (6)$$

Where  $\log h_t$ : the log of the variance series, which makes the leverage effect exponential rather than quadratic. This ensure the estimates are non-negative.

$\varphi$ : constant

$\eta$ : ARCH effects

$\lambda$ : Asymmetric Effects

$\theta$ : GARCH effects

Where,  $\hat{u}_t = (y_t - \hat{y}_t)$ , the estimate error in time  $t$  can be used obtain the estimated conditional variance.

### 2.2 GARCH model

The General Autoregressive Conditional Heteroscedasticity (GARCH) model was introduced by Tim Bollerslev (1986) and can be generalized to a GARCH (p,q) model:

$$h_t = \varphi + \sum_{i=1}^q b_i u_{t-i}^2 + \sum_{k=1}^p \theta_k h_{t-k} \quad (5)$$

$\varphi$ : constant

$b_i$ : coefficient of the lagged squared error term,  $b_i > 0$

$\theta_k$ : coefficient of the past variances

$h_t$ : the conditional variance at time  $t$

$h_{t-k}$ : past value of the conditional variance

$u_{t-i}^2$ : the lagged squared error term

$p$ : lagged term of the squared error

$q$ : terms of the conditional variances

For Stationarity  $b_1 + \theta_1 < 1$ . If  $>1$  and integrated GARCH process has occurred and if  $p = 0$  and  $q = 2$  reduces to ARCH (q). From the estimation of GARCH (1,1) the long run variance or volatility mean is computed as  $\frac{\varphi}{1-\theta_1-b_1}$  (Roman Kozhan, 2010).

### 2.3 TGARCH model

Threshold GARCH or GJR-GARCH model was proposed by Glosten, Jaganathan and Runkle (1993) for asymmetric volatility structure. The main target of the model is to capture asymmetries in terms of negative and positive shocks which has the conditional variance for TGARCH (p,q) model as:

GARCH.  $\gamma$  can be negative if  $\alpha_1 + \gamma > \alpha_1$  but  $\alpha_0, \alpha_i$  &  $\beta_j$  have to be positive.

### 2.4 EGARCH model

The conditional variance for the EGARCH (p, q) Model is written as:

If  $\lambda_1 = \lambda_2 = \dots = 0$  the model is symmetric, but if  $\lambda_i < 0$  indicated that bad news (negative shocks) meaning that generate larger volatility than good news.

## 3. Results

Based on the econometrics theories before running the ARCH model the exchange rate of kip per dollar should be stationary. In plot graph found the return of parallel exchange rate is stationary.

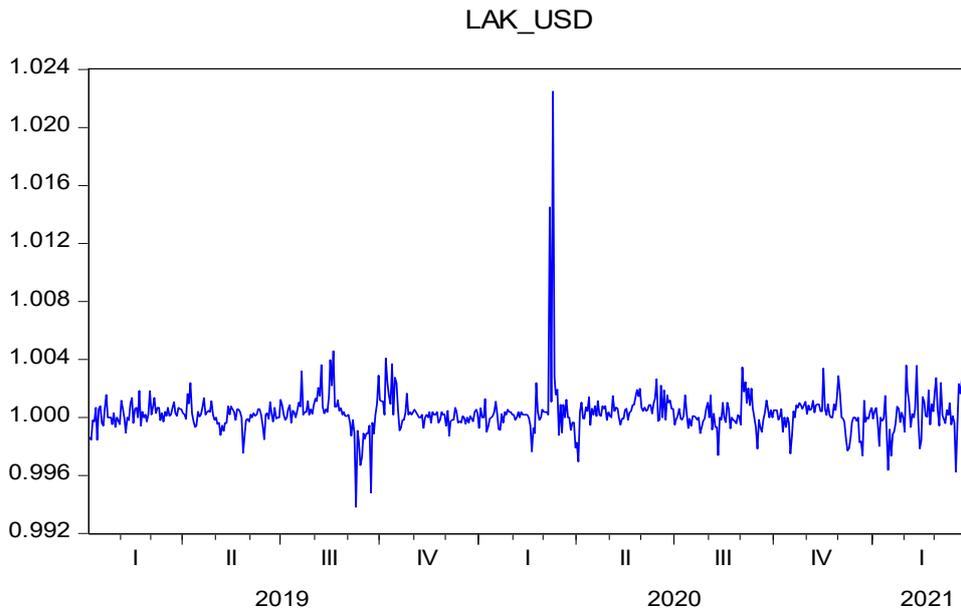


Figure 2: The Volatility of Parallel Exchange Rate

The periods of low volatility tend to be followed by periods of low volatility for a prolonged period and periods of high volatility is followed by periods of high volatility for a prolonged period, thus we continue the regression and check the residual of this model, result as below:

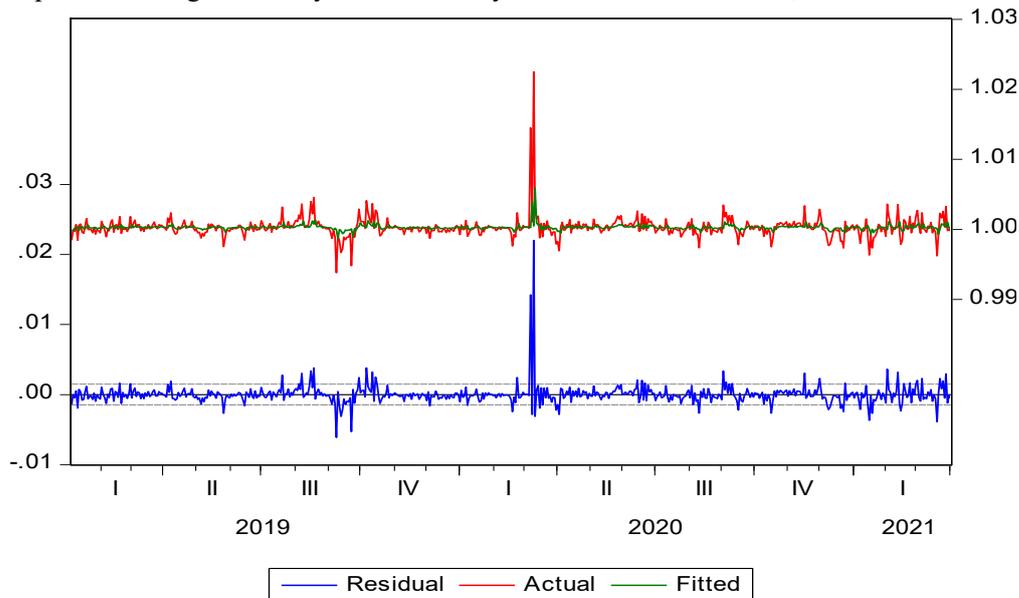


Figure 3: The Residual Volatility

From the fig 1 above expressed that the fluctuation very low for 1<sup>st</sup> quarter and 2<sup>nd</sup> quarter of 2019 but in the 3<sup>rd</sup> quarter the fluctuation has gone down. Again, in quarter four the fluctuation is very low, then in 1<sup>st</sup> quarter of 2020 the fluctuation was highest, after that its fluctuation was low again. We concluded that periods of low volatility tend to be followed by periods of low volatility for a prolonged period and periods of high volatility is followed by periods of high volatility for a prolonged period [Benoit Mandelbrot (1963)], this result indicated the researchers have all justification to run ARCH family models. To ensure, we can check the whole

by appointing ARCH test whether we should imply ARCH family model or not. Specially to check the heteroskedasticity, result in p-value=0.000 is less than 5% level of statistical meaning that we can reject null hypothesis concluded that there is ARCH effect and can run the ARCH family models. For the estimation ARCH model, the researchers tried with lag 1 to lag 3 and found that lag 2 has lowest AIC and SIC therefore we decided to use ARCH (1) model and get the equation as following:

$$\text{Mean equation: } LAK\_USD_t = a_0 = 0.43 \quad (1)$$

Forecast mean equation give the estimated mean return that it does not change over time.

$$\widehat{h}_t = 0.0000012 + 0.345\widehat{u}_{t-1}^2 \quad (2)$$

(51.78)\*      (5.201)\*  
 AIC=-10.5698    SIC=-10.5399

Note: the value in parentheses are z-statistic and \*,\*\*,\*\*\* is the statistically significant at 1%,5% and 10% respectively.

The result also indicated that the ARCH model is significant at the statistically 1% level, the time-varying volatility includes a constant plus a component which depends on past errors  $\widehat{u}_{t-1}^2$ . Z-statistics of the 1<sup>st</sup> order coefficient (5.201) suggests a significant ARCH(1) coefficient. All coefficients of the conditional variance specification meet the stability conditions of  $b_0 > 0$  and  $0 \leq b_1 < 1$

From equation (2) we can written forecast variance as following:

$$\widehat{h}_{t+1} = 0.0000012 + 0.345(LAK\_USD_t - 0.43)^2 \quad (3)$$

For the estimation of GARCH model, the research tried to test with GARCH (1,1), GARCH (1,5), GARCH (5,1) and GARCH (5,5) but found that GARCH (1,1) is the most suitable due to it all coefficients are positive and significant, therefore in this paper the researchers expressed only the results of GARCH (1,1) model and others are not considered. The estimation of GARCH (1,1) result in.

The mean Equation:

$$LAK\_USD_t = a_0 = 0.549 + 0.45LAK\_USD_{t-1} \quad (4)$$

$$h_{t+1}^2 = 0.00000077 + (\delta_1 + 0.352)h_t^2 + 0.177h_t^2(e_t^2 - 1) \quad (6)$$

(11.246)\*    (11.501)\*

For the estimation of Threshold GARCH model, researchers found that the TGARCH(1,3) is the fitted model because it has low AIC and SIC which denoted as:

Mean Equation:

$$LAK\_USD_t = 0.494 + 0.505LAK\_USD_{t-1} \quad (7)$$

$$\widehat{h}_t = 4.11E - 08 + 0.183\widehat{u}_{t-1}^2 - 0.144d_{t-1}u_{t-1}^2 + 1.886h_{t-1} - 1.661h_{t-2} + 0.672h_{t-3} \quad (8)$$

(7.921)\*    (13.626)\*    (-10.399)\*    (104.629)\*    (-67.98)\*    (61.78)\*  
 AIC=-10.6666    SIC=-10.6068

As the conditional criteria that  $\alpha_0, \alpha_i$  &  $\beta_j$  have to positive, therefore we can rewrite the equation as:

$$\widehat{h}_t = 4.11E - 08 + 0.183\widehat{u}_{t-1}^2 - 0.144d_{t-1}u_{t-1}^2 + 1.886h_{t-1} + 0.672h_{t-3} \quad (9)$$

(7.921)\*    (13.626)\*    (-10.399)\*    (104.629)\*    (61.78)\*  
 AIC=-10.6666    SIC=-10.6068

The results denoted that the coefficient  $\gamma = -0.144$  is negative and statistically significant there is leverage effect, meaning that there are

The coefficients are positive and statistically significant at 1% which the average exchange rate of parallel market of kip US dollar is 0.549 and its past value significantly forecasts the present series by 0.45 points or units.

2). The Variance Equation:

$$\widehat{h}_t = 0.00000077 + 0.177\widehat{u}_{t-1}^2 + 0.352\widehat{h}_{t-1} \quad (5)$$

(3.572)\*    (2.745)\*    (1.945)\*\*\*  
 AIC=-10.5840    SIC=-10.5467

The coefficients of the constant variance term, the ARCH and GARCH parameters are positive and statistically significant at 1% and 5% level. The results indicated that time varying volatility of GARCH (1,1) model includes a constant of 0.00000077 and its past value of 0.352 $\widehat{h}_{t-1}$  and a component which depends on the past error 0.177 $\widehat{u}_{t-1}^2$ . All coefficients of the conditional variance specification meet the stability conditions of  $0 < b_1 < 1, 0 < \theta_1 < 1$  &  $b_1 + \theta_1 < 1$ , so we satisfied with these finding because the effects of today's exchange rate able to forecast of variance for many periods in the future and see that the sum of the ARCH and GARCH parameters  $b_1 + \theta_1$  is small. And we can write the GARCH model ahead forecast as:

The coefficients are positive and statistically significant at 1% level which included a constant and its past value able to forecasting the current series or value by 0.494.

2). Variance Equation

symmetries in the news which good news has larger effects on the volatility of the market than good news.

- Positive Shock: the estimate of the time varying volatility is written as:

$$\widehat{h}_t = 0.000000411 + 0.183\widehat{u}_{t-1}^2 + 1.886h_{t-1} + 0.68h_{t-3} \quad (10)$$

- Negative Shock: the estimate of the time varying volatility is written as:

$$\widehat{h}_t = 0.000000411 + (0.183 - 0.144)\widehat{u}_{t-1}^2 + 1.886h_{t-1} + 0.672h_{t-3} \quad (11)$$

The result denoted the differences between bad news and good news on the parallel market exchange rate of kip per dollar is 0.144 which is the coefficient of the symmetric term. From these results we conclude that the news or events are very significant determinant of the parallel exchange rate volatility which good news has larger effect than bad news because  $\alpha_1 + \gamma < \alpha_1$

For EGARCH model estimation, the researchers tried to imply many lags of ARCH and GARCH but the outcome indicated EGARCH (1,1) is more satisfied than others due to the low AIC and

$$\widehat{\log h}_t = -13.30 + 0.411 \left| \frac{u_{t-1}}{\sqrt{h_{t-1}}} \right| - 0.482 \frac{u_{t-1}}{\sqrt{h_{t-1}}} + 0.029 \log(h_{t-1}) \quad (13)$$

(-14.4)\*    (10.852)\*    (-16.416)\*    (0.508)

AIC=-10.5754    SIC=-10.5306

The estimation denoted that the coefficient of the asymmetric term negative of 0.482 and statistically significant at 1% level and the exponential term,  $\lambda = e^{-0.482} = 0.617$ , indicates that for the Parallel Market Exchange Rate of kip per dollar, bad news has larger effects on the volatility of the market than the good news. And we can calculate total leverage effects likes:

- If  $u_{t-1} < 0$ , the total effect of  $u_{t-1}$  on  $\log h_t$  is:  $(1 - \lambda_1)|u_{t-1}|$
- If  $u_{t-1} > 0$ , the total effect of  $u_{t-1}$  on  $\log h_t$  is:  $(1 + \lambda_1)|u_{t-1}|$

However, the constant coefficient is negative and the previous volatility is insignificant at 5% level statistically so this model is not satisfied.

As the results of the estimation of the ARCH family models of the Parallel Market Exchange Rate of kip per dollar we can summarized as the table 1 below.

Table 1. the model's selection criteria

| Models    | Criteria |          |
|-----------|----------|----------|
|           | AIC      | SIC      |
| 1.ARCH    | -10.5698 | -10.5399 |
| 2.GARCH   | 10.5840  | -10.5467 |
| 3.TGARCH  | -10.6666 | -10.6068 |
| 4. EGARCH | -10.5754 | -10.5306 |
| Conclude  | 1        | 1        |

SIC, therefore we decided to use EGARCH (1,1) to estimate the parallel market exchange rate of kip per dollar and result as:

Mean Equation:

$$LAK\_USD_t = 0.746 + 0.253LAK\_USD_{t-1} \quad (12)$$

(475.33)\*    (161.35)\*

The meant equation is statistically significant at 1% level, included a constant and its past value significantly forecasts the current series or value by 0.253.

The Variance Equation written as:

Based on the model's select criteria guideline as Hossain Academy found that ARCH model has the lowest AIC and SIC value thus it is a fitted model and we used to predict the volatility of the parallel market's exchange rate volatility of kip per dollar in Lao PDR. Therefore, we have continued diagnostic checking serial correlation, residual distribution and heteroscedasticity and results indicated that the p-value of all lags is higher than the statistical 5% level, we cannot reject null hypothesis meaning that there is no serial correlation for the model and. For the heteroscedasticity by ARCH LM test found that the p-value equal to 0.8938, higher than the statistical 5% level we cannot reject null hypothesis that there is no heteroscedasticity. For the residual distribution test by Jarque-Bera method found that the p-value=0.000 is less than the statistical 5% level indicate we reject null hypothesis, meaning that the residual is not normally distributed but many researchers argue that is a very weak problem. So, this model able to predict the volatility of the parallel market's exchange rate volatility of kip per dollar in Lao PDR. And we have the forecast result as:

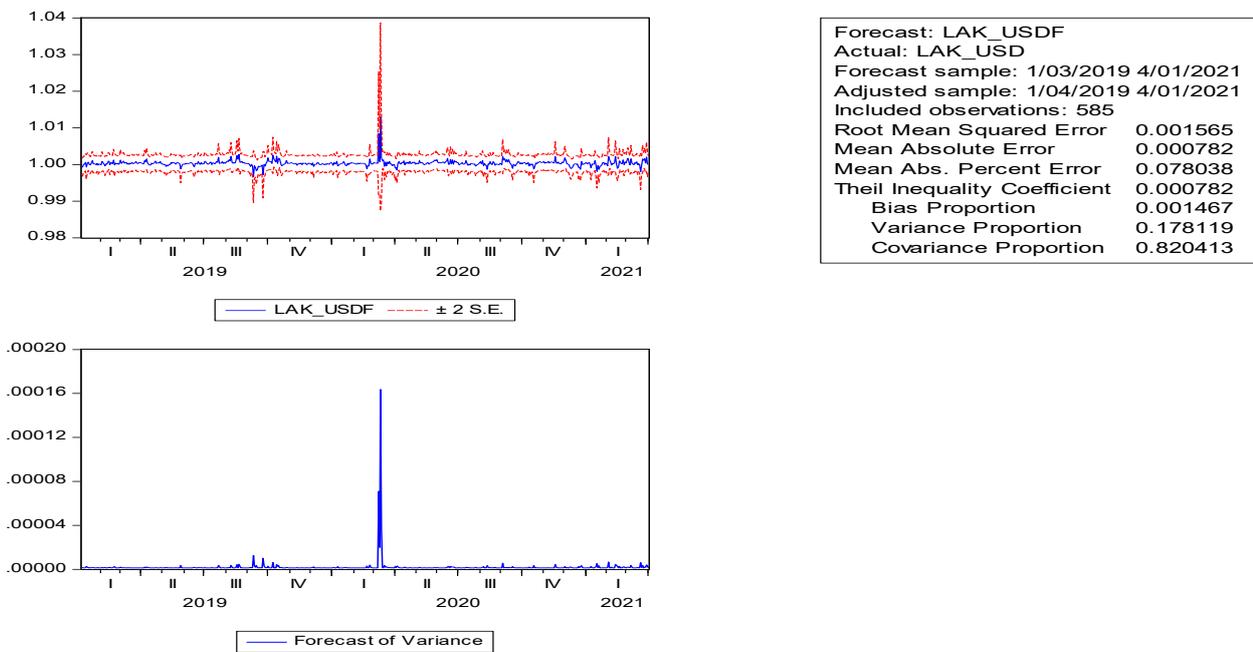


Figure 4. Residual Forecast

The results above, we see that root mean squared error, mean absolute error and mean absolute percent error are small meaning that actual kip per dollar and its forecasted, they are moving closely meaning that the predictive power of our ARCH model's forecasts are very accuracy.

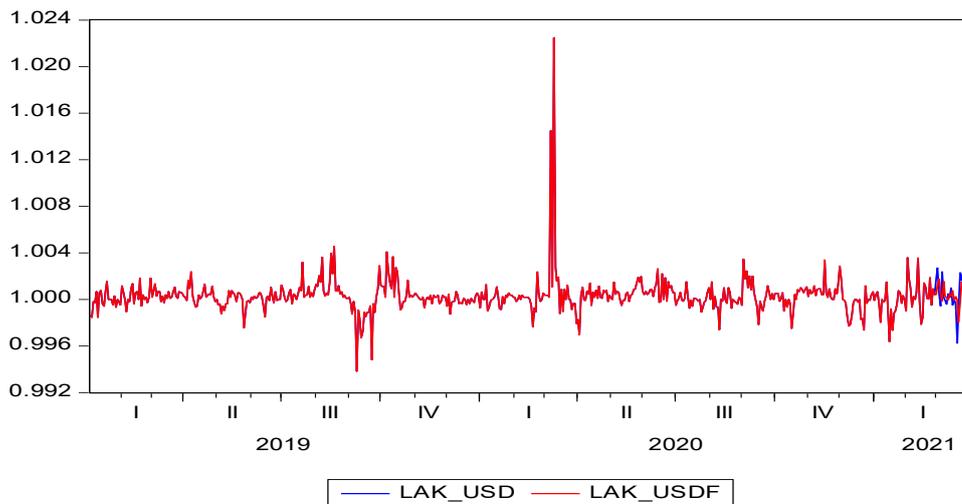


Figure 5. The Forecast for the Volatility from April 01, 2021 to May 01, 2021

In the checking of the moving of actual and forecasting volatility indicated that ability for predict our estimated ARCH model is satisfactory.

#### 4. Discussion

Based on the empirical, we point out that the ARCH family or ACHR-type models is one of the accuracy models to predict in financial sector because it can capture the asymmetric effect in exchange rate series which aligned with Manamba Epaphra (2017) that study the Modeling Exchange Rate Volatility: Application of the GARCH and EGARCH Models and he found that previous day's volatility in exchange rate can affect current

volatility of exchange rate and the estimate for asymmetric volatility suggests that positive shocks imply a higher next period conditional variance than negative shocks of the same sign. Chu Wei Chong et al (2002) also indicated that the volatility of the RM/Sterling exchange rate is persistent. In addition, Md. Shahajada Mia and Md. Siddikur Rahman (2019) suggest that GARCH (1,1) model is the best model for forecasting the monthly exchange rate volatility of Bangladesh and successfully overcome the leverage effect in the exchange rate. In addition, Chittrin Chaludong and Somporn Punpocha (2018) study the real effective exchange rate's forecast

volatility in Thailand's significantly trading countries. They found that the appropriate models in order to forecast volatility on real effective exchange rate in selected sample are MA (1) and GARCH (1,2) for Thailand, AR (1) or ARCH (1) and GARCH (2,1) for China, ARCH (1) and GARCH (2,2) for Japan while as ARCH (1), ARCH (7) and GARCH (2,1) for USA. But our study for the evidence of Laos in this paper found that ARCH (1) model is the best model for forecasting the kip per dollar exchange rate volatility of the parallel market because the root mean squared error and mean absolute error is very low, meaning that the forecasting value and actual value is very closely. In other word, the ARCH (1) forecasting is accurate for evidence of Laos.

## 5. Conclusion

According to the empirical analysis, we found that the residual volatility moves as periods of low volatility tend to be followed by periods of low volatility for a prolonged period and periods of high volatility is followed by periods of high volatility for a prolonged period and there is ARCH effect at the statistical 1% level. The outcomes of the estimation showed that ARCH (1) has the coefficient of mean equation of 1.8007 and time varying volatility in variance equation include constant and plus with the past error term. In terms of GARCH (1,1) model, all coefficients are positive and statistically significant at 1% level, the mean equation include constant and its past value significantly predicts the present series by 0.45 points. And all coefficients of the conditional variance specification meet the stability conditions of the model, but sum of the ARCH and GARCH parameters is very small. For the TGARCH (1,3) model, the mean equation includes constant and its past value also able to predict the present series by 0.494 points, but the asymmetric of the variance equation is negative and statistically significant 1 % level, meaning that the good news has larger effects on the volatility of the market than bad news. According to the EGARCH (1,1) model, the mean equation includes constant value and its past value significantly predicts current series by 0.253 points and all the coefficients of the asymmetric term of variance equation is negative and statistically significant at 1% level, meaning that bad news has larger effects on the volatility of the market than good news. However, the constant coefficient is negative and the previous volatility is insignificant at 5% level statistically so this model is not satisfied. In model's selection, we found that the AIC and SIC value of the ARCH model is lower

than others therefore we conclude that ARCH (1) model is an appropriate model to predict the parallel market's exchange rate volatility in Lao PDR especially the exchange of kip per UD dollar.

Based on these findings, the predict of this model is accuracy due to the root mean squared error and mean absolute error are lower and closely with the actual value. However, in reality it is not only depend on its volatility but also depends on other factors such as trade, interest rate, demand for foreign currency, etc. Therefore, further researchers can use others methods to be making the actual value and predict value nearly, suggested that the ARIMAX and VAR models.

## 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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