Forecasting the Exchange Rate of U.S Dollar Against the Rupiah using Model Threshold Autoregressive Conditional Heteroscedasticity (TARCH)

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FORECASTING THE EXCHANGE RATE OF U.S. DOLLAR AGAINST THE RUPIAH USING MODEL THRESHOLD AUTOREGRESSIVE CONDITIONAL HETEROSCEDASTICITY (TARCH)

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ABSTRACT

The exchange rate of U.S. dollar against the rupiah is a row of a random variable observations that can be expressed as the time series data. This is because such data is the set of ordered observations. The U.S. dollar exchange rate data used in this research is data for period 02 January 2013 to 28 may 2015. The data are heteroscedastic in nature. In addition, there is the condition of the leverage effect, namely the condition of good news and bad news are asymmetrical with respect to it volatility. Therefore, a suitable model used in this data is the model TARCH. The selection of the best model based on the least Akaike Info Criterion (AIC) and the Schwarz Criterion (SC). The best model obtained is TARCH (1,2) with equations as follows:
$\sigma_t^2 = 0{,}000000214 - 0{,}183701{\varepsilon_{t-1}}^2 - 0{,}130677{\varepsilon_{t-1}}^2 d_{t-1} - 0{,}302430{\sigma_{t-1}}^2 + 0{,}582886{\sigma_{t-2}}^2$,*and as for forecasting for the next period is 13276,7.*

Keywords: exchange rate, heteroscedasticity, asymetric, TARCH

1. INTRODUCTION

Forecasting is an event used to predict what will happen in the future time based on the value of past time (Makridakis, 1999). Forecasting is needed in various sectors like economy, financial, business and etc. In economic world, financial and investment, main topic about value in the future time is volatility of stock's value, rate of interest, and exchange rate. Time series data in financial economy sector is mostly as not stationery against average and variance, such as exchange rate data of U.S Dollar against the Rupiah often shows leverage effect, which is *bad news* and *good news* condition which gives asymmetrical effect to their volatility. The exchange rate of a country is one important indicator in economy sector. The exchange rate of U.S Dollar against the rupiah can be popular issue in economy activities. It can stimulate activities of financial transaction and banking.

Heteroscedasticity model of data is introduced by Engle in 1982. Engle introduces model of *Autoregressive Conditional Heteroscedasticity* (ARCH) in his research about England's inflation, meanwhile Bollerslev in 1986 introduces *Generalized Autoregressive Conditional Heteroscedasticity* (GARCH). Both models have assumption that negative error (*bad news* condition) or positive error (*good news* condition) gives symmetrical effects to their volatility. After that, several heteroscedasticity models which had been developed is model of *Threshold Autoregressive Conditional Heteroscedasticity* (TARCH).

TARCH model has advantage such as this model can overcome inconstant variance. Besides that, this model can be applied to overcome asymmetrical effect in Zakoian's data (1994).

2. REVIEW OF LITERATURE

Time Series

Time series is collection of observation data which is happen based on chronologically time index with constant time interval. Analysis of time series is one of statistical procedure which had been applied to forecasts structure of condition's probability that will happen in future time in the purpose of decision making (Aswi, 2006).

Requirements of data time series to be able to form model is stationer, in average or variance form. One method to form data to be stationer for average and variance by transforms data to be data *return.* According to Chen (2005), formula of *log return* can be shown below:

$$r_t = ln \frac{P_t}{P_{t-1}}, \quad (1)$$

With P_t is value of exchange rate of U.S Dollar against the Rupiah in *t*-time.

In *time series* method, main tools to identifies model from forecasted data by using plot of Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF).

Time Series Model

According to Wei (1989), several models that can be used in time row is:

1. Model *Autoregressive* (*AR*)

$$X_t = \emptyset_1 X_{t-1} + \emptyset_2 X_{t-2} + \cdots + \emptyset_p X_{t-p} + \varepsilon_t \quad (2)$$

2. *Moving Average* (*MA*) Model

$$X_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (3)$$

3. Mixture Model *ARMA(p,q)*

$$\emptyset_p(B)X_t = \theta_q(B)\varepsilon_t \quad (4)$$

Form of plot ACF and PACF is initial indicator for autocorrelation. Statistical test should been carried out to convince the initial indicator. Therefore, it is used Breusch-Godfrey test to know the data autocorrelation.

The hypothesis in this research is:

H_0 : There is no autocorrelation in residual of condition average model,

H_1: There is autocorrelation in residual of condition average model.

According to Ahmad (2015), Breusch-Godfrey formulated as:

$$t^* = (T - k)R^2, \quad (5)$$

With T is sample measure, k is lag total and R^2 is determination coefficient from regression model. H_0 is rejected if ditolak t^* value is higher than table value of χ_k^2 or probability value is less than significance level α.

Test of Heteroscedasticity Effect

Test statistic which had been used is:

$$\xi = TR^2 \quad (6)$$

H_0 is rejected if the value of ξ is higher than table value χ_k^2 or the value of probability is less than significance level α which means that there is still heteroscedasticity.

ARCH/ GARCH Model

According to Engle (1982), ARCH orde p assumed as:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 \quad (7)$$

According to Bollerslev (1986), GARCH model (*p,q*) is:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 + \beta_1\sigma_{t-1}^2 + \cdots + \beta_q\sigma_{t-q}^2$$

$$= \alpha_0 + \sum_{i=1}^{p}\alpha_i\varepsilon_{t-i}^2 + \sum_{i=1}^{q}\beta_j\sigma_{t-j}^2 \quad (8)$$

Asymmetrical

Leverage effect can be observed by making plot cross correlogram between quadrate from residual standard (${e_t}^2$) with their lagged residual standard (e_{t-k}).

TARCH Model

According to Gourieroux (1997), TARCH Model *(Threshold Autoregressive Conditional Heteroscedasticity)* is developed separately by Zakoian in 1990 and Glosten, Jaganathan and Rukle in 1993.

In general, TARCH model can be written below:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \alpha_{t-1}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \quad \sum_{m=1}^{p} \gamma_m \, \alpha_{t-m}^2 d_{t-m} \qquad (9)$$

where:

d_{t-m} : indicator for a_{t-i} with negative value

$$d_{t-m} = \begin{cases} 1, jika\ a_{t-i} < 0 \\ 0, jika\ a_{t-i} \geq 0 \end{cases}$$

With σ^2 is residual variance in t time, and α, β, γ is parameter.

In this model, good news in period $t-1\ (\varepsilon_{t-1} > 0)$ and bad news in period $t-1\ (\varepsilon_{t-1} < 0)$ has different effect to *conditional variance* in t period. Good news has effect in the parameter.

Criteria of Best Model Selection

Usual criteria used to best model selection based on the residual is *Akaike's Information Criterion* (AIC) and *Schwartz Criterion (SC)* because this both criteria is consistent to predict the parameter. Purpose of AIC is find the best prediction and the purpose of SC is find model with highest posterior probability from the models.

Both criteria is formulated below:

a. *Akaike's Information Criterion* (AIC)

   Akaike's Information Criterion (AIC) is selection criteria of the best model which had been introduced by Akaike in 1973 by considering amount of parameter in the model. According to Wei (1989), criteria of AIC can be formulated below:

$$AIC = \ln(MSE) + 2 * K/N \qquad (10)$$

b. Schwartz Criterion (SC)

   Schwartz Criterion (SC) is criteria of model selection based on the smallest value. According to Wei (1989), criteria of AIC can be formulated below:

$$SC = \ln\,(MSE) + [K * \log(N)]/N \qquad (11)$$

   where:

ln: logaritma natural

MSE :*Mean Square error*

K : amount of parameter, such as $(p + q + 1)$

N : amount of observation data

The less value of AIC and SC, used model is being better.

Meanwhile criteria that used in best model selection based on the forecasting error is *Mean Square Error (MSE)* which is formulated below:

$$MSE = \frac{1}{N}\sum_{i=1}^{N} e_t^2 \tag{12}$$

with:

e_t : $y_i - \hat{y}_i$, $\quad i = 1,2,3,\cdots,N$
y_i : actual data
$\hat{y}_i$: estimated value
N : observation amount

4. RESEARCH METHOD

This study is applied research which is related with statistic and financial economy, therefore the used method is literature study which had been applied in data of exchange rate of U.S Dollar against the rupiah. Data was taken every Monday-Friday and except of the off-days national from January 2nd until May 28th 2015 with resource from Bank Indonesia which has obtained from *official website* www.bi.go.id, accessed in June 12nd 2015 at 17.25 WITA.

Research procedure which had been applied in this research follows several data analysis, stated below:

1. Makes data plot to know stationery of data in its average and variance
2. If data is not stationer in average or variance, so the data should been transform in the forms of *log return*
3. Formation process of ARMA model,
   a. Makes ACF and PACF plot to identifies suitable ARMA model
   b. To estimates parameter of ARMA model,
   c. Does diagnostic check to ARMA model to testes feasibility of model. Model is categorized in good level if residual is not had autocorrelation and had residual variance homoscedasticity,
4. Analyze the presence of homoscedasticity effect of data by using ACF and PACF from residual quadrate of ARMA model and uses Langrange test Multiplier / LM-ARCH,
5. Form and identify ARCH/GARCH model,
   a. Looks for suitable GARCH model to make model of Heteroscedasticity dan volatility by using residual of condition average model ,

b. Looks for the best model from GARCH which is suitable by using the smallest value of AIC and SC

6. Examine asymmetrical cross correlogram between residual standard quadrate in t-time (e_t^2) with lagged standar residual in t-time (e_{t-k}),
7. Analyze TARCH model,

   a. Identifies model,

   - Looks for TARCH model which is suitable to make model of heteroscedasticity from residual of condition average model , Looks for best model from TARCH model which is suitable by using smallest value of AIC and SC,
   - residual of condition average model , with heteroscedastic

   b. Does diagnostic check to the best model to test feasibility of model,
8. Forecast volatility of log return using condition average to know the value of exchange rate forecasting of U.S Dollar to the rupiah.

5. RESULTS AND DISCUSSION

Data that had been used in this research is exchange rate data of U.S Dollar against the rupiah.

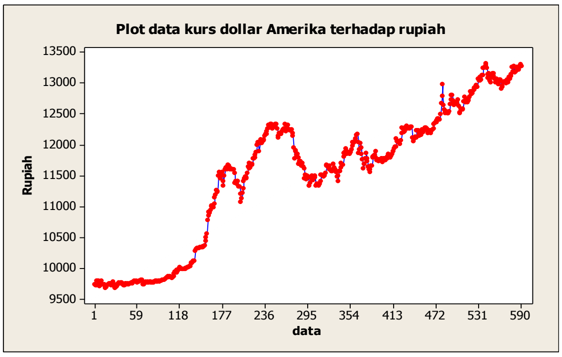

Figure 1. Plot *time series* of exchange rate data of U.S Dollar against the rupiah

The above picture shown that data get fluctuation that indicates the data is not stationer either in average or variance. It is also seen in lamda value as much as -4,00 in this case it is not fill assumption in transformation *Box-Cox*. Therefore, data should been transformed into *log return* by using equality formula

(1) This transformation makes data be more stationers.

Plot *time series* from transformation result of *log return* that was shown in Picture 2.

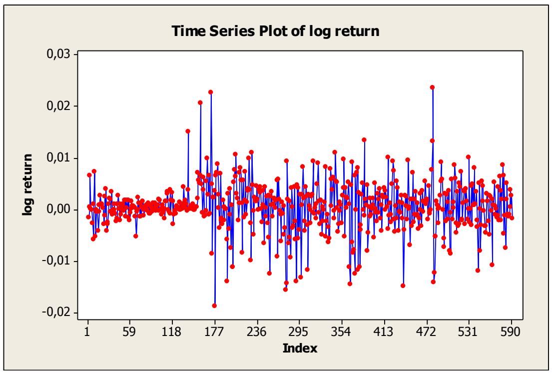

Figure 2. Plot *time series of* log return from exchange rate of U.S Dollar against the rupiah

Data stationery can be indicated by using unit root testing (Murari, 2013). One of stationery test which had been used is *Augmanted* Dickey-Fuller (ADF) to further show the accuracy of data stationery.

Table 1. Test result of ADF exchange rate of U.S Dollar against the rupiah

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-22.07744	0.0000
Test critical values:	1% level	-3.441204	
	5% level	-2.866220	
	10% level	-2.569321	

Resource: Result of data analysis (2015)

Based on the table 1 shows that probability value is 0,0000 higher from significance value $\alpha = 0{,}05$ and absolute value from t statistic is $-22{,}0774$ higher that critical value $-3{,}441204$, this is shows that data is being stationer.

Formation of ARMA Model

Identification of ARMA Model

Modelling of modeling condition average model from stasioner data can be used as by ARMA model (p,q). To identify suitable ARMA model can be seen from plot ACF and PACF. Based on the picture 3 it is seen that in plot ACF, *cut off after lag 1* and picture 4 in plot PACF is also *cut off after lag 1.* So model that might be suitable is AR(1) or MA(1) or ARMA(1,1).

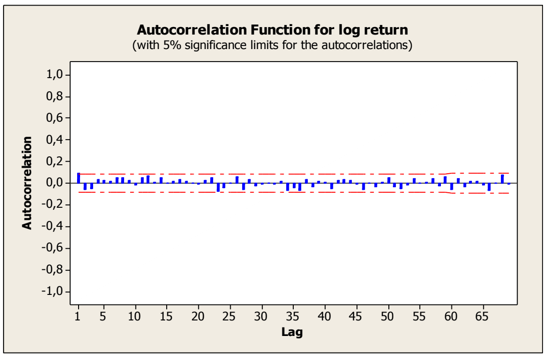

Figure 3. Plot ACF from data of exchange rate return of U.S Dollar against the rupiah

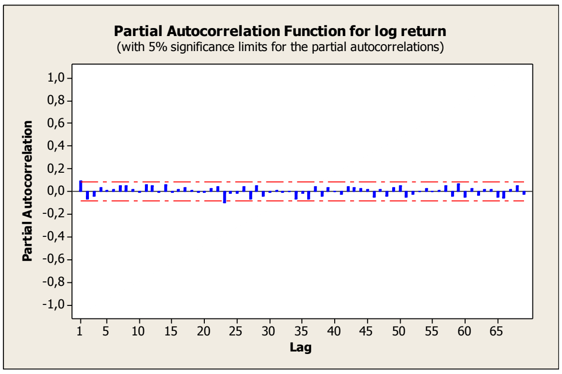

Figure 4. Plot PACF from data of exchange rate return of U.S Dollar against the rupiah

Among the three contemporary prediction model, AR(1) and MA(1) model is suitable model because the parameter is significance and fills requirement *white noise.* Result of parameter estimation from AR(1) and MA(1) model can be seen in Table 2. Result of parameter estimation shows that value of $\emptyset$ and θ significance is not similar to zero because it has probability to AR(1) as much as 0,0234 and for MA(1) is 0,0108, and both of them is less from significance value $\alpha = 0{,}05$. However, the more suitable model is *time series* model which has smaller value of AIC and SC. Therefore, the best model is MA(1) model. MA(1) model which had been obtained is

$$Z_t = \varepsilon_t + 0{,}1048\varepsilon_{t-1} \qquad (13)$$

With ε_t is residual produced from the model in t time.

Table 2. Estimation result of AR(1) and MA(1) model in data log return

	Model AR	Model MA
Variable	$\emptyset$	θ
Coefficient	0,093340	0,104845
Error Stdr.	0,041067	0,040990
t-statistic	2,272843	2,557846
Probability	0,0234	0,0108
AIC	-7,85973	-7,86257
SB	-7,84488	-7,84774

Resource: Result of data analysis (2015)

Diagnostic Test of ARMA Model

Condition average model stated in good category if residual is not have autocorrelation. Residual autocorrelation can be detected by using statistic test Breuch-Godfrey. Probability value of Breuch-Godfrey test for MA (1) model is 0,9957. This value is higher than significance level $\alpha = 0{,}05$ so H_0 is not rejected. So it can be concluded that MA(1) model do not have autocorrelation.

Test of Heteroscedasticity Effect

Model residual and MA (1) should been tested by test of heteroscedasticity effect. Test of heteroscedasticity effect in MA (1) model includes test of residual autocorrelation or quadrate residual.

Heteroscedasticity in one model will be identified if model residual does not have autocorrelation or it has autocorrelation in the quadrate of model residual. Autocorrelation in model residual quadrate in MA(1) model can be seen from the value of ACF and PACF which had been served in Picture 5.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.216	0.216	27.745	
		2	0.120	0.077	36.323	0.000
		3	0.040	-0.001	37.264	0.000
		4	0.007	-0.010	37.294	0.000
		5	0.016	0.014	37.439	0.000
		6	0.157	0.160	52.169	0.000
		7	0.060	-0.004	54.301	0.000
		8	0.011	-0.034	54.373	0.000
		9	0.005	-0.001	54.386	0.000
		10	0.019	0.027	54.612	0.000
		11	0.052	0.050	56.256	0.000
		12	0.028	-0.022	56.738	0.000
		13	0.046	0.026	58.006	0.000
		14	0.024	0.013	58.342	0.000
		15	0.148	0.152	71.740	0.000
		16	0.002	-0.070	71.742	0.000
		17	0.101	0.075	77.916	0.000
		18	-0.022	-0.064	78.201	0.000
		19	-0.015	-0.012	78.340	0.000
		20	-0.009	0.001	78.395	0.000

Figure 5. Plot ACF and PACF residual quadrate of MA(1) Model

Value of ACF in lag 1 and PACF in lag 1 and lag 2 is significant from zero which is means that residual quadrate has autocorrelation. It is also empowered by statistical test until lag 20 that gives smaller possibility than $\alpha = 0{,}05$ so it can be concluded that residual quadrate from MA(1) model has autocorrelation. The presence of autocorrelation in residual quadrate in MA(1) model identifies presence of heteroscedastisity effect.

Test of residual LM ARCH

Heteroscedasticity effect also can be known by using test Lagrange Multiplier (LM-ARCH) with formula in Equation 6. If the value of Obs*R-squared > table value χ_k^2 or probability value less than significance level $\alpha = 0{,}05$ so we can rejects H_0 and accepts H_1, it is means that there is effect of ARCH. Result of test Lagrange Multiplier from residual MA(1) model use Software Eviews 7.1 which had been served in Table 3.

Table 3 result of test LM-ARCH residual MA(1) Model.

Heteroscedasticity Test: ARCH

F-statistic	16.170 28	Prob. F(2,586)	0.00 0
Obs*R-squared	30.805 99	Prob. Chi-Square(2)	0.00 0

Based on the Table 3 shows that when lag 2 the value of *obs. R Square* as much as 30.80599>table value χ_k^2 (df = 1 in $\alpha = 5\%$) as much as 3,8415. In table 3 can also be seen that statistic of LM test until lag 2 for residual MA(1) model produce probability value 0,0000. This value is less than $\alpha = 0{,}05$ so H_0 is rejected. It can be concluded that in residual MA(1) model has effect of ARCH or heteroscedastic effect. Therefore, forecasting by using ARMA model had assumption infraction so it is continued to formation of model ARCH/GARCH model.

Formation of GARCH Model

Quadrate residual of MA(1) model has heteroscedastisty effect, so MA(1) model can be modeled by using GARCH model (p,q). To identifies suitable GARCH model by using plot ACF and PACF from quadrate residual of MA(1) model.

Identification of plot ACF and PACF is decrease exponentially so it gives possibility to suitable model for quadrate residual of MA(1) model is GARCH(1,0), GARCH(1,1), GARCH(2,1) or GARCH(1,2). Result of parameter estimation shows that significant quadrate residual of MA(1) model is GARCH(1,0) model which has probability value less than $\alpha = 0{,}05$ and it has smallest value of AIC and SC. Therefore, to make model of quadrate residual of MA(1) model is used GARCH (1,0) model below:

$\sigma_t^2 = 0{,}00000000209 + 0{,}171429\varepsilon_{t-1}^2$,(14)

with $\varepsilon_t$adalah residual of MA(1) model in t time.

Asymmetrical of GARCH Model

Bad news or good news condition which gives asymmetrical effect to the volatility can be known by using cross correlogram. Cross correlogram for MA(1) model is served in figure 6.

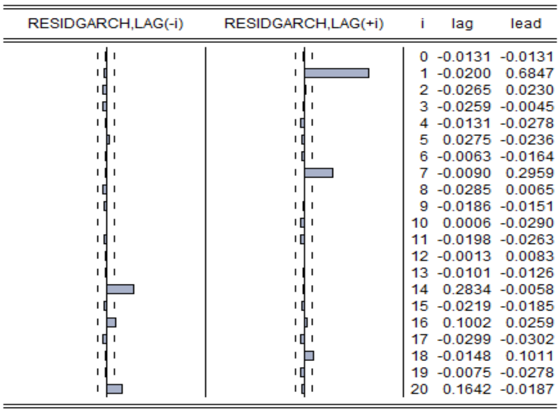

Figure 6. Plot cross corelogram between standardized quadrate residual with standardized lagged residual from GARCH (1,0)

Picture 6 shows that cross correlogram between standardized quadrate residual in t time (e_t^2) with standardized lagged residual in lag $t-k$ (e_{t-k}). Picture 6 shows that there is different value significant with zero. It is means that data in bad news and good news condition give asymmetrical effect to their volatility.

Formation of TARCH Model

Test of heteroscedasticity effect and test of model asymmetrically gives result that residual of MA(1) model contains heteroscedasticity effect and bad news or good news condition give asymmetrical effect to their volatility. Therefore, it can be carried out to the next level, that is make model of heteroscedasticity residual and MA(1) model by using TARCH model.

According to Zakoian (1994), estimation of TARCH parameter uses BHHH model (Berndt, Hall, Hall & Hausman), by using software Eviews 7.1 gives result that TARCH model can be used to make model of residual quadrate from MA(1) model is TARCH(1,0), TARCH(1,1),TARCH(1,2) and TARCH (2,1). Result of parameter estimation from residual quadrate from MA(1) model can be seen in Table 4.

Table 4. Estimation result of TARCH model from residual quadrate MA(1) model

	TARCH (0,1)	TARCH (1,1)	TARCH (1,2)	TARCH (2,1)
ω	244E-09	171E-09	183E-09	52E-09
Prob	0,0000	0,0000	0,0000	0,0000
α_1	0,284015	0,121314	0,148639	0,190829
Prob	0,0000	0,0000	0,0000	0,0000
α_2	-	-	-	0,112815
Prob	-	-	-	0,0000
γ_1	-2,06514	-4,35738	-4,57239	0,597441
Prob	0,0008	0,0000	0,000	0,0001
γ_2		-	-	-3,78487
Prob		-	-	0,0000
β_1	-	0,641818	0,045685	0,644383
Prob	-	0,0000	0,0000	0.0000
β_2	-	-	0,554662	-
Prob	-	-	0,0000	-
AIC	-17,0363	-17,0564	-17,0611	-17,0539
SC	-17,0066	-17,0193	-17,0166	-17,0020

Resource: Result of data analysis (2015)

Chosen model is model which has smallest value of AIC and SC. Therefore, to make model of heteroscedascity residual quadrate from MA(1) model from log return exchange rate of U.S Dollar against the rupiah can use TARCH (1,2) model. Obtained model is

$$\sigma_t^2 = 0{,}00000000183 + 0{,}148639{\varepsilon_{t-1}}^2 - 4{,}572396{\varepsilon_{t-1}}^2 d_{t-1} + 0{,}045685{\sigma_{t-1}}^2 - 0{,}554662{\sigma_{t-2}}^2 \quad (15)$$

with $d_{t-1} = \begin{cases} 1, \text{ untuk } \varepsilon_t < 0 \\ 0, \text{untuk } \varepsilon_t \geq 0 \end{cases}$'

ε_t is residual of condition average model.

After more suitable model of heteroscedastic is obtained, the next step is to estimate parameter of TARCH (1,2) model together. Estimation result shows that the suitable model for untuk log return of TARCH (1,2) is

$$\sigma_t^2 = 0{,}000000214 - 0{,}183701{\varepsilon_{t-1}}^2 - 0{,}130677{\varepsilon_{t-1}}^2 d_{t-1} - 0{,}302430{\sigma_{t-1}}^2 + 0{,}582886{\sigma_{t-2}}^2 \quad (16)$$

Forecasting

Data forecasting of log return from TARCH (1,2) model with residual MA(1) model. Data is categorized in good level if the forecasting value approaches the value of real data. Obtained model is

$$\sigma_t^2 = 0{,}000000214 - 0{,}183701{\varepsilon_{t-1}}^2 - 0{,}130677{\varepsilon_{t-1}}^2 d_{t-1} - 0{,}302430{\sigma_{t-1}}^2 + 0{,}582886{\sigma_{t-2}}^2 \quad (17)$$

Result of volatility forecasting of log return for next period is 0.00043357. Log return is not the real data so it should been transform in their initial forms to see the forecasting result of exchange rate of U.S Dollar against the rupiah. Based on the Equation (1) to transforms it in their initial forms used the equation of $P_t = P_{t-1}e^{r_t}$.

The forecasting is used to looks for the value of exchange rate forecasting of U.S Dollar against the rupiah based on forecasting value of log return. The result of forecasting can be seen in Table 6.

Table 6. Forecasting result of exchange rate of U.S Dollar against the rupiah by using TARCH(1,2) model

Period	Date	Forecasting result Log Return	Forecasting Result
592	29-05-2015	0.00043357	Rp.13276,76

Resource: Result of data analysis (2015)

6. CONCLUSION

Based on the research result, it can be concluded that:

1. The best model to forecast data of exchange rate of U.S Dollar to the rupiah period of January 2nd 2013 until May 28th 2015 which had been transformed in the form of log *return* is *TARCH (1,2)* model with orde *1* of residual from MA(1) model.

2. *TARCH (1,2)* model with orde *1* from ARMA (0,1) model which has been obtained from data is

$$\sigma_t^2 = 0{,}000000214 - 0{,}183701\varepsilon_{t-1}{}^2 - 0{,}130677\varepsilon_{t-1}{}^2 d_{t-1} - 0{,}302430\sigma_{t-1}{}^2 + 0{,}582886\sigma_{t-2}{}^2$$

3. Forecasting value of exchange rate of U.S Dollar against the rupiah in the next period is Rp. 13276,76. This forecasting value is approaches the value of real data.

In this research, to make data model with inconstant variance and there is *leverage effect* using TARCH model. Forecasting result using TARCH model give good news to the investor. To the readers which has interested to develop this research is suggested to use another asymmetrical model to make model of the data.

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