A GARCH Study on Exchange Rate Determinants: A Case of Malaysia

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Abstract

The study aims to look at macroeconomic variables' impact on volatility of exchange rate in both short and long run. The relationship between real effective exchange rate volatility and macroeconomic variables such as gross domestic product deflator, total export in percentage of GDP, inflation rate, coefficient of inflation rate and lending interest rate have been analyzed with the help of statistical tool. This research is based on secondary data obtained from World Bank website, International Monetary Fund website and Statistical Department of Malaysia. The study uses a sample of 35 observations, starting from 1980 to 2014 annually. Unit root test is used to determine the stationarity of the variables. The existence of the stationary data will lead to a long run relationship of macroeconomic determinants, while the techniques of co-integration model are used to determine the long run relationship of some macroeconomic variables on the volatility of exchange rate. The error correction model is used to generate a short run model on this study by generating residual or error correction term. The findings revealed that the coefficient of the gross domestic product deflator, total export in percentage of GDP, and inflation rate are significant toward the volatility of real effective exchange rate in the long run. On the other hand, only the coefficient of inflation rate, and lending interest rate have significant relationship with the real effective exchange rate volatility in the short run.

Keywords: Error Correction Model; GARCH; Malaysia; real effective exchange rate; volatility

1. Introduction

Exchange rate can be expressed as a nation's currency price in terms of another currency. In other words, exchange rate is also well known as a conversion factor, a ratio or a multiplier depending on the direction of conversion. Exchange rate has been one of the most triggers to crucial issues between countries from both the descriptive and policy prescription perspectives. According to Morina et al, (2020), a crucial key of macroeconomic factor that can affect international trade and the real economy of each country is the exchange rate. Exchange rates are exposed to several instabilities in the market which may result in currency volatility. Exchange rate volatility (ERV) can be understood as some defined risk which connect to the exchange rate fluctuations (Abdoh et al, 2016). While the fluctuations are essential to understand the functions of exchange rates, it is also crucial to investigate the possible determinants of the exchange rate in order to ensure its stability is maintained over the long run.

It is worthy to mention on the purchasing-power parity (PPP) which is considered one of the popular theories with regards to exchange rate determination. The theory, which was originally developed by a Swedish economist indicated that two exchange rates move in proportion to the ratio of the price level in particular currencies. In other words, one unit of a particular currency should be equivalent to buying similar amount of goods regardless of in which country. As a result, countries with relatively higher inflation should have depreciating currencies, while countries with low inflation rates should have their currencies appreciating. (Mankiw, 2012).

We can also relate the macroeconomic policies that either directly or indirectly impact key variables such as the real effective exchange rate (REER), inflation rate, current account balance, fiscal deficit and the level of international reserves. There have been studies in the past that looked into the relationship of exchange rates with other macroeconomic variables mentioned above such as one by Udoh et. al (2012). In this study, they found factors including industrial capacity utilization rate, commercial banks' lending rate, total import and foreign private investment had significant long run relationship towards exchange rate volatility. While Udoh et. al (2012) did not find long run relationship of inflation and exchange rate volatility, Inyiama et. al (2014) did find inflation rate to have positive relationship with exchange rate.

Arize A. C et al. (2014) studied the long-run and the short-run impact of real effective exchange rate volatility on real export demand. They implemented the GARCH model and the ARDL estimator was employed to identify estimates for the short and long run. Findings from their analysis show a stationary long-run equilibrium relationship between the real exchange rate volatility with foreign economic activity, real exports, and relative export price. They also proved that the results are consistent with economic theory through the significance and magnitude of results. Overall, key findings show that exchange rate volatility has negative effects in the short and long run.

It is interesting to see similar studies done on the Malaysian setting that look at the exchange rate volatility by implementing the GARCH model; as the model is considered an adequate one to measure exchange rate volatility as mentioned in Abdalla (2012). Another study by Abdullah et. al (2017) found that modelling the forecasting of exchange rate volatility was best done with the GARCH (1,1) model as the model satisfy the diagnostic test and able to show improved forecasting accuracy.The aim of this study it to analyze macroeconomic determinants of exchange rate volatility (ERV) in Malaysia. Therefore, the objectives of this paper include the following:

1. To investigate various macroeconomics variables leading acute variations in the real effective exchange rates volatility
2. To analyze the short run and the long run impact of some macroeconomic variables on the real effective exchange rate volatility.
3. To examine the extent of co-integration between of macroeconomic determinants and real effective exchange rate volatility.

2. Materials and Methods

The data used include the real effective exchange rate (REER) which is used to calculate its volatility (REERV), gross domestic products deflator (GDP), foreign direct investment net inflows in percentages of GDP (FDI), total export in percentage of GDP (EX), lending interest rate (IR) and inflation rate (INFR). The data was obtained from World Bank website, International Monetary Fund website and Statistical Department of Malaysia. Annual data for each variable comprises of a sample of 35 observations, starting from 1980 to 2014. This study used data in range 1980 to 2014 due to availability of consistency in each data.

2.1 Measuring real effective exchange rate volatility (REERV)

2.1.1 Generalized Autoregressive Conditional Heteroscedasticity (GARCH) Technique

In this paper, the first step is to generate the volatility for REER, which is based on the GARCH (1,1) model, following Abdullah et. al (2017). The GARCH (1, 1) process is a covariance-stationary white noise process if and only if $\alpha_1 + \beta < 1$ The variance of the covariance-stationary process is given by $\alpha_0/(1 - \alpha_1 - \beta)$. The GARCH model contains the mean and variance equations, summarized as Equation 1 and 2 below.

$$Log\ REER_t = \alpha_0 + \alpha_1 LogREER_{t-1} + \epsilon_t \qquad (1)$$

Where

$REER_t$ - Real effective exchange rate at time *t*

$REER_{t-1}$ -Real effective exchange rate at time *t-1*

ϵ_t - Error term at time *t* ; ϵ_t~Niid N(0,δ^2)

Equation 1 is the mean equation to derive the error term, ε_t while Equation 2, H_t represents the proxy of real effective exchange rate volatility, generated using Eviews.

$$H_t = \beta_0 + \beta_1 \epsilon_{t-1}^2 + \beta_2 H_{t-1} \quad (2)$$

where;

H_t - Conditional variance of ϵ_t or proxy of real effective exchange rate volatility

ϵ_{t-1}^2 - Past shocks or volatility – this is referred as ARCH

H_{t-1} - Past variance - this is referred as GARCH

In order to ensure that Equation (2) will be stationary, the persistence of volatility shocks, $\sum \beta_0 + \sum \beta_1$ must be lesser than 1. In other words, volatility shocks will be much persistent. As the sum of α a nd β approaches unity, shocks die out rather slowly, assuming that normality holds.

2.1.2 Analytical Techniques

Based on the objectives in this study, the empirical models are specified in Equation 3 below:

$$h_t = \delta_0 + \delta_1 Ln\ GDP_t + \delta_2 Ln\ FDI_t + \delta_3 Ln\ EX_t + \delta_4 Ln\ INFR_t + \delta_5 Ln\ IR_t + C_t \quad (3)$$

where;

h_t - Real effective exchange rate volatility at time *t*

GDP_t - Gross domestic product deflator at time *t*

FDI_t - Net inflows of foreign direct investment at time *t*

EX_t -Total export in percentage of GDP at time *t*

$INFL_t$ - Inflation rate (%) at time *t*

IR_t - Lending interest rate at time *t*

C_t - Error term at time *t*

2.1.3 Unit Root Test

The unit root test examines each variable for its stationarity. One of the most common tests for such process is the Augmented Dickey Fuller Test, short-formed as ADF test which was developed by Dicker and Fuller in 1979. In this process, if variables tested are not stationary at level form but happen to be stationary at the first difference, the time series variables should be further tested to see the co-integrating relationships among them. The term level form in this case refer to constant trend, where data is expressed in terms of its original measurement, which means there is no long run relationship, a short run relationship may exist and no need for cointegration estimation. While the first difference would involve changes from one period to the next.

2.1.4 Co- Integration Test

The co-integration concept was developed by Granger in 1981 which is popularly known to be essential in time series analysis. The test involves associating variables over the long run and initially variables are not integrated at the same level. In this case, Engle and Granger method was used, followed by Johansen co-integration test such as in Nguyen & Do (2020), Devkota & Panta (2018), Abdalla (2012), Udoh et. al (2012) to see if there is any co-integrating relationship between variables involved. After establishing the stationarity of each time series data, the next process is to identify the lag length to be used for further analysis; that is the lag length of the vector autoregressive system. Following the appropriate lag, the Johansen Cointegration test is employed to see the long-run equilibrium relationship between the variables involved and the exchange rate. The study applied Engle and Granger two-step technique and Johansen co-integration test to examine co-integration relationship among time series variables based on Equation 3. The pre-condition for applying the standard procedure of the co-integrations test of any series is that the variables in consideration must be integrated of the same order or non-stationary individually.

2.1.5 Error Correction Model (ECM)

The analysis is continued with the Error Correction Model (ECM). The steps that follow is to estimate the ECM model in order to capture the dynamics in the exchange rate volatility equation as shown in Equation 4 below, in the short run; at the same time to identify the adjustment speed in reaction to departures from the ECM for the exchange rate volatility in Malaysia. Equation 4 which is based on Equation 3 is shown below:

$$\Delta h_t = \delta_0 + \delta_1 \Delta Ln\, GDP_t + \delta_2 \Delta Ln\, FDI_t + \delta_3 \Delta Ln\, EX_t + \delta_4 \Delta Ln\, INFR_t + \delta_5 \Delta Ln\, IR_t + \delta_6 \Delta Ln\, h_{t-1} + \delta_7 ECM_{t-1} + C_t \tag{4}$$

Where;

Δh_t	- First difference of REERV at time *t*
ΔGDP_t	- First difference of GDP deflator at time *t*
ΔFDI_t	- First difference of net inflows of FDI at time *t*
ΔEX_t	- First difference of total exports as a percentage of GDP at time *t*
$\Delta \mathrm{INFL}_t$	- First difference of inflation rate (%) at time *t*
ΔIR_t	- First difference of lending interest rate at time *t*
ΔLnh_{t-1}	- First difference of real REERV at time *t-1*
ECM_{t-1}	-Error correction term (ECM), at time *t-1*
C_t	-Error term at time *t*

Equation 4 above identifies the variables defined at first difference, while the coefficient (δ) in ECM_{t-1} measure the diversion from the equilibrium in period (*t-1*).

3. Results and Discussion

Based on the data collected, the GARCH (1,1) model was generated from E-Views. It is shown in Table 1 below.

Table 1. The GARCH (1,1) model on measuring the real effective exchange rate volatility.

VARIABLE	COEFFICIENT	STD. ERROR	Z-STAT	PROB.
LREER2	0.949677	0.040572	23.40716	0.0000
C	0.229303	0.193930	1.1842400	0.0985
VARIANCE EQUATION				
C	0.001387	0.003037	0.456603	0.1973
RESID(-1)^2	-0.087877	0.123003	-0.714428	0.0000
GARCH(-1)	0.682146	0.772506	0.883030	0.0000

The GARCH (1,1) model which include the result for mean Equation 1 and the variance equation as for Equation 2 are shown below:

$$Log\ REER_t = 0.229303 + 0.949677\ LogREER_{t-1} + \epsilon_t \tag{5}$$

$$H_t = 0.0001387 - 0.087877\epsilon_{t-1}^2 + 0.682146H_{t-1} \tag{6}$$

The (H_t) series was generated from the result of Equation 2 above by using E-Views and was adopted in the further analysis of the study, which are unit root test, Engle-Granger two step technique, co-integration test followed by ECM. In other words, Equation 5 and 6 above only serve as the justification for using the GARCH (1,1) model to proceed with further analysis. This was decided based on the p-values that are less than 5% significance level for the residuals and real effective exchange rate.

3.1 Unit Root Test

Unit root test is employed to test stationary properties using an autoregressive model. It is to determine either the data stationary at level or at first differences or at second differences. Augmented Dickey-Fuller test was used as it is valid for large samples. If the ADF test is rejecting null hypothesis of unit root test, then the series is stationary at level form. If not, the data need to be test for first difference or second difference. The p-value should be less than 5% of confidence level in order for the model to be stationary. The significant level, α can be either 0.05, 0.01 or 0.1. If p-value is less than the significant level, the null hypothesis is rejected. It shows that the independent and dependent variables have a significant positive or negative relationship which means it is statistically significant to each other. If not the result will be vice versa. The null hypothesis is generally defined as the presence of a unit root and the alternative hypothesis is either stationarity, trend stationarity or explosive root depending on the test used. The hypothesis testing used in this test is:

Null hypothesis, H_0 = The series is not stationary and has unit root

Alternative hypothesis, H_1 = The series is stationary and has no unit root

Table 2 below shows result of unit root test for independent variables which consists of real effective exchange rate (REER), Gross Domestic Products Deflator (GDP), net inflows of foreign direct investment in percentages of GDP (FDI), total export in percentage of GDP (EX), lending interest rate (IR) and inflation rate (INFR). Based on the result of unit root test, most of the variables were non stationary at level form but stationary at the first difference. These include gross domestic product deflator (LGDP), total export in percentage of GDP (LEX) and lending interest rate (LIR). While the result of unit root test for the proxy of real exchange rate volatility (H_t), nets inflow of foreign direct investment (LFDI), and inflation rate (LINFR) show that these variables are stationary at level form and first difference. Based on Table 2, only LDFI and LINFR are stationary at level form, therefore it is necessary to perform unit root testing at first difference. All the variables have *p*-value less than 0.05 at first difference. Hence these it can be concluded that all variables are stationary at first difference; thus they are futher tested for co-integrating relationship.

Table 2. The ADF Test for all variables.

VARIABLES	ADF TEST				SERIES I(N)
	LEVEL FORM		FIRST DIFFERENCE		
	T-Statistic	p-value	T-statistic	p-value	
H_t	-3.090441	0.0363	-7.198370	0.0000	Stationary at level form and first difference
LGDP	-0.051085	0.9471	-7.380368	0.0000	Stationary at first difference
LDFI	-3.509382	0.0134	-8.757487	0.0000	Stationary at level form and first difference
LEX	-1.838691	0.3563	-3.695841	0.0000	Stationary at first difference
LINFR	-3.952372	0.0043	-4.738695	0.0005	Stationary at level form and first difference
LIR	-0.345631	0.9079	-5.113844	0.00027	Stationary at first difference

A closer look at the data for exchange rate shows that its volatility was high during the 1997 – 1999 period which could be representing the situation during the world financial crisis. Recovering from the crisis, the volatility is seen to slow down until 2014 as seen in Figure 1.

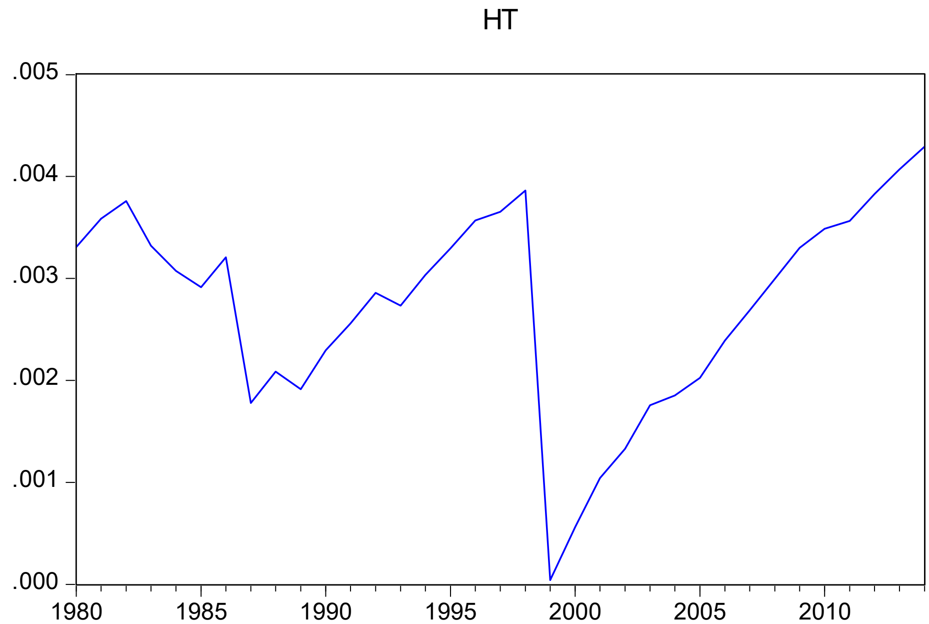

Figure 1. Real effective exchange rate volatility (HT).

3.2 Co-integration

In this part of analysis, the time series will be tested by using the Engle and Granger two-step technique. The residual for Equation 3 needs to be generated and known as error correction term (ECM). Again, it will utilize the ADF test and Engle-Granger critical values.

Table 3. The unit root test for residuals (ECM) in level at constant

VARIABLES	ADF TEST	
	LEVEL	
	T-STATISTIC	PROB.
ECM	-3.572886	0.0115

Based on the result, the residuals or error correction terms represent as ECM. In the Engel-Granger two-step technique, the residual of the model is generated and tested using Augmented Dickey Fuller or ADF test. Next, the residual should be tested by the Engle-Granger critical values for unit root test. Based on the result in the Table 3 above, the residual of the equation ECM is found stationary at 5% and 10% of Engle and Granger critical value which are -3.34 and -3.04. The p-value < 5% and 10% and t-stat < critical value, it means that variables in the time series such as H_t, LGDP, LFDI, LEX, LINFR and LIR are co-integrated. In other words, they have a long run relationship or equilibrium between them.

It is shown in Table 4 below that the Johansen co-integration test, the trace and the maximum eigenvalue test statistic were all significant at certain rank levels. The null hypothesis for the Johansen Cointegration test is that there is no cointegration. Therefore, for *p*-values of less than 5% will be considered as rejecting the null hypothesis.

Table 4: The result of Johansen Cointegration test Unrestricted Cointegration Rank Test (Trace)

HYPOTHESIZED NO. OF CE(S)	EIGENVALUE	TRACE STATISTIC	P-VALUE
NONE	0.857808	142.2815	0.0000
AT MOST 1	0.528242	74.01136	0.0222
AT MOST 2	0.418098	47.71625	0.0515

Table 5: The result of Johansen Cointegration test Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

HYPOTHESIZED NO. OF CE(S)	EIGENVALUE	TRACE STATISTIC	P-VALUE
NONE	0.857808	68.27012	0.0000
AT MOST 1	0.528242	26.29511	0.3030
AT MOST 2	0.418098	18.95088	0.4183

Based on the result in Table 4, the *p*-value is less than 5% for ranks up to at most 1 in the table; therefore, we reject the null hypothesis that there is at most one cointegrating relationship. In other words, it shows that trace test indicates two co-integrating equations. Through the maximum eigenvalue test in Table 5, this indicates a maximum of one co-integrating equation at the 5% level. This implies that there exists a cointegration relationship between the variables. Then, the model is tested for the long run equation of REERV based on Equation 3.

3.3 Long-Run Relationship

The model is then tested for the long run relationship based on equation 3 to analyze the long run impact of the said variables on the REERV. The result is in Table 6 as shown below.

Table 6. The result for long run relationship

VARIABLE	COEFFICIENT	STD. ERROR	T-STATISTIC	PROB.
LGDP	0.002968	0.000964	3.078384	0.0043
LFDI	-0.000143	0.000170	-0.838884	0.4080
LEX	-0.002198	0.000639	-3.442611	0.0017
LINFR	0.000393	0.000187	2.099704	0.0440
LIR	0.001876	0.001070	1.753076	0.0895
C	-0.003159	0.004583	-0.689211	0.4958
R-SQUARED: 0.424166				
F-STATISTIC: 4.566983				
PROB(F-STAT): 0.003094				

Based on the regression result in Table 6, the long run equation is shown below, including the coefficient of determination R^2 and F-statistic.

$$H_t = 0.002968LGDP_t - 0.000143LFDI_t - 0.002198LEX_t + 0.000393LINFR_t + 0.001876LIR_t - 0.003159 \quad (7)$$

$$R^2 = 0.424166$$
$$F = 4.566983$$

Equation 7 above identifies the variables defined at first difference, while the coefficient (δ) in ECM_{t-1} based on Equation 4 earlier measure the diversion from the equilibrium in period (*t-1*). Based on the p-values, it can be concluded that GDP, exports and inflation rate have significant long run relationship with REERV in Malaysia at the 5% significance level. However, interest rate would also play a role in the long run if a 10% significance level was chosen. From the R^2 value, it can be interpreted that the variables involved in this study explains 42.42% as the determinants of REERV. The rest would be explained by other variables which are not included in this study.

3.4 Error Correction Model

The importance of estimating the ECM model is to identify the changes in the REERV equation in the short run and to identify the speed of adjustment as a reaction to departures from the ECM that was estimated for the REERV in Malaysia as shown in Table 7 below.

Table 7: The result for short-run relationship

VARIABLE	COEFFICIENT	STD. ERROR	T-STATISTIC	PROB.
D(LGDP)	0.002281	0.003171	0.719305	0.4781
D(LFDI)	-0.000188	0.000104	-1.803106	0.0825
D(LEX)	-0.003340	0.001685	-1.982249	0.0825
D(LINFR)	0.000361	0.000146	2.473657	0.0200
D(LIR)	0.004849	0.001083	4.475868	0.0001
D(LH2	6.57E-07	0.000148	0.004448	0.9965
ECM(-1)	-0.642803	0.186398	-3.448542	0.0019
C	8.67E-05	0.000143	0.604422	0.5506
R-SQUARED: 0.589317				
F-STATISTIC:5.534873				
PROB(F-STAT):0.000497				

Based on the regression result in Table 7, the short run equation is shown below, including the coefficient of determination R^2 and F-statistic.

$$\Delta h_t = \delta_0 + 0.002281\Delta Ln\ GDP_t - 0.000188\Delta Ln\ FDI_t - 0.003340\Delta Ln\ EX_t + 0.000361\Delta Ln\ INFR_t + 0.004849\Delta Ln\ IR_t + 6.57\text{E} - 07\Delta Lnh_{t-1} - 0.642803ECM_{t-1} + 8.67\text{E} - 05 \tag{8}$$

$$R^2 = 0.589317$$

$$F = 5.534873$$

Based on the *p*-values, only inflation rate and interest rate have significant relationship with REERV in the short run at 5% significant level.

4. Conclusion

In the GARCH (1, 1) model, the real effective exchange rate volatility (*Ht*) was estimated, and the series was generated from EViews. The series show that the real effective exchange rate volatility is highly volatile in 1997-1999 as Malaysia face the worst effect due to the world financial crisis. Then, the real effective exchange rate volatility was slowly recovering from the effect of the world financial crisis until 2014.

In the unit root test, it was found that most of the variables were non stationary at level. However, they are stationary at first difference except for the net inflows of foreign direct investment (FDI) and inflation rate (LINFR) which happen to be stationary at both levels. This result indicates there is a need to check for co-integrating relationship among the variables.

Based on both long and short run, inflation rate is the only variable that have significant relationship with the dependent variable. The gross domestic product deflator and total export in percentage of GDP have significant relationship with the REERV in long run while interest rate have significant relationship with the real effective exchange rate volatility in short run. However, if we opt for a 10% significance level, interest rate will also be significant in the long run. It can be seen that both coefficient of determination in the short and long run are 42.42% and 58.93% respectively. The F-statistic for these are significant at the 10% level.

A new study needs to be carried out by adding other relevant macroeconomic variables on finding the long run and the short run relationship between real effective exchange rate and other macroeconomic variables. This study will show a more significant result if there are more independent variables added and the coefficient of determination R^2 will increase as it explains the total variation. The period of the study is needed to be extended to a longer period. In addition, further research should focus on comparison between countries especially among ASEAN countries.

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