Foreign exchange volatility modeling of Southeast Asian major economies

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A R T I C L E   I N F O

A B S T R A C T

This study investigates the exchange rate volatility model in Southeast Asian countries. The countries selected were Indonesia, Malaysia, Thailand, The Philippines, Vietnam, and Singapore. This study aims to model the volatility of the regional currency exchange rate against the international currency, i.e., the US Dollar. The period covered in this study extended from 1 January 2013 until 31 July 2019. These were the daily exchange rates of 7 currencies of Southeast Asian countries. The currency involved were Indonesian Rupiah (IDR), Malaysian Ringgit (MYR), Thai Baht (THB), The Philippine Peso (PHP), Vietnam Dong (VND), and Singaporean Dollar (SGD). All currencies were measured in the exchange rate against the US Dollar (USD). The result indicated that PARCH model is the best method to explain the movement of MYR, VND, and SGD. GARCH can model THB and PHP. Only IDR that has volatility explainable by TARCH.

A B S T R A K

Penelitian ini menginvestigasi model volatilitas kurs mata uang untuk negara-negara Asia Tenggara. Negara yang menjadi sampel adalah Indonesia, Malaysia, Thailand, Filipina, Vietnam dan Singapura. Tujuan penelitian ini adalah memodelkan volatilitas kurs mata uang regional terhadap mata uang internasional yaitu US Dollar. Periode penelitian ini dimulai dari tanggal 1 Januari 2013 sampai dengan 31 Juli 2019. Data yang digunakan adalah kurs mata uang harian 7 negara Asia Tenggara tersebut. Mata uang yang menjadi sampel penelitian adalah Rupiah Indonesia (IDR), Ringgit Malaysia (MYR), Baht Thailand (THB), Peso Filipina (PHP), Dong Vietnam (VND), dan Dollar Singapura (SGD). Hasil penelitian menunjukkan bahwa model PARCH adalah model yang cocok untuk memetakan volatilitas MYR, VND, dan SGD. Model GARCH adalah model volatilitas THB dan PHP. Hanya IDR yang memiliki volatilitas yang dapat dijelaskan oleh model TARCH.

1. INTRODUCTION

Exchange rate volatility has a significant effect on the economy. Besides, there are many factors that can cause fluctuation of a currency against another currency. In this condition, there could be long-term and short-term fluctuations in the exchange rate. The variation of the exchange rate can render the planning and predicting activities difficult. It is seen as a kind of risk. Volatility in exchange rates has many ramifications that can con-tribute either positively or negatively to trade.

Aristotelous (2001), Hayakawa and Kimura (2009), Kim (2017), Meniago and Eita (2017) and Senadza and Diaba (2017) have documented the detrimental effects of volatility on trade. An unstable exchange rate significantly undermines exporting activities. Volatility considerably depresses the export side of a country due to the increase in the price of the exported goods that result in contracted sales of the exported goods. The in-crease in price affects the demand for the products abroad. On the other hand, Cheong, Mehari, and Williams (2005) examined how volatility can be beneficial for import activities. Volatility in exchange rate results in a cheap rate for import. After the volatility occurs, there is a

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surge in import goods into a country—the domestic demand for imported products increases. Kumar, Bhutto, Mangrio, and Kalhoro (2019) found that the exchange rate affects domestic consumption in the long-run and short-run altogether. It has a positive correlation. When the exchange rate depreciates, demand will suffer. The contraction of demand happens through an inflationary mechanism. Depreciation of the exchange rate will increase the price of goods and services that later depresses demand. The volatility of the exchange rate also has tremendous impacts on the debt servicing ability of the government. In an economy that still relies on external debt for financing, volatility on the exchange rate can render debt servicing an arduous task. Debt servicing ability plummets when the local currency depreciates. In that condition, there will be more ex-pensive debt repayment. Fida, Khan, and Sohail (2012) give evidence on how external debt and exchange rate volatility cointegrates one another.

Monetary policy also depends on the role played by exchange rate volatility (Adeoye and Saibu 2014; Audzei and Brázdik 2015). It contributes to exemplify shocks to the economy that later affects inflation and aggregated demand. Exemplified shocks will trigger a response by the central bank to increase or decrease the interest rate (Krušković 2017).

This study investigates the exchange rate volatility model in Southeast Asian countries. The countries selected are Indonesia, Malaysia, Thailand, The Philippines, Vietnam, and Singapore. A severe financial crisis hit this region in 1998. During the crisis, the governments of the countries switched from a fixed exchange rate to a floating exchange rate regime to weather the crisis (Cieleback 1998).

The crisis triggered the financial re-forms in the countries and corroborated the idea of the ASEAN Economic Community. Mongid (2006) investigated the convergence of monetary and economic data among Southeast Asian countries that are members of the ASEAN organization. He found that there was still no convergence of monetary and economic data as a reflection of how convergent were the Southeast Asian countries should they intend to form a regional monetary union. However, a loose monetary union could be applied as a step forward towards ASEAN's monetary and economic integration (Mongid 2006).

This study aims to model the fluctuation of the regional currencies exchange rate against the international currency, i.e., the US Dollar. The

volatility measures are an essential indicator for Southeast Asian countries as one regional economic and monetary area. Governments of Southeast Asian countries and investors can deliberate over the strength of the currencies and the feasibility of the idea of ASEAN economic and monetary integration.

2. THEORETICAL FRAMEWORK AND HYPOTHESES

Many studies have examined the volatility model with a country setting. In this case, quantitative research predominantly models the volatility using a time-varying autoregressive model. Some researchers focused on African countries. For example, using the sample of Tanzania foreign exchange rate, Epaphra (2016) found initial evidence of the ARCH type volatility pattern. Volatility clustering, non-stationarity, serial correlation, and non-normality indicates the justification of the ARCH family model application.

GARCH (1, 1) has the best predictive power for modeling the exchange rate with low mean absolute error, and root means square error. For example, May and Farrell (2018) examined the volatility of South African's Rand. They found evidence of volatility persistence amid structural breaks. By employing a GARCH framework, the asymmetric GARCH showed the leverage effects, meaning adverse shocks result in higher subsequent year volatility than positive shocks. Emenike (2018) investigated volatility spillover among the currency of Gambia, Nigeria, and West Africa. He employed the GARCH (1,1)-BEKK model. He chose this model because it can evaluate the possibility of interaction within specific volatility of more than two series. It can also determine the spillover effect in the time series observations and volatility persistence.

The currencies of West Africa, Gambia, and Nigeria were found to cluster in their volatilities. The exchange rate of Nigerian Naira and West African CFA franc also interact with one another. Volatility spillover and shocks were found to be in both ways and bidirectional. However, Gambian dalasi influenced West African CFA Franc without any reciprocal action of the latter. Ramzan, Ramzan, and Zahid (2012) and Abdullah, Siddiqua, Siddiquee, and Hossain (2017) modeled the volatility with the South Asia setting. Ramzan et al. (2012) examined volatility in the Pakistani Rupee exchange rate. They compared the analysis of the ARCH family and ARMA model. GARCH (1, 2) successfully modeled the fluctuations while

EGARCH (1, 2) could overcome the leverage effect present in the model.

Abdullah et al. (2017) modeled the variations in Bangladeshi Taka. Under the assumption of normal distribution and Student's t-error distribution, they employed the ARCH family model as the framework. They found that AR (2)-GARCH (1, 1) to be the perfect model to map the volatility pattern. They also found that Student's t-error distribution could help satisfy the model to meet the diagnostic test. Pilbeam and Langeland (2015) investigated several exchange rates involving USD. They found that GARCH models were not instrumental in predicting volatility in times of low and high volatility. They used three classes of GARCH, namely GARCH (1,1), EGARCH (1,1), and GJR-GARCH (1,1). None of the GARCH models could map the data well.

Abdullah et al. (2017) investigated volatility modeling within a European setting. She modeled the Romanian Leu fluctuation according to the ARCH-GARCH family. She found that it followed the pattern of the ARCH model. There was also the high asymmetry of the ARCH process involved regarding information content. Bošnjak, Bilas, and Novak (2016) examined the movement of Croatian Kuna (HRK) against USD and EUR. GARCH (1,1) was found to be the best framework to model USD/HRK volatility, while GARCH (2,1) could model EUR/HRK movement.

There was no indication of the existence of asymmetry effect on the GARCH model, be it in EUR or USD against HKR. Petrica and Stancu (2017) also examined the exchange rate of Romanian Leu. However, they did it for the exchange rate of the Euro to Leu. By applying ARCH family models, they found that EGARCH and PARCH models to be the best for modeling Leu volatility. EGARCH (2,1) with order 2 for information asymmetry could also predict daily exchange rate return. Dritsaki (2019) studied the instability of EUR/USD by employing ARCH, GARCH, and EGARCH model. She found that to model daily exchange rate return, ARIMA (0, 0, 1)-EGARCH (1, 1) could per-form the modeling. The model, along with generalized error distribution, could also cope with the leverage effect. Besides, ARIMA (0, 0, 1)-EGARCH (1, 1) can also conduct the forecasting of the volatility needed both in the static and dynamic procedure. However, a static process showed better forecasting impact.

3. RESEARCH METHOD

The period covered by this study extended from 1 January 2013 until 31 July 2019. This was a daily exchange rate of 6 currencies of Southeast Asian countries. The currency involved were Indonesian Rupiah (IDR), Malaysian Ringgit (MYR), Thai Baht (THB), The Philippine Peso (PHP), Vietnam Dong (VND), and Singaporean Dollar (SGD). This study measured all currencies in the exchange rate against the US Dollar (USD). Since the exchange rate inclined to be no-stationary, this study employed the return value of the exchange rate. Exchange rate return calculation is as follows:

$$r_{it} = ln\ (C_{it}/C_{it-1})$$

C_{it} refers to the currency exchange rate. The term i shows a particular currency of the specific country, while the term t indicates the time.

This study employed the models of ARCH family models. However, before proceeding to estimate the volatility of the return, this study first specified the mean return equation. The mean return is pivotal. The misspecification of the mean return could result in failing to capture the autocorrelation effect of return volatility. Referring to Abdullah et al. (2017), this study used all the mean return equations. Mean return equations are the equation with only a constant, the equation with a constant and an autoregressive component (t-1), and the equation with a constant and two autoregressive components (t-1 and t-2). The equations for mean return are as follows:

$$r = a + e_t \tag{1}$$
$$r = a + \beta_1\ r_{t-1} + e_t \tag{2}$$
$$r = a + \beta_1\ r_{t-1} + \beta_2\ r_{t-2} + e_t \tag{3}$$

All the mean return equations include e_t as the error term. After establishing the equation mean, this study proceeded with testing the ARCH effect. The examination of the existence of the ARCH effect involves the residuals generated by the above equation. The model to test the arch effect is as follows:

$$e_t^2 = \gamma_0 + \gamma_1 e_{t-1}^2 + v_t$$

The ARCH effect is indicated by the significance of the coefficient γ_1. Whenever the coefficient is significant, the ARCH family model would be employed to model the volatility. The models involved were ARCH, GARCH, EGARCH,

TGARCH, and PARCH. The models are as follows:

1. ARCH:

$$\sigma_t^2 = \lambda + \sum_{i=1}^{s} \alpha_i \, e_{t-i}^2$$

2. GARCH:

$$\sigma_t^2 = \lambda + \sum_{i=1}^{s} \alpha_i \, e_{t-i}^2 + \sum_{j=1}^{v} \delta_j \, \sigma_{t-j}^2$$

3. EGARCH:

$$\log(\sigma_t^2) = \lambda + \sum_{i=1}^{s} \alpha_i \frac{\|e_{t-i}\|}{\sigma_{t-i}} + \sum_{k=1}^{u} \tau_k \frac{e_{t-k}}{\sigma_{t-k}} + \sum_{j=1}^{v} \delta_j \, \log(\sigma_{t-j}^2)$$

4. TGARCH:

$$\sigma_t^2 = \lambda + \sum_{i=1}^{s} (\alpha_i + \tau_i . \varphi_{e_{t-1}}) \, e_{t-i}^2 + \sum_{j=1}^{v} \delta_j \, \sigma_{t-j}^2$$

5. PARCH:

$$\sigma_t^\eta = \lambda + \sum_{i=1}^{s} \alpha_i \, f_i \, e_{t-i} + \sum_{j=1}^{v} \delta_j \, \sigma_{t-j}^\eta ,$$

where $f_i \, e_{t-i} = (| \, e_{t-1}\| - \tau_k \, e_{t-1})_\eta$

This study employed all the models against all the currencies used in the sample. The ARCH family consists of one component of ARCH and one element of GARCH for all models (1, 1), except for ARCH that only consists of a component of ARCH itself.

4. DATA ANALYSIS AND DISCUSSION

Before the analysis, the researcher examined the volatility of each currency visually. By plotting the exchange rate return against time, the researcher could get the first impression of the currency volatility. Figure 1 shows the result of graphing the volatility of the currencies.
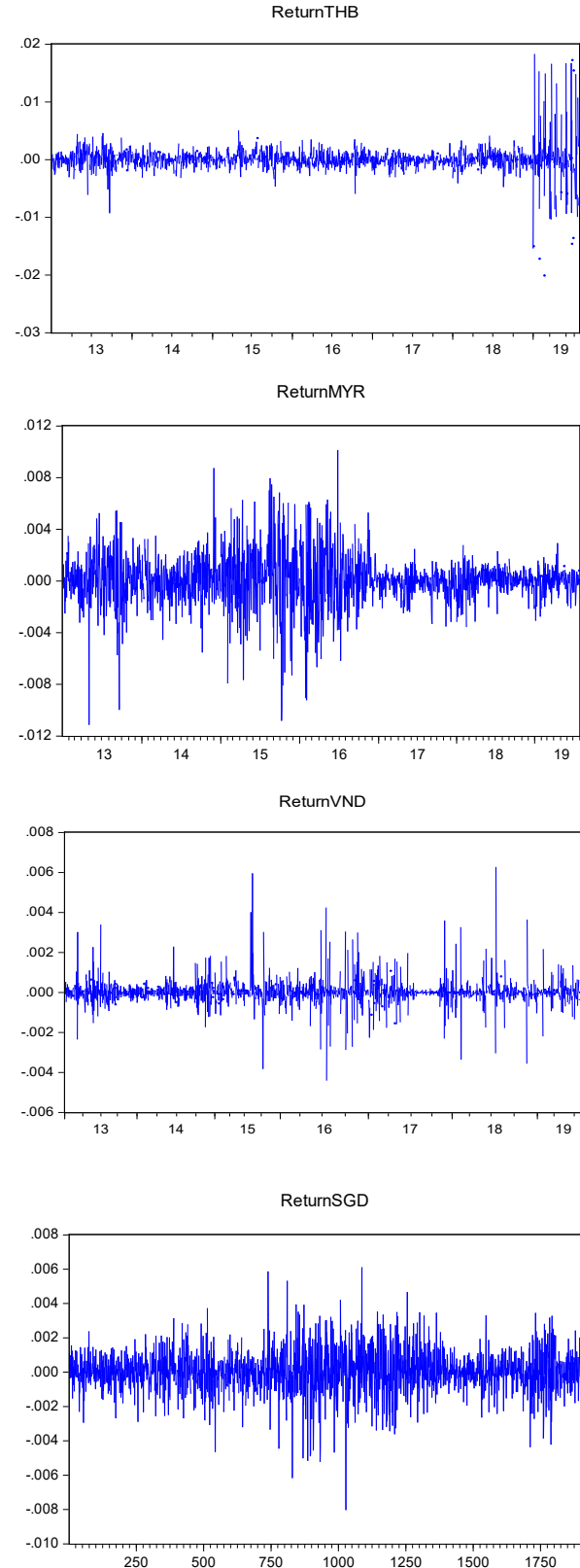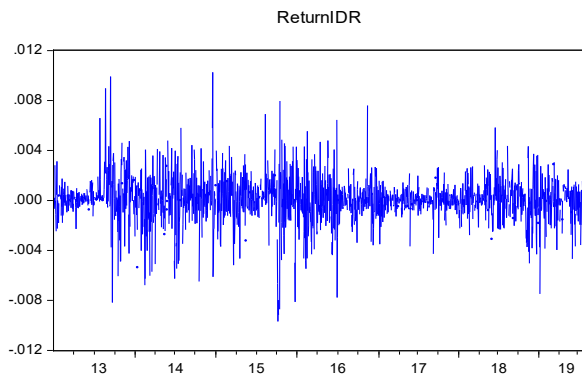

Figure 1.
The Volatility of Southeast Asian Currencies

Source: Data Processed, 2019

The researcher can see that the majority of the currencies are volatile. A Large cluster of return volatility is usually followed by also significant volatility and small return accompanies other small return.

Table 1
Descriptive Statistics

No	Currencies	Min	Max	Average	Std Deviation
1	IDR	-0.17910034	0.18294192	0.00010027	0.0607895
2	MYR	-0.01112525	0.01014379	0.00008266	0.0019882
3	PHP	-0.01636559	0.01627556	0.00005905	0.0012568
4	THB	-0.02016565	0.01830594	0.00000264	0.0023071
5	VND	-0.00440971	0.00627199	0.00002844	0.00064790
6	SGD	-0.00802508	0.00611780	0.00002701	0.0012318

Source: Data Processed, 2019

There is a presence of ARCH effect on the volatility. Indonesian Rupiah (IDR), Malaysian Ringgit (MYR), and Singaporean Dollar (SGD) provide an indication of massive fluctuation in the currencies. These currencies regularly experience significant fluctuation in a closed interval. The thick lines indicate how the turbulence was experienced by the currencies.

For Thai Baht (THB), there is a stark contrast during the last period. Tall swings exist at the end of the graph. This means that Thai Baht had been unstable lately. However, for the majority of the research period, Thai Baht (THB) tends to be stable before mid-2018. There was somewhat some insignificant fluctuation. However, in the last period, it began to experience substantial variation. The Philippine Peso (PHP) experienced extreme volatility only at the beginning of the research period. After that, volatility was inclined to be mild. In the onset and nearing the end, the volatility tends to be medium. Vietnamese Dong (VND) also exhibits the case of extreme volatility. The volatility swings immensely at times. That shows instability in the currency return. To give a clearer view of the behavior of the data, the result of descriptive statistics is presented. Descriptive statistics include the minimum and maximum value, average, and standard deviations. Table 1 shows the descriptive statistics.

Table 2 shows that Indonesia Rupiah (IDR) has the most minimum, maximum, average, and standard deviation. This shows that Indonesia Rupiah was the most volatile currency during the research period. The most minimum and maximum means the swings in Indonesian Rupiah (IDR) are more than any other currencies. Indonesian Rupiah (IDR) experienced massive turbulence. On the other hand, Vietnamese Dong (VND) was the most stable currency in the Southeast Asia region. Its min, max, and standard deviation are the smallest. This shows how stable the Vietnam-ese Dong (VND) was. Its average is some-what bigger than Thai Baht (THB) (0.00002844>0.00000264). Thai Baht (THB) has the smallest average. This is an indicator of the mean-reversion characteristics. However, turbulent Thai Baht (THB) was, it would always return to its mean.

Before proceeding to ARCH testing, the researcher first conducted a stationarity test. Augmented Dickey-Fuller is the method chosen to assess the stationarity of the currency return. The stationarity test is essential to ensure that there is no spurious relationship. The result of the stationarity test is presented in Table 2.

Table 2
Stationarity Test

Indonesia Rupiah (IDR)

ADF Test	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-37.11025	0.0000
Test critical values: 1% level	-3.434224	
5% level	-2.863138	
10% level	-2.567669	

Malaysian Ringgit (MYR)

ADF Test		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-38.64573	0.0000
Test critical values:	1% level	-3.434207	
	5% level	-2.863130	
	10% level	-2.567664	

The Philippine Peso (PNP)

ADF Test		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-40.61188	0.0000
Test critical values:	1% level	-3.434252	
	5% level	-2.863150	
	10% level	-2.567675	

Thai Baht (THB)

ADF Test		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-27.83583	0.0000
Test critical values:	1% level	-3.434224	
	5% level	-2.863138	
	10% level	-2.567669	

Vietnamese Dong (VND)

ADF Test		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-35.07924	0.0000
Test critical values:	1% level	-3.434099	
	5% level	-2.863083	
	10% level	-2.567639	

Singaporean Dollar (SGD)

ADF Test		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-44.74898	0.0001
Test critical values:	1% level	-3.433604	
	5% level	-2.862864	
	10% level	-2.567521	

Source: Data Processed, 2019

***significant at 0.01, **significant at 0.05, *significant at 0.1

The null hypothesis of the Dickey-Fuller test is that the series have unit-roots. This means the data is not stationary. The result of the test shows the data of all the currency returns investigated in this study has a probability lower than 0.05. It indicates that the unit root is not present in the data. All of the data are stationary, and the problem of spurious relationship does not exist.

After investigating the stationarity, the researcher proceeded with the ARCH effect test. There are three mean equations in this study. The first equation consists of a mean component and a constant. The second equation also contains a mean

element and a constant. However, the researcher, in this case, add a lag one autoregressive element. The third equation includes two autoregressive components.

This study examines further the residuals derived from these three equations for the arch effect by regressing the squared residuals against lag one squared residuals (an autoregressive component of residuals). The result of the mean equation test is presented in Appendix 1. After this, the researcher tested the ARCH effect. ARCH effect test includes variance as the dependent variable, and if the coefficient of the lagged squared residuals were

significant, there would be an ARCH effect. The   result of the test is present-ed in Table 3.

Table 3
Result of ARCH Effect Testing

Indonesian Rupiah (IDR)

Variables	Coefficients		
	1	2	3
ARCH Effect			
Constant	0.000002***	0.000002***	0.00000235***
	(0.0000002)	(0.0000002)	(0.0000002)
e_{t-1}^2	0.340848***	0.329446***	0.329551***
	(0.023496)	(0.023604)	(0.023610)
F Statistics	210.44***	194.7988***	194.8212***
Probability	0.0000	0.0000	0.0000

Malaysian Ringgit (MYR)

Variables	Coefficients		
	1	2	3
ARCH Effect			
Constant	0.000003***	0.000003***	0.00000304***
	(0.0000002)	(0.0000002)	(0.0000002)
e_{t-1}^2	0.231388***	0.230833***	0.230535***
	(0.024261)	(0.024272)	(0.024281)
F Statistics	90.96476***	90.44293***	90.14536***
Probability	0.0000	0.0000	0.0000

Thai Baht (THB)

Variables	Coefficients		
	1	2	3
ARCH Effect			
Constant	0.0000033***	0.00000353***	0.00000361***
	(0.0000006)	(0.0000005)	(0.0000005)
e_{t-1}^2	0.379371***	0.279035***	0.258150***
	(0.023125)	(0.024074)	(0.024228)
F Statistics	269.1317***	134.3421***	113.5274***
Probability	0.0000	0.0000	0.0000

The Philippine Peso (PHP)

Variables	Coefficients		
	1	2	3
ARCH Effect			
Constant	0.0000008***	0.0000008***	0.000000818***
	(0.0000002)	(0.00000021)	(0.00000021)
e_{t-1}^2	0.484723***	0.481546***	0.481126***
	(0.021935)	(0.021986)	(0.021999)
F Statistics	488.324***	479.6943***	478.3104***
Probability	0.0000	0.0000	0.0000

Vietnamese Dong (VND)

Variables	Coefficients		
	1	**2**	**3**
ARCH Effect			
Constant	0.0000003***	0.0000002***	0.000000271***
	(0.00000004)	(0.00000004)	(0.00000003)
e^2_{t-1}	0.247637***	0.287242***	0.287649***
	(0.023830)	(0.023567)	(0.023571)
F Statistics	107.9913***	148.557***	148.9302***
Probability	0.0000	0.0000	0.0000

Singaporean Dollar (SGD)

Variables	Coefficients		
	1	**2**	**3**
ARCH Effect			
Constant	0.0000014***	0.0000014***	0.00000141***
	(0.00000009)	(0.000000009)	(0.00000009)
e^2_{t-1}	0.98380***	0.100493***	0.09573***
	(0.023245)	(0.023481)	(0.023761)
F Statistics	17.91314***	18.31592***	16.84745***
Probability	0.0000	0.0000	0.0000

Source: Data Processed, 2019
***significant at 0.01, **significant at 0.05, *significant at 0.1

ARCH effect presented in all currencies that contain significant time-varying volatility properties. The p-value is very close to zero. All the currencies that experience the ARCH effect exhibit a robust model fit for the ARCH effect model. The coefficients of squared residuals are all significant at 0.01. The residuals derived from all three mean equations are substantial. Therefore, this study can safely infer that Southeast Asian currencies are very volatile in their exchange rate against Dollar. As an area that was once known as the seven little dragons, this should be of no surprise. Ever since the currency cri-sis of 1997-1998, the region has switched to the floating-rate regime. Now that the nature of the volatility is known, the ARCH family must be employed to model the volatility clustering of currency return. This study first investigated the Indonesian Rupiah (IDR). By using the ARCH family model testing, the researcher derives the results as in Table 4.

Table 4
Volatility Modeling for IDR

Indonesian Rupiah (IDR)

Variables	Test Coefficients				
	ARCH (1)	**GARCH (1)**	**EGARCH (1,1)**	**TGARCH (1,1)**	**PARCH (1,1)**
Λ	0.000006***	0.00000008***	-0.662536***	0.0000006***	0.0000002
	(0.00000005)	(0.000000009)	(0.057288)	(0.000000009)	(0.0000002)
A	0.402636***	0.116325***	0.219997***	0.136949***	0.111220***
	(0.039059)	(0.009483)	(0.012675)	(0.012699)	(0.01011)
δ		0.865162***	0.960425***	0.879566***	1.837021***
		(0.009890)	(0.003979)	(0.008828)	(0.175521)
τ			0.040545***		-0.141031***
			(0.007522)		(0.032071)

Indonesian Rupiah (IDR)

Variables	Test Coefficients				
	ARCH (1)	GARCH (1)	EGARCH (1,1)	TGARCH (1,1)	PARCH (1,1)
$a + \tau.\varphi$				0.056683*** (0.012938)	
H					1.837021*** (0.0175521
AIC	-9.870420	-9.959003	-9.956494	-9.962878	-9.961850
SIC	-9.860357	-9.945586	-9.939723	-9.946106	-9.941724

Source: Data Processed, 2019

***significant at 0.01, **significant at 0.05, *significant at 0.1

The coefficients are entirely significant at the level of 0.01. Therefore, this study can provide evidence that time-varying volatility ap-plies to Indonesian Rupiah (IDR). Table 2 shows the amount of the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC). The best ARCH model for Indonesian Rupiah (IDR) is the one with the lowest value of AIC and SIC. TGARCH and PARCH have the lowest value for AIC (-9.962878 and -9.96185). In terms of SIC, GARCH and TGARCH record the lowest amount of -9.945586 and -9.946106. In this case, TGARCH has the lowest IAC and SIC. TGARCH model can also capture the leverage effect. Therefore, bad news tends to have more impact on future conditional volatility than good news. The coefficient of α + τ.φ, which is positive and significant, indicates the existence of the leverage effect. Yet, TGARCH (1,1) model is the best model for modeling the Indonesian Rupiah (IDR) volatility. Table 5 displays the result for Malaysian Ringgit (MYR).

Table 5
Volatility Modeling for MYR

Malaysian Ringgit (MYR)

Variables	Test Coefficients				
	ARCH (1)	GARCH (1)	EGARCH (1,1)	TGARCH (1,1)	PARCH (1,1)
λ	0.000002*** (0.00000006)	0.00000002*** (0.000000005)	-0.373627*** (0.052358)	0.000000026*** (0.000000006)	0.0000012 (0.0000019)
a	0.630103*** (0.044212)	0.120131*** (0.0011313)	0.227677*** (0.019435)	0.129999*** (0.014203)	0.12456*** (0.011854)
δ		0.883808*** (0.01059)	0.98427*** (0.003492)	0.881701*** (0.010666)	0.891795*** (0.010274)
τ			-0.006455*** (0.009534)		0.003276 (0.041102)
$a + \tau.\varphi$				-0.016345*** (0.016816)	
η					1.429744*** (0.227779)
AIC	-9.758843	-10.04972	-9.956494	-10.04882	-10.05009
SIC	-9.748816	-10.03635	-9.939723	-10.03210	-10.03004

Source: Data Processed, 2019

***significant at 0.01, **significant at 0.05, *significant at 0.1

Overall, the result for Malaysian Ringgit (MYR) shows that the coefficients are statistically significant at 0.01. The ARCH (1) model contains substantial variables. However, its AIC and SIC are bigger than the PARCH model (-9.758843 and -9.748816 > -10.05009 and -10.03004). GARCH model can explain the volatility better than the ARCH model (-9.758843 and-9.748816 > -10.04972 and -10.03635), and all the coefficients are statistically significant at 0.01. In the PARCH model, the constant is not substantial. However, the PARCH model is the best model since it contains the lowest value of AIC and SIC. Therefore, this study concludes that the PARCH (1, 1) model best explains the Malaysian Ringgit (MYR). Table 6 shows the estimation result for Thai Baht (THB).

Table 6
Volatility Modeling for THB

Thai Baht (THB)

Variables	Test Coefficients				
	ARCH (1)	GARCH (1)	EGARCH (1,1)	TGARCH (1,1)	PARCH (1,1)
λ	0.0000024*** (0.00000002)	0.00000002*** (0.000000004)	-0.105796*** (0.014962)	0.000000042*** (0.000000005)	0.00000005 (0.00000009)
a	0.632765*** (0.024739)	0.054788*** (0.004228)	0.161971*** (0.007324)	0.075991*** (0.014203)	0.091217*** (0.013822)
δ		0.943602*** (0.003979)	0.1000416*** (0.001105)	0.899491*** (0.06202)	0.891795*** (0.010274)
τ			-0.03715*** (0.004982)		0.070449** (0.02926)
$a + \tau.\varphi$				0.042062*** (0.016816)	
η					2.730899*** (0.303523)
AIC	-9.739412	-10.14752	-10.12993	-10.14837	-10.15043
SIC	-9.729630	-10.13412	-10.11317	-10.13162	-10.13033

Source: Data Processed, 2019
   ***significant at 0.01, **significant at 0.05, *significant at 0.1

In modeling the Thai Baht (THB), all ARCH family contain significant coefficients. The ARCH (1) model provides a significant coefficient but with more value of AIC and SIC compared to the other models. GARCH mod-el signifies the lowest value of SIC of all models (-10.13412). TGARCH model can capture the leverage effect. The coefficient of α + τ.φ is positive and significant. EGARCH also indicates the leverage effect in which its factor of τ is negative. Therefore, whenever bad news hits the economy, the volatility of the currency will be higher than when receiving good news. The PARCH model coefficient is significant at 0.05 (p-value of 0.016). The high p-value is somewhat unusual, considering all other factors are significant at 0.01 level. However, PARCH has the lowest AIC value. Therefore, the researcher can infer that two models explain the volatility of THB the best; they are GARCH and PARCH. Nevertheless, since SIC imposes a more massive penalty than AIC for including longer lags, it is conservatively safe to infer that SIC matters more. Therefore, the volatility of Thai Baht (THB) is better explained by the GARCH model. Table 7 displays the result of the Vietnamese Dong (VND):

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Table 7
Volatility Modeling for VND

Vietnamese Dong (VND)

Variables	Test Coefficients				
	ARCH (1)	GARCH (1)	EGARCH (1,1)	TGARCH (1,1)	PARCH (1,1)
λ	0.0000305*** (0.00000002)	0.0000001*** (0.0000000023)	-11.46776*** (0.442987)	0.000000098*** (0.000000003)	0.00000006 (0.00000144)
α	0.420034*** (0.032378)	0.320498*** (0.020621)	0.583058*** (0.032411)	0.230806*** (0.031587)	0.295752*** (0.028494)
δ		0.479121*** (0.010147)	0.255864*** (0.029250)	0.489210*** (0.001105)	0.403001*** (0.040217)
τ			-0.156241*** (0.029258)		0.129325** (0.033142)
α + τ.φ				0.170868*** (0.042962)	
η					2.97595*** (0.287285)
AIC	-12.1012	-12.12345	-12.12830	-12.12717	-12.13838
SIC	-12.0914	-12.11037	-12.11196	-12.11083	-12.11877

Source: Data Processed, 2019
***significant at 0.01, **significant at 0.05, *significant at 0.1

Table 7 shows how strong is the presence of time-varying volatility features in Vietnamese Dong (VND). All models contain significant coefficients, except for the constant's coefficient in PARCH. The ARCH (1) model has the most value of AIC and SIC. So it can be ruled out that ARCH is the best model for explaining the volatility. GARCH model also is not the best model despite its significant coefficients. EGARCH and TGARCH both can capture the leverage effect that happens to VND volatility. The coefficient of α + τ.φ is positive (in TGARCH), and the coefficient of τ is negative in EGARCH. EGARCH has better information content than TGARCH. PARCH model can best explain Vietnamese Dong (VND) volatility by having the lowest value of AIC and SIC. Table 6 displays result for the Philippine Peso (PHP).

Table 8
Volatility Modeling for PHP

Philippine Peso (PHP)

Variables	Test Coefficients				
	ARCH (1)	GARCH (1)	EGARCH (1,1)	TGARCH (1,1)	PARCH (1,1)
λ	0.0000013*** (0.00000001)	0.00000003*** (0.000000004)	-0.438427*** (0.038119)	0.00000003*** (0.000000005)	0.0000002 (0.000002)
α	0.095314*** (0.0015168)	0.079251*** (0.010111)	0.160596*** (0.013122)	0.089827*** (0.01221)	0.076802*** (0.010811)
δ		0.901611*** (0.009861)	0.97668*** (0.002551)	0.905397*** (0.010047)	0.908011*** (0.009265)
τ			0.0272*** (0.009385)		-0.134497** (0.061604)
α + τ.φ				-0.034456*** (0.013138)	
η					1.729769*** (0.17136)
AIC	-10.62767	-10.73616	-10.73005	-10.73729	-10.73671
SIC	-10.61755	-10.72267	-10.71319	-10.72042	-10.71648

Source: Data Processed, 2019
***significant at 0.01, **significant at 0.05, *significant at 0.1

The Philippine Peso (PHP) also has a substantial property of time-varying volatility. All the coefficients are significant except for the constant in the PARCH model. The ARCH (1) model contains all substantial coefficients but with most AIC and SIC. GARCH model also has significant coefficients with the lowest value of SIC. Its AIC is just slightly more than TGARCH, which has the lowest AIC. No indication of leverage effect present for the

Philippine Peso (PHP). Both EGARCH and TGARCH do not signify the leverage effect. PARCH model contains the lowest value of AIC. Again, this study has two models with the lowest AIC and SIC. In this case, SIC is better because it is stricter than AIC. For the Philippine Peso (PHP), GARCH is the best model to map the volatility. Table 9 presents the result for Singaporean Dollar (SGD).

Table 9
Volatility Modeling for SGD

Singaporean Dollar (SGD)

Variables	Test Coefficients				
	ARCH (1)	**GARCH (1,1)**	**EGARCH (1,1)**	**TGARCH (1,1)**	**PARCH (1,1)**
λ	0.0000012***	0.0000000067***	-0.126399***	0.000000005***	0.0000834
	(0.00000003)	(0.000000001)	(0.023837)	(0.000000001)	(0.000101)
a	0.203692***	0.031667***	0.072548***	0.040975***	0.034183***
	(0.024949)	(0.004)	(0.0008466)	(0.005429)	(0.003973)
δ		0.963959***	0.994547***	0.966349***	0.969479***
		(0.004436)	(0.001502)	(0.004442)	(0.003721)
τ			0.019608***		-0.340655**
			(0.005961)		(0.118899)
$a + \tau.\varphi$				-0.021926**	
				(0.00639)	
η					0.629301***
					(0.163579)
AIC	-10.5892	-10.70664	-10.7136	-10.70894	-10.71396
SIC	-10.58041	-10.69493	-10.69896	-10.6943	-10.69639

Source: Data Processed, 2019

***significant at 0.01, **significant at 0.05, *significant at 0.1

ARCH family model has proven that the Singaporean Dollar (SGD) is prone to time-varying volatility. In this case, the volatility increases with time. All the coefficients have been shown to be significant except for the constant's coefficient in the PARCH model (p-value 0.4071). The ARCH (1) model has the most AIC and SIC value (-10.5892 and -10.58041). EGARCH and PARCH have a very close AIC (-10.7136 and -10.71396) and SIC (- 10.69493 and

10.69639). They are the lowest of all. The leverage effect is present in SGD volatility. EGARCH and TARCH can capture how SGD reacts more when there is bad news other than good news. Overall, PARCH is the best model to explain the volatility in Singaporean Dollar (SGD). By having examined the best ARCH family model for each currency, the researcher can summarize the result as in Table 10.

Table 10
Summary of ARCH Family Model

No	Currency	ARCH Family Model
1	Indonesian Rupiah (IDR)	TGARCH (1,1)
2	Malaysian Ringgit (MYR)	PARCH (1,1)
3	Thai Baht (THB)	GARCH (1)
4	Vietnamese Dong (VND)	PARCH (1,1)
5	Philippine Peso (PNP)	GARCH (1)
6	Singaporean Dollar (SGD)	PARCH (1,1)

Table 10 indicates that PARCH and GARCH are the predominant models. All the currencies examined suffer from time-varying volatility. Over time, the variance of the currencies will be larger than before. The Southeast Asia region is prone to currency instability. The increasing variance implies that countries in this region should take a step to curb their currencies' fluctuations. Failure to mitigate time-varying volatility as early as possible will result in currency fluctuation spiraling out of control in the later years.

5. CONCLUSION, IMPLICATION, SUGGESTION, AND LIMITATIONS

Southeast Asia region was infamous for its 1997 crisis. Before 1997, many countries had adopted a fixed exchange rate mechanism. Economic growth had been tremendous. However, fundamentally, the sustainability of economic productivity and financial soundness had been questionable. For example, the financial institution governance had been lack of and subjected to political power. The crisis started with the Thai Baht (THB). The government was forced to float the Thai Baht (THB) ex-change rate against USD. Not long after that, the mess spilled over to other neigh-boring countries. Even Malaysia was forced to impose capital control to prevent USD reserve from depleting.

Indonesia was said to experience the worst financial crisis in the region. Its currency weakened from six to eight times from the precrisis level. As a region that still relies on debt to spur its growth, the volatility of the exchange rate could have a tremendous negative impact on the debt burden. During the crisis, almost all countries forced to forego their pegged currency mechanism to switch to a floating rate. More than twenty years after the disaster, currencies in this region are still very volatile. Those currencies exhibit the behavior of time-varying volatility.

In this study, ARCH family models were employed to investigate the best model that can describe the volatility of the currencies. PARCH is the best method to explain the movement of Malaysian Ringgit (MYR), Vietnamese Dong (VND), and Singaporean Dollar (SGD). GARCH can describe the volatility of Thai Baht (THB) and the Philippine Peso (PHP). Only Indonesian Rupiah (IDR) has volatility explainable by TARCH.

As a precaution, the regulator and government should be wary of their currencies' behavior because the volatility in-creases with time. This should raise a realization for governments and central banks, due to increased risks as time passes. In the later period, currency volatility will be larger. This research provides further evidence of monetary convergence. Malaysia Ringgit (MYR), Vietnamese Dong (VND), and Singaporean Dollar (SGD) behave the same way. This same behavior implies more synchronization in monetary and economic activities. Thai Baht (THB) and The Philippine Peso (PNP) also show identical volatility movement. Only Indonesia Rupiah (IDR) behave differently.

Mongid (2006) provides evidence of non-convergence among ASEAN countries' economic and monetary data. He suggested ASEAN take further steps to spur trade and growth among the countries. Preepremmote, Santipolvut, and Puttitanun (2018) found evidence that economic integration will be beneficial to ASEAN member countries. Economic integration will provide strength to weather financial crises and economic difficulties. However, it is imperative to minimize economic integration or disparities in economic and monetary activities. Otherwise, economic integration will fail to achieve its intended task. This research provides evidence that some Southeast Asian countries begin to have parallel economic and monetary activities. Therefore, steps should be taken to further increase economic integration in this region. Future research could endeavor to contribute to the measurement of economic integration among Southeast Asian countries.

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APPENDIX 1: Mean Equation Test Result

Indonesian Rupiah (IDR)

a	0.0001000** (0.0000469)	0.0000932** (0.00000468)	0.0000932** (0.0000469)
β_1		0.075199*** (0.024920)	0.075305** (0.025008)
β_2			-0.001072 (0.025008)

Malaysian Ringgit (MYR)

a	0.0000827* (0.0000495)	0.0000798 (0.0000496)	0.0000782 (0.0000497)
β_1		0.036888 (0.024922)	0.036562 (0.024950)
β_2			0.010354 (0.024950)

Thailand Baht (THB)

a	0.0000026 (0.0000576)	0.0000056 (0.0000551)	0.00000639 (0.000055)
β_1		-0.292620*** (0.023945)	-0.314308*** (0.025055)
β_2			-0.072853*** (0.025145)

Vietnamese Dong (VND)

a	0.0000284 (0.0000159)	0.0000371** (0.0000152)	0.0000393*** (0.0000152)
β_1		-0.300364*** (0.023460)	-0.320728*** (0.02455)
β_2			-0.068085*** (0.02455)

The Philippine Peso (PHP)

a	0.0000591 (0.0000315)	0.0000613* (0.0000315)	0.000062** (0.0000316)
β_1		-0.017546 (0.025055)	-0.018455 (0.025087)
β_2			0.001764 (0.025076)

Singaporean Dollar (SGD)

a	0.0000262 (0.0000288)	0.0000271* (0.0000291)	0.0000297 (0.0000294)
β_1		-0.028883 (0.023337)	-0.025947 (0.023567)
β_2			-0.031790 (0.023613)