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MODELLING THE VOLATILITY OF RUBBER PRICES IN ASEAN-3

Norlee Ramli[♣]
Universiti Kebangsaan Malaysia

Abu Hassan Shaari Md Noor
Universiti Kebangsaan Malaysia

Tamat Sarmidi
Universiti Kebangsaan Malaysia

Fathin Faizah Said
Universiti Kebangsaan Malaysia

Abdul Hafizh Mohd Azam
Universiti Kebangsaan Malaysia

ABSTRACT

Rubber industry has always been vulnerable to the price volatility of standard rubber, which subverts the benefits of rubber production to the local economy. The objectives of this article are to study the volatility of rubber prices and its causality in three countries of main rubber producer namely Malaysia, Thailand and Indonesia as well as synthetic rubber and crude oil. Univariate Generalized Autoregressive Conditional Heteroscedastic (GARCH)-Family models such as an ordinary GARCH, GARCH-M, EGARCH and TGARCH are applied to determine the best model for volatility evaluation. Granger causality test is performed to observe the short-run relationship amongst ASEAN-3. The results denote that conditional variance is determined by past innovation and past conditional variance (volatility). The significance of leverage effect with negative coefficient value shows the existence of asymmetric effect at the same magnitude for Malaysia rubber prices, synthetic rubber prices and crude oil prices. This study indicates the evidence of bidirectional short-run Granger causality using VAR between the prices where any shocks occur at one country will give some impacts to the other countries.

Keywords*:* Natural rubber price; Volatility; Univariate GARCH; Granger causality (VAR)

1. INTRODUCTION

Natural rubber is one of the very important raw materials in most industries in the world. In recent years, the global economy was found to improve gradually, the demand for natural rubber is increasing, and so is the price of natural rubber. Generally, there are two types of rubber namely natural rubber which is known as latex and synthetic rubber. Natural rubber is tapped from rubber

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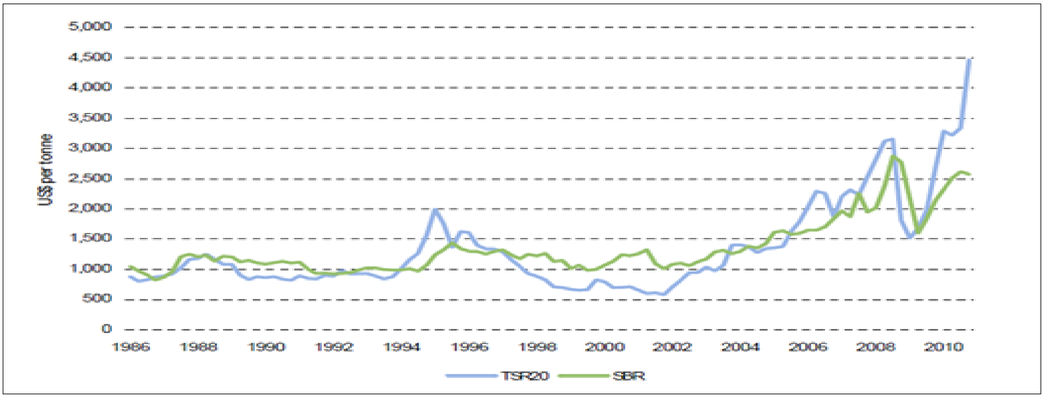
[♣] Corresponding Author: Norlee Ramli, Faculty of Economics and Management,Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia; Email; norlee.ukm@gmail.com Tel: 603-8921-3753; Fax: 603-8925-1821.

trees (average maturity is 4 years with an average lifespan of 25 years). Synthetic rubber is oil-based product whose price is largely influenced by the price of crude oil. The global economic situation has deeply affected the secular price trend and production of natural rubber. In addition, due to the growth of the synthetic rubber industry which acts as a substitute for natural rubber, synthetic rubber prices are also becoming increasingly important. When the supply of natural rubber is insufficient or when prices rise, producers tend to choose a type of synthetic rubber which is cheaper than natural rubber (Khin et.al 2013). Like natural rubber, synthetic rubber which is a petrochemical product also has a high volatility, in parallel with the volatility of crude oil prices. The decline in crude oil price causes synthetic rubber price to be cheaper and this in turn reduces the demand for natural rubber. On the contrary, when there is an increase in the price of crude oil, the price of synthetic rubber increases and consumers will switch to natural rubber, thus natural rubber is highly demanded. As such, it is interesting to study the causal relationship between the volatility of natural rubber prices, synthetic rubber price and crude oil price for better understanding on the trend and pattern occurred.

Based on the volume of trade, Indonesia, Thailand and Malaysia are the leading producer and exporter of natural rubber in the world. Total production of natural rubber in three countries is estimated about 8.37 million tons in 2015, representing nearly 68.23% of the total world production (Yanita et.al 2016).

The current use of the world for rubber amounted to around 18 million tonnes per year, consisting of 48% natural rubber (NR), 20% solids styrene butadiene rubber (SBR), 14% latex styrene butadiene (SB), 12% polybutadiene, 5% ethylene propylene diene monomer (EPDM), 2% polychloroprene, 2% nitrile and 7% other synthetic. Therefore, the natural rubber is still the largest share in terms of quantity by type of latex used (Jumpasut 2002). Demand for elastomers, both synthetic rubber (SR) and natural rubber also increased at a rate of 3-4% per year, in line with the improvement of living standards around the world. Global economic decline is affecting the demand of natural rubber, causing the market price is at its lowest level in 30 years (Ghazali et. al 2015).

Figure 1: Natural and Synthetic Rubber Prices (Comparison)



***Source*:** TSR20: SICOM, SBR: US export unit values, USITC

The fundamental factors affecting the price of natural rubber is demand and supply, while all other factors have indirect effects through changes in the fundamentals of demand and supply. In addition, the volatility of world crude oil prices will also affect the price of natural rubber in which the cause behind the fall in rubber prices is none other than crude oil (Kottayam, 2016). This is because crude oil prices affect the cost of production of various goods including synthetic rubber in which 95% of its production is based on crude oil. It is also likely due to global aggregate demand affect both the price of crude oil and synthetic rubber (Sussman & Zohar, 2015). Figure 1 shows the behavior of rubber price which is in parallel with synthetic rubber price for the last 22 years (1986-2010), whenever one price is high then the other price will be low.

The objectives of this article are to model and study the volatility of rubber prices in Asean-3 countries namely Malaysia, Indonesia and Thailand, as the main world rubber producers, synthetic rubber prices and crude oil prices between the periods of 2001 to 2016 using univariate Generalized Autoregressive Conditional Heteroscedastic (GARCH)-Family models. The causality relationship between volatility of natural rubber prices, synthetic rubber prices and crude oil prices are estimated using Vector Autoregressive (VAR) model. The proxies involve are Standard Malaysia Rubber 20 (SMR20), Standard Thailand Rubber 20 (STR20), Standard Indonesia Rubber 20 (SIR20), synthetic rubber (SR) and world crude oil (OILC).

The remaining contents of this article consist of literature review in section 2, methodology in section 3, results and discussion in section 4, conclusion in section 5 and finally the policy implication in section 6.

2. LITERATURE REVIEW

Engle (1982) had introduced the Autoregressive Conditional Heteroscedastic (ARCH) model to overcome the classical assumption on serial correlation, heteroscedasticity and normality. In the meantime, Bollerslev (1986) proposed a Generalized ARCH (GARCH) model, which is the improvement of ARCH model by allowing the conditional variance to be an Autoregressive Moving Average (ARMA) process. The Exponential GARCH (EGARCH) model was proposed by Nelson (1991) to take into account the asymmetric effect while threshold GARCH (TGARCH) was introduced by Zakoian (1994) to estimate the asymmetric effect in the market.

The general model autoregressive conditional heteroskedasticity (GARCH), developed by Engle (1982) and Bolleslev (1986), has proven to be a useful tool to explain empirically momentum in the conditional variance. In GARCH, there is constantly shock to the variance in accordance to structural autoregressive moving average (ARMA). GARCH (p, q) allow random disturbance conditional variance depends linearly on the square of the error term. In addition, the specification of GARCH (1,1) has proven to be a suitable model for time series data.

The study that estimates the volatility conditional, covariance and volatility correlation of future returns of rubber prices using Copula-based GARCH model with empirical results show that the volatility of the price of synthetic rubber is almost equal to the volatility of crude oil prices, indicating the relationship between the two variables (Liang and Yang 2013).

The trend of volatility in natural rubber price of Malaysia for RSS 1 (Ribbed Smoked Sheet Grade 1) and SMR 20 (Standard Malaysian Rubber Grade 20) was studied using EGARCH and GJR-GARCH models in order to capture the asymmetry (leverage effect) in the variance whereas both models generally did not support asymmetry in the pattern of volatility of both RSS 1 and SMR 20 (Isa & Jamil, 2004).

Another study is performed on the impact of world crude oil price on the supply, demand, stock, synthetic rubber and natural rubber (NR) prices (represented by SMR20) of the Malaysian NR industry using econometric system of equations. A preliminary data analysis focused on univariate properties of the data series for unit root. The Granger causality test is conducted to examine the direction and relationship between the variables. The Vector Error Correction Method (VECM) is used where the results indicate that crude oil price and the supply, demand, stock, synthetic and natural rubber (SMR20) prices are significantly co-integrated, which means that the long-term equilibrium between the variables are met (Khin et al. 2013).

3. METHODOLOGY

The univariate Generalized Autoregressive Conditional Heteroscedastic (GARCH)- models are applied namely GARCH(1,1), GARCH(1,1)-M, EGARCH(1,1), EGARCH(1,1)-M, TGARCH(1,1)and TGARCH(1,1)-M in order to model the price return of natural rubber prices (namely SMR20, STR20 and SIR20), synthetic rubber prices and crude oil prices with a period from February 2001 until October 2016 on weekly basis, which resulting in a total 4090 observations. The symmetric volatility of price return is determined using GARCH(1,1) and GARCH(1,1)-M. On the other hand, EGARCH, EGARCH(1,1)-M, TGARCH and TGARCH(1,1)-M models are used to measure the asymmetric volatility. The mean and variance equations involve in analysing the volatility, in which an Autoregressive Moving Average (ARMA) model for mean equation is used to capture the random walk of the estimated series whilst GARCH model is used for variance equation to estimate the volatility.

3.1. Symmetric GARCH models

3.1.1 The Generalized Autoregressive Conditional Heteroscedastic (GARCH) model

This model is extended from original Autoregressive Conditional Heteroscedastic (ARCH), say with a simple GARCH(1,1):

Mean equation $$rp_t = \mu + \phi_1 rp_{t-1} + \varepsilon_t \quad (1)$$

Variance equation $$\sigma^2_t = \omega + \alpha_1\varepsilon^2_{t-1} + \beta_1\sigma^2_{t-1} \quad (2)$$

where $\omega > 0$, $\alpha_1 \geq 0$, *and* $\beta_1 \geq 0$, and :
μ= average return
rp_t = return of the asset at time t
ε_t = residual return = $v_t\sqrt{h_t}$
σ^2_v =1 and
$$h_t = \theta_0 + \sum^{q}_{i=1} \theta_i\varepsilon^2_{t-i} + \sum^{p}_{i=1} \delta_i\, h_{t-I} \quad (3)$$
where σ^2_t stand for conditional variance.

The return is represented as a linear function of its own lag which is lag 1for mean equation. Variance equation is depending on previous news and previous volatility (own lag of conditional variance). The previous news known as the ARCH term is used to measure the clustering effect. On the other hand the past conditional variance known as GARCH term is used to determine the persistency of the volatility.

3.1.2. The Generalized Autoregressive Conditional Heteroscedastic-in-Mean (GARCH-M)[1]

The GARCH-M model is suitable to study on asset market which the return of security may depend on its volatility. This model allowed the conditional variance to be inside the mean equation where risk premium can be estimate. A simple model that can be defined properly is GARCH-M(1,1):

Mean equation : $rp_t = \mu + \o_1 rp_{t-1} + \lambda\sigma^2_t + \varepsilon_t$ (4)

Variance equation: $\sigma^2_t = \omega + \alpha_1\varepsilon^2_{t-1} + \beta_1\sigma^2_{t-1}$ (5)

The variance equation is same like previous ordinary GARCH model but the mean equation is different. The parameter λ is called the risk premium parameter where the positive value of the parameter indicates higher risk is associated with high return. Meanwhile, the significant of the parameter shows the compensation to investor if they take the risk in holding the asset.

3.2. Asymmetric GARCH model

3.2.1. The Exponential Generalized Autoregressive Conditional Heteroscedastic (EGARCH) Model

The leverage effect can be measured using an asymmetric GARCH model where bad news increases volatility rather than good news at the same magnitude.
Basic EGARCH(1,1) model is written as below:

Mean equation: $rp_t = \mu + \o_1 rp_{t-1} + \varepsilon_t$ (6)

Variance equation: $ln\sigma^2{}_t = \omega + \beta_1 ln\sigma^2{}_{t-1} + \alpha_1 \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma\,\frac{\varepsilon_{t-1}}{\sigma_{t-1}}$ (7)

where leverage parameter, γ is expected to be negative and significant where negative shock will have greater impact on volatility rather than positive shock.

3.2.2 The Threshold Generalized Autoregressive Conditional Heteroscedastic (TGARCH) Model

Zakoian (1994) has developed TGARCH model to estimate leverage effect with basic specification of TGARCH(1,1) is written as below:

Mean equation: $rp_t = \mu + \o_1 rp_{t-1} + \varepsilon_t$ (8)

Variance equation: $\sigma^2{}_t = \omega + \alpha_1\varepsilon^2{}_{t-1} + \beta_1\sigma^2{}_{t-1} + \gamma d_{t-1}\varepsilon^2{}_{t-1}$ (9)

where d_{t-1} = dummy variable:
d_{t-1}= 1, if ${\varepsilon^2}_{t-1}$ < 0, bad news
= 0, if ${\varepsilon^2}_{t-1}$ > 0, good news

where leverage effect parameter, γ is expected to be positive and significant which are different from EGARCH model.

3.3. Error distribution

3.3.1 Normal distribution

The Gaussian distribution which is the normal distribution is the most popular distribution used where the log-likelihood functions is written as below:

$$L_{normal} = -\, {}^{1}\!/_{2} \sum_{t=1}^{T} [\ln(2\pi) + \ln(\sigma_t^2) + z_t] \qquad (10)$$

where T = number of observations.

3.4. Data

The univariate GARCH models are estimated using weekly data on return prices of natural rubber namely Standard Malaysia Rubber 20 (SMR20), Standard Thailand Rubber 20 (STR20) and Standard Indonesia Rubber 20 (SIR20), synthetic rubber prices (SR) and crude oil prices (OILC) for the period February 2001 to October 2016 giving a total of 4090 observations. All data are obtained from Reuters, Malaysian Rubber Board (MRB) and Data Stream..
Weekly return prices, rp_t are calculated as below:

$$rp_t = [\log(close_t) - \log(close_{t-1})] \times 100 \qquad (11)$$

where;
$Close_t$ = closing price at the current time (t)
$Close_{t-1}$ = closing price at the previous day (t-1)

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistic of return series of SMR20, STR20, SIR20, SR and OILC

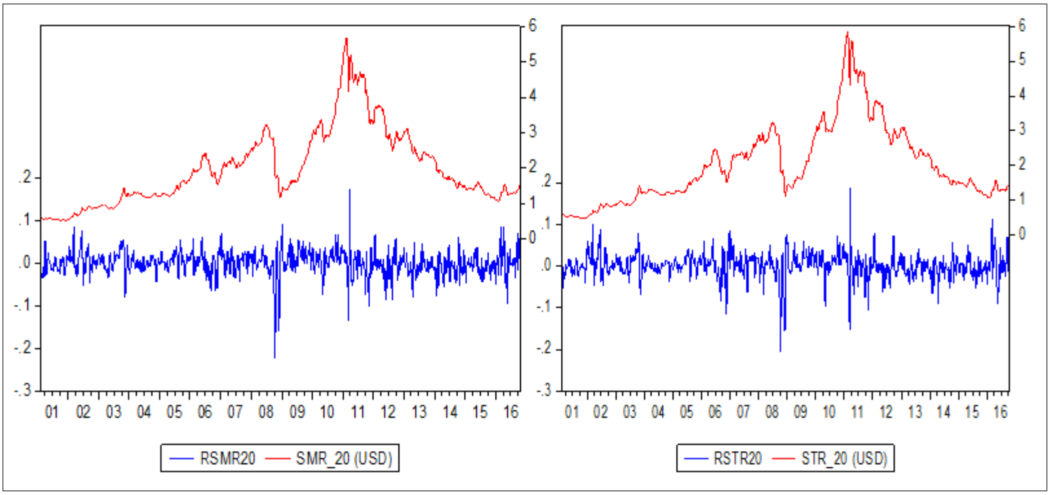
Descriptive Statistics provides useful information on estimated series such as values of mean, median, standard deviation, skewness, kurtosis and others. Description on series normality and clustered or dispersed data also can be gathered.

Table 1: Descriptive Statistics of Return Series of SMR20, STR20, SIR20, SR and OILC

	RSMR20	RSTR20	RSIR20	RSR	ROILC
Mean	0.0011	0.0011	0.0011	0.0014	0.0004
Median	0.0024	0.0012	0.0021	0.0000	0.0036
Maximum	0.1731	0.1880	0.1799	0.2564	0.1486
Minimum	-0.2232	-0.2037	-0.2340	-0.4232	-0.2305
Std. Dev.	0.0306	0.0309	0.0350	0.0540	0.04204
Skewness	-0.8996	-0.8140	-0.9232	-0.8624	-0.6591
Kurtosis	9.9580	10.3462	11.2683	11.3171	5.2671
Jarque-Bera	1760.4280	1929.6930	2446.2900	2459.0490	234.4082
Probability	0.0000	0.0000	0.0000	0.0000	0.0000

From table 1, mean value of all series is positive signifying a positive return series where small holders are still making a profit despite the uncertain price of natural rubber. The average return of Malaysia is slightly lower as compared to Indonesia and Thailand. Same goes to the maximum return where Thailand and Indonesia are slightly higher than Malaysia which is about 7.9% and 3.8% respectively. All series are negatively skewed distributions with high kurtosis (leptokurtic) identifying the return series are not normally distributed (according to statistical theory, normal distribution is whenever kurtosis value is 3 and skewness value is 0), and is strongly supported by rejection of null hypothesis for Jarque-Bera (probability values are less than 0.05).

Figure 2: Price and Return Series of SMR20, STR20, SIR20, SR and OILC
(Red Line represent the Price and Blue Line denote the Return)



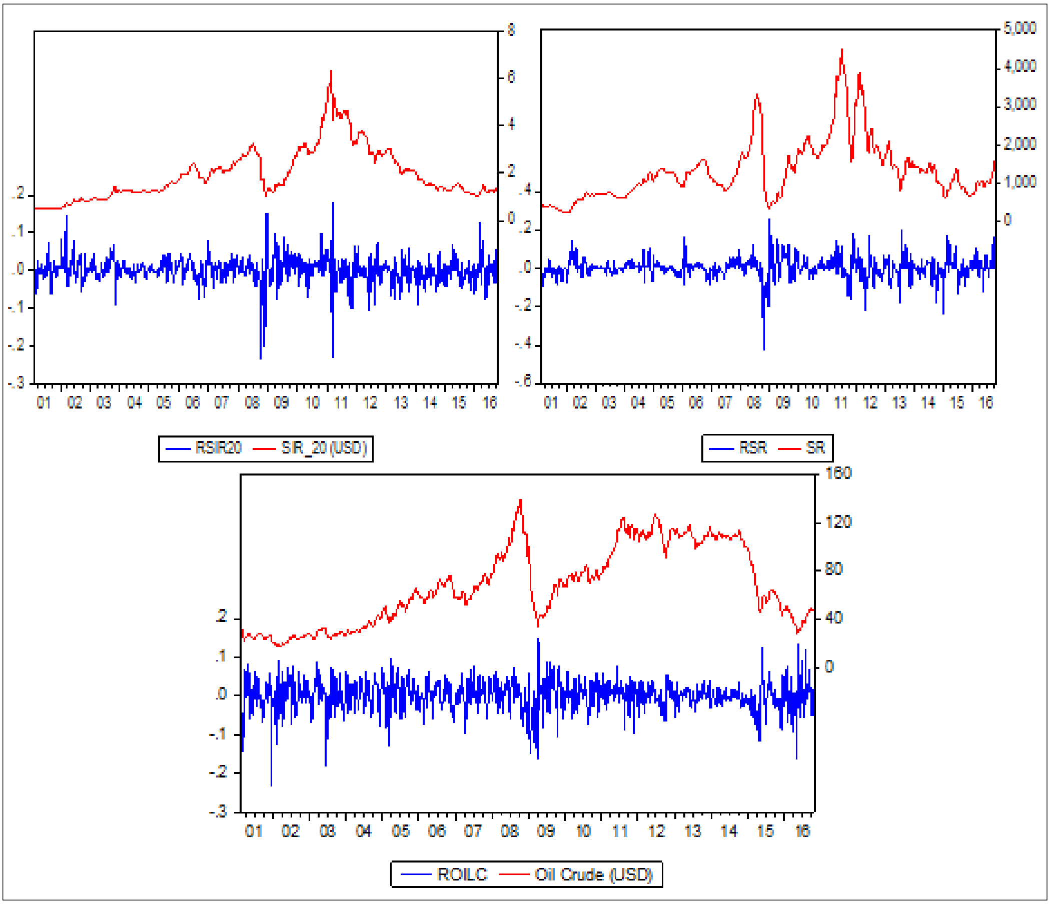
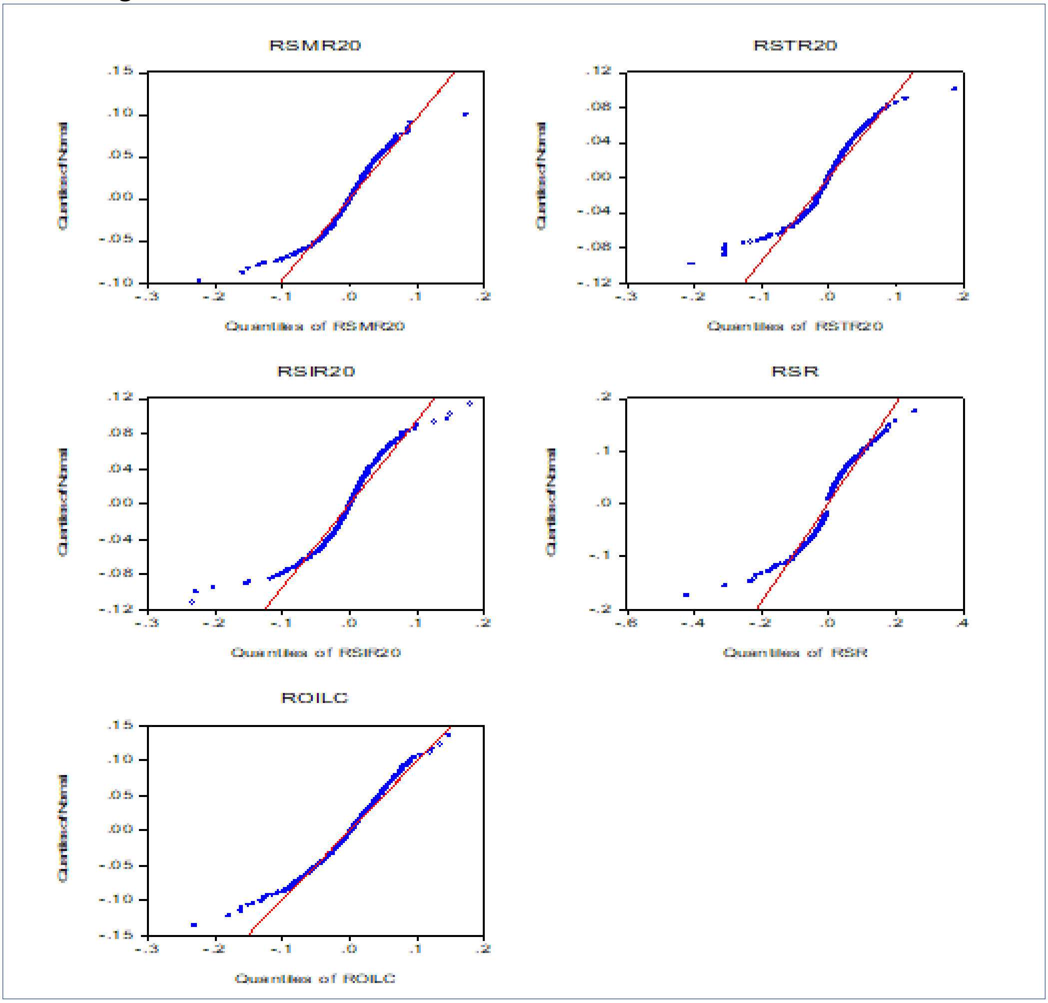


Figure 2 shows the graphical analysis of price and return series of SMR20, STR20, SIR20, SR and OILC where the existence of volatility clustering can clearly be seen. The dynamics of rubber prices in ASEAN-3 are also interesting as they throw some light on the correlation existence and rubber market pattern amongst countries region which are in contrast with synthetic rubber and crude oil prices. In 2008, when the crude oil price increased, the same goes to synthetic rubber price, whereas the rubber prices found to be plunged drastically in ASEAN-3. 2001 to 2008 exhibits a serenity period by the increasing trend of the prices before it started to crash in the middle of 2008 due to the global subprime crisis. As such, there exists leverage effect where the bad news increases volatility rather than good news at the same magnitude. Due to the shocks hitting the global market in 2011, the rubber prices reached the maximum price level ever with more than ten times higher than the lowest price level recorded in this research period. Whilst at the same time, the price of synthetic rubber was declined. Depending on the nature of the shocks hitting the global market, the trend of dynamics rubber prices is obviously affected.

4.2. Quantile-Quantile (Q-Q) Plots

Figure 3: Q-Q Plots of Return Series for SMR20, STR20, SIR20, SR and OILC



Data which is scattered along the red line of the Q-Q plot is said to follow normal distribution. From Figure 3, the graphs clearly shown the deviation of return series from the red line indicating that data are not normally distributed.

4.3. Unit-Root-Test

Table 2: Unit Root Test

Indeks	Siri	ADF		PP		KPSS	
		I	I & T	I	I & T	I	I & T
SMR20	Price	-1.8879	-1.6400	-1.7354	-1.4412	1.2146***	0.5456***
	Return	-18.0460***	-18.1186***	-17.9401***	-18.0295***	0.3193	0.0491
STR20	Price	-1.7066	-1.4057	-1.6970	-1.3883	1.2022***	0.5481***
	Return	-17.6721***	-17.7438***	-17.5498***	-17.6401***	0.3218	0.0492
SIR20	Price	-1.7179	-1.4414	-1.8585	-1.6165	1.1095***	0.5337***
	Return	-20.2458***	-20.3133***	-20.2087***	-20.3331***	0.3015	0.0474
SR	Price	-3.4712*	-3.679*	-2.9877*	-3.1490**	1.0127***	0.3991***
	Return	-12.6835***	-12.6798***	-16.3405***	-16.3321***	0.0368	0.0236
OILC	Price	-1.6582	-1.3134	-1.7847	-1.5769	1.8812***	0.4084***
	Return	-13.9446***	-13.9992***	-22.3664***	-22.3432***	0.1649	0.0670

***Note**:* *** indicates 1% significant level

Unit root test is to determine the stationarity level of the series. Table 2 shows unit root test of price and return series for SMR20, STR20, SIR20, SR and OILC. The order of integration of the series were tested using Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt_Shin (KPSS). Table 2 shows that series of price are not non-stationary whilst series of return are stationary at level. Hence Autoregressive Moving Average (ARMA) can be applied as return series fulfil the requirement of stationary at level.

4.4. Modelling the volatility of SMR20, STR20, SIR20, SR and OILC

Tables 3, 4 and 5 below show the estimation results of SMR20, STR20 and SIR20 return series using GARCH-Family models. From the tables, coefficient AR(1), **Ø** is found significant for all models, indicating current return is determine by its past value one period. On top of that, the significant of the AR term also shows the inefficiency of the rubber market since the return can be predicted by its previous value. This has been well documented in the efficient market theory by Fama (1970) through weak form hypothesis. Thus, its show that the rubber market is not efficient. Meanwhile the conditional variance is depending on past news about volatility and past one period before of volatility based on significant values gathered for ARCH term (α) and GARCH term (β). In addition, the summation of ARCH term and GARCH term ($\alpha + \beta$) measure the persistency of the volatility either it is an explosive process or reverting process. Almost all models have a summation value close to one, signifying the persistency of the volatility.

Table 3: SMR20 Estimation (Malaysia)

Coefficient	AR(1) GARCH(1,1)	AR(1) GARCH(1,1) -M	AR(1) EGARCH(1,1)	AR(1) EGARCH(1,1) -M	AR(1) TGARCH(1,1)	AR(1) TGARCH(1,1)-M
Mean Equation						
μ	0.0019	0.0021	0.0012	0.0023	0.0013	0.0013
Ø	0.4303***	0.4295***	0.4413***	0.4311***	0.4331***	0.4328***
λ	-	-0.4048	-	-2.9570	-	-0.0935
Variance Equation						
ω	0.0001***	0.0001***	-1.6112***	-1.5625***	0.0001***	0.0001***
α	0.2692***	0.2688***	0.4720***	0.4690***	0.1946***	0.1947***
β	0.5933***	0.5953***	0.8310***	0.8371***	0.5952***	0.5958***
ɣ	-	-	-0.0466*	-0.0441*	0.1138**	0.1135**
α + β	0.8625	0.8641	-	-	0.7897	0.7905
LL	1873.5910	1873.6010	1872.8240	1873.0470	1875.0250	1875.0260
AIC	-4.5687	-4.5663	-4.5644	-4.5625	-4.5697	-4.5673
SBC	-4.5399	-4.5317	-4.5298	-4.5222	-4.5352	-4.5270
s	-0.2571	-0.2572	-0.1991	-0.2058	-0.2290	-0.2290
k	4.1691	4.1748	4.1860	4.2301	4.1164	4.1169
Diagnostic Test						
Q (12)	0.056	0.0570	0.0560	0.0530	0.0760	0.0760
Q (24)	0.114	0.1150	0.1260	0.1220	0.1340	0.1350
ARCH (5)	0.5453	0.5353	0.4966	0.4366	0.5930	0.5901
ARCH (10)	0.182	0.1887	0.0925	0.1222	0.2034	0.2043

Note: ***, **, * denotes significant at 1%, 5% and 10%

Table 4: STR20 Estimation (Thailand)

Coefficient	AR(1) GARCH(1,1)	AR(1) GARCH(1,1) -M	AR(1) EGARCH(1,1)	AR(1) EGARCH(1,1) -M	AR(1) TGARCH(1,1)	AR(1) TGARCH(1,1)-M
Mean Equation						
μ	0.0022	0.0019	0.0018	0.0013	0.0017	0.0013
Ø	0.5106***	0.5109***	0.5032***	0.5021***	0.5126***	0.5149***
λ	-	1.4774	-	2.2401	-	1.6018

Coefficient	AR(1) GARCH(1,1)	AR(1) GARCH(1,1) -M	AR(1) EGARCH(1,1)	AR(1) EGARCH(1,1) -M	AR(1) TGARCH(1,1)	AR(1) TGARCH(1,1)- M
Variance Equation						
ω	0.0001***	0.0001***	-1.6914***	-1.7612***	0.0001***	0.0001***
α	0.3625***	0.3664***	0.5529***	0.5634***	0.3118***	0.3135***
β	0.5416***	0.5320***	0.828689***	0.8205***	0.5302***	0.5192***
ɣ	-	-	-0.036891	-0.0367	0.0920	0.0940
α + β	0.9041	0.8984	-	-	0.8420	0.8327
LL	1902.3990	1902.6270	1902.55	1902.8050	1902.9340	1903.1640
AIC	-4.6391	-4.6372	-4.637043	-4.6352	-4.6380	-4.6361
SBC	-4.6103	-4.6027	-4.602518	-4.5949	-4.6035	-4.5958
s	-0.2874	-0.2770	-0.239454	-0.2249	-0.2596	-0.2486
k	5.2716	5.2218	5.286423	5.1989	5.2387	5.1989
Diagnostic Test						
Q (12)	0.2760	0.2500	0.2190	0.1680	0.3130	0.2890
Q (24)	0.2690	0.2360	0.2430	0.1930	0.2680	0.2360
ARCH (5)	0.9421	0.9383	0.9225	0.8941	0.9662	0.9617
ARCH(10)	0.9618	0.9536	0.9456	0.9173	0.9638	0.9529

Note: ***, **, * denotes significant at 1%, 5% and 10%

Table 5: SIR20 Estimation (Indonesia)

Coefficient	AR(1) GARCH(1,1)	AR(1) GARCH(1,1) -M	AR(1) EGARCH(1,1)	AR(1) EGARCH(1,1) -M	AR(1) TGARCH(1,1)	AR(1) TGARCH(1,1)- M
Mean Equation						
μ	0.0017	0.0018	0.0020	0.0003	0.0017	0.0018
Ø	0.3918***	0.3916***	0.3899***	0.3948***	0.3918***	0.3917***
λ	-	-0.1418	-	1.1089	-	-0.1152
Variance Equation						
ω	0.0002***	0.0002***	-1.6155***	-1.6571***	0.0002***	0.0002***
α	0.2785***	0.2782***	0.4530***	0.4603***	0.2835***	0.2830***
β	0.5631***	0.5635***	0.8188***	0.8137***	0.5631***	0.5634***
ɣ	-	-	-0.0164	-0.0207	-0.0079	-0.0075
α + β	0.8416	0.8417	-	-	0.8466	0.8464
LL	1746.2670	1746.2690	1745.2050	1745.2430	1746.2730	1746.2740
AIC	-4.2574	-4.2549	-4.2523	-4.2500	-4.2549	-4.2525

Coefficient	AR(1) GARCH(1,1)	AR(1) GARCH(1,1) -M	AR(1) EGARCH(1,1)	AR(1) EGARCH(1,1) -M	AR(1) TGARCH(1,1)	AR(1) TGARCH(1,1)-M
SBC	-4.2286	-4.2204	-4.2178	-4.2097	-4.2204	-4.2122
s	-0.1225	-0.1231	-0.1052	-0.1179	-0.1267	-0.1270
k	5.4106	5.4128	5.7143	5.6867	5.4108	5.4126
			Diagnostic Test			
Q (12)	0.4680	0.4730	0.4100	0.3790	0.4670	0.4710
Q (24)	0.2920	0.2940	0.2690	0.2560	0.2920	0.2940
ARCH (5)	0.4677	0.4632	0.4571	0.4866	0.4711	0.4672
ARCH (10)	0.3755	0.3743	0.2067	0.215	0.3819	0.3806

Note: ***, **, * denotes significant at 1%, 5% and 10%

GARCH(1,1)-M known as GARCH-in-Mean allows the conditional variance in the mean equation and, is applied to measure the risk premium where it is normally used for estimation the stock market or any financial data. Normally positive value of risk premium indicates that higher risk is associated with higher return and negative value of the risk premium parameter denotes higher risk is associated with lower return.

Exponential GARCH or EGARCH (1,1) model is used in this analysis as to determine the existence of leverage effect measured by the gamma (γ) coefficient. Asymmetric effect is therefore exists when the value of (γ) coefficient found to be significant. As for the negative value of the coefficient is an indication of bad news increases volatility for next period rather than good news at the same magnitude. The Empirical results show that value of γ found to be significant and negative in the case of SMR20 (-0.04655), SR (-0.052196) and OILC (-0.069865) but not significant for STR20 and SIR20. Therefore SMR20, SR and OILC exhibit leverage effect since the results gathered indicate the negative and significant of the leverage parameter.

Threshold GARCH known as (TGARCH) is another GARCH model that is used to estimate an asymmetric effect. However the value of γ is expected to be positive to indicate the presence of leverage effect which contradicting from the previous EGARCH model. As before, the empirical results show that value of γ found to be significant and positive in the case of SMR20 (0.113809), SR (0.090258) and OILC (0.06878) indicating the presence of leverage effect. However there is no leverage effect in the case of STR20 and SIR20 as γ coefficient value is not significant.

Table 6: Best Model Estimation for SMR20, STR20, SIR20, SR and OILC

	SMR20	**STR20**	**SIR20**	**SR**	**OILC**
Coefficient	**AR(1) TGARCH (1,1)**	**AR(1) GARCH(1,1)**	**AR(1) GARCH (1,1)**	**AR(1) EGARCH (1,1)**	**AR(1) EGARCH(1,1)-M**
Mean Equation					
μ	0.0013	0.0022	0.0017	0.0018	-0.0034
Ø	0.4331***	0.5106***	0.3918***	0.4830***	0.2881***
λ	-	-	-	-	2.5151
Variance Equation					
ω	0.0001***	0.0001***	0.0002***	-0.5810***	-0.3015***
α	0.1946***	0.3625***	0.2785***	0.3401***	0.1514***
β	0.5952***	0.5416***	0.5631***	0.3401***	0.9722***
ɣ	0.1138**	-	-	-0.0522***	-0.0699***
α + β	0.7897	0.9041	0.8416	0.6802	1.123502
LL	1875.0250	1902.3990	1746.2670	1479.0350	1534.8750
AIC	-4.5697	-4.6391	-4.2574	-3.6016	-3.7356
SBC	-4.5352	-4.6104	-4.2286	-3.5670	-3.6954
s	-0.2290	-0.2874	-0.1225	-0.0202	-0.6270
k	4.1164	5.2716	5.4106	6.8615	5.0169
Diagnostic Test					
Q (12)	0.0760	0.2760	0.4680	0.1120	0.3740
Q (24)	0.1340	0.2690	0.2920	0.3640	0.4320
ARCH (5)	0.5930	0.9421	0.4677	0.5045	0.9521
ARCH (10)	0.2034	0.9618	0.3755	0.4027	0.8643

Note: ***, **, * denotes significant at 1%, 5% and 10%

Table 6 shows the overall results of the best model from four different univariate GARCH-family models for each return series. Based on the values of AIC, SBC and LL, besides of significant values on certain parameters, the best model for each return series is selected. AR(1) TGARCH(1,1) is the best model for SMR20 while AR(1) GARCH(1,1) model for STR20 and AR(1) GARCH(1,1) model is for SIR20. As for SR return series, the best model is AR(1) EGARCH(1,1) and AR(1) EGARCH(1,1)-M found to be the best model for OILC return series.

4.5. Volatility Profile

Figure 4: Volatility Profile of SMR20, STR20, SIR20, SR and OIL

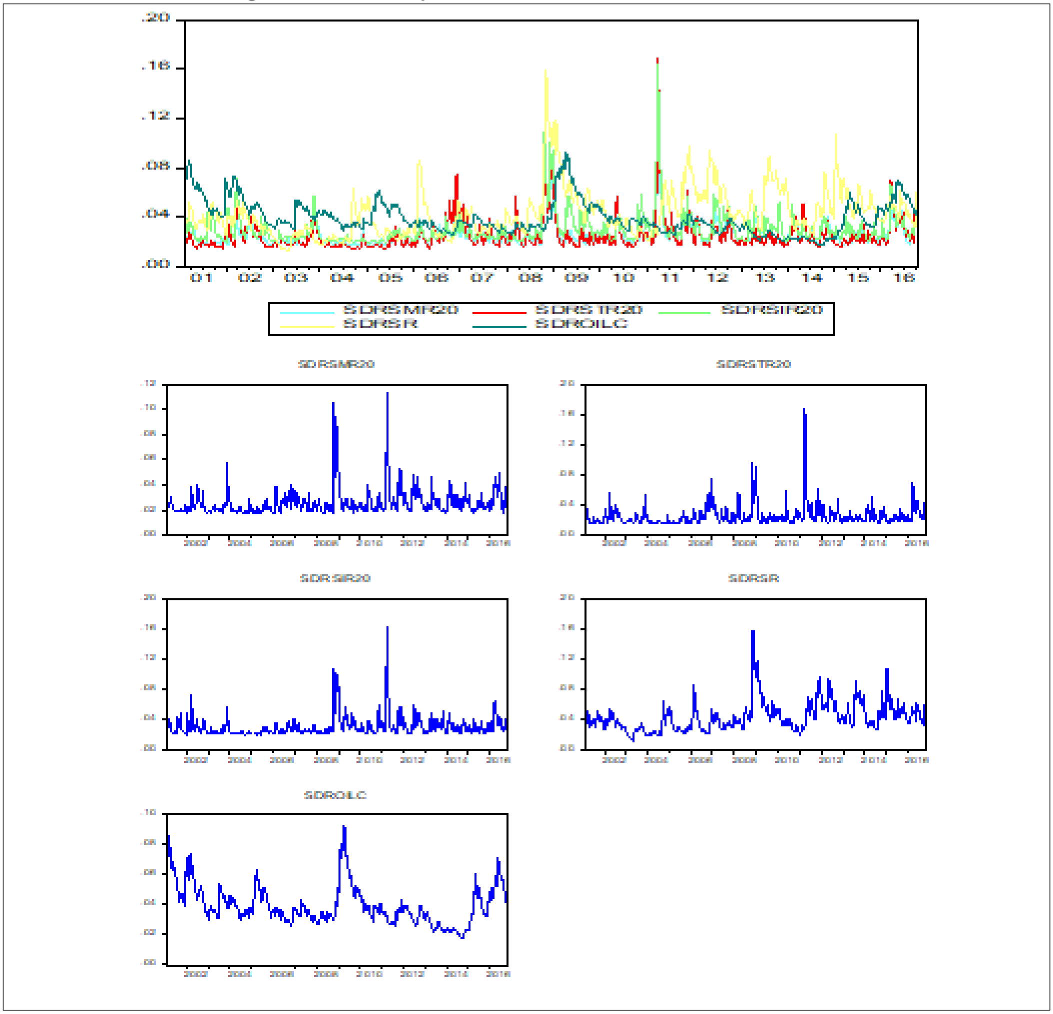


Figure 4 shows the volatility profile of return series for SMR20, STR20, SIR20, SR and OILC in multiple and single graphs. Period with high volatile market can be determined through Volatility profile. Spill over effect from United States during the global financial crisis in 2007 to 2008 can be seen from the graphs where prices are highly volatile for all countries.

4.6. Granger Causality

Unit root test need to be performed as to determine the stationary of volatility series. Monthly volatility series are used as to prevent bias and inconsistency estimation by averaging the daily data series.

Table 7: Unit Root Test of Volatility Series

SERIES	LEVEL	
	ADF	PP
VOLSMR20	-6.9992***	-6.7051***
VOLSTR20	-7.0377***	-7.0907***
VOLSIR	-7.2785***	-7.1665***
VOLSR	-4.2783***	-4.4168***
VOLOILC	-4.8838***	-3.4544**

Note**:** ***, **denote significant at 1% and 5%.

Table 7 shows that all series are integrated of order or I(0) where null hypothesis of non-stationary series is rejected at 1% significant level.

Table 8: Granger Causality of SMR20, STR20, SIR20, SR and OILC

Dependent Variable	**VOLSMR20**	**VOLSTR20**	**VOLSIR20**	**VOLSR**	**VOLOILC**
VOLSMR20	-	6.5531**	14.418***	3.1298	2.5652
VOLSTR20	2.8170	-	30.6004***	0.2554	3.0119
VOLSIR20	1.3047	6.9964**	-	3.3253	0.5796
VOLSR	2.8222	1.9333	5.3342*	-	4.6215*
VOLOILC	0.0213	4.4875	8.6561**	8.9703**	-

Note**:** ***, **, * denote significant at 1%, 5% and 10%.

Table 8 shows the Granger short-run causality between the volatility series of SMR20, STR20, SIR20, SR and OILC where lag 7 is used for running the analysis (chosen by 2 out of 5selection criteria). The empirical results show the existence of bidirectional causality between volatility of Standard Thailand Rubber price(STR20) (VOLSTR20) and Standard Indonesia Rubber price(SIR20) (VOLSIR20) and between volatility of crude oil price(OILC) (VOLOILC) and synthetic rubber price(SR) (VOLSR). VOLSTR20 found to granger cause VOSIR20 at 1% significant level while VOLSIR20 found to granger cause VOLSTR20 at 5% significant level. This indicates that both series contain information on each other which may help to forecast future uncertainty. On top of that, there are little evidence of VOLSR to granger cause VOLOILC while there is enough evidence on the other side. It is interesting to note that volatility of Standard Malaysian Rubber (VOLSMR20) Granger cause VOLSTR20 and VOLSIR20 but the converse is not true. This imply that, any shocks from Malaysian rubber market will give some impacts to Thailand and Indonesian rubber market volatility but anything happened from those markets did not influence the volatility of Malaysian rubber market.

5. CONCLUSION

This article studies the volatility of return price of Standard Malaysia Rubber (SMR20), Standard Thailand Rubber (STR20), Standard Indonesia Rubber (SIR20), synthetic rubber and crude oil using univariate Generalized Autoregressive Conditional Heteroscedastic (GARCH)-family model for the period of February 2001 to October 2016. The functional coefficient autoregression of order p (AR(p)) with the conditional variance specified as a general nonlinear first order generalized autoregressive conditional heteroskedasticity (GARCH(1,1)) model is applied. Six different GARCH models were applied in this study namely Generalized Autoregressive Conditional Heteroscedastic (GARCH(1,1)) and Generalized Autoregressive Conditional Heteroscedastic-in-Mean (GARCH(1,1)-M) which are an ordinary or symmetric GARCH, an asymmetric Exponential Generalized Autoregressive Conditional Heteroscedastic (EGARCH(1,1)), Exponential Generalized Autoregressive Conditional Heteroscedastic-in-Mean (EGARCH(1,1)-M), Threshold Generalized Autoregressive Conditional Heteroscedastic (TGARCH(1,1)) and Threshold Generalized Autoregressive Conditional Heteroscedastic-in-Mean (TGARCH(1,1)-M) which are used to measure the leverage effect. Modelling the volatility is best handled using GARCH model as heteroscedasticity problem can be prevented. Furthermore, significant of the ARCH term (α) and the GARCH term (β) values signify that future volatility is depending on its past innovation and past volatility and summation of both terms, ($\alpha + \beta$) indicates the persistency of the volatility. The higher is the persistency, the longer it takes to die-off. However, from the results gathered, return series of Thailand and Indonesia indicate the absence of leverage effect as ɣ is not significant. The empirical evidence shows that the best volatility model of SMR20 is presented by AR(1) TGARCH(1,1), while STR20 best model is AR(1) GARCH(1,1) and AR(1) GARCH(1,1) for SIR20. As for SR, AR(1) EGARCH(1,1) found to be the best volatility model and OILC is presented by AR(1) EGARCH(1,1)-M model. The dynamics of rubber prices in ASEAN-3 can obviously be observed where the trend is very much affected by the global shocks occurred in the market. There are also an evidence of the existence of bidirectional and single directional Granger causality between the series of volatility. The results gathered show that the volatility of Standard Malaysian Rubber (VOLSMR20) Granger cause VOLSTR20 and VOLSIR20 but the converse is not true The research indicates that the three main world rubber producers are associated to each other where any shocks from Malaysian rubber market will give some impacts to Thailand and Indonesian rubber market volatility. Therefore, it is very crucial for the three countries to cooperate together to establish the best policy to cater for any consequences occurred due to high volatility of rubber prices.

6. POLICY IMPLICATION

The natural rubber industry plays an important role in the formation of the country's economy for Malaysia, Thailand and Indonesia. It is noted that ASEAN-3 has a close ties between them which may be caused by factors such as the geographical environment as well as the same weather, cultural and political systems, and so on. Hence, this close relationship has the potential to be exposed to the transmission risk of volatility in markets within the context of the ASEAN region itself. This can be seen in the wake of the global financial crisis which has been the same as dragging the economy of the ASEAN region in the worst-hit crisis. The situation is exacerbated by the close relationship between the natural rubber market as close ties create a catalyst medium for the risk-spreading process or massive volatility spillover in a large scale and in a short time of period (Mori 2015). In line with the regression findings that found significant correlation to transmission of shocks, it is particularly important for the ASEAN-3 countries to create a comprehensive policy to offset the natural rubber price market that has undergone a change as the response to the shocks received. It is therefore very crucial for these three countries to establish certain policies in regulating the stability of the natural rubber industry, particularly in the ASEAN region.

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