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Volatility Spillover Effects In Asean-5 Stock Market: Does The Different Oil Price Era Change The Pattern?

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Abstrak

Penelitian ini bertujuan untuk mengetahui pola transmisi volatilitas di pasar saham negara-negara ASEAN-5 (Indonesia, Malaysia, Thailand, Singapura dan Filipina) dengan menggunakan goncangan makro (diproksikan oleh harga minyak-Brent); hubungan antar pasar keuangan (diproksikan oleh Indeks Dow Jones) dan kondisi fundamental suatu negara (diproksikan oleh nilai tukar) sebagai sumber volatilitas. Penelitian ini mengaplikasikan model VAR dan Model Asimetris GARCH (1,1)-BEKK menggunakan data harian pasar saham dan nilai tukar di negara-negara ASEAN-5; harga minyak dunia (Brent) dan Dow Jones Industrial Average Index dalam rentang 4 Januari 2012 hingga 30 Juni 2017. Hasil penelitian menunjukkan bahwa seluruh variabel independen memiliki transmisi volatilitas yang signifikan terhadap pasar saham di negara–negara ASEAN-5. Selanjutnya, untuk melihat apakah terdapat perbedaan pola transmisi volatilitas, kami membagi data menjadi dua periode yakni era "*High-Oil Price*" dan era "*Low-Oil Price*". Selain memperlihatkan perbedaan tingkat volatilitas, kami juga menemukan perbedaan pola transmisi volatilitas pada pasar saham Malaysia (KLCI); pasar saham Thailand (SETI) dan pasar saham Filipina (PSEI) diantara kedua era tersebut.

Abstract

The aim of this study is to identify the pattern of volatility transmission in ASEAN-5 (Indonesia, Malaysia, Thailand, Singapore and the Philippines) stock market by examine Global Macro Shocks (Brent oil price as a proxy); Cross-Market Linkages (Dow Jones Index as a proxy); and Economic Fundamental (exchange rate as a proxy) as the sources of volatility. This paper utilizing VAR and asymmetric GARCH (1,1)-BEKK model using the daily data of each ASEAN-5 stock market and exchange rate; Brent Oil price and Dow Jones Industrial Average Index between 4 January 2012 and 30 June 2017. The result shows that all independent variables have a significant volatility transmission to every ASEAN-5 stock market. Then in order to capture the different volatility transmission pattern, we divided the data into two periods which are "High-Oil Price" era and "Low-Oil Price" era. Besides the different rate of volatility, we also find a different pattern of volatility transmission at Malaysia stock market (KLCI); Thailand stock market (SETI); and at Philippines stock market (PSEI) between these two eras.[*]

1. INTRODUCTION

Over the past few decades, the analyses of stock market volatility always become an interesting subject for all economic agents, from researchers, investors, and regulators. modeling of volatility provides substantial information on the risk patterns involved in investment, and transaction processes (Mallikarjunappa and Afsal, 2008), it provides an opportunity to get some capital gain (Kartika, 2010), and minimizing the capital risk (Purbawati and Dana, 2016). Aside, stock market volatility reflects a country's fundamental volatility (Diebold and Yilmaz, 2010).

After numerous shocks, and financial crises happened, researchers have tried to connect the linkages, and interdependence between macroeconomic variables, and financial sectors. Thus, the analyses of volatility in the stock market are not only depending on stocks or financial assets, but the analyses should be interconnected to other aspects, particularly oil as one of the most important commodities. On many occasions, we witness how shocks in oil price are mostly followed by shocks in stock price. Looking back in 2014, when oil price slumped to almost 20 US dollars per barrel, the market was shaken, and the world economy was going to the recession. Therefore, it will be beneficial if we try to understand the relationship and the pattern in these variables.

The stock price can be affected by the changes in oil price through several channels. Hamilton (1983); Jones Leiby and Paik (2004) argue that the oil price changes may influence the supply-side effect by investment costs, and the availability of basic production input, in terms of trade, and wealth transfer from oil importers countries to oil exporter countries, on firms production structures, and unemployment, on monetary policies, on interest rates, and inflation, on consumption opportunities, and the demand-side effect through costs, and confidence along with demand from consumers.

And since oil price has a significant role in the global economy, numerous studies have attempted to figure out the impact of oil price on stock returns. Jones and Kaul (1996) study, found the impact of oil price cause larger changes in stock price returns on the United States, and Japan. Then, Filis et al. (2011) found the oil price shocks had a negative effect in oil-exporting (Canada, Mexico, and Brazil), and the oil-importing stock market (USA, Germany, and the Netherlands), although there is no difference time-varying correlation among these two countries group. Hossenidoust et al. (2013) found the positive impact of oil price on the mean equation of the ASEAN-5 stock market index, and the author also found the volatility of the gold market only has a significant effect on the volatility of Malaysia, and Singapore stock markets. Mohaddes and Pesaran (2016) found a stable negative relationship between oil price, and equity price from 1946 to 2016 in 27 different countries, except in 2008, and 2016 when researchers found a positive relationship between oil, and equity price (at lower oil price sub-era).

Then since the financial liberalization has risen around the globe, financial market movement is not only dependent on itself. It Started by Liu (2007) who found the greater reaction of asymmetries in returns of the ASEAN stock markets to the US downturns rather than the Chinese shocks market in all ASEAN markets. Then, Sok-Gee and Karim (2010) found the stock market returns, and volatility in the ASEAN 5 are mostly influenced by the stock market in the United States relative to the Japanese. Balcilar et al. (2015) also found greater effects of causality in return, and volatility from the U.S. rather than Japan on the Pacific-Rim stock markets. Tuan et al. (2015), found in the short run, there is no volatility spillover from Indian economic activities to ASEAN-5 stock markets. But there is volatility spillover from stock markets of Indonesia, and Singapore to Indian economic activities. Lee and Goh (2016) found the U.S. market is the main source of the mean spillover effects for the ASEAN-5 stock market. Then, the Authors also found the ASEAN market tends to react more strongly towards unfavorable U.S. market news.

Dornbusch and Claesens (2000) bring to mind that dependencies among countries (or cross-market) stock price movement is not the only way to estimate spillover volatility. Authors defined that local (fundamental) economic condition and global shocks help predict the spillover. Engle and West (2003) stated one thing that reflects the fundamental condition is

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exchange rate, just because the exchange rate is influenced by other fundamental variables, such as relative money supplies, outputs, inflation rates, and interest rates. Reaffirmed by Sarno and Schmeling (2014), they found that exchange rates have strong, and significant predictive power for future macro fundamentals.

Arifin and Syahruddin (2011) found evidence that the exchange rate (local currency per unit of US dollar) fluctuations have strong influence on the volatility of the stock market in ASEAN-5 countries. Then, Jebran and Iqbal (2016) also found bidirectional asymmetric volatility spillover between the stock market, and the foreign exchange market of Pakistan, China, Hong Kong, and Sri Lanka. Conversely, Konstantina (2014) found there is no volatility spillover between the stock and foreign exchange markets in Canada, and the United Kingdom.

Based on the results, and contradictions on the kinds of literature, we try to examine whether the volatility spillover does exist in ASEAN-5 (Singapore, Indonesia, Thailand, Malaysia, and Philippines) stock market. Furthermore, we want to validate a further relationship between shocks in oil price, world stock market, foreign exchange rates, and stock price, on different oil price eras which are "High-Oil Price", and "Low-Oil Price".

By looking at the source of volatility spillover into the stock market in ASEAN-5, authors brought two main questions into this paper;

1. What is the main determinant of volatility spillover in each stock market in the ASEAN-5 countries?
2. Does the difference of the oil price era change the pattern of volatility spillover in the ASEAN-5 stock market?

The importance of carrying out this study is the results can be useful for the investor (private), policymaker (regulator), also researchers. The Investor can use the results as a rationale to take any action to maximize return or to minimize the risk of the portfolio in the ASEAN-5 stock market. Subsequently, regulator can use the results of this study as a policy-based regulatory to take a preventive, and proactive economic policy among the different eras of oil prices in the future, especially in terms of financial and economic stabilization. Lastly, the authors hope this study can contribute as a part of volatility research in ASEAN-5 stock market studies, and can be enhanced by the other researcher in the future.

2. LITERATURE REVIEW

The liberalization process has led the financial market integration, and linkages developing from time to time (Saadah, 2013). This phenomenon contributed to propagate numerous financial contagions, stock market crashes, and financial crises that happened over the last decades. Therefore, it would be so important if we carry out to study and to connect the relationship between global macro shocks, fundamental economic, and stock market through the volatility spillover. Then, based on contagion issues, Dornbusch and Claesens (2000) define that the source of the risk of spillover could become from global macro shocks, cross-market linkages (or dependencies among countries), and economic fundamentals. Therefore, the authors divide the literature review according to the channel of volatility spillover studied.

2.1. Global Macro Shocks Volatility (Between Oil Price, and Stock Market)

Ono (2011) used the VAR model to examine the impact of oil prices on real stock returns for BRIC (Brazil, Russia, India, and China) over January 1999 through September 2010. The author found real stock returns positively responded to the oil price indicators, with statistical significance for China, India, and Russia, otherwise Brazil did not show any significant response.

Hossenidoust et al. (2013) employed the EGARCH, and MEGARCH model to examine the spillover effect of oil, and gold volatility on ASEAN-5 stock returns volatility over the 2000 to 2013 era. The author found the positive, and significant impact of oil price on the mean equation of all stock market index, but invariance equation oil price only significant for the case of Malaysia, and Singapore. Then, the author also found the volatility of the gold market only had a significant effect on the volatility of Malaysia, and Singapore stock markets.

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Hersugondo et al. (2015) used GARCH(1,1) model to examine the effects of world oil price (WTI) changes on the stock market returns in Southeast Asia. The author used monthly data between January 2003 to December 2013 and found the positive significant volatility spillover effect of WTI to Malaysia capital market (KLCI), and Thailand capital market (SET), but the author had not found a significant effect of world oil price change to the Indonesia stock market (JKSE) return. While Rahmanto et al. (2016) investigated the short-term response of Indonesian sector stock indices to crude oil price changes on 6 August 2007 to 19 October 2015. By using linear, and asymmetric models, the authors found the significant short-term relationship between the changes of world crude oil price and rate of return for all sectors in JKSE.

2.2 Cross-market linkages volatility (between stock market, and another stock market)

Sok-Gee and Karim (2010) examined volatility spillovers among the ASEAN-5 stock market with the United States stock market (S&P500), and Japan stock market (Nikkei-225) between 1 March 1999, and 31 December 2007. The authors employed the EGARCH model and found the stock market returns are highly dependent on their past returns. Besides, stock market returns and volatility in the ASEAN 5 are more influenced by the stock market in the United States relative to the Japanese.

Balcilar et al. (2015), adopted a non-parametric quantile causality approach to examine the causal effects of the U.S., and Japan stock markets on the stock markets of the Pacific-Rim region. The author used daily data between 6 June 1989, and 25 June 2014. They found significant evidence of causality in return, and volatility at different points of the conditional distributions of returns, with the greater effects from the U.S. than from Japan.

Lee and Goh (2016) examined the linkages among the ASEAN-5 stock exchanges, and their relationship with the Hong Kong, and U.S. markets by using the multivariate GARCH approach for the Pre-Crisis Era (between 2 January 2002, and 15 August 2007), Crisis Era (between 29 September 2008, and 17 February 2009), and Post-Crisis Era (between 7 May 2009, and 29 December 2011). The authors found The U.S. market is the main source of the mean spillover effects. Although the past-volatility and past-shock spillover effects from the Hong Kong market are larger, while the ASEAN markets tend to react stronger towards unfavorable U.S. market news.

Joshi (2011) examined the return, and volatility spillover among Asian stock markets in India (BSE), Hongkong (Hang Seng), Japan (N225), China (SSE), Jakarta (JKSE), and Korea (KS11) used GARCH-BEKK model during 2 February 2007 to 29 February 2010. The author found bidirectional volatility linkages between BSE, and Hang Seng, N225, JKSE, and KS11; between Hang Seng with N225, JKSE, and KS11; between N225 with SSE, JKSE, and KS11; between SSE with JKSE, and KS11; and between JKSE, and KS11. The author also found unidirectional volatility spillover from Hang Seng to SSE, and from SSE to BSE.

2.3 Economic fundamental volatility (between exchange rate, and stock market)

Arifin and Syahruddin (2011) used daily data (between 1 July 1997, and 26 April 2010), and consider the bivariate VAR(1)-GARCH(1,1) model with BEKK representation to examine the spillover effect between equity market (stock market index), and currency market (local currency per unit of US Dollar) in ASEAN-5. The authors consider to divide the era of observation into three sub era, which is the Asian Crisis era, the Subprime Crisis era, and the Non-Crisis era. The author found evidence that the currency fluctuation in ASEAN-5 countries during the crisis strongly affects the volatility of the stock market in the economy, except for Singapore during the subprime crisis era.

Valls and Chulia (2014) applied bivariate VAR-GARCH using the BEKK model to analyze the volatility transmission between stock, and currency market in the ten Asian countries (Japan, China, Hongkong South Korea, Singapore, Taiwan, Philippines, Indonesia, Malaysia, and Thailand). The author found the volatility spillover from the currency market to the stock market at all economies considered, except for China (since they adopted the peg currency exchange rate)., and by divide the sample era into two sub-sample era, which is Before global financial crisis (1 January 2003 to 14 August 2007), and After global financial crisis (15 August

2007 to 31 January 2014), the author found the impact of the financial crisis change the pattern of behavior in the stock market only at Hongkong, Philippines, and Malaysia.

Konstantina (2014) used the BEKK-GARCH model to estimate volatility transmission between the stock market indices, and the currency price of Canada, and the United Kingdom respectively. By using weekly data between January 1990, and December 2013, the author found no volatility spillovers between the stock and forex market.

Yu and Liao (2017) examined volatility spillover effects between stock returns, the exchange rate of returns, and money rate in China. The author considered daily data from 22 July 2005 to 11 July 2016. The authors utilized the VAR model and asymmetric GARCH(1,1)-BEKK model, and found unidirectional mean spillover effect from the currency market, and the stock market, then the authors found bidirectional mean spillover effect between stock market, and money market, also between currency market, and money market.

3. DATA, and METHODOLOGY

The empirical data use for present study consists of:

Group	Symbol	Description	Unit	Source
Control	BRENT	Brent Spot oil price	USD Per Barrel	EIA
	DJIA	Dow Jones Industrial Average	Index	Investing
Indonesia	IDR	Indonesia Exchange Rate (Rupiah)	USD/IDR	Investing
	JKSE	Jakarta Stock Exchange Composite Index	Index	
Malaysia	MYR	Malaysia Exchange Rate (Ringgit)	USD/MYR	Investing
	KLCI	FTSE Kuala Lumpur Composite Index	Index	
Thailand	THB	Thailand Exchange Rate (Baht)	USD/THB	Investing
	SETI	SET Index	Index	
Singapore	SGD	Singapore Exchange Rate (Dollar)	USD/SGD	Investing
	SGXI	Straits Times Index - Singapore	Index	
Philippines	PHP	Philippines Exchange Rate (Peso)	USD/PHP	Investing
	PSEI	Philippines Stock Exchange Composite Index	Index	

We use daily data, from January 2nd, 2012 to June 30th, 2017, with a total of 1402 observations. Along with the era, we also divide the series into two eras, which are "*High-Oil Price*" era (between January 2nd, 2012, and December 5th, 2014), and "*Low-Oil Price*" era (between December 8th, 2014, and June 30th, 2017). These dates are chosen to capture different economic moments (especially oil prices), whereas the "*High-Oil Price*" era reflects the period when BRENT is above USD 68 per barrel, and the "*Low-Oil Price*" era reflects the period when BRENT is below USD 68 per barrel. The threshold of oil price at USD 68 per barrel is the breakeven of external oil prices from Saudi Arabia between 2012 and 2016.

3.1 Descriptive Statistics

The analysis of the present study transformed data into the return (continuously compounded return) form of the series. Table 1, and figure 1 (below) shows the behavior of the series, and returns of each series for each era's ("*Full Sample*", "*High-Oil Price*", and "*Low-Oil Price*") of observation.

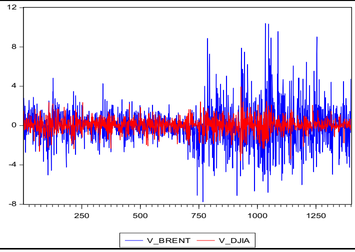
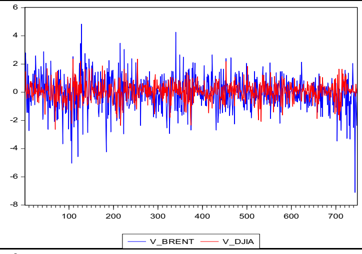
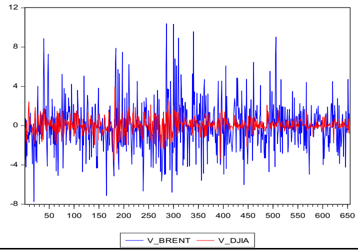
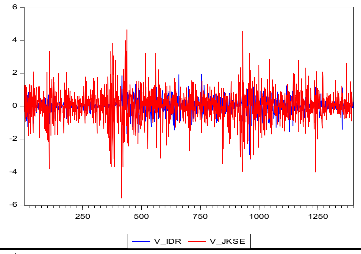
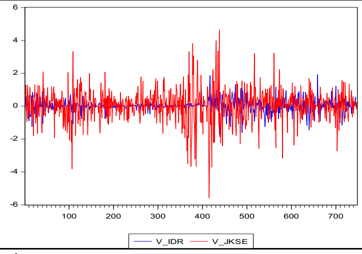
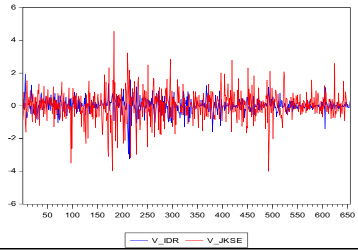
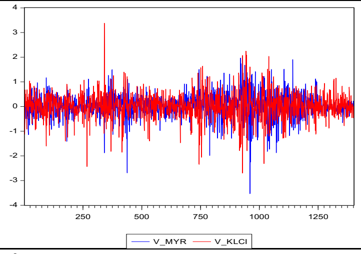
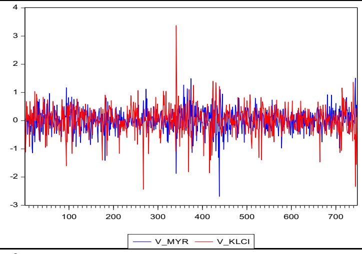
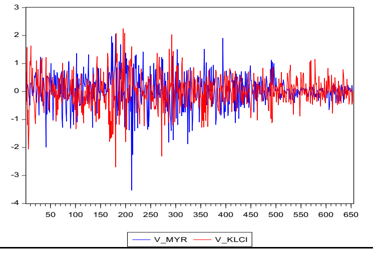
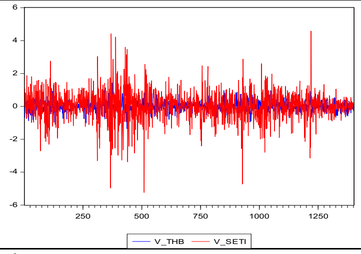
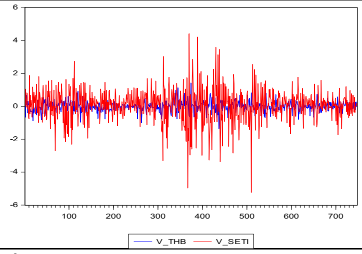
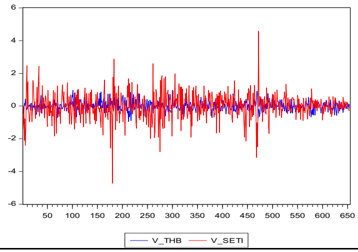
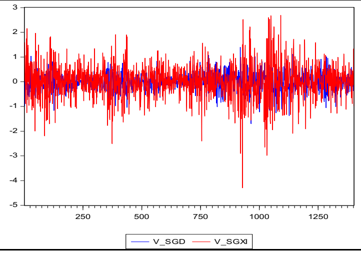
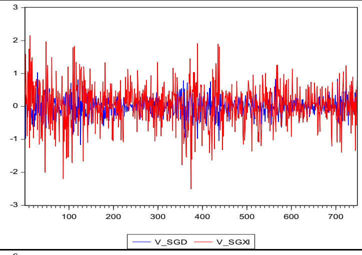
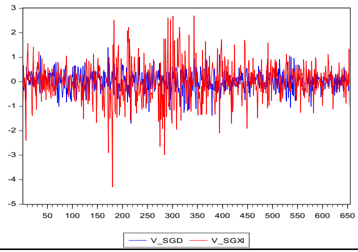
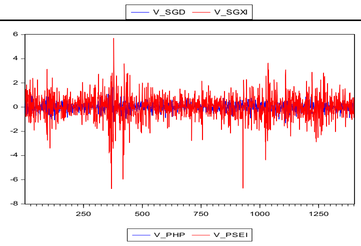
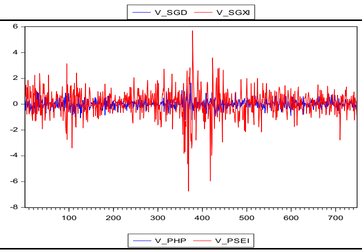
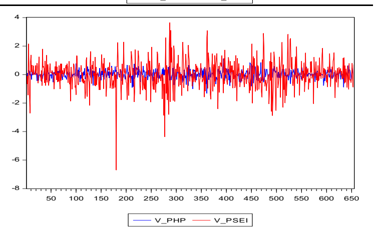
TABLE 1: Summary Statistics

Group	Statistic	Full Sample		High-Oil Price		Low-Oil Price	
Control		V_BRENT	V_DJIA	V_BRENT	V_DJIA	V_BRENT	V_DJIA
	Mean	-0.0402	0.0426	-0.0546	0.0538	-0.0237	0.0298
	Std. Dev.	1.9584	0.7424	1.2094	0.6730	2.5603	0.8148
	Skewness	0.5481	-0.2329	-0.3950	-0.2467	0.5591	-0.2040
	Kurtosis	6.7426	5.2940	5.4975	4.4223	4.6276	5.4714
	Jarque-Bera	1.9584	0.7424	1.2094	0.6730	2.5603	0.8148
Indonesia		V_IDR	V_JKSE	V_IDR	V_JKSE	V_IDR	V_JKSE
	Mean	0.0282	0.0348	0.0414	0.0461	0.0131	0.0218
	Std. Dev.	0.3931	0.9655	0.3678	1.0228	0.4199	0.8960
	Skewness	-0.7434	-0.3130	-0.0650	-0.3327	-1.2338	-0.2875
	Kurtosis	11.5579	6.5311	7.5809	6.4690	13.7685	6.3463
	Jarque-Bera	4407.45	751.29	654.54	388.86	3325.83	314.14
Malaysia		V_MYR	V_KLCI	V_MYR	V_KLCI	V_MYR	V_KLCI
	Mean	0.0228	0.0115	0.0129	0.0190	0.0341	0.0030
	Std. Dev.	0.4838	0.5342	0.3938	0.4814	0.5697	0.5890
	Skewness	-0.5310	-0.1654	-0.5199	-0.2122	-0.5329	-0.1178
	Kurtosis	7.5919	6.3697	7.2577	8.3805	6.6091	4.9709
	Jarque-Bera	1297.62	669.72	598.68	907.87	385.89	107.37
Thailand		V_THB	V_SETI	V_THB	V_SETI	V_THB	V_SETI
	Mean	0.0058	0.0346	0.0068	0.0641	0.0046	0.0009
	Std. Dev.	0.2913	0.8981	0.3000	0.9794	0.2812	0.7944
	Skewness	0.0888	-0.3390	-0.0840	-0.4234	0.3269	-0.2099
	Kurtosis	4.6621	7.1229	5.1094	6.6946	3.9587	7.3616
	Jarque-Bera	163.23	1019.82	139.56	447.77	36.69	523.20
Singapore		SGD	SGXI	SGD	SGXI	SGD	SGXI
	Mean	0.0048	0.0166	0.0030	0.0325	0.0069	-0.0015
	Std. Dev.	0.3388	0.7055	0.2810	0.6248	0.3948	0.7879
	Skewness	-0.2422	-0.2053	-0.1459	-0.1626	-0.2758	-0.1981
	Kurtosis	4.5676	5.2321	4.2050	3.9936	4.0861	5.4003
	Jarque-Bera	157.25	300.89	47.91	34.07	40.44	161.27
Philippines		PHP	PSEI	PHP	PSEI	PHP	PSEI
	Mean	0.0105	0.0470	0.0031	0.0729	0.0190	0.0173
	Std. Dev.	0.3128	1.0272	0.3274	1.0605	0.2952	0.9876
	Skewness	0.0840	-0.6291	0.2981	-0.7442	-0.2308	-0.4788
	Kurtosis	4.8617	8.1508	5.2315	8.8102	4.1639	7.1175
	Jarque-Bera	204.11	1642.31	166.28	1121.18	42.72	486.99
Observations		**1402**	**1402**	**748**	**748**	**654**	**654**

For all erass ("*Full Sample*", "*High-Oil Price*", and "*Low-Oil Price*"), the average daily return of the BRENT is negative, represents the declining trend of the BRENT oil price along the period of observation. The average daily of DJIA and all ASEAN-5 stock market (except SGXI at "Low-Oil Price" era) are positive for all eras, represents the daily positive trend of all stock markets along the period of observation. Then the positive sign at daily return mean for all ASEAN-5 exchange rates show the depreciation of all ASEAN-5 exchange rates to USD for along observation.

Since the series are transformed into the return series (figure 1, below), all of these series have a kurtosis value larger than 3 along the period of observation, which means that leptokurtic has a thick tail. The Jarque Bera test also indicates that all of the series are not normally distributed. It means we can appropriate to use the ARCH-GARCH model into the series (Bollerslev, 1986).

FIGURE 1: Return of the Series

Group	Variable	*Full Sample*	*High-Oil Price* Era	*Low-Oil Price* Era
Control Variable	DJIA - BRENT			
Indonesia	IDR - JKSE			
Malaysia	MYR - KLCI			
Thailand	THB - SETI			
Singapore	SGD - SGXI			
Philippines	PHP - PSEI			

3.2 Methodology

Multivariate GARCH models have been designed to model the conditional covariance (and volatility) matrix of multiple time series that potentially useful development regarding the parameterization of conditional cross-moment rather than the univariate model (Worthington

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and Higgs, 2004). It also gives valuable information on risk measures associated with a given set of financial assets (Hafner and Herwartz, 2006).

The basis of the GARCH model is defined as:

$Y_t = \alpha + \Gamma Y_{t-1} + \varepsilon_t$

$\varepsilon_t / I_{t-1} \approx N(0, H_t)$.. (eq.1)

Where Y_t is a 4 x 1 vector of daily returns at time *t*. α represents 4 x 1 vector of constants. Γ is a 4 x 4 matrix for parameters associated with the lagged returns. Y_{t-1} is the 4 x 4 vector matrix of the relationship of the returns across series. ε_t is the 4 x 1 vector of random error. H_t is the 4 x 4 conditional variance-covariance matrix, and I_{t-1} is the series information available at time t-1.

Engle and Kroner (1995) introduced Baba Engel Kroner Kraft (BEKK) model which guarantees by construction that the variance-covariance matrices in the system are positive definite (Bauwens et al., 2006; Beirne et al., 2009). The positive-definiteness of the covariance matrix contrast than VEC(H) model or DVEC model, and CCC or DCC model, where covariance matrix could be negative, and should be imposed a restriction (Bollerslev et al., 1988; Engle and Kroner, 1995; Bauwens et al., 2006; Peters, 2008; Righia and Ceretta, 2012; and Mokengoy, 2015).

The compact form of the BEKK model is defined as:

$H_t = A'A + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + C'H_{t-1}C$ .... (eq.2)

Where H_t is the conditional variance-covariance matrix in *t*. *A*, *B*, and *C* are matrices of parameters to be estimated. In other words, when using 4 variables the matrices in eq.2 become as follows:

$$\boldsymbol{A} = \begin{bmatrix} a_{11t} & a_{12t} & a_{13t} & a_{14t} \\ 0 & a_{22t} & a_{23t} & a_{24t} \\ 0 & 0 & a_{33t} & a_{34t} \\ 0 & 0 & 0 & a_{44t} \end{bmatrix} \quad \boldsymbol{C} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{bmatrix}$$

$$\boldsymbol{B} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}$$

.... (eq.3)

In this model, the *A* matrices being upper triangular has 10 parameters and being positive definite matrices which are used to ensure the positive definiteness of H_t. The *B* matrices are 4 x 4 matrix of parameters and have conditional variances that are correlated with past squared errors to capture the effects of shocks or unanticipated events. Then the *C* matrices are 4 x 4 of parameters that can represent how current levels of conditional variances are affected by past conditional variances. So, it makes this model has 25 estimated elements for the variances.

The off-diagonal elements of *B* and *C* provide evidence of interdependence between variables, while the diagonal elements capture any persistence among them (Konstantina, 2014). So, it allows us to identify effects if lagged shocks or event or volatility transmission between series (Worthington & Higgs, 2004; and Valls & Chulia, 2014).

And since the eq.2 consist of variance-covariance matrices in eq.3, the general BEKK model in the case of N = 4 is:

$$\begin{bmatrix} h_{11t} & h_{12t} & h_{13t} & h_{14t} \\ h_{21t} & h_{22t} & h_{23t} & h_{24t} \\ h_{31t} & h_{32t} & h_{33t} & h_{34t} \\ h_{41t} & h_{42t} & h_{43t} & h_{44t} \end{bmatrix}$$

$$= \begin{bmatrix} a_{11t} & a_{12t} & a_{13t} & a_{14t} \\ 0 & a_{22t} & a_{23t} & a_{24t} \\ 0 & 0 & a_{33t} & a_{34t} \\ 0 & 0 & 0 & a_{44t} \end{bmatrix}' \begin{bmatrix} a_{11t} & a_{12t} & a_{13t} & a_{14t} \\ 0 & a_{22t} & a_{23t} & a_{24t} \\ 0 & 0 & a_{33t} & a_{34t} \\ 0 & 0 & 0 & a_{44t} \end{bmatrix}$$

$$+ \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \\ \varepsilon_{3t-1} \\ \varepsilon_{4t-1} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \\ \varepsilon_{3t-1} \\ \varepsilon_{4t-1} \end{bmatrix}' \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}$$

$$+ \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{bmatrix} \begin{bmatrix} h_{11t-1} & h_{12t-1} & h_{13t-1} & h_{14t-1} \\ h_{21t-1} & h_{22t-1} & h_{23t-1} & h_{24t-1} \\ h_{31t-1} & h_{32t-1} & h_{33t-1} & h_{34t-1} \\ h_{41t-1} & h_{42t-1} & h_{43t-1} & h_{44t-1} \end{bmatrix}' \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{bmatrix}$$

.... (eq.4)

To see the volatility transmission among series for all stock market in ASEAN-5, we only focus on the equations h_{44t}. Mathematically the volatility spillover equation in the multivariate BEKK-GARCH (1,1) model for stock market return becomes :

$$\begin{aligned} h_{44t} = a_{44}^2 &+ (b_{14}^2\varepsilon_{1t-1}^2 + 2b_{14}b_{24}\varepsilon_{1t-1}\varepsilon_{2t-1} + 2b_{14}b_{34}\varepsilon_{1t-1}\varepsilon_{3t-1} + 2b_{14}b_{44}\varepsilon_{1t-1}\varepsilon_{4t-1} \\ &+ b_{24}^2\varepsilon_{2t-1}^2 + 2b_{24}b_{34}\varepsilon_{2t-1}\varepsilon_{3t-1} + 2b_{24}b_{44}\varepsilon_{2t-1}\varepsilon_{4t-1} \\ &+ b_{34}^2\varepsilon_{3t-1}^2 + 2b_{34}b_{44}\varepsilon_{3t-1}\varepsilon_{4t-1} \\ &+ b_{44}^2\varepsilon_{4t-1}^2) \\ &+ (c_{14}^2 h_{11t-1} + c_{14}c_{24}h_{12t-1} + c_{14}c_{34}h_{13t-1} + c_{14}c_{44}h_{14t-1} \\ &+ c_{24}c_{21}h_{21t-1} + c_{24}^2 h_{22t-1} + c_{24}c_{34}h_{23t-1} + c_{24}c_{44}h_{24t-1} \\ &+ c_{34}c_{14}h_{31t-1} + c_{34}c_{24}h_{32t-1} + c_{34}^2 h_{33t-1} + c_{34}c_{44}h_{34t-1} \\ &+ c_{44}c_{14}h_{41t-1} + c_{44}c_{24}h_{42t-1} + c_{44}c_{34}h_{43t-1} + c_{44}^2 h_{44t-1}) \end{aligned}$$ .... (eq.5)

The a_{44}^2 represents the constant level of each stock market volatility. Parameter b_{14}^2 ; b_{24}^2 ; b_{34}^2 and b_{44}^2 capture the impact of the of BRENT, DJIA, each exchange rate, and past volatility of stock market on every stock market volatility. The c_{14}^2 ; c_{24}^2 ; c_{34}^2 and c_{44}^2 represent the volatility transmission of BRENT, DJIA, each exchange rate,, and past volatility of the stock market to every stock market in ASEAN-5. Then, ε_{1t-1}^2 ; ε_{2t-1}^2; ε_{3t-1}^2 and ε_{4t-1}^2 represent the unexpected change or shocks from each series in era time t-1.

Under the assumption of conditional normality, the parameters of BEKK-GARCH system (eq.5) are estimated by maximizing the log-likelihood function:

$$L(\theta) = -\frac{TN}{2}\ln 2\pi - \frac{1}{2}\Sigma_{t=1}^{T}(\ln|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t)$$ .... (eq.6)

Where T is the number of observations that are going to be used to estimate the parameters. N is the number of variables in the system. The Θ is a vector of all parameters to be estimated., and H_t will be replaced by his specification according to the appropriate BEKK-GARCH parameterizations.

4. Empirical Results

To apply the BEKK model, we first analyze the stationarity of the variables by applying the Augmented Dickey-Fuller test (Dickey & Fuller, 1979), and the Phillips-Perron test (Phillips & Perron, 1988). Table 2 (below) presents the empirical results of unit root analyses. The ADF, and PP test for all variables represent the similar results of stationarity. It shows all return variables are stationer at the level. So, the unit root test results statistically confirm to transform the series into the return value.

TABLE 2: Unit root results

Group	Statistic	Full Sample		High-Oil Price		Low-Oil Price	
		V_BRENT	V_DJIA	V_BRENT	V_DJIA	V_BRENT	V_DJIA
Control	ADF-test	-36.3935***	-18.7299***	-27.0890***	-28.1410***	-24.2025***	-13.3609***
	PP-test	-36.5272***	-37.9343***	-27.0892***	-28.1271***	-24.1892***	-25.7939***
		V_IDR	V_JKSE	V_IDR	V_JKSE	V_IDR	V_JKSE
Indonesia	ADF-test	-33.7512***	-24.1665***	-10.3370***	-17.8623***	-12.9646***	-16.2924***
	PP- test	-34.0311***	-35.4087***	-24.6954***	-25.5226***	-23.2165***	-24.6640***
		V_MYR	V_KLCI	V_MYR	V_KLCI	V_MYR	V_KLCI
Malaysia	ADF-test	-36.3212***	-34.1920***	-15.1776***	-25.0017***	-24.4612***	-23.3080***
	PP-test	-36.4006***	-34.0701***	-27.6683***	-25.0017***	-24.5001***	-23.2096***
		V_THB	V_SETI	V_THB	V_SETI	V_THB	V_SETI
Thailand	ADF-test	-34.7695***	-36.2319***	-25.8157***	-26.9296***	-9.0482***	-24.2002***
	PP-test	-34.8258***	-36.2149***	-25.8454***	-26.9279***	-23.6118***	-24.2215***
		SGD	SGXI	SGD	SGXI	SGD	SGXI
Singapore	ADF-test	-31.7305***	-10.6034***	-24.0789***	-7.6472***	-21.3111***	-23.1066***
	PP-test	-48.3556***	-35.7184***	-39.1596***	-27.6515***	-31.1607***	-23.0445***
		PHP	PSEI	PHP	PSEI	PHP	PSEI
Philippines	ADF-test	-10.3765***	-20.8089***	-7.1090***	-25.8193***	-19.0597***	-24.6856***
	PP-test	-37.9840***	-35.8981***	-28.2241***	-25.8193***	-25.4696***	-24.7860***

Note : Include trend, and intercept in test equation
*** : Significant at 1% level

First, we make an index for the control variables (BRENT, and DJIA), the exchange rate (IDR, MYR, THB, SGD, PHP), and the stock market (JKSE, KLCI, SETI, FTSE, PSEI). The indexed are 1, 2, 3 and 4 respectively. For example, in Indonesia, BRENT and DJIA are indexed 1 and 2, then IDR and JKSE are indexed 3 and 4, and so on. Then, to examine the multicollinearity among variables, we are using the correlation matrix.[2] We divide the correlation matrix according to each country model. As a result, we're not found multicollinearity among series.

TABLE 3: Lag Optimal

Stock Market	Full Sample	High-Oil Price Era	Low-Oil Price Era
JKSE	3	3	1
KLCI	1	1	1
SETI	2	2	1
SGXI	2	1	2
PSEI	5	3	5

The BEKK model estimated simultaneously by the maximum likelihood method, preceded by the VAR model. According to the selection criterion[3], we find the difference of the optimal lag between each stock market model. After finding the optimal lag, we estimate the coefficient for the conditional mean return equation of each ASEAN-5 stock market presented in Table 4 (below).[4]

As seen in table 4, under a 10% significant level, we find the return of JKSE significantly influenced by the lagged return of BRENT and DJIA in all erass. Then, we find the lagged return of IDR are significantly influenced the return of JKSE only at the "*Full Sample*", and "*High-Oil Price*" era. It shows there was a mean spillover effect from BRENT and DJIA to JKSE in all eras. But the IDR only shows the mean spillover effect at the "*Full Sample*", and "*High-Oil Price*" era to JKSE.

Then, at a 10% significant level, we show there is the mean spillover effect from BRENT, DJIA, and MYR to KLCI in all erass. Also, we accept the mean spillover effect from BRENT, DJIA, and SGD to SGXI in all erass. The non-significant of THB to SETI at "*High-Oil Price*" era,

[2] Look at appendix (part B-correlation matrix)
[3] Based on the best lag order selection criteria shown by LR-test, FPE (Final Prediction Error), AIC (Akaike Information Criterion), SC (Schwarz Information Criterion) and HQ (Hannan-Quinn Information Criterion)
[4] Captured the parameters of Γ matrix in eq.1

and "*Low-Oil Price*" era, also the non-significant PHP to PSEI at "*High-Oil Price*" era, and "*Low-Oil Price*" era shows there was no mean spillover effect from exchange rate return to stock market return in Thailand, and Philippines under the 10% significant level.

The BEKK-GARCH estimated results capture the price volatility, and cross volatility spillovers among series into each ASEAN-5 stock market, also indicating the presence of ARCH (shown by the matrix B), and GARCH effects (shown by the matrix C). All of the BEKK models at table 4 (below) show no evidence of autocorrelation in the standardized residuals (indicated by the *p-values* of Portmanteau-test greater than 0.05). In particular, $b_{14}^2 + c_{14}^2 < 1$; $b_{24}^2 + c_{24}^2 < 1$; $b_{34}^2 + c_{34}^2 < 1$ and also $b_{44}^2 + c_{44}^2 < 1$ for all model represents that conditional variances is finite, and the series are strictly stationary. So, we can conclude that the BEKK model is robust and correctly specified.

In JKSE model, under 10% significant level, we can see the coefficient b_{14}^2 is positive-significant at "*High-Oil Price*" era, which reflects the ARCH effect between the return of BRENT to the return of JKSE. Then it can be interpreted as the positive-significant impact of the BRENT oil price shock on the JKSE volatility at "*High-Oil Price*" era. The b_{34}^2 reflects the ARCH effect between the return of IDR to the return of JKSE at "*Full Sample*" and the "*Low-Oil Price*" era. The b_{44}^2 is positive-significant in all eras, which can be interpreted as the positive-significant impact of JKSE shock on the JKSE volatility. Then the significant parameters of c_{14}^2 ; c_{24}^2 and c_{34}^2 reflects the GARCH effects, which can be interpreted as volatility transmission of the return BRENT, DJIA and IDR to the return of JKSE along period of observation. The increasing coefficient parameter of c_{14}^2 at the "*Low-Oil Price*" era rather than two other periods show the increasing rate of volatility transmission from BRENT to IHSG among periods of observation. Then significant of c_{44}^2 can be interpreted as the volatility persistence of the JKSE overtime for all eras.

In KLCI model, coefficient parameter b_{24}^2 ; b_{34}^2 ; b_{44}^2 which means the ARCH effect exists from the return of DJIA to KLCI at "*Low Oil Price*" era; MYR to KLCI at the "*Full Sample*" and "*Low-Oil Price*" era and from KLCI itself at all eras. The volatility spillover by GARCH effect exists from BRENT, and MYR to KLCI at all eras; DJIA to KLCI at "*Full Sample*", and "*Low-Oil Price*" era and also from past historical volatility of KLCI at all eras. The increase of coefficient parameter c_{14}^2 at *Low-Oil Price*" era also shows the increasing rate of volatility transmission from BRENT to KLCI among periods of observation. For the SETI model, the ARCH effect showed by coefficient parameter b_{34}^2 ; b_{44}^2 exists from THB to SETI at the "*Full Sample*" and "*High-Oil Price*" era;, and from SETI itself at all eras. The volatility spillover by GARCH effect exists from BRENT, DJIA and past volatility of SETI to SETI at all eras and from THB to SETI at the "*Full Sample*" and "*High-Oil Price*" era. However, there is a weakening of coefficient parameter c_{14}^2 at *low-oil price era* different than KLCI, and JKSE.

In SGXI model, coefficient parameter b_{14}^2; b_{24}^2; b_{44}^2 which means the ARCH effect exists from BRENT, and SGXI itself at all eras; from DJIA to SGXI at "*High-Oil Price*" era, and "*Low-Oil Price*" era and from SGD to SGXI at "*High-Oil Price*" era. Then the volatility spillover by GARCH effect exists from all series (BRENT, DJIA, SGD, and past SGXI) to SGXI at all eras of observation. Coefficient parameter c_{14}^2; also shows a greater impact at "*Low-Oil Price*" era compares to the "*High-Oil Price*" era. Lastly, the PSEI model shows the ARCH effect exists from PSEI itself at all eras and from PHP to PSEI at the "*Low-Oil Price*" era. The GARCH effects exist from DJIA, PHP, and past PSEI to PSEI at all eras; then from BRENT to PSEI at the "*Full Sample*", and "*High-Oil Price*" era. The coefficient parameter c_{14}^2 also stronger at "*Low-Oil Price*" era shows the increasing rate of volatility transmission from BRENT to PSEI.

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TABLE 4: Estimation results of the BEKK-Model

Para-meters	JKSE			KLCI			SETI			SGXI			PSEI		
	Full Sample	High-Oil Price	Low-Oil Price	Full Sample	High-Oil Price	Low-Oil Price	Full Sample	High-Oil Price	Low-Oil Price	Full Sample	High-Oil Price	Low-Oil Price	Full Sample	High-Oil Price	Low-Oil Price
Panel A: Mean Equation (VAR)															
$y(1,4)_{t-1}$	0.0097^{**}	0.0093^{**}	0.0136^{**}	0.0293^{***}	0.0434^{**}	0.0246^{***}	0.0010^{**}	0.0056^{**}	0.0013^{**}	0.0275^{***}	0.0286^{**}	0.0273^{**}	0.0249^{**}	-0.0091^{**}	0.0355^{**}
$y(1,4)_{t-2}$	-0.0072^{**}	-0.0001^{**}	-	-	-	-	0.0063^{**}	0.0411^{**}	-	0.0088^{***}	-	0.0100^{**}	-0.0101^{**}	-0.0055^{**}	-0.0073^{**}
$y(1,4)_{t-3}$	-0.0096^{**}	-0.0372^{**}	-	-	-	-	-	-	-	-	-	-	0.0110^{**}	-0.0029^{**}	0.0165^{**}
$y(1,4)_{t-4}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.0060^{**}	-	-0.0027^{**}
$y(1,4)_{t-5}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.0201^{**}	-	-0.0321^{**}
$y(2,4)_{t-1}$	0.3783^{**}	0.4398^{*}	0.3351^{**}	0.2135^{**}	0.1802^{**}	0.2413^{**}	0.2315^{**}	0.2697^{*}	0.2004^{**}	0.3310^{**}	0.3499^{**}	0.3135^{**}	0.4100^{**}	0.4631^{*}	0.3457^{**}
$y(2,4)_{t-2}$	-0.0769^{**}	-0.0530^{*}	-	-	-	-	0.0756^{**}	0.1244^{*}	-	0.0639^{**}	-	0.0603^{**}	-0.0183^{**}	-0.028^{*}	0.0204^{**}
$y(2,4)_{t-3}$	0.0399^{**}	0.1420^{*}	-	-	-	-	-	-	-	-	-	-	-0.0302^{**}	-0.0177^{*}	-0.0450^{**}
$y(2,4)_{t-4}$	-	-	-	-	-	-	-	-	-	-	-	-	0.0964^{**}	-	0.0777^{**}
$y(2,4)_{t-5}$	-	-	-	-	-	-	-	-	-	-	-	-	0.0108^{**}	-	-0.0108^{**}
$y(3,4)_{t-1}$	-0.1180^{*}	-0.1229	-0.0987^{*}	-0.0748^{**}	-0.0622^{**}	-0.0801^{**}	-0.3369^{*}	-0.2591	-0.4256	-0.2899^{*}	-0.2513^{**}	-0.2898^{*}	-0.3313^{*}	-0.2288	-0.4555
$y(3,4)_{t-2}$	-0.0243^{*}	-0.0653	-	-	-	-	-0.1515^{*}	-0.1142	-	-0.0220^{*}	-	-0.0178^{*}	-0.3070^{*}	-0.4020	-0.0992
$y(3,4)_{t-3}$	-0.0862^{*}	-0.1585	-	-	-	-	-	-	-	-	-	-	-0.2979^{*}	-0.4085	-0.1362
$y(3,4)_{t-4}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.0323^{*}	-	-0.0948
$y(3,4)_{t-5}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.2080^{*}	-	-0.0353
$y(4,4)_{t-1}$	0.0196^{**}	0.0334^{**}	-0.0270^{**}	0.0222^{**}	0.0540^{**}	-0.0049^{**}	-0.0563^{**}	-0.0578^{**}	-0.0409^{**}	-0.0903^{**}	-0.1173^{**}	-0.0374^{**}	-0.0241^{**}	-0.0080^{**}	-0.0241^{**}
$y(4,4)_{t-2}$	-0.0312^{**}	-0.0568^{**}	-	-	-	-	-0.0362^{**}	-0.0356^{**}	-	-0.0431^{**}	-	-0.0914^{**}	-0.0488^{**}	-0.0184^{**}	-0.0666^{**}
$y(4,4)_{t-3}$	-0.1357^{**}	-0.1640^{**}	-	-	-	-	-	-	-	-	-	-	-0.1005^{**}	-0.1082^{**}	-0.0665^{**}
$y(4,4)_{t-4}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.0610^{**}	-	-0.0133^{**}
$y(4,4)_{t-5}$	-	-	-	-	-	-	-	-	-	-	-	-	-0.0677^{**}	-	0.0175^{**}
α_4	0.0305^{**}	0.0375^{**}	0.0155^{**}	0.0051^{**}	0.0115^{**}	$-5.7E-06^{**}$	0.0273^{**}	0.0525^{**}	-0.0007^{**}	0.0040^{**}	0.0196^{**}	-0.0097^{**}	0.0521^{**}	0.0606^{**}	0.0236^{**}
Panel B: Volatility Equation (BEKK)															
b_{14}^2	0.0399	0.0648^{**}	-0.0028	0.0132	0.0080	-0.0039	0.0339	0.0310	0.0544	0.0165	0.1054^{***}	0.0349^{*}	0.0249	0.0567	0.0331
b_{24}^2	0.0088	0.0143	0.0211	-0.0213	-0.0312	-0.0998^{*}	0.0128	0.0079	0.0195	0.0187^{*}	0.0472^{**}	0.1008^{***}	0.0119	0.0095	0.0044
b_{34}^2	0.0227^{**}	0.0217	0.0805^{**}	0.0346^{***}	-0.0049	0.0569^{***}	0.0137^{*}	0.0206^{*}	0.0288	0.0110	0.0400^{**}	0.0418	0.0073	0.0125	-0.0694^{**}
b_{44}^2	0.0951^{***}	0.0830^{***}	0.1853^{***}	0.1090^{***}	0.1919^{***}	0.0789^{***}	0.0848^{***}	0.1127^{***}	0.0618^{***}	0.0689^{***}	0.0529^{***}	0.0751^{***}	0.1069^{***}	0.0846^{***}	0.2109^{***}
c_{14}^2	0.7233^{***}	0.6185^{***}	0.9478^{***}	0.7512^{***}	0.7454^{***}	0.9004^{***}	0.8124^{***}	0.8095^{***}	0.7684^{***}	0.9477^{***}	0.5877^{***}	0.9002^{***}	0.8043^{***}	0.0484	0.8100^{***}
c_{24}^2	0.9669^{***}	0.9631^{***}	0.8077^{***}	0.6293^{***}	0.7360^{***}	-0.1942	0.9524^{***}	0.9530^{***}	0.9395^{***}	0.9424^{***}	0.7738^{***}	0.7505^{***}	0.9618^{***}	0.9511^{***}	0.9643^{***}
c_{34}^2	0.9480^{***}	0.9565^{***}	0.7070^{***}	0.8383^{***}	0.8513^{***}	0.8933^{***}	0.9680^{***}	0.9597^{***}	0.3290	0.9710^{***}	0.8654^{***}	0.8837^{***}	0.9808^{***}	0.9687^{***}	0.8189^{***}
c_{44}^2	0.0399^{***}	0.8896^{**}	-0.6591^{***}	0.7723^{***}	0.3493^{***}	0.8684^{***}	0.9049^{***}	0.8664^{***}	0.9331^{***}	0.9023^{***}	0.9148^{***}	0.8969^{***}	0.8472^{***}	0.9008^{***}	0.5517^{***}
Panel C: Diagnostic Test															
P-test (-1)	46.72	39.80	11.69	17.70	4.73	41.75	15.59	12.06	12.00	24.52	4.52	9.95	46.92	21.88	7.30
p-value	-0.53	-0.79	-0.77	-0.34	-1.00	0.12	-0.99	-1.00	-0.74	-0.83	-1.00	-1.00	-1.00	-1.00	-0.97

Note : P-Test (Portmanteau test); ***(significant at 1% level); ** (significant at 5% level); * (significant at 10% level).

Based on the results at the table 4 (above), the volatility transmission pattern can be explained as follows:

a. The JKSE's Model
There is a positive significant transmission of volatility between the BRENT, DJIA and IDR to the JKSE in all erass.
b. The KLCI's Model
There is a positive significant transmission of volatility between the BRENT and MYR to the KLCI in all erass. But, the DJIA only have a positive significant volatility transmission to the KLCI in the "*Full Sample*" and "*High Oil Price*" era.
c. The SETI's Model
There is a positive significant transmission of volatility between the BRENT and DJIA to the SETI in all erass. But, the THB only have a positive significant volatility transmission to the SETI in the "*Full Sample*" and "*High Oil Price*" era.
d. The SGXI's Model
There is a positive significant transmission of volatility between the BRENT, DJIA and SGD to the SGXI in all erass.
e. The PSEI's Model
There is a positive significant transmission of volatility between the DJIA and PHP to the PSEI in all erass. But, the BRENT only has a positive significant volatility transmission to the PSEI in the "*Full Sample*" and "*Low Oil Price*" era.

5. Conclusion, and Policy Recommendation

5.1. Conclusion

The aim of the study is to examines the relationship between Global Macro Shocks, Cross-Market Linkages, and Economic Fundamental through volatility spillovers to ASEAN-5 (Singapore, Indonesia, Thailand, Malaysia, and the Philippines) Stock Market. Global Macro Shocks represented by Brent-oil price (BRENT), Cross-Market Linkages represented by Dow Jones index (DJIA), ASEAN-5 Economic Fundamental represented by each countries exchange rate (USD/IDR, USD/MYR, USD/THB, USD/SGD, USD/PHP), and the ASEAN-5 Stock Markets represented by the each stock market indices (JKSE, KLCI, SGXI, PSEI, and THB). We use daily data, from January 2th, 2012 to June 30th, 2017, with a total of 1402 observations. Then we divided the series into two eras, which are the "*High-Oil Price*" era (between January 2nd, 2012, and December 5th, 2014), and the "*Low-Oil Price*" era (between December 8th, 2014, and June 30th, 2017).

By applying the Multivariate (BEKK) GARCH approach, this study finds evidence of linkages in terms of return and volatility. We focus the analysis on the volatility transmission showed by the GARCH effect between the series. At the parameters results, we find an increasing rate of volatility transmission of BRENT at the "*Low-Oil Price*" era rather than at the "*High-Oil Price*" era in all stock market returns, except for the SETI. These findings confirm that most of the ASEAN-5 countries are benefited from the increasing level of oil prices. We also find the decreasing rate of DJIA's volatility transmission for all stock markets, except for the PSEI at the "*Low Oil Price*" era rather than at "*High Oil Price*" era. It shows the decreasing dependency of the ASEAN-5 stock market to the advanced stock market (DJIA) at "*Low-Oil Price*" era. Then we find a different rate of each exchange rate volatility transmission to every stock market of ASEAN-5 between the "*High-Oil Price*" era and the "*Low-Oil Price*" era. The JKSE; SETI and PSEI show the decreasing rate of volatility transmission from each exchange rate at "*Low-Oil Price*"era rather than at the "*High-Oil Price*" era, while two others stock market (KLCI and SGXI) shows inversely. In other words, during the era of "*High-Oil Price*", there will be an increasing rate (relatively) of JKSE, SETI and PSEI.

By looking at the significance of volatility transmission among series to each ASEAN-5 stock market, we also find a different pattern of volatility transmission at the KLCI; SETI; and at PSEI between these two eras. Therefore, we can conclude that the regulator should adopt different approaches to stabilize the stock market between eras, since the sources of volatility are different. For Indonesia's regulatory, at the "*High-Oil Price*" era, they should more intense to give attention to the volatility transmission that comes from the cross market linkage (proxied by the DJIA) and the economic fundamental (proxied by exchange rate). Then, at the "*Low-Oil Price*" era, regulations should be more intense to stabilize the transmission that comes from the volatility of Global Macro Shocks (proxied by Brent oil price).

The different approaches are also used as an early warning system to private and the regulator to take action as the volatility transmission happens. In general, the stable and prudent stock market, the financial markets, and the investment sectors are used to minimized risk in the economy and in order to maintain sustainable economic growth.

5.2. Policy Recommendation

1. The policymaker should concern with all channels of volatility transmission (global shocks, cross-market linkages, and economic fundamentals) to reduce the volatility at the ASEAN-5 stock market returns.
2. Since the different pattern and different rate (coefficient) of volatility transmission happen between the "*High-Oil Price*" era, and the "*Low-Oil Price*" era, a different treatment should be imposed to stabilize the volatility at the ASEAN-5 stock market returns between eras.
3. For Indonesian regulators, the different sources of volatility should beware and takes into account, since the cross-market linkage and the economic fundamental are the main sources of volatility to IHSG at the "*High-Oil Price*" era; then the Global Macro Shocks as the main source of volatility to IHSG at the "*Low-Oil Price*" era.

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7. APPENDICES

Correlation Matrix

1. Indonesia

a. *Full Sample*

	V_BRENT	V_DJIA	V_IDR	V_JKSE
V_BRENT	1.000000			
V_DJIA	0.263528	1.000000		
V_IDR	-0.111162	-0.109127	1.000000	
V_JKSE	0.115538	0.161990	-0.300129	1.000000

b. *High-Oil Price Era*

	V_BRENT	V_DJIA	V_IDR	V_JKSE
V_BRENT	1.000000			
V_DJIA	0.237476	1.000000		
V_IDR	-0.077114	-0.051264	1.000000	
V_JKSE	0.124332	0.123573	-0.262698	1.000000

c. *Low-Oil Price Era*

	V_BRENT	V_DJIA	V_IDR	V_JKSE
V_BRENT	1.000000			
V_DJIA	0.288232	1.000000		
V_IDR	-0.133844	-0.158324	1.000000	
V_JKSE	0.127796	0.207487	-0.350015	1.000000

2. Malaysia

a. *Full Sample*

	V_BRENT	V_DJIA	V_MYR	V_KLCI
V_BRENT	1.000000			
V_DJIA	0.263528	1.000000		
V_MYR	-0.229309	-0.141502	1.000000	
V_KLCI	0.077076	0.117418	-0.342552	1.000000

b. *High-Oil Price Era*

	V_BRENT	V_DJIA	V_MYR	V_KLCI
V_BRENT	1.000000			
V_DJIA	0.237476	1.000000		
V_MYR	-0.242401	-0.116820	1.000000	
V_KLCI	0.054705	0.064337	-0.302209	1.000000

c. *Low-Oil Price Era*

	V_BRENT	V_DJIA	V_MYR	V_KLCI
V_BRENT	1.000000			
V_DJIA	0.288232	1.000000		
V_MYR	-0.229290	-0.158012	1.000000	
V_KLCI	0.090728	0.158038	-0.370169	1.000000

3. Thailand

a. *Full Sample*

	V_BRENT	V_DJIA	V_THB	V_SETI
V_BRENT	1.000000			
V_DJIA	0.263528	1.000000		
V_THB	-0.127172	-0.150926	1.000000	
V_SETI	0.143675	0.212132	-0.209243	1.000000

b. *High-Oil Price Era*

	V_BRENT	V_DJIA	V_THB	V_SETI
V_BRENT	1.000000			
V_DJIA	0.237476	1.000000		
V_THB	-0.127901	-0.172780	1.000000	
V_SETI	0.143034	0.152585	-0.226424	1.000000

c. *Low-Oil Price Era*

	V_BRENT	V_DJIA	V_THB	V_SETI
V_BRENT	1.000000			
V_DJIA	0.288232	1.000000		
V_THB	-0.142402	-0.131543	1.000000	
V_SETI	0.171792	0.289792	-0.185371	1.000000

4. Singapore

a. *Full Sample*

	V_BRENT	V_DJIA	V_SGD	V_SGXI
V_BRENT	1.000000			
V_DJIA	0.263528	1.000000		
V_SGD	-0.186783	-0.221152	1.000000	
V_SGXI	0.193837	0.259920	-0.051579	1.000000

b. *High-Oil Price Era*

	V_BRENT	V_DJIA	V_SGD	V_SGXI
V_BRENT	1.000000			
V_DJIA	0.237476	1.000000		
V_SGD	-0.205153	-0.307760	1.000000	
V_SGXI	0.176116	0.237970	-0.076379	1.000000

c. *Low-Oil Price Era*

	V_BRENT	V_DJIA	V_SGD	V_SGXI
V_BRENT	1.000000			
V_DJIA	0.288232	1.000000		
V_SGD	-0.184179	-0.163780	1.000000	
V_SGXI	0.209661	0.275972	-0.035488	1.000000

5. Philippines

a. *Full Sample*

	V_BRENT	V_DJIA	V_PHP	V_PSEI
V_BRENT	1.000000			
V_DJIA	0.263528	1.000000		
V_PHP	-0.196573	-0.205145	1.000000	
V_PSEI	0.109152	0.100760	-0.124197	1.000000

b. *High-Oil Price Era*

	V_BRENT	V_DJIA	V_PHP	V_PSEI
V_BRENT	1.000000			
V_DJIA	0.237476	1.000000		
V_PHP	-0.226736	-0.151859	1.000000	
V_PSEI	0.064802	0.105661	-0.125437	1.000000

c. *Low-Oil Price Era*

	V_BRENT	V_DJIA	V_PHP	V_PSEI
V_BRENT	1.000000			
V_DJIA	0.288232	1.000000		
V_PHP	-0.206279	-0.264901	1.000000	
V_PSEI	0.149067	0.096750	-0.121124	1.000000

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