Journal of Quality Measurement and Analysis *JQMA* 15(2) 2019, 1-8
e-ISSN: 2600-8602 *http://www.ukm.my/jqma*

RELATIONSHIP BETWEEN CRUDE OIL PRICE WITH FOREIGN EXCHANGE RATES AND INTEREST RATES OF SOUTH EAST ASIAN COUNTRIES

(Hubungan antara Harga Minyak Mentah dengan Kadar Pertukaran Asing serta Kadar Faedah Asia Tenggara)

HUMAIDA BANU SAMSUDIN* & YAP CHIOU SHIN

ABSTRACT

This study measures long run relationships and short run relationships between crude oil price, foreign exchange rates and interest rates by using monthly data of Brent crude oil prices with foreign exchange rates and interest rates for seven Southeast Asian countries from January 2010 to October 2017. The long run relationship is tested using the Johansen cointegration test, while the short run relationship is tested using the Granger causality test. The Vector Error Correction Model (VECM) is built for the country with cointegration between variables. The results of the study show that cointegration is only present for Vietnam and not for six other countries. The Granger causality test found that no causal relationship could be detected between crude oil prices and foreign exchange rates for all tested countries. Unidirectional causalities detected in this study are from interest rates to foreign exchange rates for Brunei and Vietnam and from crude oil prices to Singapore's interest rates

Keywords: crude oil price; foreign exchange rate; interest rates; Johansen cointegration; Granger causality

ABSTRAK

Dalam kajian ini diukur hubungan jangka panjang dan hubungan jangka pendek antara harga minyak mentah, kadar pertukaran asing dan kadar faedah dengan menggunakan data bulanan harga minyak mentah Brent dengan kadar pertukaran asing serta kadar faedah bagi tujuh negara Asia Tenggara dari Januari 2010 hingga Oktober 2017. Hubungan jangka panjang diuji menggunakan ujian kokamiran Johansen, manakala hubungan jangka pendek diuji menggunakan ujian kebersebaban Granger. Model vektor pembetulan ralat (VECM) dibina bagi negara yang memiliki hubungan kokamiran antara pemboleh ubah. Keputusan kajian menunjukkan hubungan kokamiran hanya wujud bagi negara Vietnam dan tidak bagi enam negara yang lain. Ujian kebersebaban Granger mendapati tiada hubungan kebersebaban dapat dikesan antara harga minyak mentah dengan kadar pertukaran asing bagi semua negara yang diuji. Hubungan kebersebaban sehala yang dikesan dalam kajian ini adalah dari kadar faedah kepada kadar pertukaran asing bagi negara Brunei dan Vietnam serta dari harga minyak mentah kepada kadar faedah Singapura.

Kata kunci: harga minyak mentah; kadar pertukaran asing; kadar faedah; kokamiran Johansen; kebersebaban Granger

1. Introduction

Crude oil is the most widely traded commodity in international market. In addition, crude oil is the raw material to produce products with high demand in consumer markets like petrol and diesel. Unstable prices of petrol and diesel will greatly affect expenses of consumer and industry. Therefore, changes in crude oil prices will influence the economic growth. Crude oil price and foreign exchange rates are quantitative data that are interconnected with each other.

The relationship between crude oil and foreign exchange rates was studied by Krugman (1983) and Golub (1983). The rise in crude oil prices will appreciate the currency of crude oil exporting countries, while the currency of crude oil importing countries will depreciate. This is due to the transfer of wealth from the crude oil importing countries to the crude oil exporting countries.

Since not many existing studies use data from Southeast Asian countries to study the relationship between crude oil price with exchange rates and interest rates, this study will employ the exchange rates and interest rates of Southeast Asian countries. Besides, with the strategic geographical location, Southeast Asian countries often cooperate in economics with one another. Thus, this study is conducted to identify the effects of crude oil prices changes on foreign exchange rates and interest rates in Southeast Asian countries. Therefore, the objectives of this study include identifying long-term and short-term relationships between crude oil price and foreign exchange rates and interest rates of Southeast Asian countries and estimating an autoregressive model using crude oil price, foreign exchange rates and interest rates of Southeast Asian. The estimated models are multivariate time series model which is either vector autoregressive model (VAR) or vector error correction model (VECM) for each different country. The outcome of this study is in hope of providing additional information to the governments of Southeast Asian countries to strengthen the region's economy.

The writing of this study consists of six parts. It begins with an introduction to the backgrounds of the study with research's objectives and followed with literature review. The writing is then continued with data and preliminary analysis, method and results and ends with conclusions.

2. Literature review

Research relating to foreign exchange rates and crude oil prices are mainly focused on causal relationships and the correlation between these two economic variables. In addition, forecasting of foreign exchange rates based on crude oil prices has also been conducted. Existing studies on developed countries (Tiwari & Albulescu 2016). Buetzer *et al.* (2016) have found that the relationship between commodities, crude oil prices with foreign exchange rates does not exist in all countries of the world. This is because the price of commodities is a weak independent variable to the foreign exchange rate because commodity prices are influenced by market competition.

Dawson (2007) used the multivariate regression VAR model to identify the relationship between crude oil prices and foreign exchange rates of the Dominican Republic which is a crude oil importing country with small open economy. Monthly data for variables: crude oil futures prices, exchange rates (Dominican Republic peso/ US dollars), relative consumer price index, relative interest rates between Dominican Republic and America and trade balance in GDP are used in his study. His research found that rising crude oil prices have caused Dominican pesos to depreciate. The positive gap of consumer price indices and interest rates and deficit in trade balance have led to appreciation in Dominican Republic peso. Mohd Shahidan *et al.* (2013) studied the effects of crude oil prices and the Malaysian Ringgit exchange rate with unemployment. Granger causality has been carried out using these variables and crude oil prices was found to not affect unemployment, but the foreign exchange rate is the Granger cause for unemployed. Therefore, they conclude that unemployment can be overcome by scrutinizing foreign exchange rate movements.

Pershin *et al.* (2016) used Johansen and Juselius cointegration and the VAR model in the study of relationships of crude oil price with foreign exchange rates using daily data of nominal exchange rates, Brent crude oil prices, short-term interbank interest rates. It was found that the rise in crude oil prices had caused the local currency of three crude oil

importing African countries: Bostswana, Kenya and Tanzania to appreciate. Furthermore, the rise in crude oil prices did not influence the interest rates in the Bostswana. Meanwhile, interest rates of Kenya and Tanzania only declined over short period of time and unaffected with the rise in crude oil prices. Since the central bank has the authority to adjust the interest rate based on the economic growth of ones country, interest rates is not an external factors that can affect the price changes of crude oil. In addition, the foreign exchange rate of the three selected countries varies before and after the shock of oil prices and during the crude oil price shocks. Therefore, there is no general pattern for the effect of crude oil price on foreign exchange rates which can be inferred from Botswana, Kenya and Tanzania.

Brahmasrene *et al.* (2014) found out that there was a Granger causal relationship between crude oil import prices with the exchange rates of five crude oil exporting countries through VAR model. The fluctuations in foreign exchange rates of the crude oil exporting nations caused a short run crude oil price fluctuation. On the contrary, the crude oil price fluctuations caused a long run fluctuations in foreign exchange rates for the crude oil exporting countries in the long run. In addition, oil prices affected minimally by foreign exchange rates. The shock increase in crude oil prices had high impact on foreign exchange over the long term. It can be seen that the impact of plump in crude oil price in June 2008 has a significant impact on foreign exchange rates. When world oil prices are stable, uncertainty of currency fluctuations can be reduced.

3. Data and Preliminary Analysis

3.1. *Data*

Brent crude oil price is collected from the US Energy Information Administration (EIA) website as the crude oil price data set in this study. Foreign exchange rates and interest rates for seven Southeast Asian countries that have competitive economic performance are used in this study. The seven countries are Brunei, Indonesia, Philippines, Malaysia, Singapore, Thailand and Vietnam. These countries comprise both the net importing countries of crude oil (Philippines, Singapore, Thailand and Indonesia) as well as the net exporting countries of crude oil (Brunei, Malaysia, and Vietnam) (The World Factbook 2018). Data source of foreign exchange rates and interest rates are collected from the International Monetary Fund (IMF) online database. All data are collected from January 2010 to October 2017 with a total of 94 data for each economic variable. Crude oil price is denoted by 'OIL'. The exchange rates and interest rates for Brunei, Indonesia, Philippines, Malaysia, Singapore, Thailand and Vietnam are denoted by 'BN_Dolar', 'ID_Rupiah', 'MY_Ringgit', 'PH_Peso, 'SG_Dolar', 'TH_Baht', 'VN_Dong', 'IBN', 'IID', 'IMY', 'IPH', 'ISG', 'ITH' and 'IVN' respectively.

3.2. *Unit root test*

The unit root test is used to test stationary of the data series. Augmented Dickey-Fuller (ADF) tests is used as the unit root test in this study with null hypothesis of time series has a unit root which implies non-stationary series. The null hypothesis is rejected if the p-value is smaller than 0.05 at 5% level of significance. This concludes that the time series tested does not have a unit root and the series is stationary. The results of the ADF unit root tests for crude oil prices, foreign exchange rates and interest rates at 5% level of significance are shown in the Table 1. The unit root test has shown that all time series are non-stationary at level except the Malaysian interest rates and all series are stationary after first difference.

Table 1: Results for ADF unit root tests

Variables	Level		First difference		Integration
	t-statistics	*p*-value	*t*- statistics	*p*-value	
LOGOIL	-1.1828	0.6792	-7.3457*	0.0000	I(1)
LOGBN_DOLAR	-0.3125	0.9179	-7.6437*	0.0000	I(1)
LOGID_RUPIAH	-0.6607	0.8505	-7.5687*	0.0000	I(1)
LOGMY_RINGGIT	-0.5913	0.8664	-7.4027*	0.0000	I(1)
LOGPH_PESO	-0.5967	0.8653	-7.7829*	0.0000	I(1)
LOGSG_DOLAR	-1.7611	0.3975	-7.0878*	0.0000	I(1)
LOGTH_BAHT	-1.3547	0.6011	-6.5347*	0.0000	I(1)
LOGVN_DONG	-1.7985	0.3792	-7.3917*	0.0000	I(1)
IBN	-2.5466	0.1080	-8.9981*	0.0000	I(1)
IID	-1.5698	0.4939	-3.9144*	0.0029	I(1)
IMY	-5.6068*	0.0000	-	-	I(0)
IPH	-1.3656	0.5959	-11.3963*	0.0001	I(1)
ISG	-2.1548	0.2242	-8.2214*	0.0000	I(1)
ITH	-1.4243	0.5671	-7.3211*	0.0000	I(1)
IVN	-0.7744	0.8213	-5.8985*	0.0000	I(1)

*Denote rejections of the null hypothesis at 5% significance level.

3.3. *Lag length selection*

Lag length is an important factor to build an autoregressive model. Therefore, Akaike information criterion, AIC (Akaike 1973) is used to determine the appropriate lag length for the VAR model. VAR models with lag length, *j* that produce the lowest value for AIC statistic will be selected. In addition, VAR models with 0 to 12 lags are estimated to choose the optimal lag length for the variables. The results of optimal lag lengths are tabulated in Table 2.

Table 2: Results of AIC statistics for optimal lag lengths selection

Lag	AIC						
	Brunei	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
0	-15.9410	-11.0201	-10.5306	-12.0206*	-18.7556	-13.4875	-11.5038
1	-15.9743*	-11.0201	-10.5569*	-11.9622	-18.8468*	-13.5168*	-11.6119
2	-15.8806	-11.0813*	-10.4884	-11.8111	-18.7358	-13.4029	-11.6696*
3	-15.7495	-11.0234	-10.4164	-11.6592	-18.5942	-13.3486	-11.5152
4	-15.5824	-10.8945	-10.3325	-11.5084	-18.4767	-13.2352	-11.4575
5	-15.4656	-10.7856	-10.3079	-11.3767	-18.3549	-13.0895	-11.2853
6	-15.4148	-10.6139	-10.3499	-11.2247	-18.3109	-13.0199	-11.1330
7	-15.3897	-10.5609	-10.2963	-11.1155	-18.1578	-12.9399	-10.9751
8	-15.2558	-10.8301	-10.3754	-11.0266	-18.1698	-12.9432	-10.8811
9	-15.1907	-10.7143	-10.3438	-10.8549	-18.1522	-13.0663	-10.7711
10	-15.1597	-10.7048	-10.3872	-10.7341	-18.2892	-13.0375	-10.6505
11	-15.2731	-10.6394	-10.2937	-10.6428	-18.1835	-12.9576	-10.6586
12	-15.4221	-10.6871	-10.4004	-10.6870	-18.2533	-12.9568	-10.6032
Optimal Lag	1	2	1	0	1	1	2

*Denote the optimal lag length.

3.4. *Johansen cointegration test*

Only non-stationary series with the same order of integration are able to be tested with Johansen cointegration test (Johansen & Juselius 1990). Since the crude oil price, exchange rates and interest rates for Brunei, Indonesia, Philippines, Singapore, Thailand and Vietnam attain stationarity after first difference, these variables are integrated with order one. Presence of cointegration is tested for crude oil price and Malaysian exchange rate because only these two variables are integrated with order one. Cointegration among variables also indicates there is equilibrium long run relationship between the variables. Both trace statistics and maximum eigenvalue statistics can be used to identify the number of cointegration present among the variables. The results of the cointegration tests are reported in Table 3. When there is conflicting results from trace statistics and maximum eigenvalue statistics, this study will consider results from trace statistics.

Table 3: Results of cointegration tests

Country	H_0: No cointegration, $r = 0$		H_0: At most one cointegration, $r \leq 1$		H_0: At most two cointegrations, $r \leq 2$		Presence of cointegration
	Trace statistics	Maximum eigenvalue statistics	Trace statistics	Maximum eigenvalue statistics	Trace statistics	Maximum eigenvalue statistics	
Brunei	25.4411 [0.1463]	17.4972 [0.1498]	7.9439 [0.4714]	7.4921 [0.4327]	0.45191 [0.5015]	0.4519 [0.5015]	No
Indonesia	28.8117 [0.0646]	21.5612 [0.0435]*	7.2506 [0.5487]	7.0454 [0.4838]	0.2053 [0.6505]	0.2053 [0.6505]	No
Malaysia	9.7798 [0.2981]	9.4039 [0.2541]	0.3758 [0.5398]	0.3758 [0.5398]	-	-	No
Philippines	19.4786 [0.4589]	11.0344 [0.6439]	8.4442 [0.4192]	5.7432 [0.6464]	2.7011 [0.1003]	2.7011 [0.1003]	No
Singapore	26.7041 [0.1091]	21.2072 [0.0488]*	5.4969 [0.7540]	4.7012 [0.7790]	0.7958 [0.3723]	0.7958 [0.3723]	No
Thailand	29.2489 [0.0577]	18.9094 [0.0995]	10.3395 [0.2555]	9.5423 [0.2438]	0.7972 [0.3719]	0.7972 [0.3719]	No
Vietnam	30.8585 [0.0376]*	19.8386 [0.0750]	11.0199 [0.2103]	6.9407 [0.4962]	4.0793 [0.0434]*	4.0793 [0.0434]*	Yes

Number in [ ] indicates p-value for trace and maximum eigenvalue statistics.
The number of cointegrating vectors is denoted by r.
*Denotes rejections of null hypothesis at 5% significance level.

4. Method

Based on the results of cointegration test, countries with cointegration will have vector error correction model (VECM) estimated. Countries without cointegration among variables will only have vector autoregressive model (VAR) estimated. VAR and VECM models are very sensitive with the number lag used in the model. So, these models will be estimated with the number of lags from the results of optimal lag length selection using Akaike Information Criteria. The unit root test has verified that series at first difference will be used in estimating the models.

Every variable are endogenous variables in VAR and VECM model. Endogenous variables are variables that are defined in the model and appear on both left and right side of the equation. Therefore, each dependent variable is a function made up of its own lag values and lag values of other variables. VAR model with variables crude oil price, OIL, foreign exchange rate, E and interest rate, I and u_{it} which is the impuls or innovation in VAR model can be built as follow:

$$LOGOIL_t = c_1 + \sum_{i=1}^{k} \beta_{1i} LOGOIL_{t-i} + \sum_{j=1}^{k} \phi_{1j} LOG\, E_{t-j} + \sum_{m=1}^{k} \varphi_{1m} I_{t-m} + u_{1t}$$
$$LOGE_t = c_2 + \sum_{i=1}^{k} \beta_{2i} LOGOIL_{t-i} + \sum_{j=1}^{k} \phi_{2j} LOG\, E_{t-j} + \sum_{m=1}^{k} \varphi_{2m} I_{t-m} + u_{2t} \quad (1)$$
$$I_t = c_3 + \sum_{i=1}^{k} \beta_{3i} LOGOIL_{t-i} + \sum_{j=1}^{k} \phi_{3j} LOG\, E_{t-j} + \sum_{m=1}^{k} \varphi_{3m} I_{t-m} + u_{3t}$$

VECM model is the restricted form of VAR model. VECM model is able to cater the long run relationship in the variables. Cointegration present in non-stationary series also implies that linear combination of those series will attain stationary in the long run. VECM model with have an error correction term, ECT which functions to adjust for long run equilibrium with negative coefficient, λ as speed of adjustment to ensure convergence of the model toward equilibrium (Suharsono *et al.* 2017). VECM model with variables crude oil price (OIL) foreign exchange rate (*E)* and interest rate, *(I)* and u_{it} which is the impuls or innovation in VECM model can be built as follow:

$$\Delta LOGOIL_t = c_1 + \sum_{i=1}^{k-1} \beta_i \Delta LOGOIL_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LOG\, E_{\,t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta\, I_{t-m} + \lambda_1 ECT_{t-1} + u_{1t}$$
$$\Delta LOGE_t = c_2 + \sum_{i=1}^{k-1} \beta_i \Delta LOGOIL_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LOG\, E_{\,t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta\, I_{t-m} + \lambda_2 ECT_{t-1} + u_{2t} \quad (2)$$
$$\Delta IVN_t = c_3 + \sum_{i=1}^{k-1} \beta_i \Delta LOGOIL_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LOG\, VN\_Dong_{\,t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta\, IVN_{t-m} + \lambda_3 ECT_{t-1} + u_{3t}$$

5. Results

According to Johansen cointegration test, we find that there is no cointegration in the variables for Brunei, Indonesia, Philippines, Malaysia, Singapore dan Thailand. So, VAR model are estimated for these countries. However, the lag length suggested for variables in Philippines VAR model is zero. Therefore the model consist of only intercept and this suggest that data for Philippines with crude oil price are not compatible with VAR model. In addition, Vietnam which has cointegration in variables is estimated with VECM model. The estimated models are also tested for autocorrelation and stability to ensure the model are best fit to the data collected. Therefore, the estimated models for crude oil price, foreign exchange rate and interest rates of each countries are tabulated in Table 4.

Table 4: Results of estimated VAR and VECM models

Country	Estimated models
Brunei	$\Delta LOGOIL_t = -0.0008 + 0.2513\Delta LOGOIL_{t-1} + 0.0193\Delta LOGBN\_Dolar_{t-1} + 0.0060\Delta IBN_{t-1}$ $\Delta LOGBN\_Dolar_t = 0.0002 - 0.0161\Delta LOGOIL_{t-1} + 0.2107\Delta LOGBN\_Dolar_{t-1} - 0.0655\Delta IBN_{t-1}$ $\Delta IBN_t = -0.0025 + 0.1254\Delta LOGOIL_{t-1} + 0.6569\Delta LOGBN\_Dolar_{t-1} + 0.0363\Delta LOGIBN_{t-1}$
Malaysia	$\Delta LOGOIL_t = -0.0007 + 0.24536\Delta LOGOIL_{t-1} - 0.0663\Delta LOGMY\_Ringgit_{t-1}$ $\Delta LOGMY\_Ringgit_t = 0.0005 - 0.0375\Delta LOGOIL_{t-1} + 0.1953\Delta LOGMY\_Ringgit_{t-1}$
Indonesia	$\Delta LOGOIL_t = -0.0012 + 0.2772\Delta LOGOIL_{t-1} - 0.0735\Delta LOGOIL_{t-2} + 0.2612\Delta LOGID\_Rupiah_{t-1} - 0.3682\Delta LOGID\_Rupiah_{t-2} + 0.0076\Delta IID_{t-1} - 0.0034\Delta IID_{t-2}$ $\Delta LOGID\_Rupiah_t = 0.0007 + 0.0094\Delta LOGOIL_{t-1} + 0.0066\Delta LOGOIL_{t-2} + 0.2380\Delta LOGID\_Rupiah_{t-1} - 0.2753\Delta LOGID\_Rupiah_{t-2} + 0.0097\Delta IID_{t-1} - 0.0024\Delta IID_{t-2}$ $\Delta IID_t = -0.0057 + -0.4795\Delta LOGOIL_{t-1} + 0.1346\Delta LOGOIL_{t-2} + 2.4010\Delta LOGID_{Rupiah_{t-1}} + 1.5707\Delta LOGID\_Rupiah_{t-2} + 0.09756\Delta IID_{t-1} + 0.3940\Delta IID_{t-2}$
Singapura	$\Delta LOGOIL_t = -0.0005 + 0.2441\Delta LOGOIL_{t-1} - 0.5452\Delta LOGSG\_Dolar_{t-1} + 0.56193\Delta ISG_{t-1}$ $\Delta LOGSG\_Dolar_t = -0.0003 - 0.0256\Delta LOGOIL_{t-1} + 0.2585\Delta LOGSG\_Dolar_{t-1} - 0.0898\Delta ISG_{t-1}$ $\Delta ISG_t = -0.0009 - 0.0714\Delta LOGOIL_{t-1} - 0.1105\Delta LOGSG\_Dolar_{t-1} + 0.0861\Delta ISG_{t-1}$
Thailand	$\Delta LOGOIL_t = -0.0009 + 0.2311\Delta LOGOIL_{t-1} - 0.5596\Delta LOGTH\_Baht_{t-1} + 0.0120\Delta ITH_{t-1}$ $\Delta LOGTH\_Baht_t = 0.0043 + 0.0001\Delta LOGOIL_{t-1} + 0.3468\Delta LOGTH\_Baht_{t-1} - 0.0056\Delta ITH_{t-1}$ $\Delta ITH = 0.0031 - 0.0577\Delta LOGOIL_{t-1} + 0.3430\Delta LOGTH\_Baht_{t-1} + 0.2582\Delta ITH_{t-1}$
Vietnam	$\Delta LOGOIL_t = -0.0621 + 0.2587\Delta LOGOIL_{t-1} - 0.0877\Delta LOGOIL_{t-2} + 1.2958\Delta LOGVN\_Dong_{t-1} - 0.5101\Delta LOGVN\_Dong_{t-2} + 0.0025\Delta IVN_{t-1} + 0.0099\Delta IVN_{t-2} - 0.0011ECT_{t-1}$ $\Delta LOG\text{VN\_Dong}_t = -0.0006 + 0.0012\Delta LOGOIL_{t-1} - 0.0196\Delta LOGOIL_{t-2} + 0.2912\Delta LOGVN\_Dong_{t-1} - 0.1381\Delta LOGVN\_Dong_{t-2} - 0.0025\Delta IVN_{t-1} + 0.0041\Delta IVN_{t-2} - 0.0004ECT_{t-1}$ $\Delta IVN_t = -0.0547 + 0.2903\Delta LOGOIL_{t-1} + 0.1407\Delta LOGOIL_{t-2} - 12.3984LOG\text{VN\_Dong}_{t-1} - 12.7757LOG\text{VN\_Dong}_{t-2} + 0.3238\Delta IVN_{t-1} + 0.0323\Delta IVN_{t-2} + 0.2205ECT_{t-1}$

The estimated VAR and VECM model can be used to check causality of the variable to provide useful information about short run relationship between the variables. Unidirectional causalities are present from interest rate to exchange rate for Brunei and Vietnam and from crude oil price to Singapore interest rate. No Grange causality is present between crude oil price and exchange rate. Table 5 shows the Granger causality for each model.

Table 5: Results of estimated VAR and VECM models

Causality direction	Brunei	Indonesia	Malaysia	Singapore	Thailand	Vietnam
Exchange rate → Crude oil price	No	No	No	No	No	No
Interest rate → Crude oil price	No	No	No	No	No	No
Crude oil price → Exchange rate	No	No	No	No	No	No
Interest rate → Exchange rate	Yes	No	No	No	No	Yes
Crude oil price → Interest rate	No	No	No	Yes	No	No
Exchange rate → Interest rate	No	No	No	No	No	No

6. Conclusion

Since interest rate is Granger cause to exchange rate in Brunei and Vietnam, the movement of interest rate will lead the movement of exchange rate in the short run. It can be concluded that addition of interest rate variable significantly improves forecasting of foreign exchange rate for Brunei and Vietnam. The government of Brunei and Vietnam or investors who interested to invest in foreign exchange rate market with Brunei and Vietnam currency can make better forecast of the exchange rates for these two currencies by using lag values of interest rate of Brunei and Vietnam. Besides that, crude oil prices is Granger caused to Singapore's interest rates. Therefore, the price of crude oil is useful as predictor for Singapore's interest rate because Singapore's interest rate will have better estimation by including the lag value of crude oil price. Therefore, any party who need to take up loan or to do investment with Singapore might gain benefit if the forecast model of Singapore's interest rate takes lag values of crude oil price into account.

References

Akaike H. 1973. Information theory and an extension of the maximum likelihood principle. In *Proc. 2nd International Symposium on Information Theory*, pp. 267-281.

Brahmasrene T., Huang J-C. & Sissoko Y. 2014. Crude oil prices and exchange rates: Causality, variance decomposition and impulse response. *Energy Economics* **44**: 407-412.

Buetzer S., Habib M. M. & Stracca L. 2016. Global exchange rate configurations: Do oil shocks matter? *IMF Economic Review* **64**(3): 443-470.

Dawson J.C. 2007. The effect of oil prices on exchange rates: A case study of the Dominican Republic. *Undergraduate Economic Review* **3**(1): 23-30.

Golub S. 1983. Oil prices and exchange rates. *The Economic Journal* **93**: 576-593.

Johansen S. & Juselius K. 1990. Maximum likelihood estimation and inferences on cointegration with approach. *Oxford Bulletin of Economics and Statistics* **52**(2): 169-209.

Krugman P. 1983. Oil and the dollar. In Bhandari J. & Putnam B. (eds.) *Economic Interdependence and Flexible Exchange Rates*: 179-190. Cambridge: MIT Press.

Mohd Shahidan S., Nor Ermawati H. & Hafizah A.R. 2013. The effects of oil price changes and exchange rate volatility on unemployment: Evidence from Malaysia. *International Journal of Research in Business and Social Science* **2**(4): 72-83.

Pershin V., Molero J. C. & Gracia F. P. 2016. Exploring the oil prices and exchange rates nexus in some African economies. *Journal of Policy Modeling* **38**: 166-180.

Suharsono A., Aziza A. & Pramesti W. 2017. Comparison of vector autoregresssive (VAR) vector error correction models (VECM) for index of ASEAN stock price. In *AIP Conference Proceedings 1913 (020032)*, pp. 1-5.

The World Factbook. 2018. World. https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html (1 April 2018).

Tiwari A. K. & Albulescu C. T. 2016. Oil price and exchange rate in India: Fresh evidence from continuous wavelet approach and asymmetric, multi-horizon Granger-causality tests. *Applied Energy* **179**: 272-283.

Department of Mathematical Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 UKM Bangi
Selangor DE, MALAYSIA
E-mail: humaida@ukm.edu.my, p90312@siswa.ukm.edu.my*

*Corresponding author