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RESPONSES OF MACROECONOMY AND STOCK MARKETS TO STRUCTURAL OIL PRICE SHOCKS: NEW EVIDENCE FROM ASIAN OIL REFINERY

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Abstract

In extensive oil-related literature, less attention has been paid to Asia and particularly little evidence is known for oil-refining countries. This paper examines how the economy of an oil-refining country reacts to an oil price shock and performs cross-country comparisons with oil-exporting and oil-importing countries. Singapore (oil refiner), Japan (oil importer), and Malaysia (oil exporter) have been analysed through a SVAR model using both macroeconomic and financial variables. Results show limited reactions of both macroeconomic indicators and stock returns to an oil supply shock and an oil aggregate demand shock negatively impacts economic activities. Our findings reveal that the country's status in the oil market matters is important when an oil specific demand shock is analysed. Our findings inform policymakers of the effectiveness of using monetary policy tools such as interest rate and exchange rate to mitigate the adverse effects of an oil price shock.

Keywords: oil price, oil refining, stock return, SVAR, Asian economies

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Introduction

Oil is a leading fuel making up approximately 33% of the world energy consumption (BP 2016). Since the early work of Hamilton (1983), the relationship between oil prices and economic activities, especially the recessionary effects of higher oil prices, has become an intriguing topic for researchers. Oil is an important production input, and oil price escalation will lead to a surge in production cost (Jones *et al.* 2004). In turn, the increase in production cost will lead to the following consequences: 1) producers will be forced to either elevate the product price or reduce the quantity supplied (Ayres and Voudouris 2014); 2) consumers will reduce their consumption level (Brown and Yucel 2002; Cologni and Manera 2008; Lardic and Mignon 2006); and 3) stock markets are likely to decline due to the undesirable environment (Asteriou and Bashmakova 2013; Bachmeier 2008; Chen 2010; Ciner 2001; Jones and Kaul 1996; Miller and Ratti 2009; Papapetrou 2001; Park and Ratti 2008; Sadorsky 1999).

Recent studies highlighted that these adverse relationships only pertain to oil-importing countries while oil-exporting countries benefit from an oil price increase (Filis and Chatziantoniou 2014; Mohanty *et al.* 2011). However, so far little attention has been paid to oil-refining countries (Le and Chang 2013; Le and Chang 2015). By definition, oil refiners import crude oil from oil-producing countries, they refine and export petroleum products to other countries. This double nature of importer and exporter makes oil-refining countries a worth-investigating case since an oil price increase can influence their economy both positively and negatively.

This paper aims to fill in this gap by examining short and long-run effects that an oil price shock exercises on oil-refining countries and performing cross-country comparisons with oil-importing and oil-exporting countries. To this aim, Singapore (oil refiner), Japan (oil importer), and Malaysia (oil exporter) have been analysed. These three countries have been selected because of the following reasons:

1) oil consumption outside OECD countries has increased substantially and is mostly driven by China and emerging countries in Asia (BP 2016);

2) Singapore, besides being a net oil importer, is the world's top three oil refiner and has the largest oil refinery industry in Asia. There is no natural oil reserve in Singapore, and a lot of foreign trading activities involve in the country's oil industry. In fact, Singapore's export orientation and heavy reliance on imports make its refinery more prone to market turbulences as compared to other Asian oil refiners (Le and Chang 2013);

3) the oil-related literature is populated by studies focusing on developed countries (among others, Arouri and Rault 2012; Chen *et al.* 2014; Lippi and Nobili 2012; Peersman and Van

Robays 2012) while the effects of an oil price shock on developing countries have been less studied (Cunado and Perez de Gracia 2005; Lescaroux and Mignon 2008; Mendoza and Vera 2010). Malaysia, one of the top 10 producers of liquefied natural gas, has been chosen as a proxy for emerging economies (Ali Ahmed and Wadud 2011).

The effects of an oil price shock on both macroeconomic and financial transmission channels have been examined through the Structural Vector Autoregressive (SVAR) model using data collected from August 2000 to August 2016. In the extant literature on the macroeconomic effects of oil price shocks, the Vector Autoregressive (VAR) approach is prevalent due to its capability to explore the dynamic interdependent relationships between macroeconomic variables (Vu and Nakata 2018). Indeed, the SVAR framework has been desired by previous researchers as it gives better insights into the structure of the global oil market and, in particular, oil price fluctuations can be grouped into different types (see, among others, Cunado *et al.* 2015; Filis and Chatziantoniou 2014; Kilian 2009; Peersman and Van Robays 2012). Following this strand in the literature, we also decompose three oil shock origins: oil supply shocks caused by disruptions in global oil production, oil demand shocks driven by global real economic activity, and oil specific demand shocks reflecting oil availability in the future. In this paper, the effects of these three oil shocks on the macroeconomic and financial variables related to the three chosen countries have been analysed.

The contribution of this paper is threefold. First, the countries of our choice, except for Japan, have not been extensively researched. Second, unlike previous studies on Asian economies (Abeysinghe 2001; Cunado and Perez de Gracia 2005; Le and Chang 2013; Peersman and Van Robays 2012), we disentangle oil price shocks from three sources (supply, aggregate demand and oil specific demand). Third, the sample period consists of recent data, enabling us to take into account the two recent turbulences in global oil market (price hike in 2008 and price plummet in 2014).

The rest of the paper is organised as follows. Section 2 reviews the literature, section 3 specifies the SVAR model, section 4 outlines data description, section 5 presents the findings and section 6 wraps up with concluding remarks.

Literature Review

Oil prices, macroeconomic and financial variables

Regarding the main macroeconomic indicators that affect oil price, prior researchers have discovered a negative association between oil price and industrial production whereas a positive relation between oil price and inflation has been detected (see, *inter alia*, Arouri and Rault 2012; Chang and Wong 2003; Ciner 2001; Cologni and Manera 2008; Du *et al.* 2010; Filis and Chatziantoniou 2014; Miller and Ratti 2009). The relationship between oil price and macroeconomic variables was found to be bidirectional in the study of Jimenez-Rodriguez and Sanchez (2005) while it was unidirectional according to Hassan and Zaman (2012).

Unlike these aforementioned researchers, Ali Ahmed and Wadud (2011), Rafiq and Salim (2014) attempted to uncover the link between oil price volatility and macroeconomy. While the former authors found a significant short-run impact of oil price volatility on GDP growth for 5 out of 6 countries in the sample, the latter authors documented an adverse effect that conditional volatility of oil price exercises on both aggregate output and CPI.

By arguing that macroeconomic indicators also affect individuals' consumption and investment patterns, a large body of literature has examined the potential influence of an oil price shock on stock returns. Particularly, a negative relationship was suggested by Bachmeier (2008), Chen (2010), Ciner (2001), Filis and Chatziantoniou (2014), Huang and Guo (2008), Jones and Kaul (1996), Miller and Ratti (2009), Park and Ratti (2008). These authors attributed variations in stock prices to the change in company's cash flow, which is factored by higher production costs due to higher oil prices. Another explanation was put forward by Jones and Kaul (1996), who reasoned that oil price shocks pose some risks for the financial markets and hence, an increase in oil price might cause a drop-in share price.

In contrast, a positive link was highlighted by Arouri and Rault (2012), Jimenez-Rodriguez and Sanchez (2005), Narayan and Narayan (2010), whose researches were conducted mainly for oil-exporting countries. However, other studies documented no association between oil price changes and stock market movement (Al-Fayoumi 2009; Apergis and Miller 2009; Cong *et al.* 2008; Mohanty *et al.* 2011).

The nature of the oil price shock matters

A large strand in existing literature is shaped around the concept that not all oil price shocks are identical and thus, it is necessary to review the origin of the shock (see, for example, Barsky and Kilian 2004; Hamilton 2009; Kilian 2009; Kilian and Park 2009; Lescaroux and Mignon 2008).

Kilian (2009) first disentangled the oil price shock into demand- and supply-side, and further separated demand-side shocks into aggregate demand and precautionary demand (or oil specific demand) shocks. This second attempt demonstrates the distinction between oil price shocks that originate from an increase in world aggregate demand (for example, due to the industrialisation of developing countries like China) and those that originate from the increased demand due to uncertainty about future availability of oil. The author then uncovered the positive link between stock markets and aggregate demand shocks but a negative link between stock markets and oil specific demand shocks. Indeed, this finding is reconciled with the studies of Abhyankar *et al.* (2013), Apergis and Miller (2009), Chen *et al.* (2014), Filis *et al.* (2011), Lippi and Nobili (2012). Also disentangling the three structural oil price shocks, Aastveit *et al.* (2015) found out that GDP is positively affected by demand shocks driven by global economic activity in all regions. Regarding oil specific demand shocks, the results are divergent whilst the oil supply shock impacts economic activity negatively in North America and Europe but positively in some Asian countries.

On the contrary, the suggestion that supply-side oil shocks are significantly less important for the economy and do not exhibit any influence on either macroeconomic or financial performance has received a wealth of supports from Abhyankar *et al.* (2013), Cunado *et al.* (2015), Hamilton (2009), Kilian (2009), Lippi and Nobili (2012). This is mainly attributed by the fact that OPEC's decisions on oil supply levels are well-predicted by the markets, and hence disruptions in oil supply do not cause significant changes in oil prices. Nevertheless, the study by Chen *et al.* (2014) suggested that supply side shocks exercise a more persistent effect on stock prices.

To sum up, the dynamics of oil price shocks, macroeconomy and stock returns have been extensively researched in the available literature but findings are mixed.

Oil-related literature in Asian context

The majority of prior research has focused on Japan rather than on other Asian economies. A bulk of studies has examined Japan in comparison with other developed countries (see, among others, Apergis and Miller 2009; Burbidge and Harrison 1984; Engemann *et al.* 2011; Hutchison 1993; Peersman and Van Robays 2012) and China has been analysed in multiple research papers (Cong *et al.* 2008; Du *et al.* 2010; Tang *et al.* 2010; Wei and Guo 2017). However, few studies have been done exclusively on Asian countries, and the most recent ones are summarised in Table 1. It is noted that all of these studies have scrutinised the transmission of an oil price shock on either macroeconomic or financial channel, and SVAR is the prominent model employed. To the best of our knowledge, there exists no study testing the impacts of oil price changes arising from different origins via both macroeconomic and financial transmission channels in Asian countries. This reinforces the novelty of the current study and the value it contributes to existing literature.

Table 1. Recent oil-related studies in Asian context.

Author/Study	Country/Group	Period	Methodology	Variables employed
Bhat *et al.* (2018)	India	1994-2016	SVAR	Industrial production, interest rate, inflation, real effective exchange rate, world crude oil price, global food price, oil price volatility, food price volatility
Cai *et al.* (2017)	East Asia	1992-2015	Wavelet coherence analysis	Oil price, stock return
Cross and Nguyen (2017)	China	1992-2015	VAR	Oil price, global activity index, global industrial production, metal price index
Cunado *et al.* (2015)	Japan, India, Korea, Indonesia	1997-2014	SVAR	Oil production, global economic activity, oil price, GDP, CPI, real effective exchange rate, discount rate
Ding *et al.* (2017)	China	2005-2015	SVAR	Brent crude oil price, investor sentiment index
Ibrahim and Chancharoenchai (2014)	Thailand	1993-2010	Asymmetric cointegration test	Consumer prices, real output, oil prices, Thai baht-US dollar exchange rate
Jiranyakul (2015)	Thailand	1997-2013	Bivariate-GARCH	Oil price, real exchange rate
Kim *et al.* (2017)	China	1992-2014	TVP SVAR, SVAR, GIR VAR	Global oil production, real oil price, industrial production, CPI, real exchange rate, interest rate
Koh (2017)	Brunei	2003-2014	SVAR	Real oil price, Singapore TWI, foreign assets and reserve money of MAS, real government expenditure, real oil GDP, real non-oil GDP, CPI, short-term interest rate, real effective exchange rate
Muhammad Arshad and Ayaz (2014)	Pakistan	1990-2011	SVAR	World oil price, global food price, inflation rate, real income, money balances, nominal effective exchange rate, nominal short-term interest rate
Sek (2017)	Malaysia	1980-2015	Autoregressive distributed lag models	Oil price, CPI, PPI, import price index, industrial production index
Taghizadeh-Hesary *et al.* (2016)	Japan, the US, China	2000-2008, 2008-2013	SVAR	Oil price, natural gas price, GDP, CPI, money supply, exchange rate
Vu and Nakata (2018)	Philippines, Singapore, Thailand, Indonesia, Malaysia, Vietnam	1999-2013	SVAR	Oil production, global economic activity, oil price, industrial production index, CPI, exports, imports, nominal exchange rate, three-month money market rate

You *et al.* (2017)	China	1995-2016	Quantile regression	Industry stock returns, oil price, economic policy uncertainty index, interest rate, exchange rate
Zhu *et al.* (2014)	Asia Pacific	2000-2012	AR(p)-GARCH(1,1)-t	Oil price, stock return

Country's role in the global oil market matters

Prior studies have widely explored the oil price - macroeconomy relationship and for over the last decade, a growing number of researchers have voiced their opinion that country status as an oil importer or oil exporter matters (Bhar and Nikolova 2009; Bjornland 2009; Le and Chang 2013; Lescaroux and Mignon 2008; Mendoza and Vera 2010; Vu and Nakata 2018; Yang *et al.* 2017). Several authors have reached the conclusion that a rise in oil price would benefit oil exporters but would be harmful for oil importers (Bjornland 2009; Jimenez-Rodriguez and Sanchez 2005; Lescaroux and Mignon 2008; Mendoza and Vera 2010). Considering the magnitude of the impact, Vu and Nakata (2018) argued that the effect of an oil price increase on aggregate output and inflation in oil-importing countries is larger than in oil-exporting countries. Taghizadeh-Hesary *et al.* (2016) further pointed out that the impact of an oil price shock on GDP growth in developed oil importers is less significant than that of an emerging economy.

Regarding the relationship between oil prices and the stock market, Arouri and Rault (2012), Bashar (2006), Filis and Chatziantoniou (2014), Mohanty *et al.* (2011), Wang *et al.* (2013) all voiced their opinion that there is a positive link between the two markets in oil-exporting countries but a negative link in oil-importing countries. A contradictory finding was suggested by Abeysinghe (2001) who measured the direct and indirect impacts of an oil price increase on ten Asian economies along with the US, and concluded that the negative influences of oil price shocks even apply for net oil exporters like Indonesia and Malaysia.

While the empirical evidences comparing the oil price - macroeconomy relationship for oil-importing versus oil-exporting countries are in general less abundant in the substantial oil-related literature (Filis and Chatziantoniou 2014), little is known for oil-refining countries.

Methodology

Structural VAR model

The structural representation of the VAR model (SVAR) of order *p* takes the following general form:

$$A_0 Y_t = c_0 + \sum_{p=1}^{P} A_p Y_{t-p} + \varepsilon_t \quad (1)$$

where Y is an N-dimensional vector of variables observed over t = 1,…,T periods of time; c_0 is a constant; A_0 is a N×N contemporaneous matrix; A_p are p autoregressive coefficient matrices with p=1,….,P lag; ε_t is an N-dimensional vector of structural disturbances assumed to have zero covariance and to be serially uncorrelated. The variance-covariance matrix of the structural disturbances is a diagonal matrix where the covariance is restricted to 0 and the variance is $E(\varepsilon_t \varepsilon_t') = \sigma_i^2$ (i = 1,…,N). To derive the reduced form, we multiply both sides of the equation (1) by A_0^{-1}. The resulting equation is:

$$Y_t = a_0 + \sum_{p=1}^{P} B_p Y_{t-p} + e_t \quad (2)$$

where $a_0 = A_0^{-1} \times c_0$ and $B_p = A_0^{-1} \times A_p$. The error terms in the reduced form, i.e. e_t, are the weighted average of structural shocks ε_t, i.e. $e_t = A_0^{-1} \times \varepsilon_t$ (or $\varepsilon_t = A_0 \times e_t$).

In this study, we make use of the Cholesky decomposition of the variance-covariance matrix of the estimated residuals by imposing a recursive causal ordering on A_0 as follows:

$$\begin{bmatrix} \varepsilon_{1,t} \\ \vdots \\ \varepsilon_{N,t} \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ a_{N1} & \cdots & a_{NN} \end{bmatrix} \times \begin{bmatrix} e_{1,t} \\ \vdots \\ e_{N,t} \end{bmatrix} \quad (3)$$

Note that in the SVAR model, the order of the variables is of critical importance.

The ADF (Augmented Dickey-Fuller), PP (Phillips-Perron) and KPSS (Kwiatkowski–Phillips–Schmidt–Shin) tests will be used to check the hypothesis of stationarity. The SVAR lag length will be tested based on FPE (Final prediction error), AIC (Akaike information criterion), SC (Schwarz information criterion), and HQ (Hannan-Quinn Information Criterion). LM test will be carried out to detect autocorrelation. Additionally, stability is of paramount importance to VAR model and its related variations as instability will make some results, for instance the impulse response standard errors, invalid. In this regard, the eigenvalue stability test will be conducted by looking at the graph plotting all the inverse roots of the characteristic AR polynomial and the VAR model is said to be stable or stationary if all roots lie inside the unit circle.

Data description

This study will utilise monthly data from August 2000 to August 2016. The following 8 variables have been analysed: world oil production (OIL_PROD), global economic activity index

(ECO_ACT), crude oil price (OIL_PRICE), industrial production index (IP), consumer price index (CPI), interest rate (IR), real effective exchange rate (ER), and stock market return (ST).

The first three variables describe three sources of oil price changes in world oil market. The Dubai Fateh crude oil prices will be utilised to proxy world crude oil prices due to its more relevance in Asia. Oil price is converted into real terms in order to ensure a common shock to all countries. The global economic activity index is proxied by the dry cargo freight rates and retrieved from Kilian's website. The remaining 5 variables are country-related variables. Interest rates are benchmarked by money market rate for Malaysia and by discount rate for Japan and Singapore. Oil price and oil production are transformed into growth rates while global economic activity and macroeconomic indicators are kept at level. Stock market returns are calculated as first-differenced logs from end-of-month prices of Nikkei225, FTSE Straits Times Singapore, and FTSE Bursa Malaysia.

The Dubai Fateh historical prices are retrieved from Federal Reserve Economic Data (FRED). World oil production series are collected from the US Energy Information Administration (EIA). Macroeconomic data are retrieved from International Financial Statistics (IMF), and stock returns are collected from *Datastream*. The variables employed in this study are described in table 2 along with their data source.

Table 2. Variable description and sources.

Variables	Description	Source
OIL_PROD	World oil production level: Percentage change in world oil production	EIA
ECO_ACT	Global economic activity index represented by dry cargo freight rate	Kilian's website
OIL_PRICE	Dubai Fateh crude oil prices: Percentage change in Dubai crude oil spot prices	FRED
IP	Industrial production index. This is our measure of economic activity	IMF
CPI	Inflation rate, proxied by Consumer Price Index	
IR	Nominal interest rate: money market rate for Malaysia and discount rate for other countries	
ER	Real effective exchange rate of local currency against US dollars	
ST	Stock market returns: first-differenced logs of monthly prices of Nikkei225, FTSE Straits Times Singapore, and FTSE Bursa Malaysia indices	Datastream

Model specification

The structural disturbances are made accordingly equation (3) where *N*=8 variables and the order of the variables is as follows: 1. aggregate oil-supply shock; 2. aggregate oil-demand shock; 3. oil specific demand shock; 4. income shock; 5. price shock; 6. interest rate shock; 7. exchange rate shock; 8. stock market shock. It is worth reinforcing that the ordering of the variables is vital in the SVAR model, and the abovementioned ordering is devised by certain assumptions.

In particular, the three assumptions used to identify the oil price shocks in the first three equations are as followed. Firstly, oil supply is not influenced by demand shocks immediately as a consequence of high costs to adjust production level instantly. By contrast, oil supply can exert contemporaneous effects on both oil prices and global economic activity. Secondly, global economic activity is not contemporaneously impacted by oil specific demand shocks due to a delay in responses of the world economy to oil price movements. On the contrary, changes in global economic activity can have an instantaneous influence on oil price because of the liquidity and prompt reactions of commodity markets. Thirdly, it is argued in this study that oil price innovation can originate from all kinds of shocks, therefore oil production and aggregate demand shocks can immediately affect oil prices.

Some notable information can be extracted from the restrictions for the remaining variables. With the economy's dependence on oil, the economic activity can receive contemporaneous impacts from all three oil shocks, but not from other variables. It is reasonable that inflation cannot affect industrial production in an immediate manner due to the time lag between CPI changes and corresponding changes in demand. Even though interest rate and exchange rate could be employed to assist the economic activity, these impacts will not be revealed immediately. In addition, all three origins of oil price shocks create inflationary pressure on the economy, affecting inflation rate contemporaneously. Interest rate is an effective monetary tool for stabilising inflation rate while deviations in real effective exchange rate could lead to either imported inflation or exporting inflation. Yet, these effects cannot be observed promptly. Finally, stock returns respond contemporaneously to all shocks by the other variables, but are not expected to influence other variables contemporaneously.

Appendix A exhibits the results of ADF, PP, and KPSS tests, which confirm the stationarity of stock market variables, oil production and oil price return but indicate unit root problem with the remaining variables. Nonetheless, all series are stationary when considered at first difference. Thus, they will appear in the SVAR model in first-differenced form. Following Kilian (2009), the maximum lag length of 24 periods has been adopted in this study.

Appendix B summarises the results of the optimal lag length selection. For Japan and Singapore, both the AIC and FPE suggest two lags. The LM test then indicates the absence of autocorrelation. For Malaysia, the AIC recommends twelve lags while HQ indicates one lag and FPE suggests two lags. Following Ivanov & Kilian (2005), emphasis should be placed on AIC. Yet, such a large number of lags would be inconsistent with the lag order chosen in other similar studies in which the majority of prior researchers selected two lags. Thus, the number of lags recommended by FPE was raised and eventually four lags free the SVAR model from autocorrelation.

Regarding stability, all values in Appendix C for three countries are less than unity, demonstrating that there is no explosive variable and thus the eigenvalue stability test is satisfied.

Descriptive statistics

Figure 1 plots the variables used in the following analysis. The effects of the Global Financial Crisis 2007-2008 are witnessed by the strong plummet in global economic activity, the troughs in oil price return as well as the peaks in inflation rates in Singapore and Malaysia. Nikkei index exhibits a substantial drop in 2008 as expected from the spread of the Great Recession whereas the pattern is not clear for both FTSE Straits Times Singapore index and FTSE Bursa Malaysia index. The rationale could be that the exposure of Singapore banks to subprime mortgage is limited thanks to its well-regulated market whilst the stock market in Malaysia is not well-established.

Different characteristics of the variables being employed are displayed in Table 3. Oil variables exhibit the highest volatility as compared to macroeconomic and financial variables. As expected, stock market return in Malaysia is the most volatile among three stock market variables, due to its less well-established nature. Notably, global economic activity index with a negative mean signals global economic contraction during the period under consideration. Besides, the negative mean of the effective exchange rate in Malaysia is expected as the consequence of the currency crisis in 2015. Finally, as suggested by the Jarque-Bera test as well as the skewness and kurtosis measures, the industrial production index (IP) in Japan and Singapore are the only two normally distributed variables at the significance level of 5%.

Figure 1. Plots of variables under investigation, from August 2000 to August 2016.

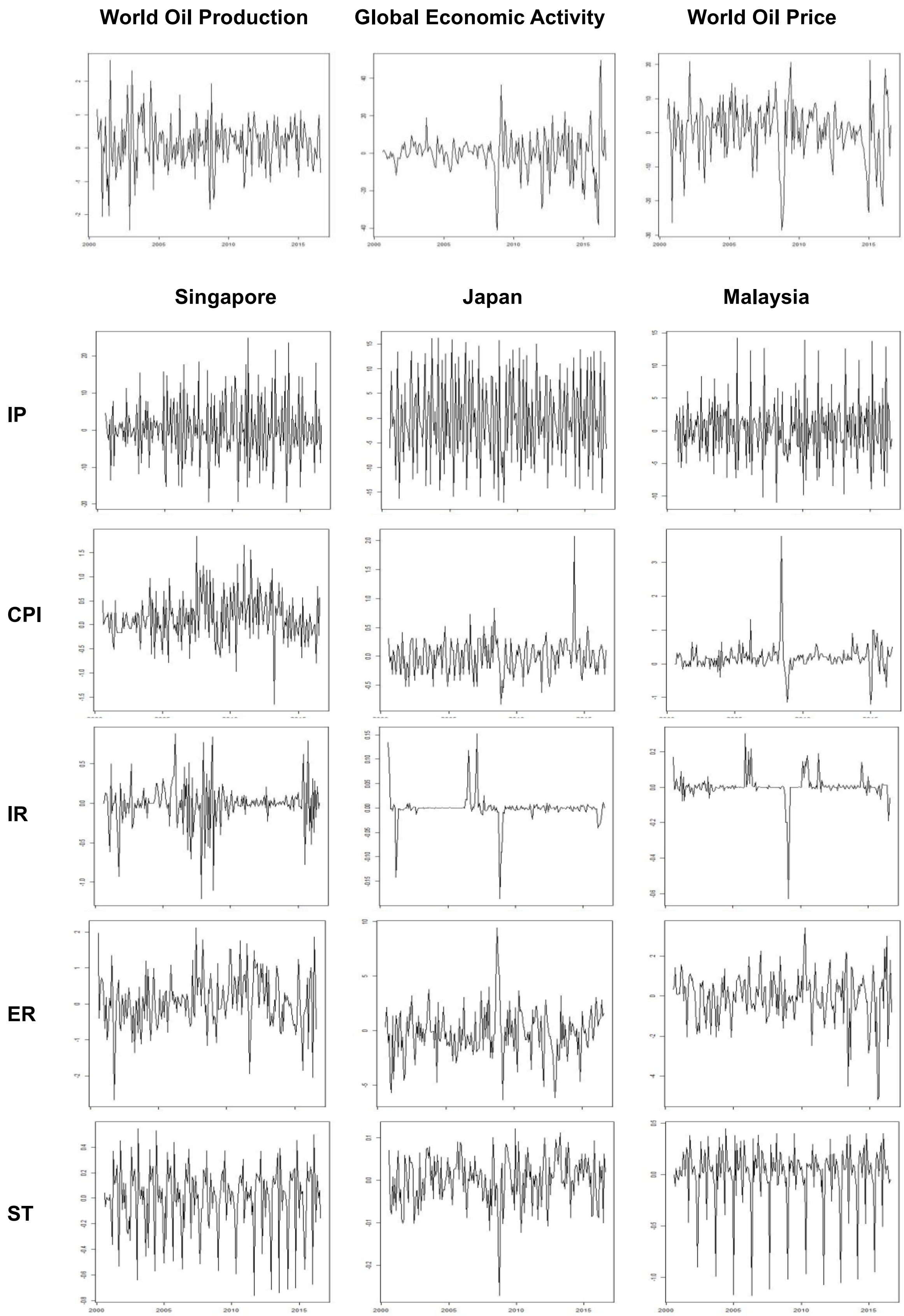
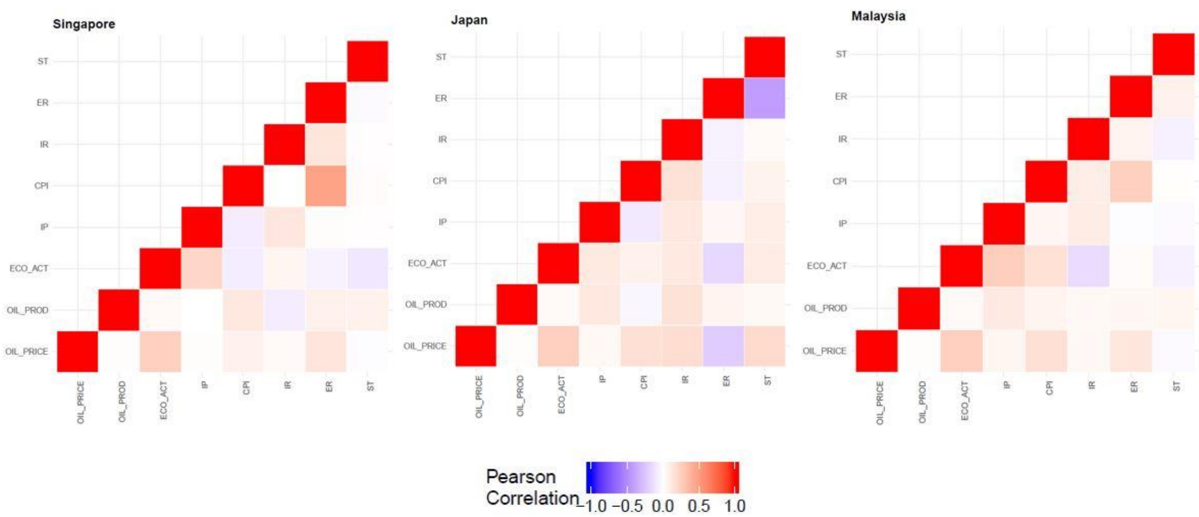


Table 3. Descriptive statistics of variables under examination.

	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Probability
OIL_PROD	0.116	0.763	-0.137	4.223	12.620	0.002
ECO_ACT	-0.212	11.265	-0.092	7.204	142.369	0.000
OIL_PRICE	0.647	8.500	-0.775	4.391	34.892	0.000
Singapore						
IP	0.243	8.497	0.307	3.181	3.300	0.192
CPI	0.144	0.500	0.318	4.110	13.145	0.001
IR	-0.011	0.282	-0.637	6.824	130.667	0.000
ER	0.072	0.752	-0.077	3.943	7.348	0.025
ST	0.002	0.260	-0.886	3.937	32.290	0.000
Japan						
IP	-0.076	8.442	0.049	2.230	4.849	0.089
CPI	0.004	0.312	1.360	11.809	683.555	0.000
IR	0.000	0.030	-0.272	20.599	2493.056	0.000
ER	-0.198	2.165	0.215	5.026	34.507	0.000
ST	0.000	0.058	-0.738	4.620	38.632	0.000
Malaysia						
IP	0.226	4.804	0.460	3.655	10.269	0.006
CPI	0.182	0.408	3.287	34.110	8130.520	0.000
IR	0.002	0.077	-3.165	31.518	6862.559	0.000
ER	-0.039	1.231	-0.910	5.996	98.795	0.000
ST	0.004	0.309	-2.173	8.300	377.788	0.000

Figure 2 reports the correlation matrices among variables under examination. It is apparent that oil price returns are negatively correlated with the stock market performance in Malaysia and Singapore as it has usually been suggested by past literature. Another high correlation figure dictates the oil price-CPI relationship in Japan and Malaysia, reflecting the heavy dependence on oil in these two economies. A negative and relatively high correlation between oil price and effective real exchange rate is noticed in Japan, confirming the country's status of a large oil importer.

Figure 2. Heatmaps of the pairwise correlation of the variables under consideration.



Empirical findings

Contemporaneous relationships

Table 4 displays the contemporaneous coefficients. Oil aggregate demand shocks exert a positive contemporaneous influence on economic activity in all three countries, which is expected, whilst affecting the interest rate positively for Japan and negatively for Malaysia. On the other hand, oil supply shocks exercise a positive influence on the economic activity in Japan and Malaysia. The finding for Malaysia – a net oil exporter is anticipated but the result for Japan – a net oil importer is rather surprising. It is also obvious that oil specific demand shocks exhibit a negative effect on interest rate in Japan and real effective exchange rate in Singapore, but a positive effect on interest rate in Malaysia. Furthermore, only oil specific demand shock is influencing contemporaneously the stock performance variable.

These results designate the importance of oil specific demand shock - expectations for the future availability of oil. Rationally, changes in predictions for oil shortage in the future can lead to market turbulences, which would be beneficial to the economy of an oil exporter like Malaysia whilst harmful to the economy of an oil importer like Japan. Optimistic economic conditions in oil exporting countries usually couple with increasing inflation, which is in turn related to a positive respond from interest rate as seen in the case of Malaysia. The opposite holds for oil importing countries as observed from Japan.

Table 4. SVAR contemporaneous coefficients.

Response of	Shock origins	Japan	Malaysia	Singapore
OIL_PROD	Oil supply	1.457***	1.410***	1.402***
OIL_PRICE	Oil aggregate demand	-0.136*	0.115	-0.124*
	Oil specific demand	-0.124***	0.126***	-0.124***
ECO_ACT	Oil aggregate demand	0.097***	0.102***	0.099***
IP	Oil supply	0.250**	0.162**	0.028
	Oil aggregate demand	0.193***	0.189**	0.161**
	Economic activity	0.177***	0.299***	0.153***
CPI	Inflation	3.394***	2.712***	2.063***
IR	Oil aggregate demand	0.140*	-0.156**	0.053
	Oil specific demand	-0.102	0.139*	-0.026
	Interest rate	44.117***	16.050***	3.701***
ER	Oil specific demand	0.097	0.078	-0.162*
	Inflation	0.049	0.308***	0.533***
	Interest rate	0.129*	0.004	0.169**
	Exchange rate	0.496***	0.909***	1.625***
ST	Oil specific demand	0.147*	-0.055	-0.003
	Economic activity	0.147*	-0.031	-0.048
	Exchange rate	-0.425***	0.093	0.0005
	Stock market	19.011***	3.268***	3.858***

Note: only coefficients significant for at least one of the three countries are reported. ***, **, * denote significance at 1%, 5%, and 10%.

Accumulated lagged responses

Oil supply shock

It is evident from Figure 3 that oil supply shocks exert limited effects on the economic activity of all three countries notwithstanding the country's position in the oil market. More specifically, the industrial production index in Japan decreases until the 4^{th} month and this impact fades out afterwards. Malaysia's industrial production index also reduced but this effect is insignificant 5 months after the initial shock and becomes at a minimal in 20 months' time. Singapore's industrial production index does not demonstrate any clear significant response.

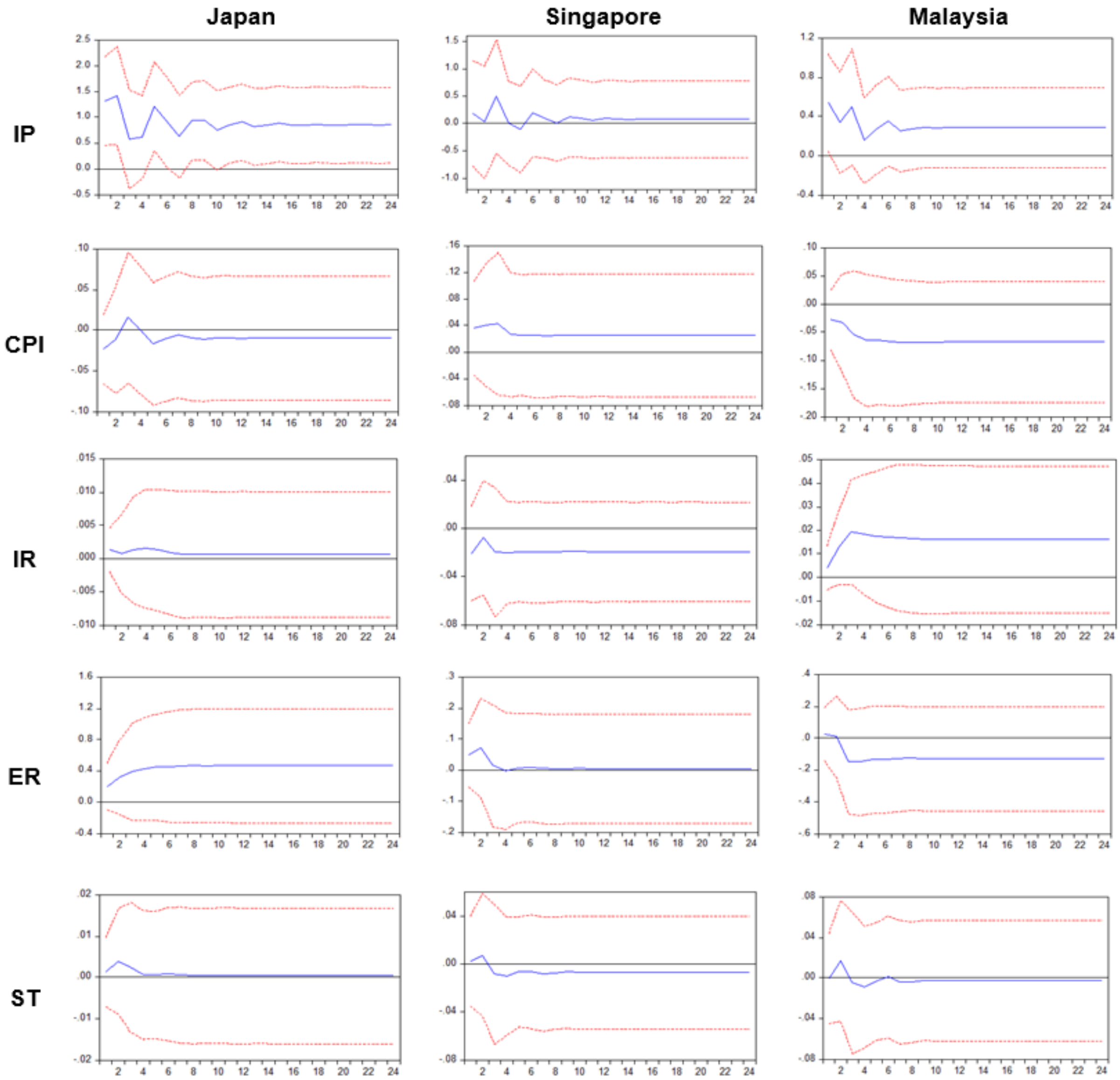
The aforementioned results are probably the consequences of the structural changes that have been implemented in all three countries. For instance, in Japan, more nuclear and renewable energy power plants have been constructed following the government's plan to diversify the energy supply sources. Additionally, Japan's population is aging at an accelerating speed while youngsters are moving to urban habitats, leading to a gradual fall in oil demand (Taghizadeh-Hesary *et al.* 2016).

Turning to CPI, Malaysia and Singapore do not show any clear responses whereas there is a slight increase in Japan's CPI. This marginal rise is probably factored by the cost-push inflation typically seen in a large oil importer.

It is noticeable that interest rates in Malaysia and Singapore respond positively to a positive oil supply shock in the short run whilst interest rate in Japan declines mildly. A decrease in real effective exchange rate is witnessed in Malaysia though with a delay of three months whereas Singapore does not exhibit any significant response.

Finally, the stock returns in both Japan and Singapore remain largely unaffected. The stock returns in Malaysia respond positively to a positive supply shock, reflecting the prosperous economic conditions thanks to the country's position of a large oil exporter. However, the response from Malaysia's stock market is shown with a delay probably due to the inefficiency of its newly-established stock market in reflecting the available information in the financial markets.

Figure 3. Accumulated impulse response functions to an oil supply shock.

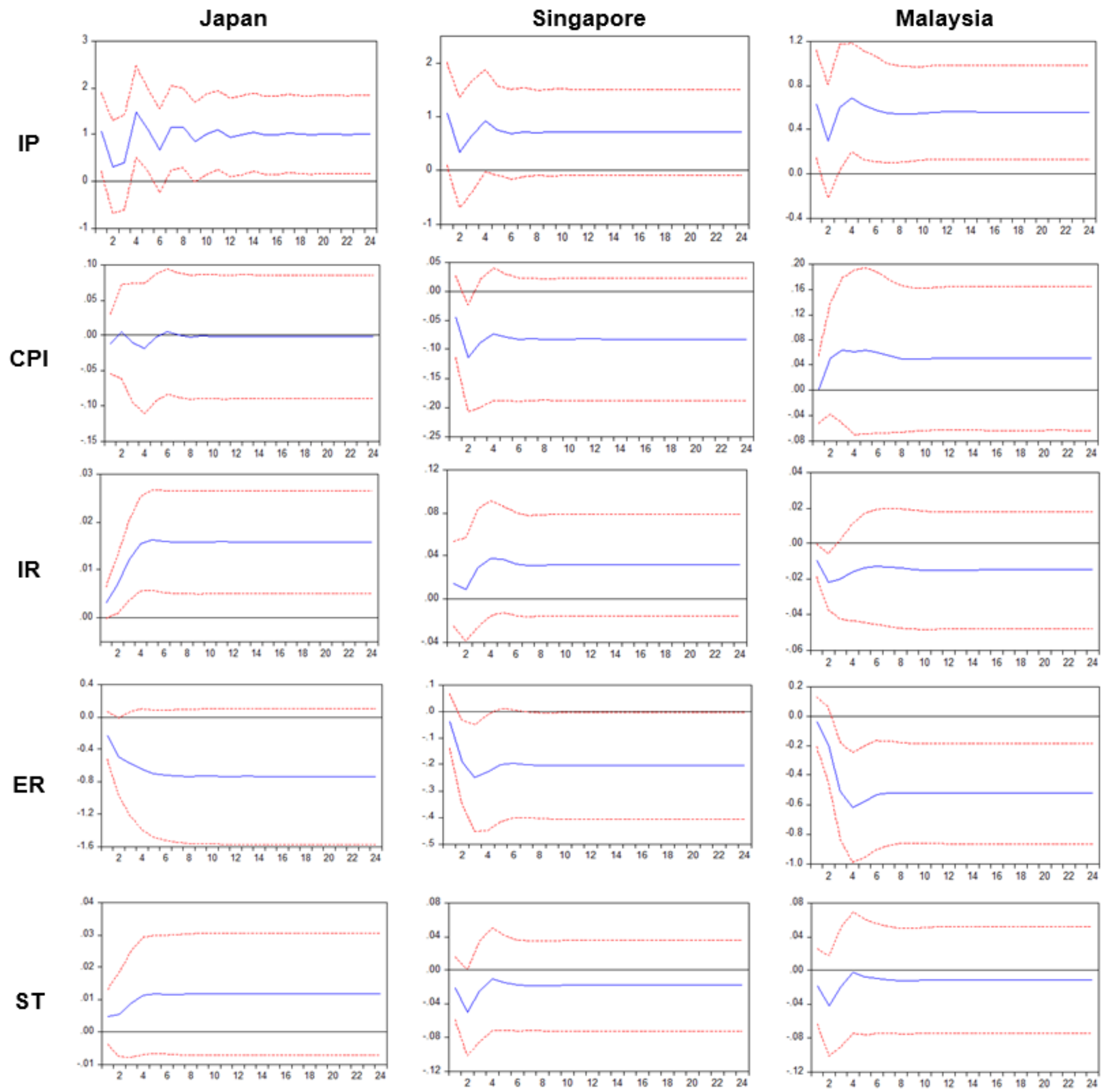


Oil demand shock driven by global economic activity

Figure 4 clearly shows that economic activities in all three countries negatively react after the oil demand shock. A common pattern is that the industrial production index decreases in the first two months and the impact loses its significance onwards.

This finding is in disagreement with the short-lived positive responses of real GDPs to an oil demand shock both in advanced economies (Lippi and Nobili 2012; Peersman and Van Robays 2012) and in Asian emerging economies (Aastveit *et al.* 2015; Cunado *et al.* 2015). A feasible explanation could be that robust world economic conditions reinforce the oil demand for production in individual country, which is heavily dependent on oil as a key factor of production, thus the unexpected oil price increase is likely to impair the economic growth. In fact, this result is unanticipated for Malaysia – a net oil-exporting country. The contribution of Malaysia's net oil export to the GDP is inconsiderable (0.1% in 2013) while the proportion of gas export is bigger (more than 6% of GDP in 2013). In the meanwhile, its economy has not concentrated on oil and gas, but rather diversified with manufacturing and service sector making up over 80% of the output (IMF 2015). Hence, even the stronger exports of oil and gas thanks to a boost in the world economic activity is not able to dominate the surge in oil price, leading to a drop in economic activity.

Figure 4. Accumulated impulse response functions to an aggregate demand oil shock.



With regard to CPI, Japan experiences a mild growth, which eventually dies out in 18 months' time. CPI in Malaysia responds positively while a slight decline is seen in Singapore, yet these responses become not clear and vanish about 2 months later. These findings could be reasoned by the state energy subsidies, which would soften the transmission of oil price shocks to CPIs in Malaysia and Singapore. Differences in the response of interest rate to the shock exist across the countries and can be explained by the contemporaneous coefficients.

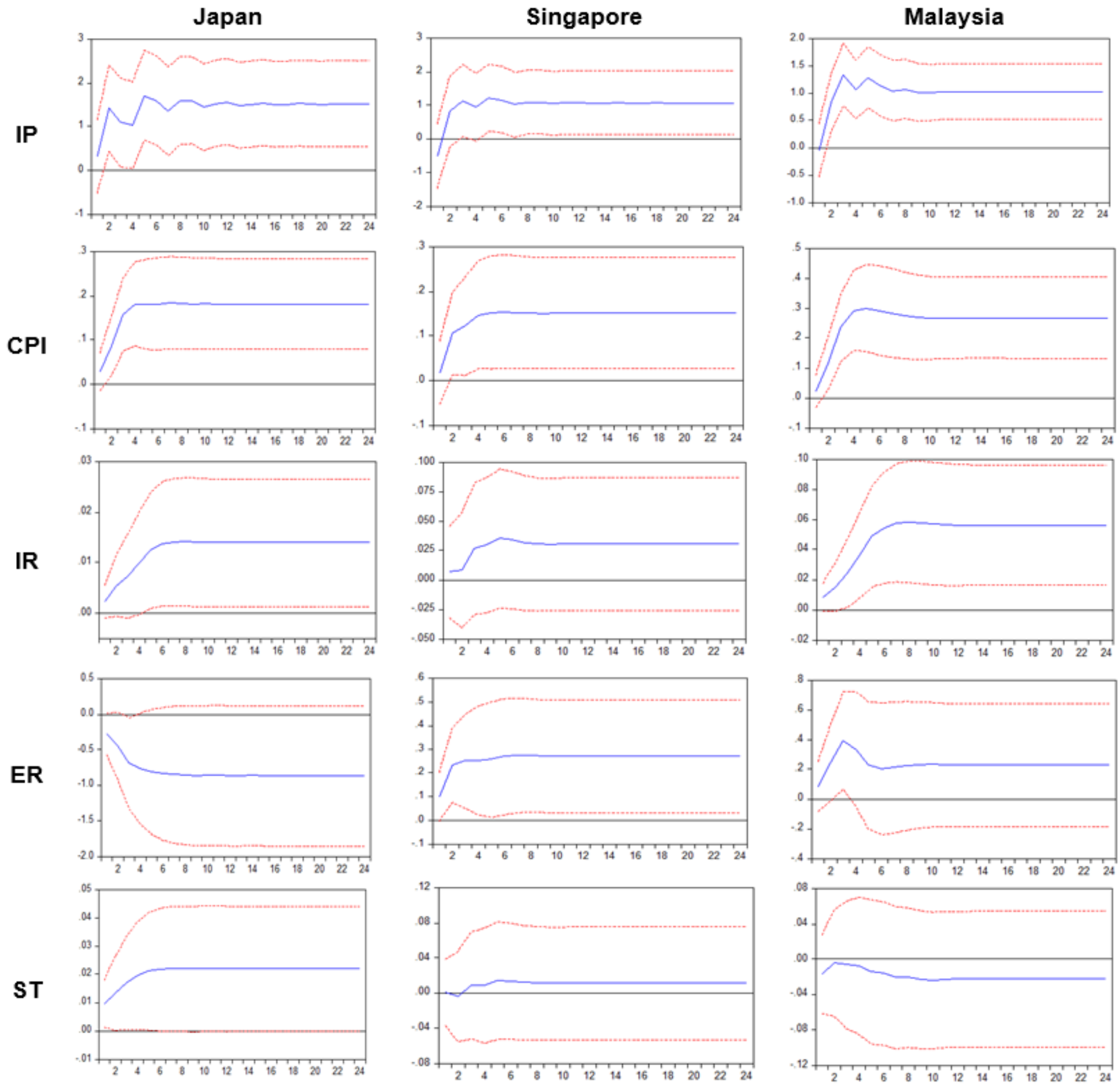
When it comes to real effective exchange rate, three countries experience quite similar responses. In Japan, a mild decrease is noted, testifying the theoretical linkage between oil market and currency market as described by Le and Chang (2013) and Coudert *et al.* (2011): an oil-importing (oil-exporting) country might witness exchange rate depreciation (appreciation) when oil prices go up and appreciation (depreciation) when oil prices go down. Nonetheless, the effect turns to be negligible at a fast pace, reflecting the gain from more robust export activities due to stronger global economic conditions. Real effective exchange rate in Malaysia responds negatively to the shock, which is in line with the fact that the country lost its position of being a net oil exporter in 2013 (Cunado *et al.* 2015). A similar response is observed in Singapore although the impact is rather short-lived. Here, the short-run nature of the negative response indicates that in the medium and long run, the appreciating impact from oil-refining activities predominates.

Singapore's stock market slightly declines immediately after the shock, but bounces back after the third month. This finding again establishes that benefits from oil refinement in the long run will dominate the harmful effect from oil imports in the short run.

Oil specific demand shock

An oil specific demand shock will bolster both oil production and oil price without any positive benefits in global economic activity. In Figure 5, economic activity in Japan witnesses an unsteady increase while a strong climb is witnessed in Malaysia and Singapore. Here, the country's position in the oil market plays a crucial role. Without a rise in the general global economic conditions, there is no strong supporting cushion for the economic activity of a country relying heavily on exports like Japan. Simultaneously, an increase in oil price is likely to result in a tumble in the economy of an oil importer via escalating production costs. By contrast, Malaysia and Singapore, being the large oil exporter and oil refiner, certainly benefit from an oil surge. However, this effect is relatively short-lived as its magnitude shrinks after the first three months because of the emerging demand-pull inflation.

Figure 5. Accumulated impulse response functions to an oil specific demand shock.



CPI in all three countries reacts positively to the positive oil specific demand shock in the short run. On one hand, increasing CPI in Japan is attributed by the rising cost of factors of production. On the other hand, growing CPI in Malaysia and Singapore again underpins the significance of demand-pull inflation. However, in the medium and long term, a robust decline in CPI is documented. Both real effective exchange rates in Malaysia and Singapore respond positively after the initial shock, and an overall decrease occurs in Japan. In addition, it is worth noting that the response of interest rate to the shock is positive for only the first 6 months after the impact, and this effect becomes negligible in the medium term in all three countries.

With regard to the stock market performance, Malaysia and Singapore exhibit a marginal positive response even though Japan shows an unclear response. This is theoretically expected as favourable economic conditions supporting the stock market in oil-exporting countries but undesirable conditions pertaining in oil-importing countries.

Discussion and conclusion

This paper aims 1) to examine short and long-run effects that an oil price shock exercises on oil-refining countries and 2) to perform cross-country comparisons with oil-importing and oil-exporting countries. Therefore, Singapore (oil refiner), Japan (oil importer), and Malaysia (oil exporter) have been analysed using the SVAR model based on Cholesky decomposition.

Utilising monthly data from August 2000 to August 2016, we find evidence suggesting that an oil price shock can distinctly affect the macroeconomy and stock market performance depending on its origins. Table 5 sums up the main findings. Both macroeconomic and financial variables do not show clear responses to an oil supply shock. Industrial production in all countries responds negatively to an oil demand shock driven by global economic activity. CPIs in Japan and Malaysia respond positively while the opposite is witnessed in Singapore. Stock market in Japan mildly declines and the reverse holds for other two countries. Regarding an oil specific demand shock, the country's status in the oil market matters with Japan experiences an unsteady increase in economic activity and insignificant response from stock return. CPIs and economic activities in Malaysia and Singapore respond positively to the shock whilst no significant responses from the stock market are shown in these two countries. The situation in Singapore can be largely attributed to the compensation between short-term negative effects from oil importing and long-term benefits from oil refining.

Table 5. Summary of the SVAR response to a positive impulse.

		Singapore	**Japan**	**Malaysia**
Oil supply shock	IP	0	-	-
	CPI	0	+	0
	IR	+	-	+
	ER	0	+	- D
	ST	0	0	+ D
Aggregate demand shock	IP	-	-	-
	CPI	-	+	+
	IR	0	+	-
	ER	-	-	-
	ST	+	0	+
Oil specific demand shock	IP	+	+	+
	CPI	+	+	+
	IR	+D	+	+
	ER	+	-	+
	ST	+D	0	+

Note: "+" denotes a positive response, "-" denotes a negative response, "0" denotes no clear response and "D" denotes a delay in the response by the variables.

Our results regarding the responses of inflation to an oil price shock, especially from the demand side, are inconsistent with the suggestion made by Hamilton (2009), Lescaroux and Mignon (2008) that since 1980s oil price increase cannot heighten the inflation level in the economy. However, this finding reconciles with what was documented in the work by Filis and Chatziantoniou (2014) for Russia and eight European countries and Cunado *et al.* (2015) in Asian context. Furthermore, our results indicate clear and significant responses of interest rate and real effective exchange rate to stabilise the inflation level, especially in the case of an oil specific demand shock. Real effective exchange rate in Singapore, where exchange rate adjustments are employed as a monetary policy tool, is inclined to rise immediately in respond to the accelerating inflation level. Japan and Malaysia, where interest rate is a monetary tool for inflation stabilisation, witness a contemporaneous increase in interest rate to restrict the climbing inflationary pressures driven by an oil price increase.

Our results inform policymakers of the effectiveness of using monetary policy tools such as interest rate and exchange rate to mitigate the adverse effects of an oil price shock. However, our research is not without limitations and our findings should be interpreted with care. One major limitation pertain the transformation of our variables operated before the adoption of the SVAR model. By converting oil production and oil price series into growth rates, some useful information regarding the trends disappear. This could be overcome by applying Vector Error Correction Model (VECM) with oil production and oil price series kept in level. It would also be worthy to compare the results obtained from the SVAR and VECM models for a deeper analysis. Furthermore, we acknowledge that the pre-set ordering of the variables in the SVAR model is critical and it is quite tricky to impose such restrictions for some variables. Thus, sensitivity analysis could be conducted to examine whether the accumulated impulse response functions of our key variables remain unchanged with different orderings. Another interesting question for future research is whether the economic and financial market variables respond differently to an oil price shock in economic turbulences and in stable periods. Finally, other economic variables such as bond returns, term spread, default spread, political stability and economic policy uncertainty could be incorporated into the econometric model.

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Appendix A. Unit root statistics.

	ADF		PP		KPSS	
	C	C & T	C	C & T	C	C & T
OIL_PROD	-12.81***	-12.79	-15.08***	-14.87***	0.03	0.03
Δ OIL_PROD	-11.72***	-11.68***	-49.05***	-48.86***	0.02	0.02
OIL_PRICE	-9.82***	-9.86***	-9.56***	-9.57***	0.31	0.07
Δ OIL_PRICE	-9.09***	-9.06***	-81.52***	-79.95***	0.16	0.15**
ECO_ACT	-2.28	-2.78	-2.01	-2.48	0.69**	0.36***
Δ ECO_ACT	-10.47***	-10.47***	-10.00***	-10.16***	0.10	0.04
Singapore						
IP	-1.10	-3.33*	-2.16	-8.93***	1.60***	0.12*
Δ IP	-19.40***	-19.35***	-41.65***	-41.82***	0.5**	0.5***
CPI	0.08	-1.20	0.14	-1.69	1.64***	0.28***
Δ CPI	-5.72***	-5.74***	-16.07***	-16.07***	0.33	0.27***
IR	-1.77	-1.79	-1.94	-1.97	0.79***	0.12*
Δ IR	-18.35***	-18.32***	-18.35***	-18.32***	0.10	0.09
ER	-0.08	-1.62	-0.19	-1.65	1.29***	0.32***
Δ ER	-12.31***	-12.40***	-12.31***	-12.40***	0.33	0.19*
ST	-16.72***	-16.94***	-26.12***	-25.99***	0.22	0.22
Δ ST	-16.09***	-16.04***	-158.30***	-160.34***	0.11	0.10
Japan						
IP	-3.14**	-3.37*	-8.37***	-26.85***	0.37*	0.14*
Δ IP	-4.95***	-4.95***	-26.86***	-26.76***	0.03	0.02
CPI	-1.96	-2.25	-1.61	-1.84	0.28	0.23***
Δ CPI	-11.34***	-11.44***	-11.15***	-11.24***	0.22	0.05
IR	-2.24	-2.23	-1.91	-1.9	0.18***	0.18***
Δ IR	-8.56***	-8.51***	-8.53***	-8.48***	0.11	0.06
ER	-2.33	-2.38	-2.22	-2.28	0.91***	0.15**
Δ ER	-10.42***	-10.46***	-10.37***	-10.41***	0.12	0.08
ST	-11.70 ***	-11.78***	-11.79***	-11.86***	0.16	0.07
Δ ST	-12.99***	-12,96***	-52.30***	-52.08***	0.09	0.07
Malaysia						
IP	-1.17	-1.84	-2.10	-4.75***	1.34***	0.22***
Δ IP	-4.20***	-4.19***	-34.93***	-34.74***	0.09	0.09
CPI	0.32	-3.59**	0.56	-3.01	1.71***	0.17**
Δ CPI	-9.67***	-9.69***	-9.56***	-9.54***	0.11	0.03
IR	-2.30	-2.35	-2.37	-2.36	0.17***	0.09***
Δ IR	-8.53***	-8.50***	-8.53***	-8.50***	0.05	0.05
ER	-2.19	-2.27	-1.98	-2.07	0.15	0.16**
Δ ER	-11.14***	-11.14***	-10.92***	-10.91***	0.10	0.06
ST	-13.06***	-13.35***	-16.57***	-16.52***	0.02	0.02
Δ ST	-17.24***	-17.21***	-71.28***	-70.96***	0.23	0.23

Note: The series of first difference is denoted by Δ. Two specifications with intercept (C) and intercept along with trend (C & T) are considered. ***, **, * denote significance at 1%, 5%, and 10%.

Appendix B. Lag length criteria.

Singapore

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2520.148	NA	187.2261	27.93533	28.07670*	27.99265*
1	-2415.957	198.0191	120.1668	27.49124	28.76357	28.00707
2	-2349.935	119.6433	117.9566*	27.46889*	29.87218	28.44324
3	-2290.633	102.2214	125.4626	27.52081	31.05506	28.95367
4	-2234.081	92.48270	138.8054	27.60311	32.26832	29.49448
5	-2179.820	83.93987	159.4407	27.71072	33.50689	30.06061
6	-2117.543	90.83530	170.2836	27.72975	34.65689	30.53816
7	-2074.980	58.31759	230.6396	27.96663	36.02473	31.23356
8	-2008.513	85.19602	245.7772	27.93937	37.12842	31.66481
9	-1961.847	55.68949	335.7866	28.13091	38.45092	32.31486
10	-1900.105	68.22358	402.6268	28.15585	39.60683	32.79832
11	-1804.924	96.75812*	348.6135	27.81132	40.39325	32.91230
12	-1720.636	78.23411	359.2337	27.58714	41.30003	33.14664

Japan

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2520.148	NA	187.2261	27.93533	28.07670*	27.99265*
1	-2415.957	198.0191	120.1668	27.49124	28.76357	28.00707
2	-2349.935	119.6433	117.9566*	27.46889*	29.87218	28.44324
3	-2290.633	102.2214	125.4626	27.52081	31.05506	28.95367
4	-2234.081	92.48270	138.8054	27.60311	32.26832	29.49448
5	-2179.820	83.93987	159.4407	27.71072	33.50689	30.06061
6	-2117.543	90.83530	170.2836	27.72975	34.65689	30.53816
7	-2074.980	58.31759	230.6396	27.96663	36.02473	31.23356
8	-2008.513	85.19602	245.7772	27.93937	37.12842	31.66481
9	-1961.847	55.68949	335.7866	28.13091	38.45092	32.31486
10	-1900.105	68.22358	402.6268	28.15585	39.60683	32.79832
11	-1804.924	96.75812*	348.6135	27.81132	40.39325	32.91230
12	-1720.636	78.23411	359.2337	27.58714	41.30003	33.14664

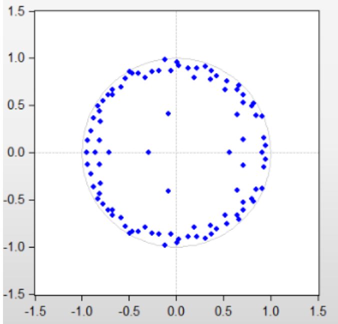
Malaysia

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2285.382	NA	13.98838	25.34124	25.48261*	25.39856
1	-2127.430	300.1967	4.956675	24.30309	25.57543	24.81892*
2	-2042.816	153.3335	3.961976*	24.07532	26.47861	25.04966
3	-2001.755	70.77872	5.155117	24.32879	27.86304	25.76165
4	-1950.222	84.27624	6.028537	24.46654	29.13175	26.35791
5	-1890.365	92.59648	6.509552	24.51232	30.30849	26.86221
6	-1842.442	69.89832	8.147224	24.68997	31.61710	27.49837
7	-1794.222	66.06897	10.36627	24.86433	32.92243	28.13126
8	-1710.913	106.7830	9.170863	24.65097	33.84003	28.37641
9	-1652.325	69.91741	10.98292	24.71077	35.03078	28.89473
10	-1558.418	103.7650	9.230028	24.38031	35.83128	29.02277
11	-1468.593	91.31328	8.479055	24.09495	36.67688	29.19594
12	-1352.844	107.4355*	6.171691	23.52314*	37.23603	29.08264

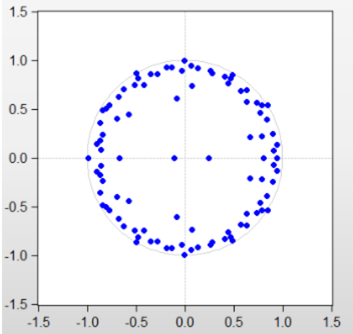
* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix C. Eigenvalue test for stability.

Singapore



Japan



Malaysia