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The effects of oil price shocks on Asian exchange rates: Evidence from quantile regression analysis

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ABSTRACT

This paper investigates the effects of oil price shocks on Asian exchange rates. We employ quantile regression analysis and allow for structural breaks and asymmetry. Our results indicate that positive and negative oil price shocks have asymmetrical effects on exchange rate returns that vary in significance, size, and sign throughout the distribution of exchange rate returns. The impact of oil price shocks is also affected by market conditions (bearish and bullish currency markets). During bullish markets in domestic currencies, (at lower quantiles of currency movements in terms of U.S. dollar exchange rates), rising oil prices cause further appreciation for Indonesia, Korea, the Philippines, and Thailand currencies. During bearish markets in the domestic currencies (at higher quantiles of exchange rate movements in terms of U.S. dollar exchange rates), rising (falling) oil price causes further currency depreciation for Indonesia (Malaysia). Thus, currencies respond differently to oil price shocks under extreme bullish or bearish currency market conditions and the impact of rising or falling oil prices on foreign exchange markets can vary by country and market conditions.

1. Introduction

In the aftermath of the oil price shocks of the 1970s, the U.S. and other economies went into a recession. As a result, many studies have investigated the impact of oil price shocks on a variety of economic variables. For example, Hamilton (1983) and Mork (1989) show that oil price shocks negatively affect GDP, while Cunado and Perez de Gracia (2005) find that oil prices Granger-cause economic growth in Japan, South Korea, and Thailand. Jin (2008) reports that oil price increases negatively affect growth in Japan and China, while Rafiq et al. (2008) find that oil price volatility has a significant impact on unemployment and investment in Thailand. Du et al. (2010) find a significant effect of oil prices on growth and inflation in China and Fan et al. (2013) show the short-term impact of oil price shocks on the Chinese economy. Generally, oil price shocks negatively impact output in oil importing countries, such as for Greece (Papapetrou, 2013) and Turkey (Bahmani-Oskooee et al., 2017a, 2017b). Similarly, Cunado and Perez de Gracia (2014) find that oil price changes negatively affect stock market returns for 12 oil-importing European countries. In contrast, Nusair (2016) notes that rising oil prices lead to increased output in GCC countries and Dizaji (2014) reports a similar impact of oil prices for the Iranian economy. Allegret et al. (2014) show that rising oil prices improve current account balances across a sample of 27 oil-exporting countries. Overall, the literature indicates that oil price changes affect oil importing and exporting countries differently. Also, the impact of oil price shocks is asymmetrical within countries. For example, Wang (2013) finds that the impact of rising oil prices on personal consumption expenditures is greater than the effects from falling oil prices.

Although the majority of studies have focused on the impact of oil price shocks on real economic variables, the effects on exchange rates is equally important and the focus of this paper. In theory, it is well established that an oil-exporting (importing) country may experience currency appreciation (depreciation) in response to rising oil prices, and currency depreciation (appreciation) in response to falling oil prices (Golub, 1983). Rising real oil prices may worsen the trade balance for an oil-importing country, which may require real currency depreciation to improve the country's competitiveness (Zhou, 1995). Chen and Chen (2007) show that real oil prices may have been the dominant source of real exchange rate movements in the G7 in recent decades. Hence, examining the impact of oil price shocks on exchange rates should be particularly important for policy makers across a range of countries.

In this paper, we study the impact of oil price shocks on certain Asian countries' dollar exchange rates. The countries are Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, and Thailand. Our paper investigates the dependence of Asian exchange rates on oil price shocks,

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and whether the dependence is symmetric or asymmetric. To address asymmetries, we employ the quantile regression (QR) approach, which is an extension of ordinary least squares (OLS) regression.

Several studies have examined the relationship between oil prices and exchange rates, but they mainly focused on developed countries. Studies such as Amano and van Norden, 1998; Chaudhuri and Daniel, 1998; Chen and Chen, 2007; Huang and Guo, 2007; Korhonen and Juurikkala, 2009; Lizardo and Mollick, 2010; Méndez-Carbajo, 2011; Brahamsrene et al., 2014; Habib et al., 2016; Pershin et al., 2016; and Al Rasasi (2017) employ linear models, while Benhmad, 2012; Czudaj and Beckmann, 2013; Tiwari et al., 2013; Ahmad and Hernandez, 2013; Atems et al., 2015; Basher et al., 2016; Coudert and Mignon, 2016; Wen et al., 2017 address the relationship between oil price shocks and exchange rates using nonlinear models. Overall, the results from both types of studies are mixed. For instance, Amano and van Norden (1998) conclude that oil prices have been a major source of U.S. real exchange rate shocks. Similarly, Chen and Chen (2007) find that real oil prices have been the dominant source of movements in the real exchange rates of the G7 countries, while Korhonen and Juurikkala (2009) report that the price of oil has a statistically significant positive impact on OPEC countries' real exchange rates. In contrast, Habib et al. (2016) find no systematic evidence that the currencies of oil exporters appreciate against those of oil importers. Huang and Guo (2007) find that real oil price shocks lead to only a minor appreciation in China's Renminbi long-term real exchange rate and Reboredo (2012) argues that the dependence between oil prices and exchange rates is generally quite weak. Another possibility is that dependence relationship is quite complex and that it may vary over time. For example, Benhmad (2012) has identified a complex causal relationship between real oil prices and the U.S. real effective exchange rate that varies depending on the time scale or frequency range. Tiwari et al. (2013) find evidence of causal relationship between the price of oil and the real effective exchange of India only at higher time scales, with no evidence of causality at lower time scales.

A common feature of these studies is that they ignore the likelihood that the effects of oil price shocks on exchange rates might vary throughout the distribution of exchange rate returns. In particular, these studies ignore the distributional heterogeneity of exchange rate returns (Su et al., 2016). In similar studies related to stock markets, Sim and Zhou (2015) point out that stock market returns may react differently to oil price shocks when the stock market is low (bearish) than when it is high (bullish). The market may also react differently (asymmetrically) to positive oil price shocks than to negative shocks. Similarly, foreign exchange markets may react differently to oil price shocks when foreign exchange markets are bearish than when they are bullish, and the effects may be asymmetric for positive and negative shocks.

Against this background, the aim of this paper is to examine the effects of oil price shocks on the real exchange rates of some Asian countries, using QR analysis. Furthermore, we allow for structural breaks and asymmetries in the relationship between the two variables. The motivation for choosing the Asian countries is twofold. First, the limited number of studies examining the impacts of oil price shocks on Asian exchange rates and second, the important role that the Asian countries play in the global economy. In particular, in the aftermath of the 1997 Asian financial crisis, demand for oil decreased, which caused the price of oil to decrease from an average of $18 a barrel in the third quarter of 1997 to an average of $11 by the end of 1998. Consequently, oil revenues for oil-exporting countries decreased, causing financial panics in some countries; the 1998 Russian crisis, for instance. As a result of the crisis, commodity prices decreased, which caused the currencies of Canada, Australia and New Zealand to depreciate; given their strong trade links with the Asian countries (Corsetti et al., 1999).

To the best of our knowledge, this is the first paper to examine the relationship between oil price shocks and exchange rates for the Asian countries using QR analysis. Previously, Su et al. (2016) has employed QR analysis to examine the effects of oil price shocks on the exchange rates of Australia, the European Union countries, Japan, Canada, Mexico, Norway, and the U.K. Also, our work builds on some of the literature using QR analysis to examine the effects of oil price shocks on stock market returns—for example, Nusair and Al-Khasawneh (2017) for the GCC countries, You et al. (2017), Zhu et al. (2015, 2016), and Sim and Zhou (2015) for China, Mensi et al. (2014) for the U.S. and emerging markets, and Lee and Zeng (2011) who examine the impact of oil price changes on the stock returns of the G7 countries. In addition, quantile analysis (including QR analysis, quantile unit root tests, and quantile cointegration) has received increasing attention in recent years and applied to wide areas in the economics and finance literature. For example, Bahmani-Oskooee et al. (2017a, 2017b) and Bahmani-Oskooee and Ranjbar (2016) apply quantile unit root tests to purchasing power parity (PPP), Xiao (2009) apply quantile cointegration to asset pricing model, and Shahbaz et al. (2018) use quantile cointegration to examine the role of globalization in energy consumption.

The next section provides the literature review and section three presents the Theory and methodology. Section four provides the empirical analysis and section five concludes.

2. Literature review

This section briefly reviews the limited number of articles that examine the relationship between oil prices and exchange rates in Asian countries. In general, these studies assume that the relationship between the two variables is constant throughout the distribution of exchange rate return, and hence employ linear models. For example, Hussain et al. (2017) employ a detrended cross-correlation approach to investigate the co-movement of oil price and exchange rate for 12 Asian countries.[1] Employing daily data over the period May 2006–May 2016, the authors find a weak negative cross-correlation between the two variables for most of the countries. Using the Johansen cointegration test, Nusair and Kisswani (2015) examine the long-run relationship between oil prices and the real exchange rates of Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, and Thailand. Employing quarterly data over the period 1973:2–2011:2 and allowing for structural breaks in the cointegrating vector, the authors find evidence of cointegration in all but Japan and the Philippines. In addition, they find evidence of bidirectional causality for Malaysia and Thailand, unidirectional causality from exchange rates to oil prices for Korea, the Philippines and Singapore, unidirectional causality from oil prices to the exchange rate in Indonesia, and no evidence of causality for Japan. Employing VAR analysis, Granger causality tests, and impulse response analysis on daily data over the period January 2003–June 2010, Turhan et al. (2013) find that a rise in the price of oil leads to a significant appreciation in the currencies of a sample of emerging markets that included Indonesia, the Philippines, and Korea relative to the U.S. dollar. Using Engle and Granger and Johansen cointegration tests, Tsen (2011) finds that the real price of oil, terms of trade, productivity differential, and reserve differential to be important factors determining the real exchange rates of Japan, Korea, and Hong Kong. Using cointegration tests, Lizardo and Mollick (2010) find that a rising oil price causes significant depreciation in the currencies of net-oil importing countries, such as Japan, against the U.S dollar. Chinn (2000) finds that rising oil prices depreciate the currencies of Japan and Korea and appreciate the Indonesian rupiah against the U.S dollar. Similarly, Wang and Dunne (2003) find, using the Johansen cointegration test, that rising oil prices cause appreciation in the currencies of Indonesia, Malaysia, Singapore, and Thailand; and depreciation in the currencies of Japan, Korea, and the Philippines.

[1] China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan.

3. Theory and methodology

Fluctuations in the price of oil may have considerable consequences on economic activity in both oil-importing and oil-exporting countries. Theoretically, there are various channels through which oil price shocks may affect economic activity.[2] In terms of oil-importing countries, the general consensus supports the theoretical prediction of supply-side shock models that rising oil prices lead to higher price levels and lower output (Brown and Yücel, 2002). For example, Hamilton (1983) and Mork (1989) find a negative relation between oil price shocks and GDP and show that oil shocks are responsible for economic recessions. Nasseh and Elyasiani (1984) find that the 1973 energy price shock generated a major inflationary impulse in the U.S, Canada, the U.K, Germany and France. As for oil-exporting countries, rising oil prices lead to income transfers from oil-importing to oil-exporting countries, resulting in higher national income, greater purchasing power, and increased consumer demand in oil-exporting countries.

As for the link between the price of oil and the exchange rate, oil price shocks may be transmitted to exchange rates through two main channels: the terms of trade (ToT) channel and the wealth effect channel (Bodenstein et al., 2011). The economic literature identifies ToT as one of the potential determinants of the real exchange rate, and the price of oil is one of the main drivers of ToT in both oil exporting and importing countries. To demonstrate the link between the real exchange rate and the price of oil, Amano and van Norden (1998) propose a model of two sectors in the home and foreign country, producing two goods (tradable and non-tradable), using two inputs (labor and oil), and each sector uses both labor (non-tradable input) and oil (tradable input) in producing the two goods.[3] Then, and following Chen and Chen (2007), the log-linear approximation of the domestic and foreign price indexes are given by

$$p_t^D = \alpha^D p_t^{TD} + (1-\alpha^D) p_t^{ND} \tag{1}$$

$$p_t^F = \alpha^F p_t^{TF} + (1-\alpha^F) p_t^{NF} \tag{2}$$

where p_t^D and p_t^F are the price indexes in the home and foreign country at time t. p_t^{TD}, p_t^{ND}, p_t^{TF}, and p_t^{NF} are the prices of traded and non-traded goods in the home and foreign country, respectively. α^D, $(1-\alpha^D)$, α^F, and $(1-\alpha^F)$ are the expenditure shares on traded and non-traded goods in the home and foreign country. The logarithm of the bilateral real exchange rate (Q_t) is defined as the nominal exchange rate adjusted for changes in the home and foreign price levels:

$$Q_t = s_t + p_t^F - p_t^D \tag{3}$$

where s_t is the logarithm of the nominal exchange rate defined as units of the domestic currency per unit of the foreign currency. Incorporating Eqs. (1) and (2) into Eq. (3) yields

$$Q_t = \left(s_t + p_t^{TF} - p_t^{TD}\right) + (1-\alpha^D)\left(p_t^{TD} - p_t^{ND}\right) - (1-\alpha^F)\left(p_t^{TF} - p_t^{NF}\right) \tag{4}$$

Eq. (4) shows that the price of oil (tradable) is linked to the real exchange rate. Specifically, if the home country is more dependent on imported oil, an increase in the real price of oil may increase the prices of tradable goods in the home country by a greater proportion than in the foreign country, which causes a real depreciation of the domestic currency. Moreover, since the increase in the real price of oil may worsen ToT, the home country may have to increase the nominal exchange rate—leading to further real depreciation of the domestic currency (Chen and Chen, 2007). Conversely, for an oil-exporting country, an increase in the real price of oil may lead to currency appreciation as prices of non-tradable goods increase relative to tradable goods.

The second channel focuses on the balance of payments and international portfolio choices (Krugman, 1983a, 1983b; Golub, 1983). According to this channel, oil-price movements may be linked to wealth transfer from oil-importing to oil-exporting countries. The long-run equilibrium real exchange rate depends on the geographic distribution of imports of oil-exporting countries, but not on their portfolio choices. For instance, if oil-exporting countries have a strong preference for dollar-denominated assets, but not for U.S. goods, then a rise in oil price will cause the dollar to appreciate in the short run, but not in the long-run.

In this paper, we use quantile regression (QR) analysis to examine the impact of oil price shocks on Asian exchange rates. First introduced by Koenker and Bassett (1978), QR is an extension to the standard ordinary least squares regression (OLS) model. The OLS approach, which summarizes the average relationship between explanatory variable (s) and the dependent variable based on the conditional mean of the dependent variable, gives only a partial view of the relationship (Mosteller and Tukey, 1977). The use of QR analysis, on the other hand, has several advantages over other models, such as the OLS model. First, QR analysis describes the relationship at different points in the conditional distribution of the dependent variable, which gives a more comprehensive picture of dependence including asymmetric and nonlinear relationships between explanatory variable(s) over the range of values of the dependent variable (Baur, 2013). In particular, using QR analysis, we can infer information on the co-movement between exchange rate and oil returns in specific market conditions; such as, when the market is bullish (upper quantile), or bearish (lower quantile), or normal (intermediate quantile) where the market is neither bearish nor bullish (Naifar, 2016; Mensi et al., 2014). Second, QR analysis allows for the possibility that shocks of different signs and magnitudes to have different impacts on the real exchange rate (Hosseinkouchack and Wolters, 2013). Thus, the use of QR analysis allows the effects of explanatory variables (covariates) to differ across conditional quantiles. Third, changes in the degree of dependence can be tested for each quantile of the distribution (Baur, 2013). Other advantages of using QR model include that QR is more robust to non-normal errors, presence of outliers in the observations, skewness, heterogeneity in the dependent variable than OLS (Zhu et al., 2016), and invariant to monotonic transformations (Baum, 2013).

To establish a benchmark, the following standard OLS specification is utilized

$$q_t = \beta_0 + \beta_1 p_{ot} + \psi D_t + \upsilon_t \tag{5}$$

where q_t is the real exchange rate return computed as the first difference of the natural logarithm of the real exchange rate ($q_t = ln\,(Q_t/Q_{t-1}) * 100$), where Q_t is the real exchange rate at time t, defined as the nominal exchange rate adjusted for inflation in the home and foreign country. The nominal exchange rate is defined as domestic currency units per one U.S. dollar so that an increase indicates appreciation in the U.S. dollar, or depreciation in the domestic (Asian) currency. p_{ot} is oil price return computed as the first difference of the natural logarithm of the price of oil ($p_{ot} = ln\,(OP_t/OP_{t-1}) * 100$), where OP_t is the real price of oil expressed in domestic (Asian) currency. The real price of oil is calculated by converting the U.S. dollar price of oil into domestic currency at the going market exchange rate (the nominal exchange rate), then deflating it by the domestic price level. $D_t = (D_{t1}, \ldots, D_{nt})'$ is a vector of n dummy variables, with $D_{jt} = 1$ if observation t belongs to the j^{th} period, and 0 otherwise, and υ_t is a random error term.

Eq. (5) assumes a linear relationship between oil and exchange rate returns and that rising and falling oil prices have symmetrical effects on exchange rate returns. However, there is significant evidence that oil price shocks may have asymmetrical/nonlinear impact on economic and financial variables. For example, Mork (1989) finds oil price

[2] For a discussion of these channels, see Kilian (2008), Lardic and Mignon (2006, 2008), Brown and Yücel (2002).

[3] In addition, the model relies on the assumptions of constant return to scale production technology, no economic profit, and inputs are mobile between the two sectors.

changes to have asymmetrical impact on the U.S. economic activity and that the effects of oil price increases were different from those of the decreases, and that oil price decreases were not statistically significant.

To allow for asymmetry, oil returns (p_{ot}) are decomposed into positive (p_{ot}^{+}) and negative (p_{ot}^{-}) changes, with $p_{ot}^{+} = max\,(p_{ot}, 0)$ and $p_{ot}^{-} = min\,(p_{ot}, 0)$, and then incorporated into Eq. (5) to yield

$$q_t = \beta_0 + \beta^{+} p_{ot}^{+} + \beta^{-} p_{ot}^{-} + \psi D_t + \epsilon_t \tag{6}$$

Models (5) and (6) can answer the questions "are oil price shocks important for exchange rate returns?" and "do positive and/or negative oil price shocks influence exchange market returns differently?" However, these models cannot answer the important question: "do oil price shocks impact exchange rate returns differently for markets with low returns (when the market is bearish) than for markets with high returns (when the market is bearish)?" and "do positive and negative oil price shocks impact foreign exchange market returns differently for markets with low returns than for markets with high returns?" These important questions can be answered using QR.

QR models the conditional τth quantile of the dependent variable for some value of $\tau \in (0,1)$. Thus, the conditional quantile model for q_t given x_t can be written as

$$Q_{q_t}(\tau/x_t) = \alpha^{\tau} + x_t'\beta^{\tau} \tag{7}$$

where $Q_{q_t}(\tau/x_t)$ is the conditional τth quantile of the dependent variable q_t, α^{τ} is the intercept, which is allowed to depend on τ, β^{τ} is the vector of coefficients associated with τth quantile, and x' is a vector of explanatory variables (which includes oil return and other variables that may affect exchange rate return). The coefficients of the τth quantile of the conditional distribution are defined as a solution to the minimization problem (Koenker and Bassett, 1978),

$$\min_{\hat{\beta} \in \mathbb{R}^{\kappa}} \left[\sum_{t:q_t \geq \alpha^{\tau} + x_t'\hat{\beta}^{\tau}} \tau \left| q_t - \alpha^{\tau} - x_t'\hat{\beta}^{\tau} \right| + \sum_{t:q_t < \alpha^{\tau} + x_t'\hat{\beta}^{\tau}} (1-\tau) \left| q_t - \alpha^{\tau} - x_t'\hat{\beta}^{\tau} \right| \right] \tag{8}$$

which can be written as a minimization of the weighted deviations from the conditional quantile

$$\min_{\hat{\beta} \in \mathbb{R}^{\kappa}} \sum_t \rho_{\tau}\left(q_t - \alpha^{\tau} - x_t'\hat{\beta}^{\tau}\right) \tag{9}$$

where ρ_{τ} is a weighting factor called a check function, defined for any $\tau \in (0,1)$ as

$$\rho_{\tau}(\xi_t) = \begin{cases} \tau\xi_t, & if \quad \xi_t \geq 0 \\ (\tau-1)\xi_t, & if \quad \xi_t < 0 \end{cases} \tag{10}$$

where $\xi_t = q_t - \alpha^{\tau} - x_t'\beta^{\tau}$. Thus, QR is a weighted regression with different weights given to data points depending upon whether the points are above or below the line of best fit (Binder and Coad, 2011). In other words, the QR model minimizes the sum of residuals where positive residuals receive a weight of τ and negative residuals receive a weight of $1 - \tau$.

To study the effects of oil price shocks on exchange rate returns using QR analysis, we write the following QR models corresponding to the standard OLS models in Eqs. (5) and (6)

$$Q_{q_t}(\tau/x_t) = \alpha_0^{\tau} + \alpha_1^{\tau} p_{ot} + \alpha_2^{\tau} D_t \tag{11}$$

$$Q_{q_t}(\tau/x_t) = \beta_0^{\tau} + \beta^{\tau+} p_{ot}^{+} + \beta^{\tau-} p_{ot}^{-} + \beta_1^{\tau} D_t \tag{12}$$

To estimate QR models in Eqs. (11) and (12), we follow previous literature (see, for example, Tiwari et al., 2018; You et al., 2017; Zhu et al., 2016; Naifar, 2016), and choose nine quantiles ($\tau = 0.10, 0.20, \ldots, 0.90$) and divide them into three regimes: low ($\tau = 0.10, 0.20, 0.30$), which corresponds to a bearish market, medium ($\tau = 0.40, 0.50, 0.60$), which corresponds to a normal market, and high ($\tau = 0.70, 0.80, 0.90$), which corresponds to a bullish market. In our paper, we define bullish (bearish) as meaning rapid recent appreciation (depreciation) of a local Asian currency relative to the U.S. dollar. Specifically, a bullish currency market means that the most recent quarterly return is in the lower quartile, or bottom three deciles, of all quarterly returns for the U.S. dollar relative to the local currency over the period 1973–2016. A bearish currency market means that the most recent quarterly return is in the upper quartile, or top three deciles, of historical quarterly returns for the U.S. dollar relative to the local Asian currency during the years 1973–2016. Medium or normal market represents a market that is neither bearish nor bullish, meaning that the last quarterly change in the exchange rate was rather small in magnitude.

4. Empirical results

4.1. Data and preliminary results

We use quarterly data over the period 1973:2–2016:4 for Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, and Thailand. The data, extracted from IMF's International Financial Statistics Online Database, contains the nominal exchange rate defined as the market rate per one U.S. dollar, the domestic and the U.S. consumer price index (CPI), and the Dubai price of oil. Real exchange rates are calculated relative to the U.S. dollar using these CPIs. The real oil prices in domestic currency are calculated by converting the U.S. dollar price of oil into domestic currency and then deflating them by the domestic CPI (2010 = 100). All variables are measured in logarithms. Given the definition of the exchange rate per one U.S. dollar, a positive change (return) indicates U.S. dollar appreciation, and a negative change (return) indicates U.S. dollar depreciation. Thus, lower exchange rate return quantiles correspond to large U.S. dollar depreciation, and higher exchange rate return quantiles correspond to large U.S. dollar appreciation.

The reason for using Dubai price of oil is twofold. First, Dubai oil price represents the benchmark oil price for the Asian countries (Fattouh, 2012), and second, oil prices (Brent, Dubai, and WTI) are highly correlated with a correlation coefficient of 99%. With this high correlation, using different oil prices will not give significantly different results (Chang and Wong, 2003). Fig. 1 plots the behavior of Brent, Dubai, and WTI oil prices. Three observations may be drawn from the plot. First, the three oil prices move in tandem with a very high correlation coefficient of 99%. Second, there are very large fluctuations in the prices of oil over the sample period, especially over the past two decades. Third, there seems to be a disconnect in the relationship between WTI and the other two prices for the period 2011Q2–2014Q2. In particular, the figure shows that while Brent and Dubai prices continued to move in tandem, WTI moved apart from the other two prices.

Fig. 2 plots the real exchange rate and the real price of oil for each country. The figure indicates that there seems to be some degree of co-movement between the two variables, suggesting a long-run relationship between the two variables. In addition, the figure shows that the two variables are dominated by major shocks over the sample period. In particular, the shocks correspond to the 1970s oil price shocks, Iraq-Iran war in the early 80s, the Plaza Accord in 1985, the collapse of oil prices in 1986, Iraq invasion of Kuwait in 1990/91 and the Gulf war, the 1997 Asian crisis, the Iraqi war in 2003, the U.S mortgage crisis in 2008, and the Arab Spring that started in Tunisia on December 2010 and spread to other countries in the Middle East, including Egypt, Libya, Syria, and Yamen. These events suggest the possibility of structural breaks in the long-run relationship between the two variables. Moreover, the figure suggests that the sample can be split into three periods:

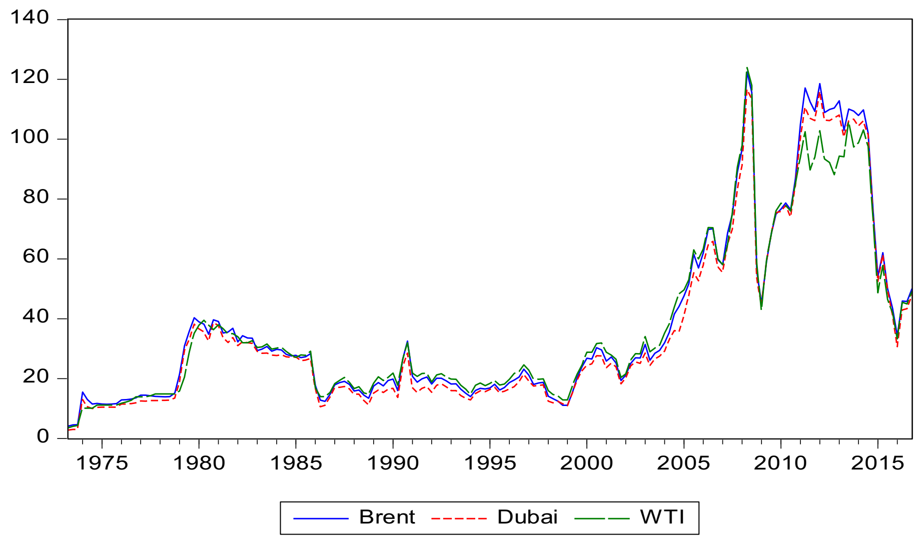


Fig. 1. the behavior of oil prices.

1973–1985, 1986–2004, and 2005–2016. The first period pertains to dramatic events including the collapse of the Bretton Woods system and the transition to the flexible exchange rate regime and the oil price shocks. Hence, in this period, the two variables show big swings and the correlation coefficients are generally low, especially in the cases of Japan, Korea, the Philippines and Thailand.

The second period coincides with Iraq-Iran war, the Plaza Accord, the collapse of prices oil, and the Asian financial crisis. This period is characterized by falling oil prices[4] and weak U.S dollar, and high and positive correlation coefficients. The third period coincides with rising demand for oil from Asia, especially China and India, rising uncertainty about the state of the U.S economy due to the financial crisis, and the Arab Spring. This period is characterized by sharp increases and large fluctuations in oil prices, a sharp fall in the value of the U.S dollar, and negative correlation coefficients in all the cases, albeit weak correlation between oil shocks and the exchange rates of Japan, Korea, the Philippines, and Singapore.

A few observations may be drawn from Fig. 2. First, the correlation coefficient for the entire period is low and weak, especially in the cases of Korea, the Philippines, Singapore, and Thailand. Second, all the correlation coefficients are positive and highest in the second period. Third, the correlation coefficients are not constant over the sample period, as they change in size and sign. For instance, for Korea and the Philippines, the correlation coefficients alternate signs from negative to positive and then to negative. For Japan, Indonesia, Malaysia, Singapore, and Thailand, the correlation coefficients change signs from positive to negative. These changes in size and sign suggest that the relationship between the two variables may not be linear and that linear models may not appropriate.

To avoid spurious regression, unit root tests are applied on the levels of the real exchange rates and real oil prices. To this end, the Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) tests are employed. If the variables are non-stationary, cointegration tests are used to test for the existence of a long-run relationship between the two variables of each country. Two residual-based cointegration tests are utilized: the standard Engle-Granger (EG) test, and the Gregory-Hansen (GH) test, which allows for a single endogenously determined structural break in the cointegrating relationship. In particular, we provide the results from three models: Model 1, which allows for a change in the intercept, Model 2 which adds a time trend to Model 1, and Model 3, which allows both the intercept and the slope to change. If there is no evidence of cointegration (long-run relationship does not exist), we then proceed to examine the short-run relationship and dependence between changes in the variables (rates of returns) using QR analysis.

Table 1 provides the results from the unit root tests. The results from the two tests confirm that all variables are non-stationary in their levels, but stationary in their first differences so that cointegration tests can be used to test for the existence of long-run relationship between the two variables. The results in Table 2 from EG and GH tests generally fail to reject the null hypothesis of no cointegration at the 5% significance level. There is evidence of cointegration only for Japan, and only at the 10% significance level. Overall, the results confirm that there is no long-run relationship between the price of oil and the exchange rate of each country.[5]

However, before proceeding to QR analysis using rates of return, we provide further preliminary analysis concerning the possibility of structural breaks in the relationship between the two variables. Since the two variables have experienced different shocks over the sample period, we apply Bai and Perron (1998, 2003) multiple structural breaks, allowing for a maximum of five breaks with a trimming parameter of 0.15, and then testing the null hypothesis of $l + 1$ vs. l sequentially determined structural breaks. Panel A in Table 3 reports the results for the relationship between the levels of the variables and Panel B reports the results between the rates of returns. The results for the levels of the variables suggest that there are four structural breaks in all the cases, except for Japan, which shows only two breaks. The breaks are clustered around mid-1985 (corresponding to the Plaza Accord and the crash of oil prices), around 1990/91 (which correspond to the Iraqi invasion of Kuwait and the First Gulf War), around 1997 (the Asian financial crisis), and around 2008 (the U.S. financial crisis). As for the relationship between the rates of returns, the results in Panel B suggest that structural breaks although present, are significantly less prevalent than in the levels. Also, for some countries, there is no evidence of structural breaks.

As we apply QR analysis, the significance of structural breaks may change throughout the distribution of exchange rate returns. Accordingly, we construct three dummy variables to capture three major events that impacted Asian markets and incorporate them into the Eqs. (5), (6), (11), and (12). The dummy variables are: D_{85} to capture the impact of the Plaza Accord, with the value one for the period

[4] Except during 1990/91 when oil prices temporarily increased due to Iraq invasion of Kuwait and the Gulf war. And then, prices started to increase in 2003.

[5] Johansen cointegration procedure was also implemented and showed no evidence of cointegration in all the cases. All unreported results are available upon request from the authors.

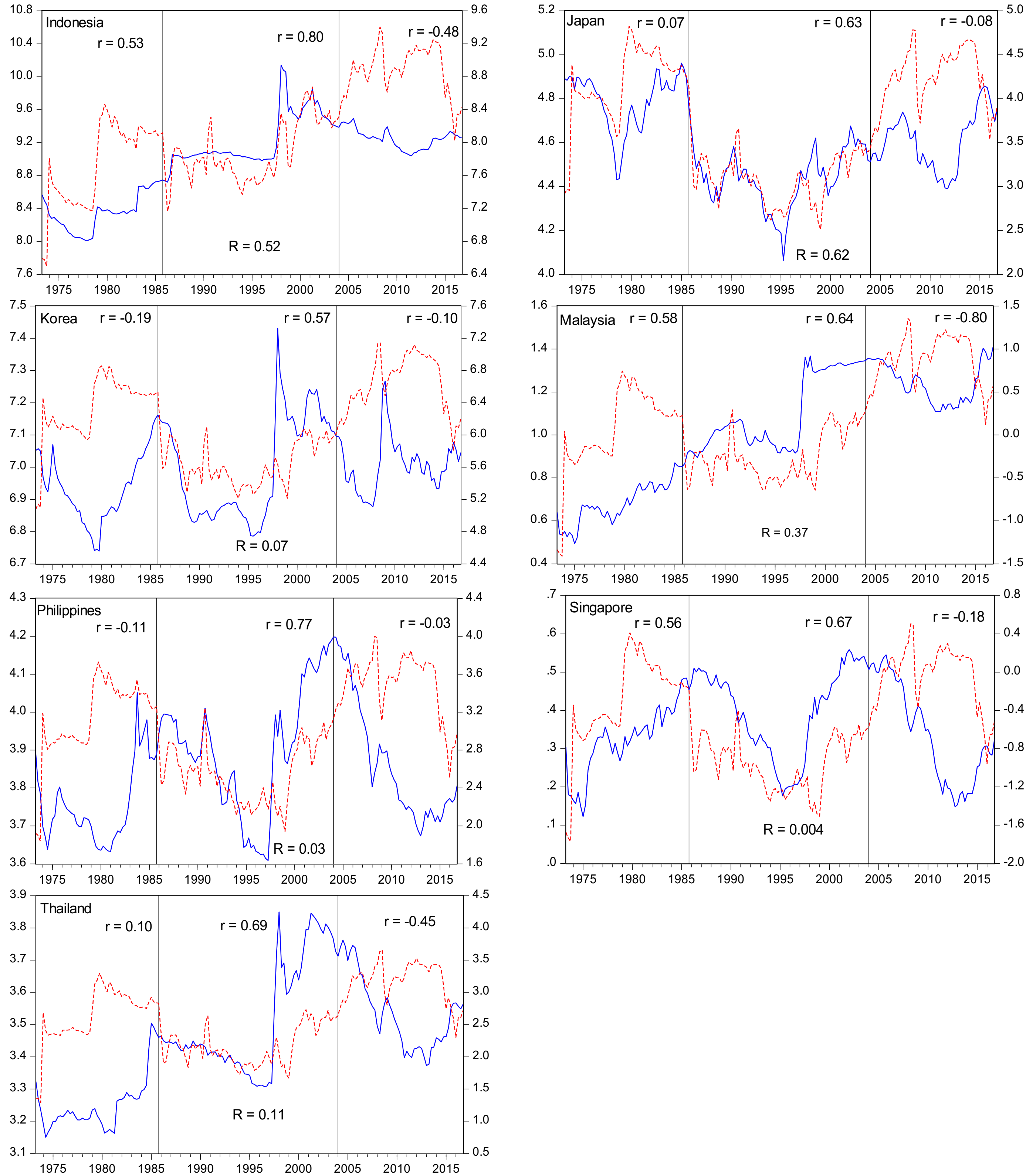


Fig. 2. the evolution of the real exchange rates and real price of oil. r stands for the correlation coefficient in each sub-period. R stands for the correlation coefficient for the entire period. The first period is 1973:2–1985:4, the second period is 1986:1–2004:1, and the third period is 2004:2–2016:4.

1985:3–1986:3, and zero otherwise. D_{97} to capture the effect of the Asian financial crisis, which takes the value one for the period 1997:3–1998:4, and zero otherwise. D_{08} to capture the effect of the 2008 U.S financial crisis, with the value one for the period 2007:4–2008:4, and zero otherwise.

Another preliminary analysis that is deemed important that we implement is Granger causality between the two variables.[6] The linear

[6] We thank an anonymous referee for suggesting to implement causality tests between the two variables.

Table 1
Unit root tests.

Country	Variable	ADF test			PP test		
		Level		First diff.	Level		First diff.
		Trend	No trend	No trend	Trend	No trend	No trend
Indonesia	*Q*	−1.69(3)	−1.48(3)	−9.11(2)*	−2.06	−1.36	−10.25*
	OP	−2.27(6)	−1.74(6)	−7.78(4)*	−3.52**	−2.73***	−12.38*
Japan	*Q*	−2.57(3)	−2.74(3)***	−5.93(2)*	−2.16	−2.38	−10.05*
	OP	−1.64(6)	−1.62(6)	−5.84(5)*	−2.24	−2.27	−12.00*
Korea	*Q*	−3.20(3)***	−2.95(3)**	−7.07(3)*	−2.90	−2.34	−9.75*
	OP	−1.64(6)	−1.56(6)	−5.95(5)*	−2.49	−2.61***	−12.53*
Malaysia	*Q*	−2.55(1)	−1.48(1)	−9.75(0)*	−2.14	−0.79	−9.58*
	OP	−1.79(6)	−1.58(6)	−5.99(5)*	−2.98	−2.87***	−12.88*
Philippines	*Q*	−2.08(1)	−2.07(1)	−10.45(0)*	−2.14	−2.06	−10.48*
	OP	−1.74(6)	−1.74(6)	−5.79(5)*	−2.56	−2.70***	−12.85*
Singapore	*Q*	−2.55(4)	−2.56(4)	−11.52(0)*	−1.87	−1.89	−11.60*
	OP	−1.73(6)	−1.77(6)	−7.62(4)*	−2.74	−2.87***	−12.50*
Thailand	*Q*	−1.81(3)	−1.62(3)	−8.62(2)*	−2.13	−1.60	−9.36*
	OP	−1.72(6)	−1.54(5)	−7.97(4)*	−2.83	−2.91**	−12.74*

Q is the logarithm of the real exchange rate and *OP* is the logarithm of the real price of oil. *, **, *** denotes rejection of the null hypothesis at the 1%, 5% and 10% significance level. The number of lags in the ADF test (in parentheses) is selected by minimizing Akaike Information Criterion (AIC). The bandwidth for PP test is selected automatically by the Newey-West Bandwidth, using the Barlett Kernel spectral estimation method. The 1%, 5% and 10% critical are −4.01, −3.44, and −3.14 for the test with a trend, and − 3.47, −2.88, and −2.58 for the test with no trend.

Table 2
Cointegration tests.

Country	Engle-Granger test				Gregory-Hansen tests					
	Trend		No trend		Model 1		Model 2		Model 3	
	Value	p-Value +	Value	p-Value +	Value	*TB*	Value	*TB*	Value	*TB*
Indonesia	−1.88(3)	0.8214	−1.84(1)	0.6133	−3.67(3)	1985:02	−4.41(2)	2004:03	−3.75(1)	1985:02
Japan	−3.35(4)	0.1476	−3.24(4)	0.0689***	−4.21(10)	1990:02	−4.82(11)***	1987:01	−4.85(10)	2001:01
Korea	−3.08(5)	0.2412	−2.99(3)	0.1193	−3.89(1)	1998:03	−4.07(1)	1998:03	−4.36(1)	1998:03
Malaysia	−2.52(2)	0.5140	−1.47(1)	0.7764	−3.33(1)	2000:02	−3.99(1)	2008:02	−3.30(0)	1998:01
Philippines	−2.07(1)	0.7432	−2.09(1)	0.4832	−3.04(12)	1997:01	−3.84(2)	2006:03	−3.10(12)	1997:01
Singapore	−2.52(4)	0.5165	−2.55(4)	0.2629	−3.23(6)	2010:01	−3.62(4)	2007:04	−3.28(6)	2010:01
Thailand	−0.250(1)	0.5271	−1.88(4)	0.5920	−4.02(1)	1998:01	−3.98(1)	2008:03	−4.11(1)	1998:01

*, **, *** denotes rejection of the null hypothesis at the 1%, 5% and 10% significance level. + indicates Mackinnon (1996) p-values. The 1%, 5%, and 10% critical values for the Gregory-Hansen tests are −5.13, −4.61, and −4.34 for Model 1, −5.45, −4.99, and − 4.72 for Model 2, −5.47, −4.95, and − 4.68 for Model 3. The critical values are provided by Gregory and Hansen (1996), Table 1. In model 1, there is a change in the intercept, whereas in Model 2, a time trend is added to the level shift model and Model 3 allows both the intercept and the slope to change. The null hypothesis in all three models is that the residuals are nonstationary or, equivalently, the real exchange rate and real oil price are not cointegrated. The alternative hypothesis is that the residuals are stationary with a one-time endogenously determined structural break in the cointegrating vector. *TB* stands for the time of the break. The number of lags in the ADF test (in parentheses) is selected by minimizing AIC.

Table 3
Bai-Perron multiple breakpoint tests of $L + 1$ vs. L sequentially determined breaks.

	0 vs. 1	1 vs. 2	2 vs. 3	3 vs. 4	4 vs 5	*Number of breaks*	*TB1*	*TB2*	*TB3*	*TB4*
Panel A. For the relationship between the real exchange rate real oil price										
Indonesia	412.03**	157.20**	48.55**	19.49**	0.00	4	1979Q4	1986Q4	1997Q4	2006Q1
Japan	84.07**	52.12**	9.68			2	1986Q2	1997Q4		
Korea	149.81**	84.78**	34.27**	30.13**	0.00	4	1983Q3	1990Q1	1997Q4	2008Q2
Malaysia	684.56**	561.53**	187.78**	125.01**	0.00	4	1979Q4	1988Q2	1997Q4	2007Q1
Philippines	163.38**	144.66**	77.84**	89.68**	0.00	4	1983Q2	1991Q3	1998Q1	2007Q3
Singapore	189.00**	115.35**	94.89**	113.42**	0.00	4	1982Q2	1990Q3	1998Q1	2010Q3
Thailand	361.24**	346.87**	152.37**	38.27**	0.00	4	1984Q4	1991Q2	1997Q4	2006Q4
Panel B. For the relationship between changes in the real exchange rate and real oil price (rates of returns)										
Indonesia	15.11**	34.87**	20.01**	25.13**	10.27	4	1981Q3	1988Q2	1995Q2	2001Q4
Japan	5.12					0				
Korea	20.41**	10.24				1	2008Q4			
Malaysia	10.83					0				
Philippines	15.27**	13.90**	3.05			2	1981Q3	2004Q2		
Singapore	9.44					0				
Thailand	6.64					0				

** Denotes significance at the 5% level. The 5% critical values for the hypotheses 0 vs. 1, 1 vs. 2, 2 vs. 3, 3 vs. 4, and 4 vs 5 breaks are 11.47, 12.95, 14.03, 14.85, and 15.29, respectively. The numbers in the cell corresponding to the null hypothesis being tested are the scaled *F-statistic* values. Bai-Perron test is implemented allowing for heterogeneous error distributions across breaks.

Table 4
Linear Granger non-causality test.

Null hypothesis	Country						
	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
k	5	7	5	4	5	6	5
$q \nRightarrow p_o$	5.571	10.957	8.658	11.80	12.039	5.345	16.131
	[0.3502]	[0.1405]	[0.1235]	[0.0257]**	[0.0343]**	[0.5004]	[0.0065]*
$p_o \nRightarrow q$	2.195	5.283	10.200	1.077	3.930	11.019	1.113
	[0.8215]	[0.6254]	[0.0698]***	[0.8981]	[0.5596]	[0.0878]***	[0.9529]

*, **, and *** indicate significance at the 1, 5, and 10% significance levels. q is the real exchange rate return, and p_o is oil price return. The number of lags (k) in the VAR model is determined by AIC, then residuals are tested for serial autocorrelation. If there is evidence of serial autocorrelation, number of lags is increased until there is no evidence of serial autocorrelation. p-Values are square bracketed. $q \nRightarrow p_o$ means q does not Granger cause p_o, and $p_o \nRightarrow q$ means p_o does not Granger cause q.

Table 5
BDS test.

Country	Variable	For return series					For residuals series from VAR model				
		$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$	$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$
Indonesia	q	6.840	7.337	7.357	7.528	7.622	4.732	5.872	6.476	6.726	6.787
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
	p_o	4.396	5.099	4.953	4.604	4.561	3.313	4.911	4.676	4.107	3.917
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0009]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0001]*
Japan	q	2.063	1.996	1.597	1.326	1.427	−0.702	0.520	0.720	0.634	0.422
		[0.0391]**	[0.0459]**	[0.1102]	[0.1850]	[0.1535]	[0.4828]	[0.6032]	[0.4714]	[0.5261]	[0.6731]
	p_o	3.145	4.447	4.689	4.379	4.519	1.392	3.995	3.721	3.220	3.428
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.1639]	[0.0001]*	[0.0002]*	[0.0013]*	[0.0006]*
Korea	q	3.959	4.090	4.567	4.921	5.258	1.860	2.870	3.136	2.850	3.628
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0629]***	[0.0041]*	[0.0017]*	[0.0044]*	[0.0003]*
	p_o	4.713	5.821	5.478	5.611	5.652	1.977	4.083	3.804	3.396	3.774
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0481]***	[0.0000]*	[0.0001]*	[0.0007]*	[0.0002]*
Malaysia	q	4.271	5.081	4.799	4.929	4.814	4.437	4.791	4.583	4.729	5.335
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
	p_o	3.928	4.830	4.761	4.448	4.813	1.775	2.927	2.226	1.863	2.083
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0759]***	[0.0034]*	[0.0260]**	[0.0625]***	[0.0373]**
Philippines	q	6.480	6.740	6.952	7.368	7.415	4.914	5.552	5.712	5.990	5.932
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
	p_o	4.878	5.678	5.571	5.376	5.610	1.305	3.636	3.438	2.948	3.336
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.1920]	[0.0003]*	[0.0006]*	[0.0032]*	[0.0008]*
Singapore	q	3.504	4.232	4.026	4.089	4.106	1.459	1.750	2.011	2.151	2.411
		[0.0005]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.1445]	[0.0800]***	[0.0443]**	[0.0315]**	[0.0159]**
	p_o	3.929	4.935	4.789	4.434	4.697	2.091	4.183	4.052	3.650	4.068
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0365]**	[0.0000]*	[0.0001]*	[0.0003]*	[0.0000]*
Thailand	q	5.060	6.026	6.343	6.384	6.451	3.614	4.384	4.822	5.088	5.263
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0003]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*
	p_o	4.634	5.619	5.496	5.382	5.719	2.776	4.233	3.845	3.230	3.435
		[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0000]*	[0.0055]*	[0.0000]*	[0.0001]*	[0.0012]*	[0.0006]*

*, **, *** indicates rejection of the null hypothesis of whiteness at 1, 5, and 10% significance levels. m stands for the number of (embedded) dimension which embed the time series into m-dimensional vectors, by taking each m successive points in the series. Value in cell represents BDS z-statistic, and p-values are in square bracket. VAR model is estimated for the return series with the number of lags selected by AIC.

Granger non-causality test is commonly used. However, as argued by Baek and Brock (1992) and Hiemstra and Jones (1994), the linear Granger causality test generally lacks power against nonlinear relationships.[7] To this end, nonlinear Granger causality tests have been proposed. One popular test is the test by Hiemstra and Jones (1994). However, Diks and Panchenko (2006) demonstrate that the test proposed by Hiemstra and Jones (1994) is sensitive to variations in the conditional distributions of the two variables, which could lead to over-rejection of the null hypothesis. Therefore, Diks and Panchenko (2006) proposed their nonparametric test, which is used to detect nonlinear causal relationships from the residuals of the linear Granger causality models. In this paper, and in order to obtain robust results, we apply the linear Granger causality test and the nonlinear tests by Hiemstra and Jones (1994) and Diks and Panchenko (2006). To implement the linear Granger causality test, a vector autoregressive (VAR) is estimated for the rates of returns on oil and exchange rates with the number of lags selected by AIC. The results, reported in Table 4, provide evidence of linear unidirectional Granger causality from the exchange to the price of oil for Malaysia, the Philippines, and Thailand, and weak or no evidence of causality from oil price to exchange rates. There is evidence of unidirectional Granger causality from oil price to exchange rate for Korea and Singapore only at the 10% significance level.

Nonetheless, this finding could be due to the presence of nonlinearity in the relationship between the two variables. To examine this possibility, we utilize the nonlinear Granger causality tests of Hiemstra and Jones (1994) and Diks and Panchenko (2006).[8] However, before testing for nonlinear Granger causality, it is important that we first determine if the variables contain nonlinearities (Francis et al., 2010).

[7] Nonlinearities and asymmetries in the impact of many economic variables, especially the price of oil have been well-documented in the literature. See, for example, Mork (1989), Lee et al. (1995) and Hamilton (1996) who document evidence of nonlinearities in the impact of oil prices on economic activity, and Akram (2004) who document evidence of nonlinearities in the impact of oil prices on the exchange rate.

[8] To save space, the tests are not discussed here. Interested reader is referred to the original papers by Hiemstra and Jones (1994) and Diks and Panchenko (2006).

Table 6
Nonlinear Granger causality test on the residuals from VAR model.

Country	$l_q = l_{p_o}$	Hiemstra and Jones (1994) test		Diks and Panchenko (2006) test	
		$q \nRightarrow p_o$	$p_o \nRightarrow q$	$q \nRightarrow p_o$	$p_o \nRightarrow q$
Indonesia	1	1.294 [0.0979]***	0.886 [0.1878]	1.050 [0.1470]	1.063 [0.1440]
	2	1.494 [0.0675]***	2.127 [0.0167]**	1.465 [0.0715]***	1.576 [0.0575]***
	3	1.358 [0.0872]***	2.072 [0.0191]**	1.464 [0.0716]***	1.490 [0.0681]***
	4	0.835 [0.2018]	2.192 [0.0142]**	0.739 [0.2299]	1.647 [0.0498]**
	5	1.090 [0.1378]	1.780 [0.0375]**	0.823 [0.2053]	1.378 [0.0841]***
	6	1.112 [0.1331]	1.343 [0.0896]***	0.639 [0.2615]	0.863 [0.1942]
	7	0.771 [0.2203]	1.168 [0.1213]	0.349 [0.7711]	0.799 [0.2123]
	8	0.840 [0.2003]	0.366 [0.3570]	0.220 [0.4130]	−0.172 [0.5622]
Japan	1	0.755 [0.2252]	−0.114 [0.5453]	0.503 [0.3074]	0.122 [0.4513]
	2	0.712 [0.2382]	0.034 [0.4866]	0.390 [0.3484]	0.131 [0.4478]
	3	0.899 [0.1844]	0.153 [0.4393]	0.542 [0.2941]	0.333 [0.3697]
	4	0.661 [0.2544]	−0.539 [0.7051]	0.189 [0.4252]	0.092 [0.4632]
	5	0.636 [0.2624]	−0.068 [0.5271]	0.626 [0.2658]	0.476 [0.3170]
	6	1.485 [0.0687]***	0.424 [0.3356]	1.172 [0.1207]	1.334 [0.0911]***
	7	1.452 [0.0733]***	0.020 [0.4919]	1.058 [0.1450]	0.586 [0.2791]
	8	0.636 [0.2625]	−0.471 [0.6812]	0.792 [0.2142]	−0.2120 [0.5840]
Korea	1	−1.001 [0.8415]	1.022 [0.1533]	−0.673 [0.7495]	0.963 [0.1677]
	2	−0.481 [0.6848]	0.573 [0.2833]	−0.690 [0.7549]	0.265 [0.3955]
	3	−0.401 [0.6558]	0.411 [0.3405]	−0.858 [0.8046]	0.146 [0.4421]
	4	−0.633 [0.7367]	1.016 [0.1548]	−0.720 [0.7637]	0.667 [0.2523]
	5	0.041 [0.4837]	1.309 [0.0953]***	−0.614 [0.7303]	0.939 [0.1739]
	6	−0.416 [0.6615]	1.604 [0.0543]***	−1.090 [0.8621]	0.772 [0.2200]
	7	−0.015 [0.5061]	0.971 [0.1658]	−0.651 [0.7425]	0.042 [0.4834]
	8	0.135 [0.4462]	0.558 [0.2885]	−0.499 [0.6912]	−0.509 [0.6948]
Malaysia	1	−1.153 [0.8756]	−0.226 [0.5895]	−1.458 [0.9276]	0.201 [0.4202]
	2	−0.996 [0.8404]	−0.349 [0.6366]	−1.306 [0.9042]	0.101 [0.4597]
	3	−1.056 [0.8546]	−0.450 [0.6735]	−1.059 [0.8551]	0.348 [0.3638]
	4	−1.560 [0.9406]	0.618 [0.2682]	−1.311 [0.9051]	1.297 [0.0973]***
	5	−1.106 [0.8657]	0.194 [0.4231]	−0.472 [0.6815]	0.765 [0.2222]
	6	−0.924 [0.8224]	0.347 [0.3647]	0.044 [0.4823]	0.835 [0.2019]
	7	−0.171 [0.5678]	−0.328 [0.6286]	01.89 [0.4249]	0.168 [0.4332]
	8	0.245 [0.4032]	−0.805 [0.7897]	0.5844 [0.2795]	−0.336 [0.6317]
Philippines	1	−0.314 [0.6232]	1.050 [0.1469]	−0.259 [0.6022]	1.159 [0.1232]
	2	−0.248 [0.5978]	0.612 [0.2703]	−0.429 [0.6659]	0.213 [0.4259]
	3	1.154 [0.1242]	1.460 [0.0721]***	0.929 [0.1764]	1.301 [0.0966]***
	4	1.422 [0.0775]***	1.619 [0.0527]***	0.697 [0.2429]	1.214 [0.1125]
	5	1.186 [0.1179]	1.465 [0.0714]***	0.722 [0.2350]	1.238 [0.1079]
	6	1.611 [0.0536]***	1.142 [0.1268]	0.598 [0.2751]	0.751 [0.2263]
	7	1.046 [0.1478]	−0.079 [0.5315]	0.633 [0.2633]	−0.483 [0.6853]
	8	0.449 [0.3267]	−0.341 [0.6334]	0.423 [0.3363]	−0.557 [0.7112]
Singapore	1	−0.093 [0.5372]	−0.306 [0.6200]	−0.291 [0.6145]	−0.519 [0.6982]
	2	0.913 [0.1806]	−0.343 [0.6344]	0.917 [0.1795]	−0.273 [0.6074]
	3	0.676 [0.2497]	−0.404 [0.6569]	0.834 [0.2021]	−0.567 [0.7145]
	4	0.767 [0.2216]	0.142 [0.4435]	0.917 [0.1796]	−0.017 [0.5066]
	5	0.975 [0.1649]	0.329 [0.3710]	0.824 [0.2049]	0.347 [0.3645]
	6	0.019 [0.4926]	−0.010 [0.5040]	−0.209 [0.5828]	0.102 [0.4594]
	7	0.516 [0.3028]	0.156 [0.4380]	0.660 [0.2546]	0.202 [0.4198]
	8	−0.283 [0.6114]	1.295 [0.0977]***	−0.057 [0.5227]	1.353 [0.0881]***
Thailand	1	1.195 [0.1160]	0.889 [0.1871]	0.989 [0.1613]	0.943 [0.1728]
	2	0.498 [0.3093]	0.784 [0.2165]	0.542 [0.2939]	0.861 [0.1945]
	3	1.275 [0.1012]	1.541 [0.0617]***	0.820 [0.2060]	1.415 [0.0785]***
	4	0.607 [0.272]	1.917 [0.0277]**	0.453 [0.3252]	1.799 [0.0360]**
	5	0.118 [0.4531]	1.083 [0.1392]	−0.334 [0.6309]	0.995 [0.1598]
	6	−0.274 [0.6080]	0.686 [0.2465]	−0.172 [0.5684]	0.713 [0.2378]
	7	−0.820 [0.7939]	0.261 [0.3972]	−0.423 [0.6637]	−0.148 [0.5588]
	8	−1.037 [0.8501]	−0.523 [0.6995]	−0.969 [0.8338]	−0.996 [0.8405]

*, **, and *** indicate significance at the 1, 5, and 10% significance levels. q is the real exchange rate return, and p_o is oil price return. p-Values are square bracketed. $q \nRightarrow p_o$ means q does not Granger cause p_o, and $p_o \nRightarrow q$ means p_o does not Granger cause q. $l_q = l_{p_o}$stands for the number of lags on the residual series used in the test, set 1 to 8. The bandwidth $\varepsilon = 1.5$.

We do this using a formal nonlinear dependence test known as the BDS test (Brock et al., 1996), which tests the null hypothesis of whiteness (independently and identically distributed series) against an unspecified alternative, including non-white linear and nonlinear dependence (Barnett et al., 1997). The results, reported in Table 5, reveal that the BDS test statistics are statistically significant in all the cases, suggesting the existence of significant nonlinearities in the univariate return series. Therefore, using the linear Granger causality test to examine the causal relationship between oil and exchange rate return series seems inappropriate. The alternative would be to use nonlinear Granger causality tests.

To implement the nonlinear Granger non-causality tests, we use the residuals from the linear VAR model used in the previous stage to calculate the linear Granger causality test, from which any linear predictive relationship has already been removed (Francis et al., 2010). Following Hiemstra and Jones (1994) and Diks and Panchenko (2006) and others, we set the lag order $l_q = l_{p_o} = 1, \ldots, 8$ and the bandwidth $\varepsilon = 1.5$. Table 6 reports the results for the residuals from the VAR model. According to the test by Hiemstra and Jones, the null hypothesis that changes in the price of oil do not Granger cause changes in the exchange rate ($p_o \nRightarrow q$) can be rejected at conventional significance levels at least one lag in the cases of Korea, Singapore, and Thailand.

This provides evidence in favor of unidirectional nonlinear Granger causality from the price of oil to the exchange rates of these countries with no evidence of the reversed causality ($q \nRightarrow p_o$). It shows evidence of unidirectional nonlinear causality from the exchange rate to oil price for Japan with no evidence of the reversed causality. It also shows bi-directional nonlinear causality for Indonesia and the Philippines, and no evidence of causality in any direction for Malaysia. Examining the results from the test by Diks and Panchenko (2006), the null hypothesis $p_o \nRightarrow q$ can be rejected for Japan, Malaysia, the Philippines, Singapore, and Thailand with no evidence of the reversed causality. The test shows evidence of bi-directional nonlinear causality for Indonesia and no evidence of causality in any direction for Korea.

Combining the results from the two nonlinear tests, we find evidence of unidirectional nonlinear Granger causality from oil price to the exchange rates of Japan, Korea, Malaysia, Singapore, and Thailand with no evidence of the reversed causality. We also find evidence of bi-directional nonlinear causality for Indonesia and the Philippines. Overall, the two tests provide some evidence in favor of nonlinear Granger causality from the price of oil to the exchange rates of the countries considered in this paper.

Empirical findings on the direction of causality between the price of oil and the exchange rate remain mixed with some studies finding causality from oil prices to exchange rates (Amano and van Norden, 1998; Lizardo and Mollick, 2010), others finding causality from exchange rates to oil prices (Zhang et al., 2008; Akram, 2004), and others finding no evidence of causality (Aleisa and Dibooglu, 2002; Breitenfeller and Cuaresma, 2008). Theoretically, whether oil prices cause exchange rates or vice versa, there are arguments that justify either direction of causality. On one hand, studies finding causality from oil prices to exchange rates support the traditional ToT argument, which suggests that oil price increases lead to a deterioration in the ToT of oil-importing countries; thus, causing their currencies to depreciate. In oil-exporting countries, oil price increases lead to currency appreciation. On the other hand, studies finding evidence of reversed causality support the view of a "*self-perpetuating cycle*" in which a weaker U.S. dollar increases oil prices, which in turn leads to even more dollar depreciation (Breitenfeller and Cuaresma, 2008). There are several reasons for this reversed causality (Breitenfeller and Cuaresma, 2008). First, since oil is invoiced in U.S. dollars in the international crude oil market, when the dollar depreciates, oil becomes cheaper in local currency terms in non-dollar economies, which could in turn increase the demand for oil in these economies and eventually increase oil prices. Second, since oil is priced in U.S. dollars, export revenues of oil-producing countries are denominated in U.S dollars. Thus, when the dollar depreciates, export revenues of these countries will decline. If these countries have a target export revenue in terms of their currencies, with a depreciating dollar they might decrease oil supply in order to hike up oil prices to achieve their target. Third, in non-dollar economies that have their currencies linked to the U.S. dollar, a depreciating dollar can trigger inflation and thus reduce the purchasing power of oil revenues in these countries. To the extent that these countries can change oil prices, they may attempt to increase prices through reducing oil supplies. Fourth, a depreciating dollar may encourage some foreign investors to increase their demand for oil as a hedge against inflation when the dollar depreciates, which might put upward pressure on oil prices. Fifth, dollar depreciation could be associated with monetary policy easing in other countries, including oil-producing countries that have their currencies pegged to the U.S dollar. This policy increases liquidity in these countries and could in turn stimulate economic activity and lead to an increase in demand for commodities, including oil, causing oil prices to increase.

Finally, Table 7 provides descriptive statistics for real oil price and exchange rate returns and Fig. 3 plots these returns. The oil market has been very volatile and risky over the sample period as indicated by the high standard deviations compared to the foreign exchange market. The distributional properties of the return series appear to be

Table 7
Descriptive statistics and unit root tests for the changes in real exchange rates and real oil prices.

	Real exchange rate							Real oil price						
	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
Mean	0.4021	−0.0776	−0.0038	0.4449	−0.0526	0.0118	0.1390	1.0561	0.5763	0.6502	1.0989	0.6013	0.6657	0.7929
Median	−0.2844	0.0569	−0.2410	0.1524	−0.1964	0.0644	−0.2609	0.0495	−0.1995	−0.3078	0.2685	0.4915	0.2154	0.2936
Maximum	67.8311	13.6559	29.0629	21.9803	16.1517	9.0464	21.9023	130.8763	143.1170	135.4118	145.2052	134.7094	142.3582	139.3036
Minimum	−48.1011	−16.1664	−13.8762	−10.1400	−14.0898	−12.4545	−17.1843	−58.0352	−85.5031	−54.6465	−66.7530	−66.8903	−69.2270	−68.5503
Std. Dev.	8.6482	5.1228	4.5722	3.3339	3.9306	2.5895	3.7285	19.0583	19.6944	17.6190	18.4251	18.3920	18.2114	18.5168
Skewness	2.4767	−0.3367	2.6861	1.8783	0.5497	−0.2685	1.7041	1.5208	1.5318	2.2676	2.4080	1.8512	2.3101	1.9838
Kurtosis	30.3696	3.3234	17.7338	13.3115	6.3459	5.7617	15.2603	15.6530	20.1763	22.7425	24.7971	19.7271	24.5012	21.3794
Probability+	0.0000	0.1322	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	174	174	174	174	174	174	174	174	174	174	174	174	174	174

+ Is the probability of the Jarque-Bera non-normality test.

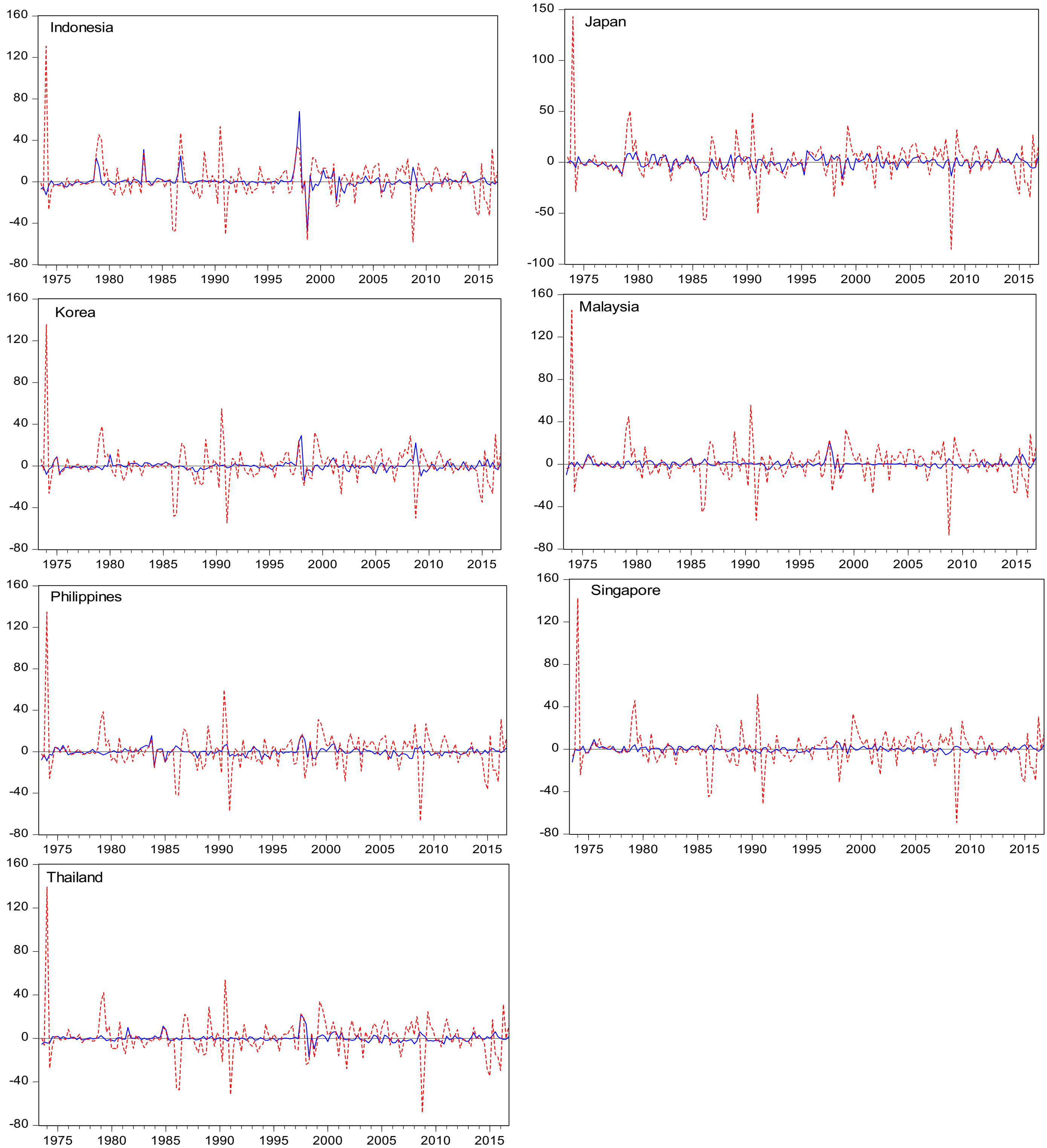


Fig. 3. oil and exchange rate returns. The solid line is the percentage change in the real exchange rate and the dotted line is the percentage change in the real price of oil.

non-normal, which is evident from the Jarque-Bera normality test that rejects the null hypothesis of normality in all the cases, except for Japan's real exchange rate. Moreover, the results suggest that all the series (except Japan's and Singapore's real exchange rate returns) exhibit positive skewness (implying that the return series are skewed to the right). All exchange rate return series have a high degree of kurtosis as the kurtosis statistic is above 3, suggesting a leptokurtic distribution and fatter tails than the normal distribution. These results indicate that the probability of observing positively extreme values is much higher than a normal distribution. The skewness and the high degree of kurtosis that are present in the return series can be explained by the fact that our sample covers a volatile period that includes the oil price shocks of the 1970s, the Iraq-Iran war, the Plaza Acord, the Iraq invasion of Kuwait, the Asian financial, the U.S. financial crisis, and the Arab Spring. Given the non-normality of exchange rate returns, QR should be preferred to OLS in the analysis that follows.

Table 8
The estimation results for the OLS and quantile models (linear model).

Country	Variable	OLS	Bearish market			Normal market			Bullish market		
			$Q_{0.1}$	$Q_{0.2}$	$Q_{0.3}$	$Q_{0.4}$	$Q_{0.5}$	$Q_{0.6}$	$Q_{0.7}$	$Q_{0.8}$	$Q_{0.9}$
Indonesia	Constant	−0.239	−4.922*	−2.323*	−1.630*	−0.979*	−0.230	0.205	0.742*	1.696*	3.826*
	p_{ot}	0.131*	−0.059*	0.024	0.040	0.043	0.042	0.027	0.026	0.069	0.111
	D_{85}	3.857	0.782	2.184**	2.272**	1.758	1.011	0.592	0.216	5.769**	3.203
	D_{97}	9.422*	−46.462*	−3.377	−3.903	−1.178	11.812*	11.559*	31.371*	28.965*	60.707*
	D_{08}	2.319	1.165	−0.827	−0.310	−0.684	−1.417	−1.627	−1.666	−3.560*	16.280**
Japan	Constant	0.172	−5.858*	−3.351*	−2.032*	−0.601	−0.001	1.041**	2.512*	3.820*	5.793*
	p_{ot}	0.070*	0.038**	0.074***	0.099**	0.099*	0.115*	0.096*	0.081***	0.087**	0.064**
	D_{85}	−7.437*	−7.356**	−3.943***	−5.161**	−6.592**	−3.922***	−5.227**	−7.498*	−8.515*	−9.928*
	D_{97}	−0.619	−9.409**	2.438	1.131	3.862	5.326*	4.421**	3.112***	1.979	0.028
	D_{08}	−3.389	−4.389	−2.784	−3.019	−4.450**	−3.674***	−6.052*	−3.725	−5.151	−2.604
Korea	Constant	−0.395	−3.980*	−2.517*	−1.598*	−0.976*	−0.311	0.237	0.623***	1.887*	2.997*
	p_{ot}	−0.023	−0.031*	−0.017	−0.008	0.012	0.002	0.005	−0.002	−0.034	−0.045
	D_{85}	0.107	0.784	0.163	0.499	0.783	0.204	−0.355	0.493	−0.705	−1.010
	D_{97}	5.379*	−10.571*	−2.056	−2.967***	−2.595	−3.363***	−0.045	22.496*	22.004*	25.723*
	D_{08}	7.585*	3.625*	6.314*	5.303*	4.452**	4.785*	4.235*	5.852***	18.456*	16.783*
Malaysia	Constant	0.201	−2.962*	−1.540*	−0.976*	−0.336	0.158	0.460**	1.008*	2.098*	2.988*
	p_{ot}	0.009	0.032*	0.022**	0.018***	0.014	0.010	0.008	0.005	−0.003	−0.009
	D_{85}	1.369	2.526*	1.103	1.070	0.435	0.864	0.572	0.630	2.730	1.588
	D_{97}	5.999*	−3.537**	−3.072	−3.673	5.563***	5.099	9.577*	10.574*	9.295*	19.200*
	D_{08}	−0.424	−1.053	−2.433**	−2.534***	−3.116***	−0.877	−1.133	0.001	−1.110	1.659
Philippines	Constant	−0.350	−3.877*	−2.327*	−1.616*	−0.906	−0.403	0.254	0.952*	1.679*	3.222*
	p_{ot}	0.016	0.010	0.019	0.025	0.020	0.014	0.002	0.036	0.045	0.061
	D_{85}	2.886***	3.254**	1.708	2.646**	1.961	1.885	1.256	4.377	5.769**	4.881***
	D_{97}	5.880*	−2.590**	−3.111**	−3.758**	7.554***	7.115***	10.885*	11.039*	10.555*	11.881*
	D_{08}	0.089	−2.744**	−4.267*	−4.987*	−5.689*	2.972	2.300	1.742	6.461	5.985
Singapore	Constant	−0.039	−2.698*	−2.248*	−1.544*	−0.448***	0.110	0.627**	1.041*	1.708*	2.802*
	p_{ot}	−0.011	−0.000	0.008	−0.012	−0.018	−0.020	−0.013	−0.016***	−0.016***	−0.009
	D_{85}	0.176	−0.312	−0.746	0.637	0.506	−0.051	−0.570	0.015	−0.680	0.656
	D_{97}	2.683**	−1.775	1.476	0.661	3.686	3.136	4.715*	4.628*	3.967*	4.302*
	D_{08}	−1.375	−2.556**	−3.097**	−2.561	−1.417	−1.932	−2.590	0.659	0.461	−0.621
Thailand	Constant	−0.027	−2.325*	−1.611*	−1.147*	−0.578*	−0.211	0.184	0.588*	1.477*	2.437*
	p_{ot}	0.016	−0.014**	−0.019**	−0.005	−0.002	−0.009	0.003	0.015	0.031***	0.030***
	D_{85}	−0.637	0.135	−0.822	−0.575	−1.045	−1.258***	−1.591**	−1.227***	0.480	−0.512
	D_{97}	4.694*	−15.160*	−8.413*	−8.639*	1.956	12.738*	12.616*	17.759*	16.555*	18.796*
	D_{08}	0.333	−2.659***	−0.375	−1.117	−1.748	−0.729	−1.303	3.862	4.077*	3.601*

*, **, *** indicate significance at the 1%, 5%, and 10% levels. We choose nine quantiles ($\tau = 0.10, 0.20, \ldots, 0.90$) and divide them into three regimes: low ($\tau = 0.10,0.20,0.30$), medium ($\tau = 0.40,0.50,0.60$), and high ($\tau = 0.70,0.80,0.90$), which corresponds to a bearish, normal, and bullish market, respectively.

4.2. Linear model

Table 8 reports the results from both the standard OLS model in Eq. (5) and QR model in Eq. (11). The results from OLS show that oil price shocks have positive significant effect on the exchange rate returns of only Indonesia and Japan, implying that rising oil price causes the currencies of Indonesia and Japan to depreciate against the U.S. dollar. The results for the remaining countries suggest that oil price changes have no significant impact on their currencies. Our result for Japan is consistent with previous studies; such as Lizardo and Mollick (2010), Chinn (2000), and Wang and Dunne (2000) who find rising oil prices to cause currency depreciation for Japan. In contrast, our result for Indonesia are not in line with those of Turhan et al. (2013), Chinn (2000), and Wang and Dunne (2000) who find rising oil prices to cause currency appreciation for Indonesia. For the rest of the countries (Korea, Malaysia, the Philippines, Singapore, and Thailand), our results that oil price shocks have no significant impact on their exchange rates are contrary to Turhan et al. (2013) who find that rising oil prices cause a significant appreciation in the currencies of the Philippines and Korea relative to the U.S. dollar, Chinn (2000) who finds rising oil prices to depreciate the currency of Korea against the U.S dollar, and Wang and Dunne (2000) who find that rising oil prices cause currency appreciation for Malaysia, Singapore, and Thailand; and depreciation for Korea and the Philippines.

At least one of the dummy variables for structural breaks is significant in each country—usually the dummy variable capturing the impact of the Asian financial crisis. However, as mentioned earlier, the OLS model summarizes the average relationship between oil price shocks and the exchange rate based on the conditional mean of the exchange rate. Since the impact of oil price shocks may vary throughout the distribution of exchange rate returns, we next use QR analysis in Eq. (11) to infer information on the co-movement between exchange rate and oil returns in specific market conditions–bullish, bearish, or normal—as reported in Table 8. Fig. 4 plots the quantile regression coefficient estimates with 95% confidence interval along with the OLS estimates. The OLS estimates of the conditional mean effect, given by the blue solid line with 95% confidence interval (dashed lines), do not vary. As for quantile coefficient estimates, for each variable, we plot the nine quantile regression estimates for $\tau = 0.1, \ldots, 0.9$ as the solid black curve with 95% confidence interval (shaded area). The QR model provides a quite different picture than the OLS model. In particular, the results show that moving up the conditional distribution, the effect of oil price changes on exchange rate returns varies in size, sign and significance. The results for Indonesia and Korea show that the effect of oil price changes on the exchange rate is significantly negative only when the market is bearish at the lower quantile ($\tau = 0.1$), with no significant effects at the other quantiles. The negative sign implies that rising oil price causes the currencies of Indonesia and Korea to appreciate only at the lower quantile ($\tau = 0.1$) when the market is bearish. Thus, at lower exchange rate return quantiles, which correspond to large U.S. dollar depreciation, or high Asian (in this case, Indonesia and Korea) currency appreciation, rising oil price causes the currencies of Indonesia and Korea to appreciate. This seems to be consistent with "*destabilizing speculative behavior*", which occurs when a currency is appreciating (depreciating) and speculators buy (sell) that currency, believing that it will appreciate (depreciate) even further.

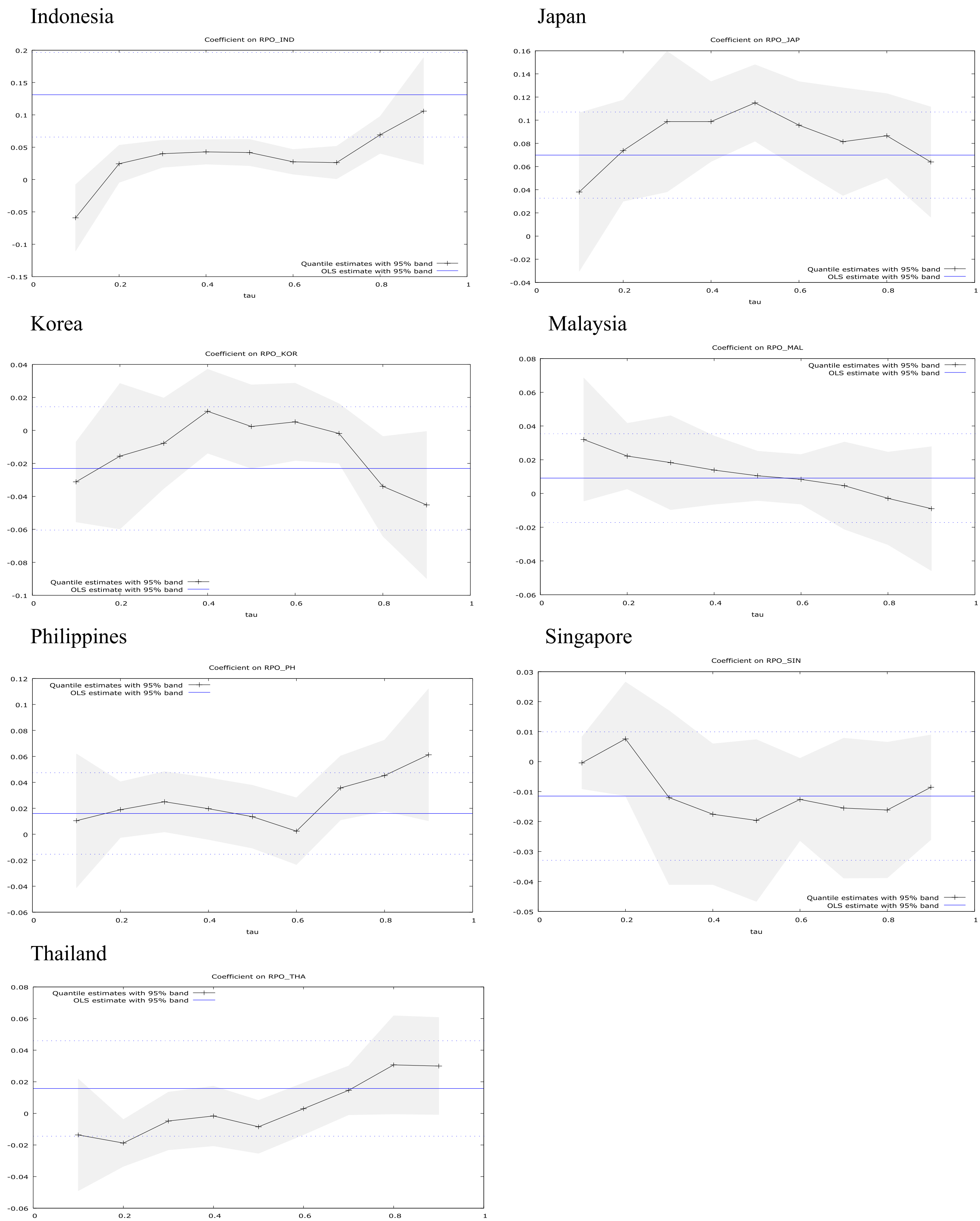


Fig. 4. Quantile regression coefficient estimates for oil price changes (linear model). Quantile regression estimates for $\tau = 0.1, \ldots, 0.9$ are given by the solid black curve with 95% confidence intervals (shaded area) for the effects of oil price shocks on real exchange rates. The OLS estimates of the conditional mean effect are given by the blue solid line with 95% confidence interval (dashed lines). Vertical axis shows the coefficient estimate of oil price changes over exchange rate return distribution, and horizontal axis shows the quantiles of real exchange rate return (the dependent variable).

The results for Japan suggest that oil price shocks affect exchange rate returns across the entire distribution of exchange rate returns. Rising oil price causes the Japanese yen to depreciate at all quantiles. This finding for Japan is consistent with the fact that for net oil-importing countries, rising oil price causes currency depreciation through the terms of trade effect. For Malaysia, oil price shocks affect the exchange rate only at lower quantiles ($\tau = 0.1, 0.2, 0.3$), when the market is bearish, with no significant effects at the other quantiles. The results show that at lower quantiles, which corresponds to high U.S. dollar depreciation, or high Malaysian ringgit appreciation, rising oil price causes the Malaysian ringgit to depreciate.

The results for the Philippines suggest that oil price shocks have no significant impact on the exchange rate at all quantiles. As for Singapore, the results show that oil price shocks have a negative significant effect on the exchange rate only at higher quantiles ($\tau = 0.7, 0.8$), when the market is bullish, with no significant effects at the other quantiles. Lastly, the results for Thailand suggest that oil price shocks affect the exchange rate both at lower quantiles ($\tau = 0.1, 0.2$), when the currency market bearish, and at higher quantiles ($\tau = 0.8, 0.9$), when the currency market is bullish. Only extreme market conditions have a significant impact on the exchange rate and the results are asymmetrical. In particular, when the market is bearish (bullish), rising oil price causes the Thai baht to appreciate (depreciate).

The general results from the QR model presented in Table 8 suggest that oil price shocks impact the exchange rates of most Asian countries (except Japan and the Philippines) only during extreme market conditions, or at lower (bearish market) and higher (bullish market) quantiles. This implies that the Asian exchange rates generally respond to oil price shocks only during periods of large currency appreciation or depreciation. During normal market conditions, oil price shocks have little impact on the exchange rates. Our results may therefore help explain why researchers choosing different time periods of analysis have arrived at a variety of conclusions about the relationship between oil price shocks and exchange rates.

Table 9 provides the *F*-test of quantile slope equality. The null hypothesis is that slope parameters are equal across the various quantiles. Rejection of the null hypothesis implies that slopes are significantly different across quantiles. The results are provided for every two quantiles (for example, $Q_{0.1} = Q_{0.2}$) and for lower quantile against the median ($Q_{0.1} = Q_{0.5}$) and higher quantile against the median ($Q_{0.5} = Q_{0.9}$). The overall results suggest that the null hypothesis of slope equality can be rejected across the different quantiles for all countries, except for the Philippines and Singapore. The test suggests that the estimated coefficients are not constant and that they vary across different quantiles.

4.3. Asymmetric model

To allow for asymmetry in the relationship between oil price shocks and exchange rate returns, oil returns (p_{ot}) are decomposed into positive (p_{ot}^{+}) and negative (p_{ot}^{-}) changes. Then, the OLS model in Eq. (6) and the QR model in Eq. (12) are estimated. Table 10 presents both the OLS estimates and the quantile estimates. Fig. 5 provides summary graphs for the quantile regression results along with the OLS estimates with 95% confidence intervals. The OLS estimates of the conditional mean effect, given by the blue solid line with 95% confidence interval (dashed lines), do not vary. As for quantile coefficient estimates, for each variable, we plot the nine quantile regression estimates for $\tau = 0.1, \ldots, 0.9$ as the solid black curve with 95% confidence interval (shaded area). Introducing asymmetry in the OLS model in Eq. (6) by differentiating between positive (p_{ot}^{+}) and negative (p_{ot}^{-}) changes provides slightly different results than in the previous section. In particular, p_{ot}^{+} and p_{ot}^{-} are significantly positive for Indonesia, implying that rising (falling) oil price causes the Indonesian rupiah to depreciate (appreciate) against the U.S. dollar, but the impact of falling oil prices on the exchange rate are higher than that for rising oil prices. The results for Japan show that only p_{ot}^{-} is significantly positive, implying that falling oil price causes the Japanese yen to appreciate against the U.S. dollar. Allowing for asymmetry in the OLS model shows that oil price shocks now have an impact on the Malaysian ringgit and the Singapore dollar. Namely, p_{ot}^{+} has a positive and significant impact on the Malaysian ringgit, suggesting that rising oil price depreciates the Malaysian ringgit, and that p_{ot}^{-} has a negative and significant impact on the Singapore dollar, implying that falling oil price depreciates the

Table 9
Quantile slope equality test (linear model).

Country	Variable	$Q_{0.1} = Q_{0.2}$	$Q_{0.2} = Q_{0.3}$	$Q_{0.3} = Q_{0.4}$	$Q_{0.4} = Q_{0.5}$	$Q_{0.5} = Q_{0.6}$	$Q_{0.6} = Q_{0.7}$	$Q_{0.7} = Q_{0.8}$	$Q_{0.8} = Q_{0.9}$	$Q_{0.1} = Q_{0.5}$	$Q_{0.5} = Q_{0.90}$
Indonesia	p_{ot}	**0.0000**	0.3758	0.8904	0.9651	0.5329	0.9655	0.4046	0.6853	**0.0056**	0.5493
	D_{85}	0.1774	0.8962	0.4766	0.3162	0.5706	0.6095	**0.0409**	0.3300	0.8810	0.4968
	D_{97}	**0.0000**	0.7852	0.1856	**0.0000**	0.9035	**0.0000**	0.4189	**0.0000**	**0.0000**	**0.0000**
	D_{08}	0.1461	0.6227	0.5435	0.2474	0.7553	0.9601	**0.0595**	**0.0052**	0.1391	**0.0090**
Japan	p_{ot}	0.2861	0.3568	1.0000	0.4296	0.2979	0.6186	0.8530	0.4198	**0.0124**	0.1278
	D_{85}	0.2129	0.4896	0.3914	**0.0978**	0.3273	0.1444	0.5038	0.3852	0.3090	**0.0098**
	D_{97}	**0.0006**	0.7184	0.4930	0.2864	0.4119	0.2404	0.3047	**0.0827**	**0.0009**	**0.0042**
	D_{08}	0.6352	0.8581	0.2643	0.5324	**0.0567**	0.5557	0.6680	0.4452	0.8606	0.7394
Korea	p_{ot}	0.4801	0.6600	0.1838	0.4390	0.8236	0.7132	0.3503	0.7328	**0.0816**	0.1678
	D_{85}	0.6970	0.7980	0.7442	0.3707	0.3936	0.2980	0.1065	0.7065	0.6714	0.3212
	D_{97}	**0.0000**	0.3960	0.7429	0.4969	0.1220	**0.0000**	0.8198	0.1109	**0.0013**	**0.0000**
	D_{08}	**0.0519**	0.3094	0.4170	0.7430	0.5600	0.4276	**0.0003**	0.5782	0.5613	**0.0001**
Malaysia	p_{ot}	0.1455	0.5413	0.4878	0.5703	0.7203	0.5177	0.1859	0.4043	**0.0366**	**0.0656**
	D_{85}	**0.0515**	0.9608	0.3337	0.5090	0.6362	0.9348	0.1447	0.4775	0.1204	0.6474
	D_{97}	0.7834	0.7458	**0.0000**	0.8242	**0.0323**	0.4974	0.3554	**0.0000**	**0.0108**	**0.0000**
	D_{08}	**0.0942**	0.9083	0.5408	0.1245	0.8583	0.4170	0.4042	**0.0533**	0.9390	0.3151
Philippines	p_{ot}	0.6939	0.7271	0.7946	0.7607	0.5954	0.2255	0.7771	0.6551	0.9303	0.3407
	D_{85}	0.2834	0.4413	0.4310	0.9371	0.5306	0.1740	0.5179	0.6862	0.4593	0.2742
	D_{97}	0.6635	0.5868	**0.0000**	0.8554	0.1805	0.9023	0.7364	0.5449	**0.0125**	0.2396
	D_{08}	0.1336	0.4652	0.5108	**0.0000**	0.5793	0.6465	0.1866	0.8937	**0.0040**	0.4924
Singapore	p_{ot}	0.4996	0.4279	0.7909	0.8225	0.3934	0.7025	0.9154	0.6858	0.2669	0.6362
	D_{85}	0.8037	0.3622	0.8972	0.4734	0.5119	0.5308	0.4937	0.4325	0.8829	0.7461
	D_{97}	**0.0917**	0.6921	0.1183	0.7518	0.3895	0.9232	0.4388	0.7193	**0.0840**	0.6640
	D_{08}	0.6172	0.6280	0.6076	0.8005	0.7397	0.1167	0.8508	0.3657	0.8458	0.6933
Thailand	p_{ot}	0.3769	0.4140	0.8173	0.5571	0.2816	0.5441	0.29662	0.9591	0.7551	**0.0508**
	D_{85}	0.1108	0.6451	0.3039	0.6312	0.4400	0.4492	0.2862	0.5268	**0.0712**	0.6289
	D_{97}	**0.0000**	0.8863	**0.0000**	**0.0000**	0.9438	**0.0049**	0.4532	0.1443	**0.0000**	**0.0000**
	D_{08}	**0.0428**	0.5171	0.5808	0.3639	0.6086	**0.0265**	0.9268	0.6091	0.3136	**0.0195**

Reported are the p-values for the null hypothesis for quantile slope equality test. Bold p-values indicate rejection of the null hypothesis of slope equality at conventional significance levels.

Table 10
The estimation results for the OLS and quantile models (asymmetric model).

Country	Variable	OLS	Bearish market			Normal market			Bullish market		
			$Q_{0.1}$	$Q_{0.2}$	$Q_{0.3}$	$Q_{0.4}$	$Q_{0.5}$	$Q_{0.6}$	$Q_{0.7}$	$Q_{0.8}$	$Q_{0.9}$
Indonesia	Constant	0.160	−2.432	−1.354*	−1.081**	−0.701**	−0.214	−0.188	−0.015	0.446	0.974
	p_{ot}^{+}	0.101**	−0.078*	−0.086*	−0.003	−0.002	0.026	0.086	0.227	0.324*	0.656
	p_{ot}^{-}	0.179*	0.212	0.133	0.097	0.048	0.043	−0.031	−0.043	−0.053	−0.162
	D_{85}	4.459	3.343	2.530***	2.096	1.714	1.012	0.921	0.594	0.027	−0.474
	D_{97}	9.948*	−33.894	−3.174	−3.829	−1.386	11.999*	11.216*	25.320*	21.537*	46.388*
	D_{08}	2.810	0.645	−1.009	−0.581	−0.256	−1.182	−2.050	−3.133**	10.419***	3.567
Japan	Constant	0.622	−3.466**	−2.895*	−1.706*	−0.686	−0.081	1.139***	2.616*	3.796*	6.637*
	p_{ot}^{+}	0.036	−0.036	0.017	0.009	0.108	0.130***	0.093	0.068	0.098	0.042
	p_{ot}^{-}	0.123*	0.325	0.121*	0.131**	0.097**	0.094**	0.115*	0.095	0.086	0.081**
	D_{85}	−6.476*	−6.080***	−4.207	−5.357	−6.512**	−5.013**	−6.063**	−6.837**	−7.841*	−10.702*
	D_{97}	0.770	−5.010	2.006	0.821	3.875	3.103	4.344**	3.202***	1.969	−0.793
	D_{08}	−2.666	−2.429	−1.110	−2.193	−4.486**	−5.371**	−4.814**	−3.528	−0.589	−3.434
Korea	Constant	−0.308	−3.751*	−1.903*	−1.178*	−0.575***	0.016	0.443	0.846**	1.833*	2.982*
	p_{ot}^{+}	−0.030	−0.032*	−0.046*	−0.051*	−0.056*	−0.060*	−0.019	−0.008	−0.032	−0.045
	p_{ot}^{-}	−0.011	0.033	0.034	0.023	0.023	0.034	0.033	0.037	−0.037	−0.095
	D_{85}	0.252	3.764*	1.964***	1.251	0.670	0.835	0.708	0.283	0.125	−0.996
	D_{97}	5.391*	−9.500*	−2.623***	−3.365***	−2.866	−3.337	−0.235	22.414*	22.006*	25.364*
	D_{08}	7.690*	3.503***	1.871	5.388*	5.080*	4.491*	4.041**	5.798***	5.503**	14.332
Malaysia	Constant	−0.106	−3.176*	−1.750*	−1.060*	−0.459***	−0.035	0.294	0.840*	1.577*	2.745*
	p_{ot}^{+}	0.032***	0.033*	0.024*	0.019**	0.021***	0.023	0.014	0.010	0.021	0.007
	p_{ot}^{-}	−0.034	−0.024	−0.004	−0.020	−0.022	−0.019	−0.050	−0.089*	−0.067**	−0.067*
	D_{85}	0.913	2.730*	1.308	1.153	0.898	0.625	−0.195	0.186	0.640	−0.528
	D_{97}	5.794*	−4.137**	−3.119	−3.964	5.623***	5.179	9.686*	9.184*	8.326*	19.080*
	D_{08}	−0.891	−0.846	−1.832	−2.459**	−0.485	−0.959	−1.084	−1.539	−0.777	−1.945
Philippines	Constant	−0.107	−2.723*	−1.759*	−1.327*	−0.560	−0.100	0.253	0.768	1.380*	3.281*
	p_{ot}^{+}	−0.002	−0.045*	−0.052*	−0.013	−0.013	−0.015	0.003	0.053	0.069***	0.037
	p_{ot}^{-}	0.045	0.104	0.060***	0.055	0.048	0.042	0.002	0.005	−0.003	0.063
	D_{85}	3.152***	2.134	1.154	2.539***	1.770	1.653	1.256	3.280	2.303	4.907
	D_{97}	5.998*	−2.430	−3.252**	−3.733**	7.552**	7.116***	10.882*	10.444*	9.610*	12.237*
	D_{08}	0.380	−3.769*	−4.721*	−5.053*	3.177	2.709	2.301	1.790	1.166	6.065
Singapore	Constant	−0.272	−2.876*	−2.623*	−1.774*	−0.769**	−0.081	0.484	0.786***	1.564*	2.779*
	p_{ot}^{+}	0.006	0.003	0.010	0.004	−0.003	−0.008	−0.012	0.010	−0.005	0.031
	p_{ot}^{-}	−0.043**	−0.039	−0.073**	−0.056**	−0.050**	−0.060**	−0.047**	−0.056	−0.026	−0.009
	D_{85}	−0.168	−0.213	−0.537	0.825	−0.162	−0.837	−0.830	−0.736	−0.963	0.679
	D_{97}	2.597**	−2.053	1.397	0.642	3.953***	3.975**	3.803**	4.650*	4.012*	4.004*
	D_{08}	−1.720	−2.418**	−2.752***	−2.396	−1.392	−1.982	−2.468	−1.892	−0.565	−0.598
Thailand	Constant	0.023	−2.325*	−1.554*	−1.141*	−0.710*	−0.380	−0.017	0.429	1.233*	2.149*
	p_{ot}^{+}	0.012	−0.014**	−0.019*	−0.022*	0.001	0.012	0.015	0.046	0.044	0.053
	p_{ot}^{-}	0.022	−0.004	−0.006	−0.004	−0.018	−0.015	−0.018	−0.010	0.006	0.024
	D_{85}	−0.561	0.605	−0.169	−0.578	−1.030	−1.093	−1.457**	−1.162***	−1.960*	−0.517
	D_{97}	4.742*	−14.942*	−8.245*	−8.624*	2.075	1.688	12.314*	17.296*	16.531*	18.567*
	D_{08}	0.403	−2.659**	−3.412***	−0.777	−0.375	−0.884	−1.295	2.369	2.628	3.839*

*, **, *** indicates significance at the 1%, 5%, and 10% levels. We choose nine quantiles ($\tau = 0.10, 0.20, \ldots, 0.90$) and divide them into three regimes: low ($\tau = 0.10, 0.20, 0.30$), medium ($\tau = 0.40, 0.50, 0.60$), and high ($\tau = 0.70, 0.80, 0.90$), which corresponds a bearish, normal, and bullish market, respectively.

Singapore dollar. For the other countries (Korea, the Philippines, and Thailand), the results show no significant impact for oil price shocks (p_{ot}^{+} and p_{ot}^{-}) on exchange rates.

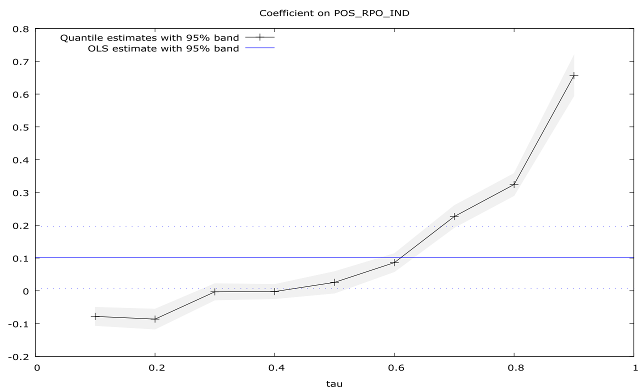
Further testing on the equality of the slope coefficient estimates on p_{ot}^{+} and p_{ot}^{-} showed that the null hypothesis could be rejected for Japan, Malaysia, and Singapore, suggesting that oil price increases and decreases in these countries have asymmetrical effects on these exchange rate return series.[9]

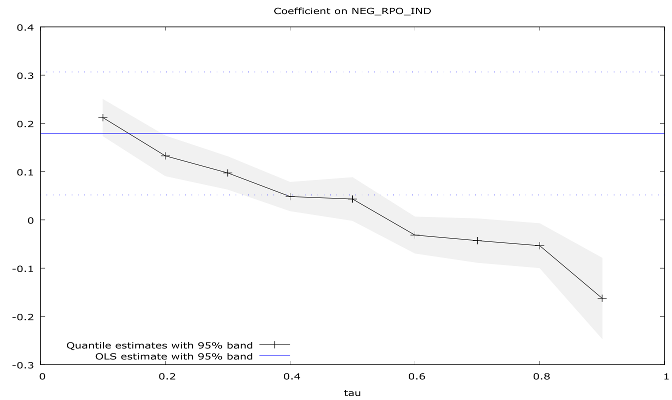
To examine the impact of the positive (p_{ot}^{+}) and negative (p_{ot}^{-}) oil price changes on the entire distribution of exchange rate returns, we now turn to the results from the QR model in Eq. (12). The results reported in Table 10 provide a different picture from the previous models in Eqs. (5), (6), and (11). In most cases, oil price shocks significantly impact exchange rates only under extreme market conditions (bullish or bearish currency markets). The Asian exchange rate series in this study respond to oil price shocks only when there is large appreciation at lower quantiles (where there is large U.S. dollar depreciation), or when there is large depreciation at higher quantiles (where there is large U.S. dollar appreciation). During normal market conditions, Asian exchange rates are not significantly impacted by oil price shocks.

A closer look at the results for each country shows that for Indonesia, Korea, and Thailand rising oil prices (p_{ot}^{+}) affect the exchange rate, but there is no significant impact for falling oil prices (p_{ot}^{-}) at any quantile. Fort the Indonesian rupiah, although p_{ot}^{+} has a negative significant impact when the market is bearish at the lower quantiles ($\tau = 0.1, 0.2, 0.3$), it has a positive significant effect at higher quantiles ($\tau = 0.8,$) or when the market is bullish. When there is large rupiah appreciation (at lower quantiles, which corresponds to large U.S. dollar depreciation), rising oil price causes the Indonesian rupiah to appreciate. At higher quantiles, which corresponds to large rupiah depreciation, or large U.S. appreciation, rising oil price causes rupiah depreciation. As for Korea, the results show that that p_{ot}^{+} has a negative significant impact on the Korean won when the market is bearish at lower quantiles ($\tau = 0.1, 0.2, 0.3$) and at medium quantiles ($\tau = 0.4, 0.5$). This implies that when there is large or normal won appreciation, rising oil prices lead to appreciation of the won. The results for Thailand show that p_{ot}^{+} has a negative significant impact on the Thai baht when the market is bearish at lower quantiles ($\tau = 0.1, 0.2, 0.3$), implying that when there is large Thai baht appreciation (US dollar depreciation), rising oil price appreciates the Thai baht. Again, the results for these countries seem to be consistent with "*destabilizing speculative behavior*".

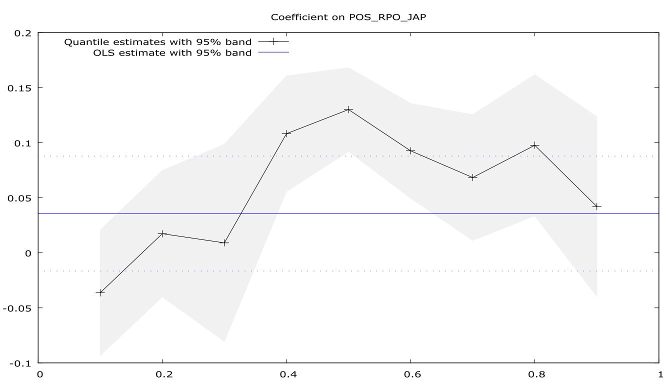
[9] Results of testing the null hypothesis on the equality of the slope coefficient estimates are not reported, but available upon request from the corresponding author.

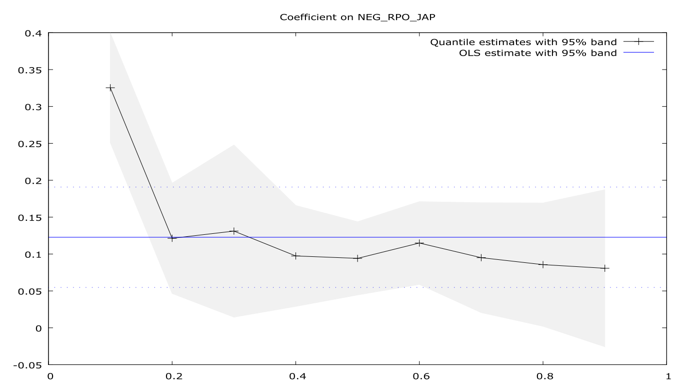
Indonesia



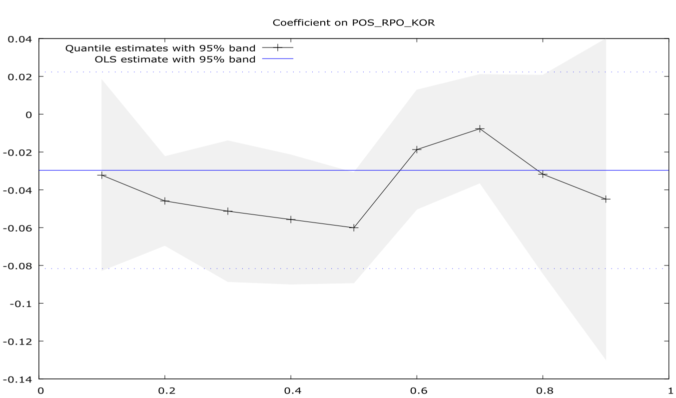


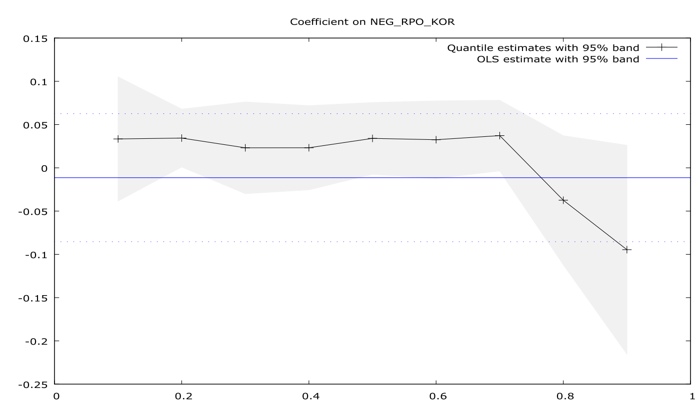
Japan



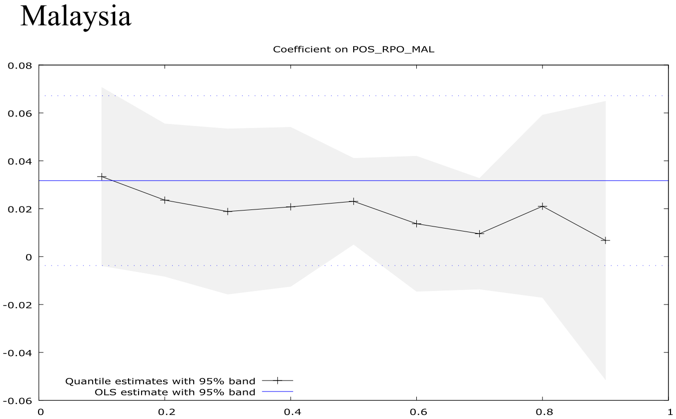


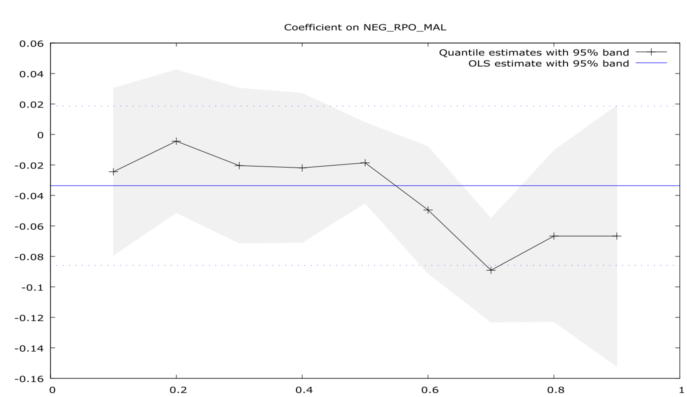
Korea





Malaysia





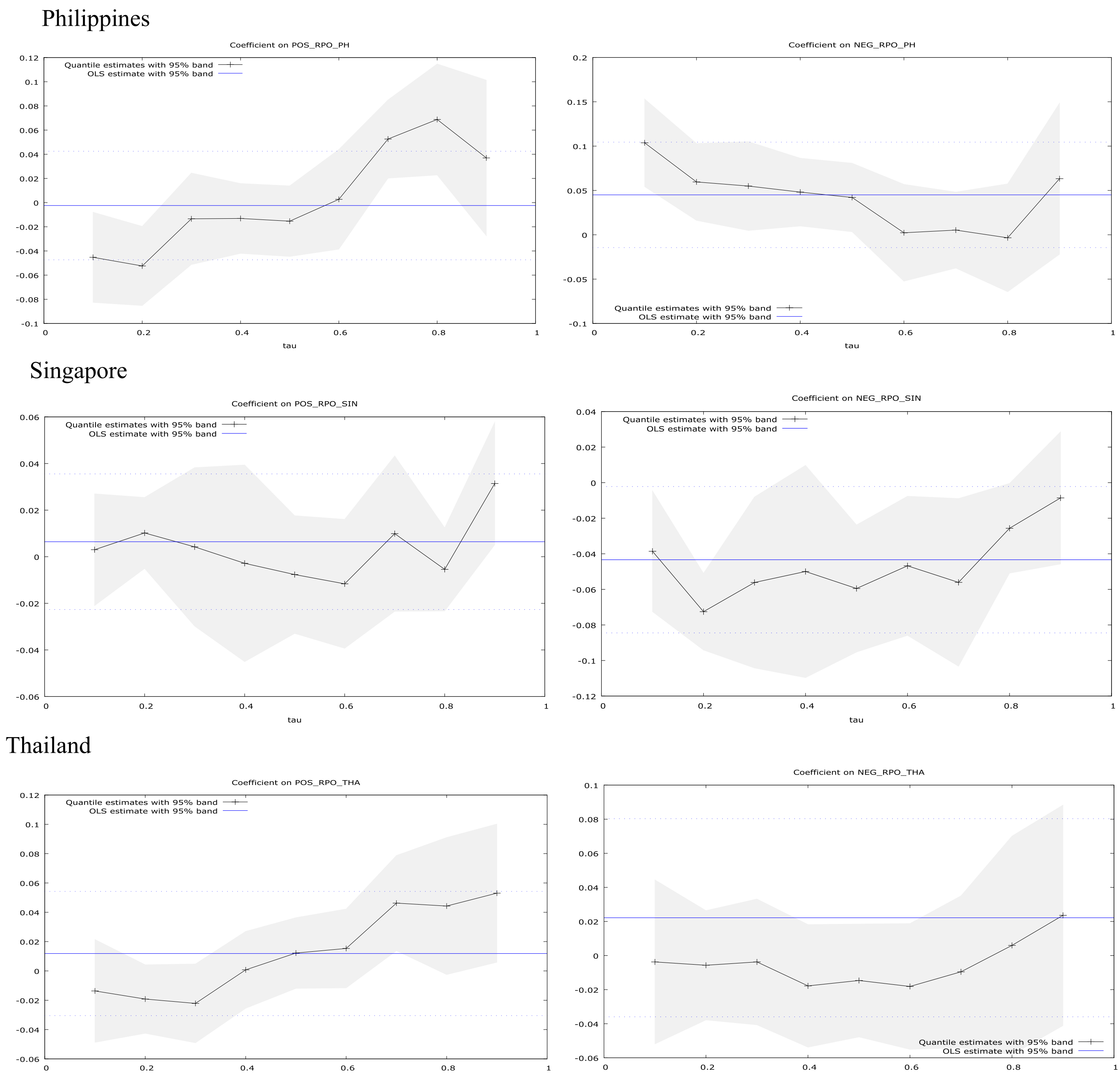


Fig. 5. Quantile regression coefficient estimates for positive and negative oil price shocks (asymmetrical model). Quantile regression estimates for $\tau = 0.1, \ldots, 0.9$ are given by the solid black curve with 95% confidence intervals (shaded area) for the effects of oil price shocks on real exchange rates. The OLS estimates of the conditional mean effect are given by the blue solid line with 95% confidence interval (dashed lines). Vertical axis shows the coefficient estimate of oil price changes over exchange rate return distribution, and horizontal axis shows the quantiles of real exchange rate return (the dependent variable).

The results for the Philippines are similar to those of Indonesia, Korea, and Thailand, except that p_{ot}^{-} has a significant positive effect on the Philippine peso at lower quantiles ($\tau = 0.1, 0.2, 0.3$). This suggests that when there is large peso appreciation, falling (rising) oil price causes the peso to depreciate (appreciate). For the Philippines, even though rising oil prices may lead to "*destabilizing speculation*" in the foreign exchange market, falling oil prices may stabilize the foreign exchange market.

Results for Japan and Singapore are similar to other countries in that falling oil prices have a greater effect on the exchange rates than rising oil prices. A rising oil price has a significant positive effect on the yen only at the median ($\tau = 0.5$), implying that a rising oil price causes yen depreciation. However, falling oil price has a significant positive effect on the yen at most of the quantiles—suggesting that falling oil prices cause yen appreciation. For Japan, extreme market conditions do not seem to be important. As for Singapore, although a rising oil price has no significant impact on the Singapore dollar at any quantile, falling oil prices have a significant negative effect on the Singapore dollar at lower and medium quantiles. This means that falling oil prices can cause Singapore dollar depreciation.

Lastly, the results for Malaysia show that a rising oil price has a significant positive effect on the Malaysian ringgit at lower quantiles ($\tau = 0.1, 0.2, 0.3, 0.4$), and that falling oil prices have a significant negative impact on the ringgit at higher quantiles ($\tau = 0.7, 0.8, 0.9$). This shows that extreme market conditions affect the ringgit, although oil prices do not impact the exchange rate under in normal market

Table 11
Quantile slope equality test (asymmetric model).

Country	Variable	$Q_{0.1}=Q_{0.2}$	$Q_{0.2}=Q_{0.3}$	$Q_{0.3}=Q_{0.4}$	$Q_{0.4}=Q_{0.5}$	$Q_{0.5}=Q_{0.6}$	$Q_{0.6}=Q_{0.7}$	$Q_{0.7}=Q_{0.8}$	$Q_{0.8}=Q_{0.9}$	$Q_{0.1}=Q_{0.5}$	$Q_{0.5}=Q_{0.9}$
Indonesia	p_{ot}^{+}	0.6109	**0.0065**	0.9766	0.6320	0.4318	0.3542	0.5420	0.4879	0.2248	0.2269
	p_{ot}^{-}	0.8886	0.6205	0.4323	0.8581	**0.0298**	0.7219	0.8433	0.5167	0.7815	0.2885
	D_{85}	0.6385	0.6627	0.7916	0.3601	0.9530	0.7543	0.6225	0.8196	0.3224	0.5756
	D_{97}	0.3447	0.7393	0.2368	**0.0000**	0.7202	**0.0364**	0.5204	**0.0942**	0.3375	**0.0052**
	D_{08}	0.2000	0.6645	0.6450	0.2584	0.3357	02878	**0.0041**	0.5122	0.2475	0.7089
Japan	p_{ot}^{+}	0.5588	0.5308	0.2722	0.7274	0.4140	0.6181	0.5710	0.3045	0.1152	0.2761
	p_{ot}^{-}	0.5226	0.7679	0.3717	0.8902	0.3550	0.6867	0.8354	0.9100	0.4860	0.7554
	D_{85}	0.6136	0.6692	0.6672	0.3419	0.9697	0.3761	0.6009	0.1367	0.7513	**0.0100**
	D_{97}	0.3535	0.7500	0.4583	0.6017	0.3982	0.3221	0.2617	**0.0167**	0.3063	0.1090
	D_{08}	0.6264	0.5215	0.1738	0.5048	0.5782	0.7414	0.4220	0.3741	0.3312	0.5626
Korea	p_{ot}^{+}	**0.0474**	0.4410	0.5392	0.5477	0.2803	0.7439	0.4481	0.7165	**0.0227**	0.7023
	p_{ot}^{-}	0.9751	0.6237	0.9976	0.4321	0.9226	0.7476	0.5620	0.7474	0.9869	0.5071
	D_{85}	**0.0569**	0.3448	0.3423	0.7721	0.8032	0.3919	0.8929	0.3326	**0.0156**	0.1674
	D_{97}	**0.0000**	0.5378	0.6885	0.7128	0.1298	**0.0000**	0.8466	0.1624	**0.0152**	**0.0000**
	D_{08}	0.3401	**0.0152**	0.7619	0.5674	0.6591	0.3992	0.8819	0.3651	0.6324	0.3423
Malaysia	p_{ot}^{+}	0.1071	0.4302	0.7730	0.8351	0.4166	0.5057	0.6915	0.6248	0.5453	0.6319
	p_{ot}^{-}	0.5566	0.6025	0.9354	0.8661	0.3681	0.3287	0.2713	1.0000	0.8800	0.1845
	D_{85}	**0.0841**	0.8247	0.6198	0.6103	0.1502	0.5216	0.7044	0.3702	**0.0235**	0.3913
	D_{97}	0.5557	0.6559	**0.0000**	0.8258	**0.0566**	0.6466	0.3801	**0.0000**	**0.0049**	**0.0000**
	D_{08}	0.2610	0.4957	0.2637	0.7750	0.9385	0.7805	0.4670	0.3234	0.9657	0.7196
Philippines	p_{ot}^{+}	0.4163	0.4175	0.9937	0.9513	0.6675	0.2736	0.7177	0.3511	0.6244	0.4102
	p_{ot}^{-}	0.7230	0.8642	0.7832	0.8337	0.3132	0.9600	0.8591	0.4488	0.6562	0.8266
	D_{85}	0.5907	0.3875	0.4096	0.9087	0.7066	0.5552	0.7181	0.4937	0.8182	0.4133
	D_{97}	0.6125	0.6905	**0.0000**	0.8524	0.1675	0.7396	0.5123	0.1550	**0.0169**	0.1861
	D_{08}	0.3877	0.7519	**0.0000**	0.7218	0.7551	0.6714	0.5731	0.4427	**0.0031**	0.6170
Singapore	p_{ot}^{+}	0.3881	0.3467	0.3040	0.4899	0.5747	0.7004	0.7253	0.4319	0.4210	0.4568
	p_{ot}^{-}	0.6270	0.3995	0.7479	0.5337	0.4304	0.7237	0.1940	0.4395	0.7973	**0.0875**
	D_{85}	0.8253	0.2823	0.1831	0.3622	0.9924	0.8990	0.7639	0.3297	0.7223	0.4781
	D_{97}	**0.0789**	0.7078	**0.0880**	0.9854	0.8591	0.4037	0.5421	0.9929	**0.0204**	0.7093
	D_{08}	0.7640	0.7328	0.4270	0.6275	0.7056	0.7509	0.4802	0.9828	0.8261	0.4855
Thailand	p_{ot}^{+}	0.3159	0.6019	0.3908	0.5843	0.8994	0.3663	0.9560	0.8855	0.4510	0.5975
	p_{ot}^{-}	0.9430	0.9259	0.4765	0.8064	0.8152	0.7247	0.3704	0.4342	0.7559	0.205
	D_{85}	0.1445	0.3871	0.3281	0.8840	0.3846	0.5196	**0.0735**	0.2848	**0.0296**	0.7110
	D_{97}	**0.0000**	0.8132	**0.0000**	0.8179	**0.0000**	**0.0098**	0.6359	0.2601	**0.0000**	**0.0000**
	D_{08}	0.5911	**0.0304**	0.7218	0.6611	0.7307	0.1089	0.9039	0.6056	0.3738	**0.0133**

Reported are the p-values for the null hypothesis for quantile slope equality test. Bold p-values indicate rejection of the null hypothesis of slope equality at conventional significance levels.

conditions. A rising oil price causes the ringgit to depreciate when there is large ringgit appreciation (at lower quantiles, which corresponds to large U.S. dollar depreciation). A falling oil price leads to ringgit depreciation when there is large ringgit depreciation (at higher quantiles, which corresponds to large U.S. dollar appreciation). The findings for Malaysia suggest that although rising oil price may stabilize the foreign exchange market for the ringgit when there is large ringgit appreciation, falling oil prices may destabilize the market when there is large ringgit depreciation.

Overall, our results from the QR model suggest that oil price shocks have asymmetrical effects on exchange rate returns. Rising oil prices have different impacts on exchange rate returns than falling oil prices. The coefficient estimates on oil price shocks are not constant throughout the distribution of exchange rate returns and the effects of these shocks on exchange rate returns vary in significance, size, and sign. For example, the results for Indonesia, Japan, the Philippines, and Thailand suggest that the effects of positive oil price shocks on exchange rate returns intensify as we move up the conditional distribution. In contrast, the effects of negative oil price shocks on exchange rate returns for Indonesia, Japan, Malaysia, and the Philippines lose intensity as we move up the conditional distribution. These findings are confirmed by the graphs of the quantile regression estimates in Fig. 5. As shown in Table 11, the null hypothesis of quantile slope equality can be rejected at most quantiles and for the low and high quantiles in all Asian countries. Another important finding is that the impact of oil price shocks on exchange rate returns is particularly affected by extreme market conditions (bearish and bullish currency markets)—especially for Indonesia, Korea, Malaysia, Thailand, and the Philippines.

As mentioned earlier that one of the advantages of using QR analysis is that it allows for the effects of the independent variables to differ over the quantiles.[10] Thus, the effect of an oil price shock may differ over quantiles of the real exchange rate. Indeed, the effects differ over the quantiles as explained above, and they vary in significance, size, and sign over the quantiles. Su et al. (2016) offer two possible explanations as to why these effects may differ over the quantiles: central bank intervention and export selection effects. According to the central bank intervention effect, when a country's currency experiences large a depreciation (appreciation) at lower (higher) quantiles, the central bank will intervene to avoid the negative effects that the large depreciation (appreciation) may have on the economy, which will reduce (increase) foreign reserves and lead to current account imbalances. Thus, at lower quantiles, for example, where there is a large U.S dollar depreciation, indicating a large Asian currency appreciation, the central bank will intervene by selling the specific Asian currency to reduce the appreciation pressure on that currency, and foreign reserves will be accumulated. The opposite will occur at higher quantiles, where there is a large U.S dollar appreciation, indicating a large Asian currency depreciation. This suggests that a significant U.S dollar appreciation (at higher quantiles) and depreciation (at lower quantiles) will heighten the effect of oil price shocks on the exchange rate due to central bank intervention.

According to the export selection effect, Berman et al. (2012) argue that high and low productivity firms react differently to currency depreciation. While high productivity firms choose to increase their export prices in response to a currency depreciation, low productivity firms

[10] To illustrate, an extra dollar increase in income may have a large effect on a low conditional quantile of consumption but a much smaller effect on a high conditional quantile of consumption. Another example is, an extra year of education may have a large effect on a low conditional quantile of income but a much smaller effect on a high conditional quantile of income.

choose to increase their export volumes. Using French firm level data, Berman et al. (2012) find that high productivity firms react to currency depreciation by increasing their export prices rather than their export volume, and find that high productivity firms react to a 10% currency depreciation by increasing their export prices by about 2%. This increase in export prices may affect the ToT, which may affect the response of the exchange rate to oil price shocks.

5. Conclusion and policy implications

The objective of this study was to examine the effects of oil price shocks on the exchange rates of seven Asian countries (Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, and Thailand), over the period 1973:2–2016:4. We focused upon the quantile regression (QR) model to examine impact of oil price shocks over a range of values of the dependent variable, which is the real dollar exchange rate for each of the seven countries. Relative to the benchmark ordinary least squares (OLS) results, QR gives a fuller picture of dependency relationships. QR identifies nuances that would not be discovered using OLS. Also, allowing for asymmetries between positive and negative oil price shocks provides further insights into the complexities of the dependency relationships.

The results suggest that oil price shocks have asymmetrical effects on exchange rate returns that depend upon the state of the currency market (bullish, normal, or bearish) and whether the oil price shock is positive or negative. Results also vary somewhat across countries. To summarize, oil price shocks generally have a greater impact on exchange rates under extreme currency market conditions rather than under normal market conditions. Rising oil prices have different impact on exchange rate returns than falling oil prices, and these effects vary throughout the distribution of exchange rate returns in terms of significance, size, and sign. For instance, when there is large currency appreciation at lower quantiles (which corresponds to large U.S. dollar depreciation), rising oil price causes further currency appreciation for Indonesia, Korea, the Philippines, and Thailand. At higher quantiles when there is large currency depreciation (which corresponds to large U.S. dollar appreciation), rising oil price causes further Indonesian rupiah depreciation. Conversely, the results for Malaysia show that when there is large ringgit depreciation (at higher quantiles, which corresponds to large U.S. dollar appreciation), falling oil price cause further Malaysian ringgit depreciation. These results for Indonesia, Korea, Malaysia, the Philippines, and Thailand appear to be consistent with the notion of "*destabilizing speculative behavior*".

Our findings have important policy implications. First, since the effects of oil price shocks are not constant throughout the distribution of returns, results based on standard OLS may not be appropriate to draw policy recommendations. Second, our results clearly show that the oil market affects the exchange rates of the Asian countries in this study. Therefore, policy-makers concerned with exchange rate stability should pay attention to changes in the oil market and what has been happening in the local currency market. The impact of oil price shocks on exchange rate returns is stronger in extreme bullish or bearish currency markets than under average market conditions. This is especially evident for Indonesia, Korea, Malaysia, Thailand, and the Philippines. Also, policy makers need to be careful because the impact of oil price shocks varies by country, whether the oil price shock is positive or negative.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2018.11.009.

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