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Review

A Review of Econometric Approaches for the Oil Price-Exchange Rate Nexus: Lessons for ASEAN-5 Countries

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Abstract: This paper reviews alternative econometric approaches the literature has used to examine the connectedness between oil prices and exchange rates and illustrates their application using quarterly data from 1970: Q1 to 2022: Q1 for ASEAN-5 countries, which are as follows: Indonesia, Malaysia, the Philippines, Singapore, and Thailand. Although most studies examining the impact of oil prices and exchange rates apply the Ordinary Least Squares (OLS) approach with symmetry, the quantile regression (QR) method is shown to offer a thorough investigation of the connectedness. For ASEAN-5 countries, we present a comparative analysis of both methodologies (OLS and QR) with and without asymmetry. Our findings suggest that asymmetric effects triggered by oil prices are noticeably heterogeneous across quantiles. Hence, future studies should allow for asymmetry in the oil price by decomposing the price into positive and negative changes to further investigate the connectedness between oil prices and exchange rates.

Keywords: quantile regression; oil price; exchange rate; asymmetries

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1. Introduction

Several empirical studies have examined the dynamic relationship between oil prices and exchange rates in the past few decades by employing different econometric approaches [1,2]. Results are at best mixed depending on the choice of empirical models, where some find a strong link between oil prices and exchange rates over the long run while others do not detect such relationships [3,4]. As a review article, this study aims to offer a comprehensive comparative analysis of the existing empirical approaches used to explore the relationship between oil prices and exchange rates, identify gaps, and recommend alternative approaches for future works.

It is important to study the oil price-exchange rate nexus for several reasons. First, fluctuations in oil prices and changes in exchange rates can both have a significant impact on international trade and trade balances, particularly for oil importers and exporters [5,6]. Second, an increase in oil prices could cause inflation, which in turn could affect exchange rates. This has implications for central bank policies that may need to raise interest rates to control inflation. Third, as a critical input in several industries, a change in the price of oil could affect the demand and supply of various currencies depending on whether nations are net oil importers or exporters.

Reviewing the different empirical approaches in the literature will enable the synthesis of knowledge by bringing together several frameworks to identify gaps and propose better approaches. We find that although a majority of previous studies have used the Ordinary Least Squares (OLS) method, the quantile regression (QR) approach offers a more flexible framework to identify the differing relationships at different parts of the dependent variable's distribution. Considering oil prices as the explanatory variable for exchange rates, a conventional OLS approach develops the relationship according to the conditional mean of the dependent variable. On the other hand, a QR approach evaluates the relationship between the dependent and independent variables by enabling distributional heterogeneity for the effects of the explanatory variable on the dependent variable.

We illustrate the implementation of these two models (OLS and QR) to investigate the impact of oil price variations on the exchange rate for five Southeast Asian countries: Indonesia, Malaysia, the Philippines, Singapore, and Thailand. These are among the biggest economies of the *Association of Southeast Asian Nations*, henceforth referred to as ASEAN-5. The ASEAN-5 countries are net oil importers and heavily rely on imported oil to meet their energy needs. The high demand for imported oil makes these countries vulnerable to fluctuations in global oil prices, such that when oil prices increase, their currencies weaken and vice versa. Furthermore, because the ASEAN-5 countries' economic growth is largely connected to energy use, these economies are expected to be more vulnerable to oil price shocks. Thus, a re-examination of the oil price-exchange rate nexus for ASEAN-5 economies supplies prompt lessons for future research in these economies. We examine the relationship based on quarterly data for the years 1970: Q1 to 2022: Q1, which covers periods of historical events that had bearings on financial and exchange rate markets such as the 1997 Asian financial crisis and the 1985 Plaza Accord.

Section 2 presents a summary of findings from earlier studies and reviews the OLS and QR procedures as key econometric approaches used to examine the relationship between oil prices and exchange rates. Section 3 applies these two approaches to the ASEAN-5 context to examine the connectedness between oil prices and exchange rates. Section 4 offers concluding remarks and recommendations for future research.

2. Review of Econometric Approaches

Oil markets can have a complex and dynamic impact on other markets, such as stock/bond markets, currency markets [7,8], and commodity markets [9]. Following the seminal works of Golub [1] and Krugman [2], the literature has extensively examined the effects of oil price fluctuations and shocks on the exchange rate, whether for developed and developing countries or oil-exporting and oil-importing countries [10,11]. In general, these studies reported varied and mixed findings, ranging from papers that reported negative effects to others that presented positive effects; some others found a bi-directional causal relationship [12], while the rest revealed insignificant effects [13]. Several of these studies examine the oil price and exchange rate relationship in different countries, such as Japan [3], the G7 countries [8] China [14,15], the Fiji Islands [16], India [17], and ASEAN countries [18–20]. Recently, Anjum and Malik [21] offered a thorough overview of the literature on the theoretical and empirical connectedness between oil prices and exchange rates. They revealed that the bidirectional causality of the oil price-exchange nexus is the overall consensus of the literature.

Theoretically, it is well known that with oil price upsurges, oil-importing countries go through currency depreciation while oil-exporting countries go through currency appreciation (see Golub [1]). When oil prices increase, the demand for the currency of the oil-exporting nation will increase because oil importers need to buy oil using the currency of the oil-exporting country. As a result, the exchange rate of the oil exporter will appreciate and that of the oil importer will weaken. Conversely, when the price of oil declines, the importing nation's currency appreciates while that of the exporter depreciates.

Chen and Chen [8] explain the theoretical connection between oil prices and exchange rates. They show that a model of traded and non-traded goods produced in the home and in foreign countries can explain the connecting channel between oil prices and exchange rates. That is, if the home country is more dependent on imported oil, a real oil price increase may raise the prices of tradable goods in the home country by a larger share than in the foreign country, and thus cause a real depreciation of the home currency.

Zhou [22] shows that the trade balance of an oil-importing country will deteriorate as a result of an oil price increase, thereby enhancing the competitiveness of the country, which might cause currency depreciation. Amano and Norden [5] indicate that oil price shocks might be a major source of fluctuation in exchange rates. Chaudhuri and Daniel [6] examine the relationship between the real exchange rates of 16 OECD countries and the real price of oil. For China, Huang and Guo [10] show that a rise in oil prices causes a long-run appreciation in the exchange rate. In the context of G7 countries, Chen and Chen [8] show that oil prices and exchange rates are interconnected, and oil prices have the capability to forecast future exchange returns. Wiegand [23], Miller and Rati [24], Narayan et al. [12], Lizardo and Mollick [13], and Basher et al. [25] show that the relationship between oil prices and exchange rates can fluctuate over various time periods, implying that it is not constant across time. Thus, policymakers in many countries often pay considerable attention to the connectedness between oil prices and exchange rates.

While the literature has often examined the impact of oil prices on exchange rates, it is important to note that several other factors determine exchange rate changes. For example, interest rate changes, economic fundamentals (growth rates and trade balances), central bank policies, and political stability have been shown to significantly affect exchange rate movements.

2.1. Ordinary Least Squares Regression

Most previous studies adopt the following linear model to examine the hypothesized relationship between oil prices and exchange rates [6,8]:

$$E_t = \alpha_0 + \alpha_1 P_t + \epsilon_t \tag{1}$$

where E_t is the real exchange rate, P_t is the real oil price, and ϵ_t is the error term. α_1 represents the conditional mean effect of real oil prices on the exchange rate. The estimated coefficient α_1 shows the long-run effect of oil price fluctuations on the exchange rate. This parameter measures whether an oil price increase leads to an exchange rate increase (appreciate) or decrease (depreciate), based on the definition of the exchange rate, whether as national currency per US dollar or US dollar per national currency. Equation (1) assumes that the effect of the oil price is symmetric (linear). That is, the oil price increase will have the same amount of effect as the decrease. However, many studies show that oil prices do not act in a symmetric way, and nonlinearity might be a better specification for modeling the oil price-exchange rate nexus [8,12,20].

To account for the asymmetric effect of oil price (P_t), other studies [11,12,20] follow Shin et al. [26] and decompose oil price into positive (P_t^+) and negative (P_t^-) changes through the partial sums.

$$P_t^+ = \sum_{i=1}^t \Delta P_i^+ = \sum_{i=1}^t \max(\Delta P_i, 0) \tag{2}$$

and

$$P_t^- = \sum_{i=1}^t \Delta P_i^- = \sum_{i=1}^t \min(\Delta P_i, 0) \tag{3}$$

Equations (2) and (3) show the partial sum process of the positive and negative changes in the oil price (P_t). This means that $P_t = P_0 + P_t^+ + P_t^-$. In this scenario, Equation (1) is amended to capture the asymmetric effect of oil prices as follows:

$$E_t = \alpha_0 + \alpha_1 P_t^+ + \alpha_2 P_t^- + \epsilon_t \tag{4}$$

Equation (4) now separates the effect of oil price increase from oil price decrease on the exchange rate. This will show if the increase in oil price has the same amount of effect as the decrease. This approach can also test if the two effects are statistically significant or not, unlike the linear model (that is, Equation (1)), which assumes a combined significant effect once α_1 was found to be statistically significant.

Using OLS for Equation (4), the estimated coefficients α_1 and α_2 represent the conditional means of the parameters. The conditional means describe the way the real exchange rate fluctuates according to oil price shocks. The variety of findings of previous studies about the oil price-exchange rate nexus might be a result of neglecting the distributional heterogeneity of the exchange rate. That is ignoring the possibility that the influence of the oil price fluctuation on the exchange rate could vary throughout the distribution. Thus, the conditional mean offers an imperfect picture of real exchange rate fluctuations at the distribution's tails. The quantile regression (QR) approach can deliver a better and more informative picture regarding the effect of oil prices on the lower and upper quantiles of the exchange rate distribution.

2.2. Quantile Regression

Koenker and Bassett [27,28] propose the QR method as an extension of the conventional Ordinary Least Squares (OLS) methodology. QR evaluates the relationship between the dependent variable and explanatory variable(s) by enabling distributional heterogeneity for the effect of the explanatory variable(s) on the dependent variable, whereas the conventional OLS develops the relationship according to the conditional mean of the dependent variable. The QR methodology further intensifies the interpretation of the findings given that the distinct coefficients are estimated for diverse quantiles of the dependent variable. Thus, QR offers a better informative representation of the relationship between the dependent and explanatory variables.

A few studies have employed QR to explore the behavior of exchange rates. For instance, Nikolaou [29] shows that QR directly detects the effect of different levels of shocks that shape the exchange rate and can capture asymmetric adjustments. Huang et al. [30] argue that QR provides a more consistent volatility forecast for exchange rates compared to other methods. Using QR, Su et al. [26] show that the effect of oil price shocks on exchange rates is heterogeneous across quantiles.

To understand the possible diverse effects of oil price shocks on real exchange rates, the general conditional quantile regression model is specified as follows [29–31]:

$$Q_{Et}(\tau/x_t) = \alpha^\tau + x_t'\beta^\tau \tag{5}$$

where Equation (5) describes the conditional τ^{th} quantile of real exchange rate return for some value of $\tau \in (0,1)$. α^τ is the intercept that is assumed to depend on τ, x' is a vector of explanatory variables, and β^τ represents the vector of coefficients linked to the τ^{th} quantile. According to Koenker and Bassett [27], the coefficient of the τ^{th} quantile of the conditional distribution is identified as a solution to the following minimization problem:

$$\min_{\beta \in \mathbb{R}^K} \sum\nolimits_t \rho_\tau (E_t - \alpha^\tau - x_t'\beta^\tau) \tag{6}$$

The ρ_τ is the check function that is designated for any $\tau \in (0,1)$ and expressed as follows:

$$\rho_\tau(\xi_t) = \begin{cases} \tau\xi_t, & \xi_t \geq 0 \\ (\tau - 1)\xi_t, & \xi_t < 0 \end{cases} \tag{7}$$

where $\xi_t = E_t - \alpha^\tau - x_t'\beta^\tau$. The QR methodology minimizes the sum of residuals where the positive residuals have a weight of τ, while the negative residuals have a weight of $1 - \tau$.

The QR model can be modified to estimate the effects of oil price shocks on exchange rate returns as follows:

$$\text{I}: \text{ Model excluding asymmetry}: \ Q_{Et}(\tau/x_t) = \alpha^\tau + \beta^\tau P_t \tag{8}$$

$$\text{II}: \text{ Model including asymmetry}: \ Q_{Et}(\tau/x_t) = \alpha^\tau + \beta^{\tau+} P_t^+ + \beta^{\tau-} P_t^- \tag{9}$$

In this study, we illustrate the implementation of OLS and QR with and without asymmetry, to assess the impact of oil price shocks on the exchange rate of the ASEAN-5 countries. The asymmetry models distinguish between positive and negative oil price variations as presented in Equations (2) and (3).

3. Analysis of ASEAN-5 Countries

Quarterly data over the period of 1970: Q1–2022: Q1 are obtained from the International Financial Statistics (IMF) Database (Source: https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b&sId=1390030341854 (accessed on 23 April 2023) for Indonesia, Malaysia, the Philippines, Singapore, and Thailand (ASEAN-5). The data includes the following: (1) ASEAN-5′s nominal exchange rates, defined as the national value per U.S. dollar; (2) ASEAN-5′s national consumer price indices (CPIs); (3) U.S. consumer price index; and (4) West Texas Intermediate (WTI) oil price (Source: https://data.imf.org/?sk=471DDDF8-D8A7-499A-81BA-5B332C01F8B9&sId=1390030341854 (accessed on 23 April 2023)).

The real exchange rate for each country is calculated relative to the U.S. dollar by using the CPI of both countries (the base year is 2010). The real oil price is computed by deflating the WTI oil price by the U.S. CPI to make it comparable across countries [31]. In addition, due to the high correlation between the three oil prices (WTI, Brent, and Dubai), using any oil price is expected to deliver analogous findings and inferences [32,33]. E_t is used to measure the real exchange rate return calculated by taking the first difference of the natural logarithm of the real exchange rate ($E_t = \ln\left(\frac{e_t}{e_{t-1}}\right) * 100$) (When testing for stationarity, the real exchange rate turns out to be non-stationary in levels but stationary in the first difference. On the other hand, the WTI oil price was found to be stationary. So, in modeling the nexus, we used the exchange rate return to avoid spurious results. The results of the unit root test are available upon request). All variables are logarithmically transformed.

An increase in the real exchange rate suggests a U.S. dollar appreciation (right tail of the distribution), and a decrease suggests a U.S. dollar depreciation (left tail of the distribution). Thus, the lower quantiles of the exchange rate distribution (e.g., at 0.10, 0.20, and 0.30 quantiles) resemble substantial U.S. dollar depreciation (national currency appreciation), while the upper quantiles (e.g., at 0.70, 0.80, and 0.90 quantiles) resemble substantial U.S. dollar appreciation (national currency depreciation). This distributional heterogeneity of the exchange rate needs to be considered when examining the oil price-exchange rate nexus.

Table 1 reports descriptive statistics of the two key variables and suggests that both the mean and standard deviation of real exchange rates are heterogeneous across countries. In addition, Figure 1 reports the time co-movement between the WTI oil price and the exchange rate for the sample countries. Figure 1 suggests a co-movement between the two variables. To verify this co-movement, Table 2 reports the correlation coefficients between the WTI oil price and exchange rate return across the sample countries. The correlation coefficients show a significant positive relationship in the case of Indonesia, the Philippines, and Thailand, but a significant negative relationship for Malaysia and Singapore. However, the correlation coefficients signify weak correlation, since the values are below 0.5 for all sample countries.

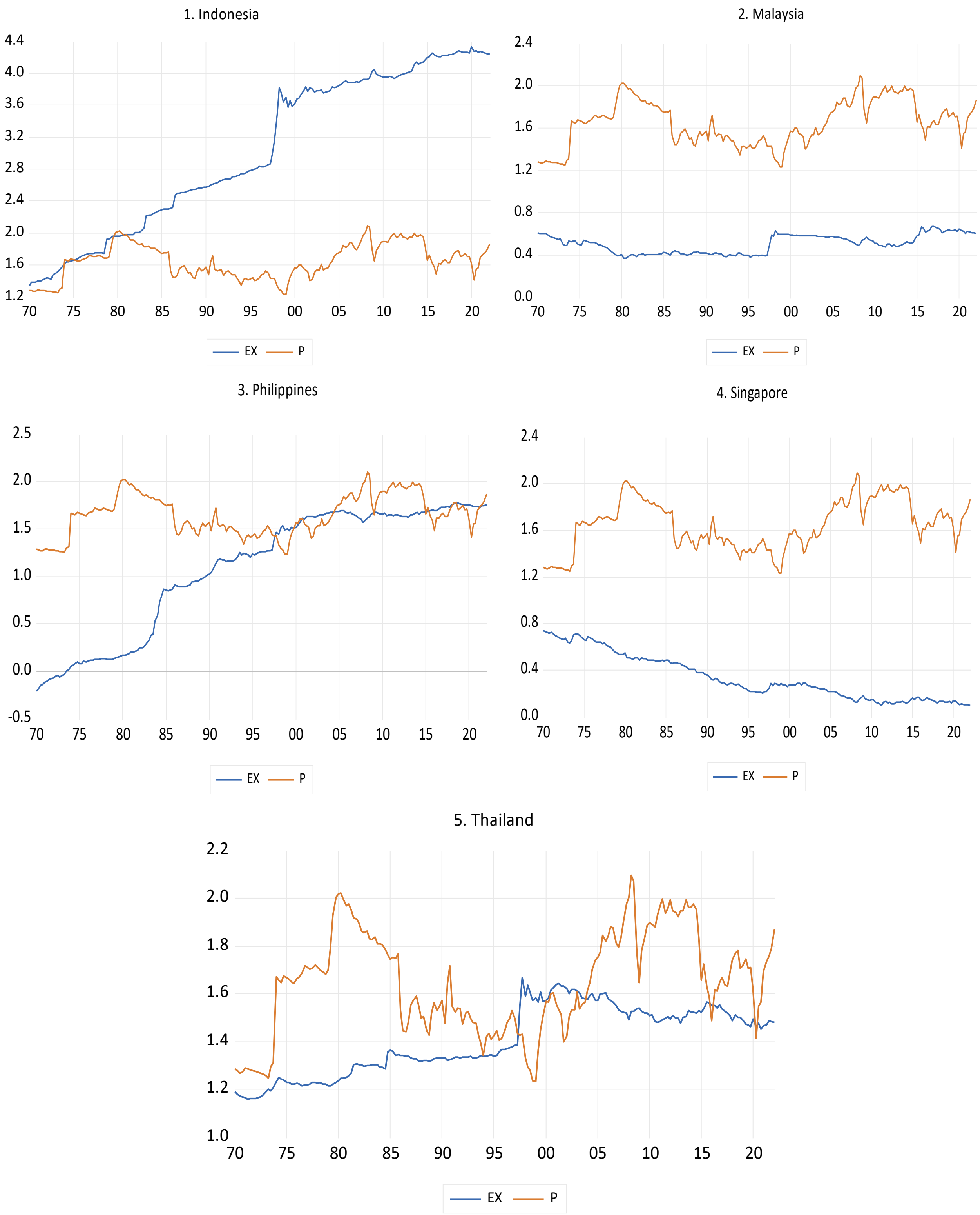

Figure 1. Time co-movement (EX is the real exchange rate and P is the oil price).

Table 1. Descriptive statistics.

	Indonesia		Malaysia		Philippines		Singapore		Thailand	
	E_t	P_t	E_t	P_t	E_t	P_t	E_t	P_t	E_t	P_t
Mean	3.017	1.647	0.506	1.647	1.084	1.647	0.334	1.647	1.405	1.647
Median	2.832	1.651	0.510	1.651	1.259	1.651	0.273	1.651	1.366	1.651
Maximum	4.327	2.096	0.674	2.096	1.779	2.096	0.736	2.096	1.667	2.096
Minimum	1.338	1.233	0.367	1.233	−0.209	1.233	0.093	1.233	1.158	1.233
Std. Dev.	0.983	0.213	0.086	0.213	0.658	0.213	0.195	0.213	0.143	0.213
Skewness	−0.171	−0.052	0.044	−0.052	−0.645	−0.052	0.593	−0.052	−0.040	−0.052
Kurtosis	1.516	2.144	1.650	2.144	1.844	2.144	2.029	2.144	1.673	2.144

Note: E_t is the real exchange rate return and P_t is real WTI oil price. The number of observations is 209.

Table 2. Correlation between the WTI oil price and exchange rate return.

	Indonesia	Malaysia	Philippines	Singapore	Thailand
	E_t	E_t	E_t	E_t	E_t
P_t	0.294 ***	−0.133 **	0.187 ***	−0.297 ***	0.191 ***
t-Statistic	4.427	−1.985	2.740	−4.475	2.795
Probability	0.000	0.036	0.007	0.000	0.006

Note: *** and ** denote significance at the 1% and 5%, respectively.

We examine the oil price-exchange rate nexus by using both the conventional OLS and quantile regression (QR) models with and without asymmetry. For the QR models used to fit Equations (8) and (9), we choose nine quantiles (τ: 0.10, 0.20, 0.30, . . . , 0.90) where the lower quantiles of the exchange rate distribution (e.g., at 0.10, 0.20, and 0.30 quantiles) resemble substantial U.S. dollar depreciation (national currency appreciations), whilst the upper quantiles (e.g., at 0.70, 0.80, and 0.90 quantiles) resemble substantial U.S. dollar appreciations (national currency depreciations).

3.1. Model Excluding Asymmetry

To better understand the different influences of WTI oil price shocks on real exchange rates, we start analyzing the determinants of the changes in the real exchange rate return at various quantiles and examine whether these changes differ across different quantiles. This is done by estimating Equation (1) corresponding to the OLS model, and Equation (8) corresponding to the QR model. Table 3 reports the estimated coefficients.

Table 3. OLS and QR coefficients (excluding asymmetry).

Country	Variable	OLS	$Q_{0.10}$	$Q_{0.20}$	$Q_{0.30}$	$Q_{0.40}$	$Q_{0.50}$	$Q_{0.60}$	$Q_{0.70}$	$Q_{0.80}$	$Q_{0.90}$
Indonesia	Constant	0.783 ^{b}	0.33	0.39	3.35 ^{a}	−1.54 ^{a}	−0.94	−0.43	2.39 ^{a}	2.82 ^{a}	3.68 ^{a}
	P_t	1.36 ^{a}	0.84 ^{a}	0.87 ^{a}	−0.60 ^{a}	2.73 ^{a}	2.53 ^{a}	2.30 ^{a}	0.84 ^{b}	0.66 ^{c}	0.33
Malaysia	Constant	0.59 ^{a}	0.39 ^{a}	0.44 ^{a}	0.47 ^{a}	0.50 ^{a}	0.66 ^{a}	0.74 ^{a}	0.76 ^{a}	0.70 ^{a}	0.68 ^{a}
	P_t	−0.05 ^{c}	0.01	−0.02 ^{b}	−0.03 ^{b}	−0.01	−0.08 ^{b}	−0.12 ^{a}	−0.12 ^{a}	−0.07 ^{b}	−0.04
Philippines	Constant	0.13	−0.62 ^{b}	−0.61 ^{c}	1.11	−0.68	0.06	0.18	1.16 ^{a}	1.37 ^{a}	1.17 ^{a}
	P_t	0.58 ^{a}	0.42 ^{b}	0.44 ^{b}	−0.15	1.13 ^{a}	0.81 ^{a}	0.76 ^{a}	0.26	0.18	0.33 ^{b}
Singapore	Constant	0.78 ^{a}	0.61 ^{a}	0.54 ^{a}	0.58 ^{a}	0.70 ^{a}	0.76 ^{a}	1.08 ^{a}	0.37	0.99 ^{a}	1.06 ^{a}
	P_t	−0.27 ^{a}	−0.28 ^{a}	−0.22 ^{a}	−0.24 ^{a}	−0.29 ^{a}	−0.31 ^{a}	−0.47 ^{a}	0.06	−0.26 ^{a}	−0.26 ^{a}
Thailand	Constant	1.19 ^{a}	1.00 ^{a}	0.93 ^{a}	1.27 ^{a}	0.83 ^{a}	0.89 ^{a}	0.97 ^{a}	1.51 ^{a}	1.73 ^{a}	1.81 ^{a}
	P_t	0.13 ^{a}	0.13 ^{a}	0.20 ^{a}	0.03	0.33 ^{a}	0.31 ^{a}	0.28 ^{a}	0.01	−0.11 ^{b}	−0.14 ^{a}

Notes: ^{a}, ^{b}, ^{c} denote significance at the 1%, 5%, and 10% significance levels, respectively.

The OLS model suggests that oil price shocks affect the real exchange rate return positively in the case of Indonesia, the Philippines, and Thailand. This means that the oil price increase will lead to U.S. dollar appreciation (national currency depreciation) in these countries. On the other hand, Table 3 shows that the U.S. dollar depreciates (national currency appreciation) because of oil price increases in Malaysia and Singapore.

Table 3 reports the QR for lower quantiles (0.10, 0.20, and 0.30), central quantiles (0.40, 0.50, 0.60), and upper quantiles (0.70, 0.80, and 0.90 quantiles). These results help verify how changes in oil price shocks affect the tails of the real exchange rate distribution. Table 3 shows that the effects of oil price shocks on exchange rate returns differ in magnitude, significance, and, in some cases, sign. This inference implies that the parameter estimates vary across the quantiles, offering a better picture of real exchange rates' fluctuations at the tails of the distribution when compared to the OLS estimates. For the U.S. dollar depreciation (the lower quantiles), Table 3 shows that for Indonesia, the estimated coefficients of the oil price are positive and statistically significant at the 0.10 and 0.20 quantiles but negative and statistically significant at the 0.30 quantile. For Malaysia, the estimated coefficients are negative and statistically significant at the 0.20 and 0.30 quantiles. For the Philippines and Thailand, the estimated coefficients are positive and statistically significant at the 0.10 and 0.20 quantiles; however, for Singapore, the estimated coefficients are negative and statistically significant at all lower quantiles (0.10, 0.20, and 0.30). In general, the impacts of oil price shocks on exchange rates are mixed and differ in size at the lower quantiles across the sample countries.

For the U.S. dollar appreciation (upper quantiles), Table 3 presents the impacts of oil price shocks on the exchange rates at the 0.70, 0.80, and 0.90 quantiles. For Indonesia, the estimated coefficients on the oil price are positive and statistically significant at the 0.70 and 0.80 quantiles, but not statistically significant at the 0.90 quantiles. For Malaysia, the estimated coefficients are negative and statistically significant at the 0.70 and 0.80 quantiles. For the Philippines, the estimated coefficients are positive and statistically significant at the 0.90 quantiles only. For Singapore, the estimated coefficients are negative and statistically significant at the 0.80 and 0.90 quantiles. As for Thailand, the estimated coefficients are negative and statistically significant at the 0.80 and 0.90 quantiles. Again, the results show that the impacts of oil price shocks on exchange rates are mixed and different in size at the upper quantiles. Generally, Table 3 confirms that the effects of oil price shocks differ all through the distribution of the exchange rate returns. Figure 2 illustrates the estimation outputs for the QR model, which are plotted over the nine quantiles with their 95% confidence interval (CI) bands indicated in orange color.

To confirm the findings of Table 3 and follow Koenker and Bassett [26], we ran a quantile slope equality test to investigate if the differences along the estimated coefficients are statistically significant across quantiles. The null hypothesis of the test states that the slopes are equal across the quantiles, whereas the alternative rejects the equality of the slopes. We conduct the test for every two consecutive quantiles (e.g., $Q_{0.10} = Q_{0.20}$, $Q_{0.20} = Q_{0.30}$, . . . , $Q_{0.80} = Q_{0.90}$). Table 4, which presents the results of the test, implies the rejection of the null hypothesis of slope equality across the different quantiles for all ASEAN-5 countries, providing support to the previous findings that estimated coefficients diverge throughout the different quantiles.

Table 4. Quantile slope equality test (excluding asymmetry).

Country	**Variable**	$\mathbf{Q_{0.10} = Q_{0.20}}$	$\mathbf{Q_{0.20} = Q_{0.30}}$	$\mathbf{Q_{0.30} = Q_{0.40}}$	$\mathbf{Q_{0.40} = Q_{0.50}}$	$\mathbf{Q_{0.50} = Q_{0.60}}$	$\mathbf{Q_{0.60} = Q_{0.70}}$	$\mathbf{Q_{0.70} = Q_{0.80}}$	$\mathbf{Q_{0.80} = Q_{0.90}}$
Indonesia	P_t	0.8824	0.0001 *	0.0000 *	0.4265	0.3696	0.0000 *	0.4949	0.2308
Malaysia	P_t	0.4673	0.0161 *	0.618	0.1268	0.0603 *	0.8988	0.0286 *	0.3967
Philippines	P_t	0.9404	0.6672	0.0348 *	0.0744 *	0.7506	0.0002 *	0.5249	0.2814
Singapore	P_t	0.0043 *	0.5988	0.132	0.6932	0.0175 *	0.0002 *	0.0631 *	0.9746
Thailand	P_t	0.0835 *	0.022 *	0.0000 *	0.498	0.3714	0.0000 *	0.066 *	0.5135

Notes: Reported values are the p-values. * Denotes rejection of the null hypothesis of slope equality at conventional significance levels.

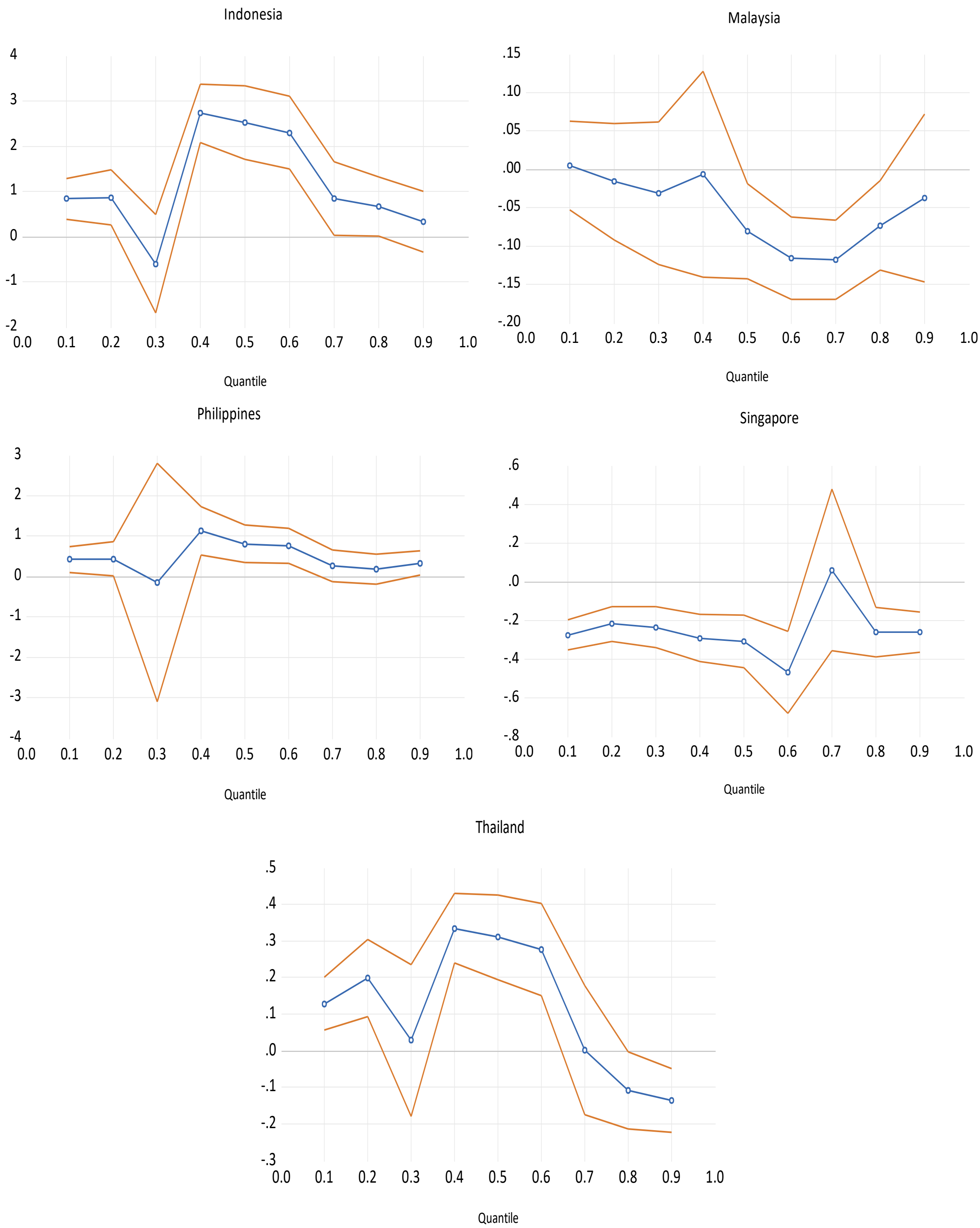

Figure 2. Effects of oil price shocks on exchange rate returns (95% CI).

3.2. Model Including Asymmetry

In this sub-section, models include oil price asymmetry, where the oil price is decomposed into positive (P_t^+) and negative (P_t^-) changes. The asymmetry is presented via Equations (4) and (9), which characterize the OLS and QR models, respectively. Table 5 presents the OLS and QR estimates, and Figure 3 illustrates the estimation outputs of the

QR model plotted over the nine quantiles with their 95% confidence interval (CI) bands indicated in orange color.

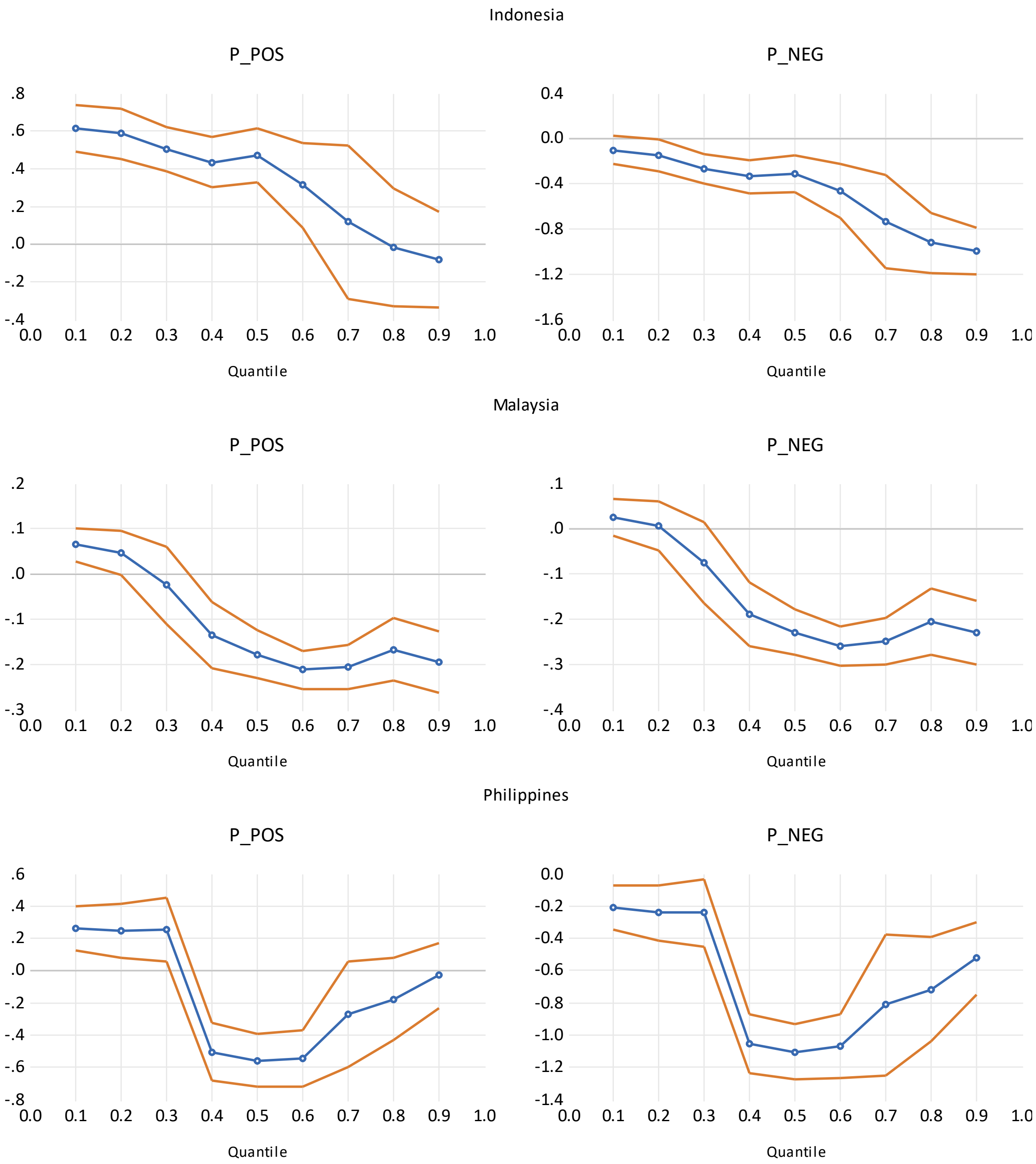

Figure 3. *Cont.*

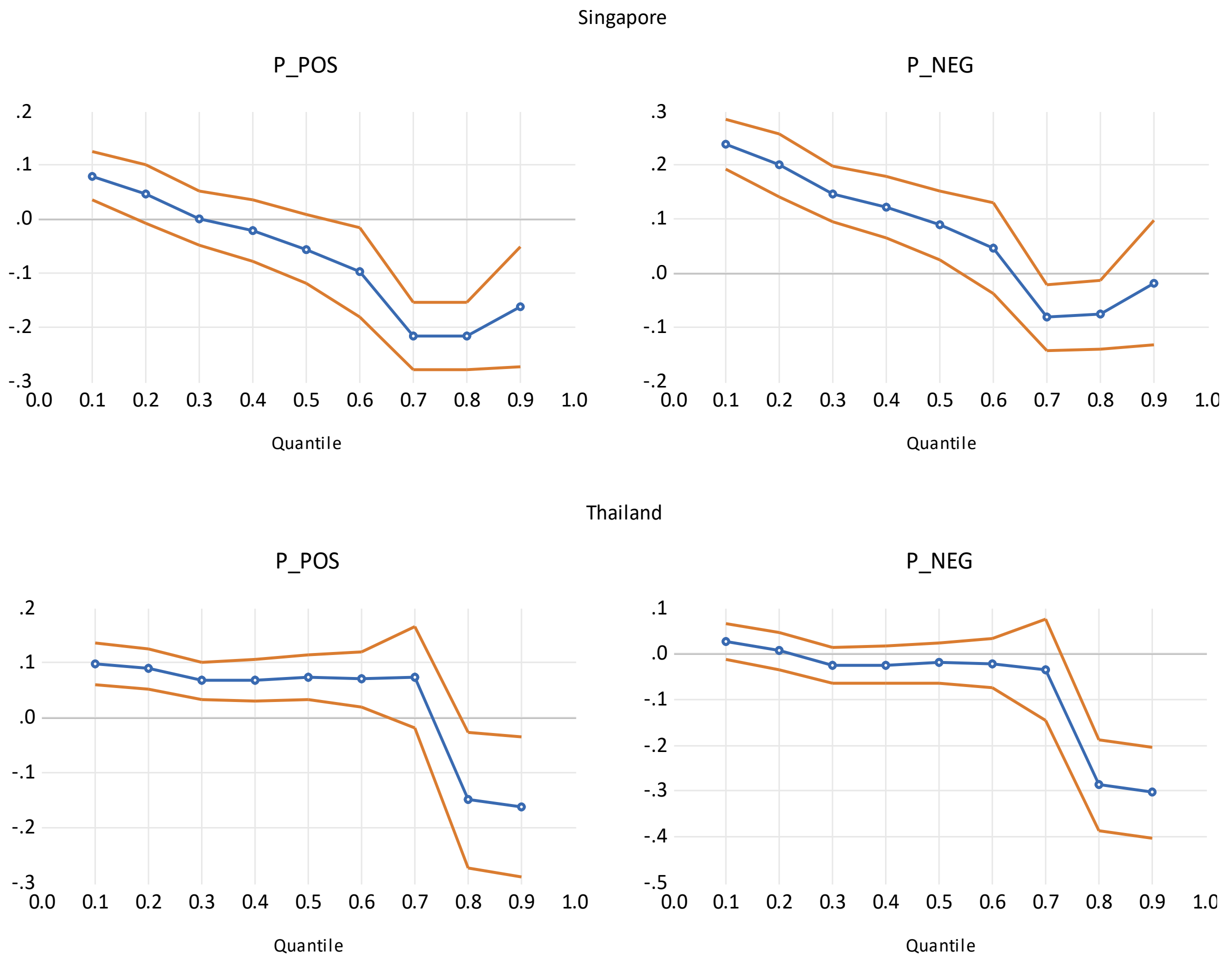

Figure 3. Asymmetric oil price shocks on exchange rate returns (95% CI). P_POS is P_t^+ and P_NEG is P_t^-.

Table 5. OLS and QR coefficients (including asymmetry).

Country	Variable	OLS	$Q_{0.10}$	$Q_{0.20}$	$Q_{0.30}$	$Q_{0.40}$	$Q_{0.50}$	$Q_{0.60}$	$Q_{0.70}$	$Q_{0.80}$	$Q_{0.90}$
Indonesia	Constant	1.68 ^{a}	1.38 ^{a}	1.40 ^{a}	1.46 ^{a}	1.51 ^{a}	1.51 ^{a}	1.65 ^{a}	1.74 ^{a}	1.87 ^{a}	1.91 ^{a}
	P_t^+	0.31 ^{a}	0.61 ^{a}	0.59 ^{a}	0.50 ^{a}	0.43 ^{a}	0.47 ^{a}	0.31 ^{a}	0.12	−0.02	−0.08
	P_t^-	−0.45 ^{a}	−0.10	−0.15 ^{b}	−0.27 ^{a}	−0.34 ^{a}	−0.31 ^{a}	−0.46 ^{a}	−0.74 ^{a}	−0.92 ^{a}	−0.99 ^{a}
Malaysia	Constant	0.47 ^{a}	0.33 ^{a}	0.36 ^{a}	0.39 ^{a}	0.46 ^{a}	0.49 ^{a}	0.53 ^{a}	0.55 ^{a}	0.56 ^{a}	0.60 ^{a}
	P_t^+	−0.11 ^{a}	0.06 ^{a}	0.05 ^{c}	−0.02	−0.14 ^{a}	−0.18 ^{a}	−0.21 ^{a}	−0.21 ^{a}	−0.17 ^{a}	−0.20 ^{a}
	P_t^-	−0.16 ^{a}	0.02	0.01	−0.08 ^{c}	−0.19 ^{a}	−0.23 ^{a}	−0.26 ^{a}	−0.25 ^{a}	−0.21 ^{a}	−0.23 ^{a}
Philippines	Constant	0.33 ^{a}	−0.09 ^{a}	−0.06 ^{c}	−0.05	0.40 ^{a}	0.47 ^{a}	0.55 ^{a}	0.51 ^{a}	0.52 ^{a}	0.62 ^{a}
	P_t^+	−0.12	0.26 ^{a}	0.24 ^{a}	0.25 ^{b}	−0.50 ^{a}	−0.56 ^{a}	−0.54 ^{a}	−0.27	−0.18	−0.03
	P_t^-	−0.61 ^{a}	−0.21 ^{a}	−0.24 ^{a}	−0.24 ^{a}	−1.05 ^{a}	−1.11 ^{a}	−1.07 ^{a}	−0.81 ^{a}	−0.72 ^{a}	−0.52 ^{a}
Singapore	Constant	0.59 ^{a}	0.47 ^{a}	0.50 ^{a}	0.53 ^{a}	0.55 ^{a}	0.57 ^{a}	0.60 ^{a}	0.68 ^{a}	0.71 ^{a}	0.73 ^{a}
	P_t^+	−0.07 ^{a}	0.08 ^{a}	0.05 ^{c}	0.01	−0.02	−0.06 ^{c}	−0.10 ^{b}	−0.22 ^{a}	−0.22 ^{a}	−0.16 ^{a}
	P_t^-	0.07 ^{a}	0.24 ^{a}	0.20 ^{a}	0.15 ^{a}	0.12 ^{a}	0.09 ^{a}	0.05	−0.08 ^{a}	−0.08 ^{b}	−0.02
Thailand	Constant	1.25 ^{a}	1.16 ^{a}	1.17 ^{a}	1.19 ^{a}	1.19 ^{a}	1.20 ^{a}	1.22 ^{a}	1.22 ^{a}	1.34 ^{a}	1.36 ^{a}
	P_t^+	−0.01	0.10 ^{a}	0.09 ^{a}	0.07 ^{a}	0.07 ^{a}	0.07 ^{a}	0.07 ^{a}	0.07	−0.15 ^{b}	−0.16 ^{b}
	P_t^-	−0.10 ^{a}	0.03	0.01	−0.03	−0.02	−0.02	−0.02	−0.03	−0.29 ^{a}	−0.30 ^{a}

Notes: ^{a}, ^{b}, ^{c} denote significance at the 1%, 5%, and 10% significance levels, respectively.

From Table 5, the estimated coefficients of the OLS model show that the positive oil price shock (P_t^+) is positive and statistically significant for Indonesia, implying a U.S. dollar appreciation (national currency depreciation), but this positive oil price shock (P_t^+) is significantly negative for Malaysia and Singapore, implying a U.S. dollar depreciation (national currency appreciation). As for the negative oil price shock (P_t^-), it is negative and statistically significant for Indonesia, Malaysia, the Philippines, and Thailand (U.S.

dollar depreciation), but it is significantly positive for Singapore (U.S. dollar appreciation). The OLS estimates suggest that the effect of the positive oil price shock (P_t^+) on exchange rate return is different from the negative oil price shock (P_t^-), indicating that asymmetry is important when examining the oil price-exchange rate nexus.

Next, we look at the findings of the QR model, reported in Table 5, to understand the asymmetric oil price effects on the different quantiles of the exchange rate returns over the entire distribution. For the U.S. dollar depreciation (the lower quantiles: 0.10, 0.20, 0.30), Table 5 shows that the positive oil price shock (P_t^+) causes a positive and significant change across all the ASEAN-5 countries, but the size of this effect varies between the countries. On the other hand, the negative oil price shock (P_t^-) causes a significant negative effect on Indonesia, Malaysia, and the Philippines, but the negative oil price shock leads to a positive and significant change in the case of Singapore. Table 5 shows that the positive oil price shock (P_t^+) triggers a larger magnitude effect than the negative oil price shock (P_t^-) at the lower quantiles.

As for the U.S. dollar appreciation (the upper quantiles: 0.70, 0.80, 0.90), Table 5 suggests that the positive oil price shock (P_t^+) generates a significant negative effect on the exchange rate returns for Malaysia, Singapore, and Thailand but an insignificant effect for Indonesia and the Philippines. In addition, the negative oil price shock (P_t^-) causes a significant negative effect on the exchange rate returns across all sample countries. However, at the upper quantiles, the negative oil price shock (P_t^-) triggers a larger magnitude effect than the positive oil price shock (P_t^+) in most cases. Generally, the QR results in Table 5 indicate that the positive and negative changes in oil price generated significantly dissimilar effects at the different quantiles of the distribution. The dissimilar effects are characterized by variations in magnitude, sign, and significance, enriching the idea that oil price shocks are asymmetric.

Finally, we examine the slope equality across the quantiles. This is done for every two consecutive quantiles (e.g., $Q_{0.10} = Q_{0.20}$, $Q_{0.20} = Q_{0.30}$, ... , $Q_{0.80} = Q_{0.90}$) for both oil price shocks (P_t^+, P_t^-). Table 6 reports the results of this test. Noticeably, Table 6 supports the rejection of the null hypothesis of slope equality across the different quantiles for all ASEAN-5 countries, supporting the fact that estimated coefficients diverge throughout the different quantiles.

Table 6. Quantile slope equality test (including asymmetry).

Country	Variable	$Q_{0.10} = Q_{0.20}$	$Q_{0.20} = Q_{0.30}$	$Q_{0.30} = Q_{0.40}$	$Q_{0.40} = Q_{0.50}$	$Q_{0.50} = Q_{0.60}$	$Q_{0.60} = Q_{0.70}$	$Q_{0.70} = Q_{0.80}$	$Q_{0.80} = Q_{0.90}$
Indonesia	P_t^+	0.6074	0.6074	0.0923 *	0.3948	0.0269 *	0.1671	0.3327	0.6065
	P_t^-	0.4076	0.4076	0.1073	0.5480	0.0420 *	0.0462 *	0.1998	0.4616
Malaysia	P_t^+	0.3357	0.0167 *	0.0000 *	0.0623 *	0.0276 *	0.6347	0.1056	0.3291
	P_t^-	0.3907	0.0077 *	0.0001 *	0.0589 *	0.0500 *	0.5274	0.0831 *	0.4416
Philippines	P_t^+	0.7828	0.8731	0.0000 *	0.3049	0.7809	0.0200 *	0.3861	0.1432
	P_t^-	0.6230	0.9880	0.0000 *	0.3542	0.5449	0.1153	0.5071	0.1164
Singapore	P_t^+	0.1304	0.0135 *	0.2130	0.0699 *	0.0809 *	0.0000 *	0.9950	0.2273
	P_t^-	0.0826 *	0.0071 *	0.1839	0.0763 *	0.0878 *	0.0000 *	0.7970	0.1995
Thailand	P_t^+	0.5600	0.0755 *	0.9372	0.6429	0.7988	0.9171	0.0000 *	0.8174
	P_t^-	0.2476	0.0279 *	0.9792	0.6732	0.9159	0.7471	0.0000 *	0.7007

Notes: Reported values are the *p*-values. * Denotes rejection of the null hypothesis of slope equality at conventional significance levels.

4. Conclusions

This paper presents a review of existing econometric approaches used to evaluate the impact of oil prices on exchange rates. The quantile regression (QR) model is used to estimate the heterogeneous impacts of oil price shocks on exchange rates, with particular emphasis on notable U.S. dollar appreciation and depreciation. The QR methodology allows estimating the distributional heterogeneity responses of the exchange rate to oil price shocks that the OLS model would be incapable of recognizing or capturing, given that OLS estimation is contingent on the conditional mean of the dependent variable. Additionally, it is important to allow for the asymmetric effect of oil price shocks (positive and negative changes) on the exchange rate to provide additional insights into the hypothesized relationship.

In this study, the OLS and QR approaches are implemented for ASEAN-5 countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) over the quarterly period of 1970: Q1–2022: Q1. The focus was on understanding the impact of oil prices over the different parts of the exchange rate distribution for each of the five countries, given that a sizable exchange rate appreciation or depreciation might lead to changes in the terms of trade of a country and its current account balances, which are seen as the focal transmission channels for oil price shocks.

There are a number of interesting findings that stem from the QR. The effect of oil price shocks on exchange rates follows distributional heterogeneity across different quantiles. The estimated coefficients on the oil price shocks across the lower and upper quantiles are significantly different, which denotes various exchange rate appreciation and depreciation across the distribution in response to oil price shocks. Moreover, the empirical findings of the QR model suggest significant asymmetrical oil price shocks on exchange rates across the distribution. In general, the oil price shocks' effects vary in magnitude, sign, and significance throughout the exchange rate distribution and across the sample countries.

The analysis presented in this study suggests that policymakers may need to consider the distributional heterogeneity of the exchange rate when setting policies, seeing that the empirical results reveal significant effects across the exchange rate distribution over various quantiles. There is also a need to be cautious when designing policies based on OLS estimations, seeing that the quantile analysis demonstrated how the effects of oil price shocks vary across the exchange rate distribution. Moreover, the results of this study suggest that asymmetric oil price shocks are a significant factor in examining the oil price-exchange rate nexus.

Examining the oil price-exchange rate nexus has important policy implications for ASEAN-5 countries. First, the impact of oil prices on exchange rates highlights the importance of external factors in shaping ASEAN economies. Since the ASEAN-5 countries are net importers of oil, they should consider the extent and magnitude of external factors (such as oil price shocks) when making decisions about other types of economic policies, such as those that incentive energy efficiency and cleaner energy generation. Other types of policies should also be designed to accommodate potential fluctuations in oil prices. Moreover, since the ASEAN-5 economies are heavily dependent on oil imports, they may benefit from regional coordination among the nations to manage the impact of oil price fluctuations on their respective economies. By understanding the factors that drive exchange rate movements, the oil-importing ASEAN countries can manage economic risk and promote stability and growth.

We forward the following recommendations for future works: First, more studies are needed to examine the relationship between the oil prices and exchange rates for the ASEAN-5 countries. Second, future studies should adopt the QR analysis that considers the shape of the conditional distribution of the exchange rate returns since previous work presumed the relationship between oil price and the exchange rate is invariable within the exchange rate distribution and considered the effect of oil price shocks solely on the mean. QR methodology can provide a more informative and thorough illustration of exchange rate fluctuations. Finally, future studies should allow for an asymmetric effect within the targeted nexus, whereas most previous works ignored the nonlinear effect within the QR analysis regarding the oil price-exchange rate nexus.

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