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# The Effect of Asymmetrical Relationship of Oil Price Shocks on Gross Domestic Product

## *(Kesan Hubungan Tak Simetri Kejutan Harga Minyak terhadap Keluaran Dalam Negara Kasar)*

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*ABSTRACT*

*This paper revisits the asymmetrical crude oil prices and Gross Domestic Product (GDP) relationship for Malaysia and Indonesia using Hansen (2000) Threshold regression method. The empirical analysis uses quarterly data for the period of 1990 (quarter 1) until 2018 (quarter 1). The paper confirms the nonlinearities in the oil price-GDP relationship for Malaysia and Indonesia. The findings reveal that when oil prices are below USD37, oil price shocks have a negative impact on Malaysian GDP, but positively affect GDP when oil price are between USD37 to USD55. Indonesia's GDP, on the other hand, responds favourably to changes in oil prices when they are below USD47, but negatively affects GDP when oil price exceeds USD47. Both countries' GDP responses to oil price shocks are linked to the issues such as the degree of oil dependency, oil self-sufficiency, and government efficiency in managing revenue from the oil sector and the ease with which critical policy adjustments take place.*

*Keywords: Crude oil price; GDP; nonlinear; asymmetric; threshold value*
*JEL: B27, C24, C32, F41*

*ABSTRAK*

*Kajian ini mengukur hubungan tak simetri antara harga minyak mentah dan Keluaran Dalam Negara Kasar (KDNK) bagi Malaysia dan Indonesia dengan menggunakan kaedah regresi Ambang Hansen (2000). Analisis empirikal menggunakan data suku tahunan untuk tempoh 1990 (suku pertama) hingga 2018 (suku pertama). Kajian ini mengesahkan hubungan tidak linear wujud di antara harga minyak mentah dan KDNK untuk Malaysia dan Indonesia. Hasil kajian menunjukkan bahawa apabila harga minyak berada di bawah USD37, kejutan harga minyak memberi kesan negatif ke atas KDNK Malaysia, tetapi memberi kesan positif ke atas KDNK apabila harga minyak berada di antara USD37 hingga USD55. KDNK Indonesia, sebaliknya, bertindak balas secara positif terhadap perubahan harga minyak apabila harga minyak berada di bawah USD47 tetapi memberi kesan negatif kepada KDNK apabila harga minyak melebihi USD47. Tindak balas KDNK terhadap kejutan harga minyak bagi kedua-dua negara berkait rapat dengan isu seperti tahap kebergantungan minyak, mandiri minyak, kecekapan kerajaan dalam menguruskan pendapatan dari sektor minyak dan kemudahan berlakunya penyesuaian dasar krtikital yang diperlukan*

*Kata kunci: Harga minyak mentah; KDNK; tidak linear; tak simetri; nilai ambang*

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## INTRODUCTION

Crude oil is unequivocally crucial to the global economy, both in the past and present and in the foreseeable future. Research on oil price shocks and their relationship to economic activities has long been ongoing. Apparently, the world has witnessed at least four more global oil shocks since its first occurrence in 1973. The most recent past was the shock in 2015. (See Appendix). In the literature, a number of studies have discussed the macro economy as a consequence of oil price shocks. The discussion highlighted reasons for the differences in the impacts. Essentially, the magnitude of the impact is subjected to the country's categorization as either a net oil exporter or otherwise (Abeysinghe 2001), in addition to the intensity of oil cost to the country's income and the consumer's flexibility for alternatives (Malik 2008). There is a consensus that the price of oil is correlated to the ensuing recession in the economy. Hamilton (1983), in his seminal work, provided empirical support on the significant relationship between economic performance and the price of oil. He showed that the recession in the US economy, post-World War II, and during the period from 1948-1972 had categorically mimicked Granger-led by a drastic rise in oil prices. His work engendered similar studies with distinct variants in data and estimation protocols (refer Burbridge & Harrison 1984 and Gisser & Goodwin 1986). Primarily, these early studies considered the relationship between the price of oil and the economy as linear or its variant log-linear.

However, the dynamicity as a consequence of the unstable environment characterizes the market for oil. In addition, it is constantly shaped by events in the past, at present and the foreseeable future. As such reliance on linear modelling, not only entails considerable difficulties in interpretation but is also problematic. The situation gives rise to non-linear statistical models, as a consequence. These models attracted considerable interest since the late 1980s. Researchers, for example included Mork in 1989, and in the 90s by both Lee et al. in 1995, and then Hamilton in 1996, and later, followed by Elder and Serletis (2010), Allegret et al. (2014), and Jo (2014). They were among those who have studied and suggested a relationship that is asymmetric between prices of oil and the economy in the aggregate.

## AN ASYMMETRIC RELATIONSHIP OF OIL PRICES AND GDP

Generally, Artami and Hara (2018) defined the asymmetric effect of a change in the price of oil as the dissimilar effect on the magnitude as a result of the same change in the price. It all depends on whether the change is positive or negative. Apparently, Mork (1989) in his empirical work, allowed for an asymmetric response due to the hike and reduction in the real price of oil through different variables. On the one hand, Lee et al. (1995) chose to represent the oil prices as an AR (4)-GARCH (1,1) as a means to segregate conditional variance from changes in the real price of oil. On the other hand, Hamilton (1996) adopted a transformation to the raw price of oil. He defined a shock in oil as the difference between the maximum price in the past four quarters and the current price. A Zero value is when the difference is positive and otherwise.

Several studies have identified channels and offered an explanation as to the cause of asymmetrical response in economic activity at the aggregate level, as a consequence of shocks in the price of oil. For instance, Lilien (1982) and Hamilton (1988) suggested the asymmetric pattern of responses due to shocks in the price of oil to the economy, as a consequence of adjustment costs. In contrast, Bohi (1989) argued that a consequent decline in the economy at the aggregate level, due to rising oil prices, was accounted for by the contractionary monetary policy. On the one hand, Ferderer (1996) highlighted the importance of financial stress and uncertainty due to changes in the price of oil. Consequently, that could magnify as well as offset to some extent, both the negative and positive effects of a hike or reduction in the price of oil. Edelstein and Kilian (2007, 2009), on the other hand, suggested precautionary saving as a motivation for asymmetry. This literature showed that rising oil prices may cause concern regarding future declines in employment and real income. As a consequence, aggregate production would be affected.

To date, there is sufficiently ample evidence on the relationship between economy at the aggregate level and the price of oil, especially in the developed economies. Notably, only few studies involved Asian economies, despite their growing importance to the world economy. The economic activity in the developing economies, categorically, is not spared by the movement in the oil price either. The impact of such changes on the economy as a whole has spread across multiple channels (Bilgin et al. 2015) as evidenced by Cunado and de Gracia (2005), Le and Chang (2013), Vu and Nakata (2014), Cunado et al. (2015), and Aziz and Dahalan (2015). Most of these studies considered the effects on price levels and output due to oil shocks, ranging from exchange rates to inflation, employment and GDP. Cunado and de Gracia (2005) for example examined the macro economy and oil prices relations for six Asian economies. The results showed that both prices and economic activities were significantly impacted by oil prices variability. Besides, the magnitude of the effect on economy, attributable to oil price volatility was very much dependent on the state of net oil dependency of the economy. The finding of Vu and Nakata (2014) is consistent with that of Cunado and de Gracia (2005). Invariably, in terms of output and price variability, oil importing countries such as the Philippines, Thailand and Singapore, are poised to be more sensitive to the environment in the world market of oil than the oil exporting nations like Malaysia and Indonesia. As previous net-oil exporters, Malaysia and Indonesia have benefited from higher crude oil prices owing to better terms of trades. However, the growing dependence on oil import due to declining production overtime means Malaysia and Indonesia, are now more vulnerable to the adverse cyclical effects of this shock as previously illustrated in the above studies.

Most of the studies used conventional time series techniques which are highly dependent on the salient features of the integrated variables involved. It is generally acknowledged that the presence of a non-linear association between macro-economic variables and oil prices undermines the conventional unit root and co-integration tests as for their reliability (Phillips 1986; Perron 1989). Detection of asymmetric norms in the long-run equilibrium adjustment process serves as an additional valuable input for a more informed policy prescription to cushion the impact of shocks in the price of oil. The reported non-linear GDP-oil price relationship for Malaysia and Indonesia, in retrospect, begs for one question; at what point are the oil price shocks turning from good to bad? The answer to this question is to determine the threshold value at which the relationship between the two variables begin to differ.

In the present context, this paper enriches the current literature on the links between Malaysia's and Indonesia's GDP and the shocks in the oil prices. It incorporates both the traditional time series method and the more recent advanced one. In particular, the study; (1) identifies precisely the characteristics of the integrated series being examined; (2) assesses the possibility of having variables related asymmetrically with the other variables as suggested by the Enders and Siklos (2001) autoregressive threshold (TAR) model; (3) estimates long-run relationships between the series considered to account for asymmetric adjustments to long-run equilibrium using threshold regression (TREG) approach developed by Hansen (2000). This paper integrates three asymmetric measures from Mork (1989), Lee et al. (1995), and Hamilton (1996) on oil price shocks, in the threshold regression models. Essentially, it enables the threshold effects to be captured. Consequently, it also enables the discerning of asymmetric GDP responses to the rise and fall in the oil price for Malaysia and Indonesia. Given that this is the first study to use this approach, it has important implications and bearings for policymakers in Malaysia and Indonesia to formulate appropriate fiscal responses in the context of the recent oil price slump and declining local oil production.

The study on the impact of oil price shock on GDP is important for both countries in determining whether or not they can still benefit from oil revenues. Since both countries have enjoyed significant benefits as oil exporters ever since their first production (1885 for Indonesia), the relationship between the oil price shock and GDP can determine the level of dependence of each country on oil in terms of income generation. The threshold analysis information helps policymakers monitor oil prices and subsequently to implement appropriate accommodation policies to overcome the shocks.

Briefly foreshadowing the key findings, the paper confirms the non-linearity of the GDP-oil price both in Malaysia and Indonesia. The paper also identifies the response differences in GDP to oil price shocks in both countries. From the results, it is observed that unanticipated shifts in oil prices adversely affect Malaysian GDP when oil prices are below USD37 but positively affect GDP when oil prices are between USD37 and USD55. For Indonesia, GDP responds positively to changes in oil prices when these are below USD47 but negatively affects GDP when oil prices exceed USD47. Both countries are likely to associate GDP response to the shocks in oil price with factors such as the degree of oil dependency, oil self-sufficiency and the ease with which changes are required. It also depends on how the government of each country uses the revenues generated by oil exports to manage the pressures arising from oil price shocks.

The article description is as follows: The next section discusses Malaysia and Indonesia's brief history as oil exporters. Section II briefly presents the literature review followed by Section III on the empiric methodology adopted. Section IV details out the data properties of the variables, in addition to, the empirical results and their analyses. Section V, finally, provides a summary and conclusion.

## A BRIEF HISTORY: MALAYSIA, INDONESIA AND OIL EXPORTERS

Malaysia's oil operations began in Miri, Sarawak, in 1910. As of January 2018, the proven oil reserves for Malaysia stood at 3.6 billion barrels and the rate for crude oil production was 705 thousand barrels per day (BP Statistical Review of World Oil 2017). The industry has been a pillar of Malaysia's growth, contributes approximately about 20 per cent to the total gross domestic product (GDP). Statistics (FIGURE 2) show that Malaysia has, since 2011, shifted to a net oil importing economy with a reduction in the contributions of oil to its revenue. This is by no means, a result of a decline in its oil production. Contribution to the Government coffer was around 12 per cent in 2017 which is about 8 per cent lower than the 2015's figure. (TABLE 1).

Indonesia's oil industry is one of the world's oldest, with earliest production starting in 1885. As of January 2018, Indonesia's proven oil reserve stands at 3.6 billion barrels (bbl), down from 4.4 bbl in 2006 and crude oil output is 881 000 barrels per day (BP World Energy Statistical Analysis 2017). Limited oil reserves and a declining production rate could no longer support domestic demand for oil (see FIGURE 1). As a result Indonesia since 2004 became a net oil importer. She left OPEC in 2008, albeit being back in 2015, signalling its commitment to the industry. Statistics show that the contribution of the industry to the state revenue systematically dropped. In 2010, it was recorded at 15 per cent and in 2015, it dramatically dropped to 5 per cent. The pattern again, continues for 2016 with a 3 per cent recorded figure. (TABLE 1).

## OIL SELF-SUFFICIENCY AND OIL RENTS

The oil self-sufficiency index (SSI) reflects the extent of dependency on oil imports for the nation. It is measured as the oil production-consumption net of the country's oil consumption. On one hand, a value of minus one (-1) signifies a complete dependency of a country on its oil imports. Conversely, a positive number (above 1) indicates the country as a net oil exporter. Over the period 1970-2004, both nations were generally oilsufficient (see FIGURE 3). Since 2004, Indonesia's production failed to tail up to the consumption need of the nation, with SSI valued below 1. For Malaysia, the SSI decreased steadily since 1990 and fell below 1 in 2011, the year Malaysia became officially a net oil importer.

Oil rents is defined as the residual value of crude oil and the total cost of producing it, at world prices. It reflects how profitable the venture is. The methods used to measure the resources of oil-producing countries and a detailed explanation of it can be found in Lange et. al. (2018). The highest oil rents for both Indonesia and Malaysia were reported in 1979, at 26 per cent and 12 per cent respectively (see FIGURE 4). Following the outbreak of the Asian financial crisis in 1998, respectively 1999-2014, Malaysia and Indonesia separately received an average of 4.8 per cent and 3.3 per cent of oil rents. When the world oil price dropped to its lowest since 2004 at USD34 per barrel in 2016, oil rents for Malaysia and Indonesia, respectively, contributed about 1.6 per cent and 0.6 per cent

An important observation from these statistics is that both nations have shifted from net oil exporters to net oil importers, with Indonesia faring worse than Malaysia in terms of deteriorating oil rents and widening gap between oil production and demand. Therefore, when quantifying the asymmetric impacts of oil prices on GDP, it is interesting to observe whether the outcome

TABLE 1. Oil-related revenue share of government revenue (%) - Malaysia and Indonesia

| Year | '04 | '05 | '06 | '07 | '08 | '09 | '10 | 11 | '12 | '13 | '14 | '15 | '16 | '17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Malaysia[a] | 23 | 27 | 35 | 35 | 38 | 39 | 34 | 34 | 32 | 31 | 28 | 20 | 13 | 12 |
| Indonesia[b] | 21 | 21 | 25 | 18 | 22 | 15 | 15 | 16 | 15 | 13 | 14 | 5 | 3 | 5 |

*Source:* [a]MIDF (2017), [b]Coopers, P.W. (2018)

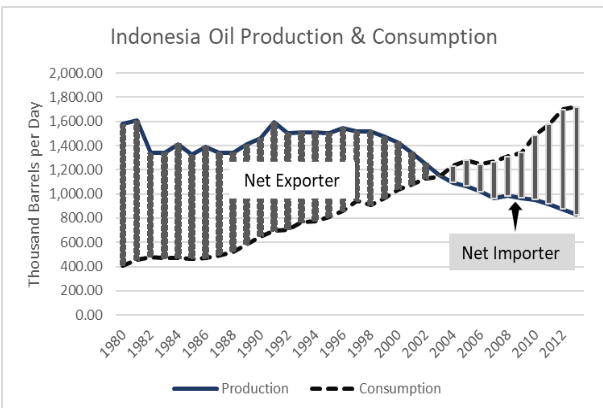


FIGURE 1. Indonesia oil production and Consumption

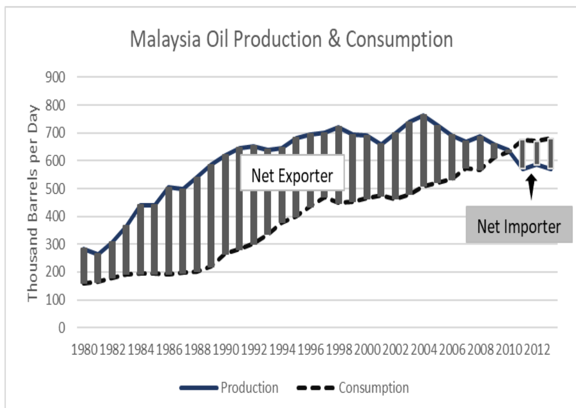


FIGURE 2. Malaysia oil production and Consumption

*Source:* International Energy Agency

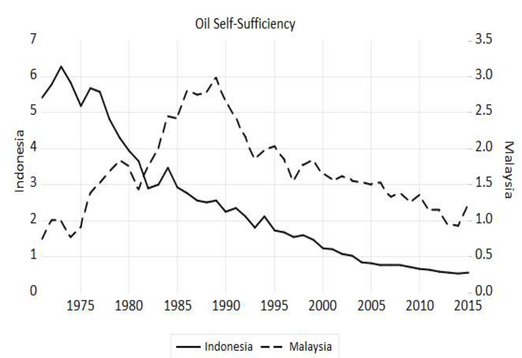


FIGURE 3. Oil self sufficiency[a]

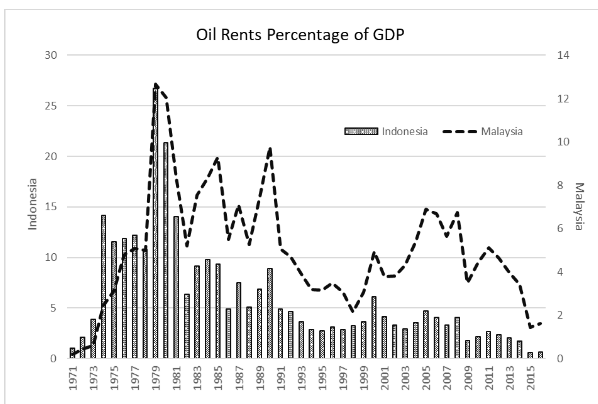


FIGURE 4. Oil rents (% of GDP)[b]

*Sources:* [a]International Energy Agency; [b]World Development Indicators would be different for both nations when considering the threshold effects of oil prices.

## LITERATURE REVIEW

The literature has generally recorded a strong long-run causality between production and oil prices with varying degrees of effect for studies focusing on Malaysia and Indonesia (see for example Abeysinghe 2001, Jalil et al. 2009, Aziz 2010, Balasubramanian 2017, Mansur 2015, Artami & Hara 2018 and Baek & Choi 2018). Abeysinghe (2001) concluded that while the direct impact on Malaysia and Indonesia, of high oil prices, was positive the apparent repercussion on growth through its trading partners was unavoidable. Both nations tended to lose out in the long run. Aziz (2010) used non-linear oil price specifications in the unrestricted VAR for Malaysia to obtain a comparable result. Significant positive shocks in oil prices boosted up aggregate production over the short run but produced a negative long-term impact on output growth. Likewise, Abdul Jalil et. al. (2009) discovered a positive direct long-run relationship of GDP to the price of oil. In particular, the authors discovered asymmetrical shift effect of oil prices on Malaysia's GDP.

Recently, Balasubramaniam (2017) presented an empirical support for a long-run non-linear relationship of oil prices to Malaysian manufacturing and industrial output. The finding concured to the view that the oil price hike significantly increased output, while the abatement in oil price had had a significant adverse effect on these two sector outputs. Mansur (2015) extended the Killian (2009) model and revealed that any of the unanticipated oil price shocks affected Indonesia's GDP. Specifically, while in the one hand, it reacted adversely as a result of oil supply shocks, on the other hand, it was impacted favourably as a result of both oil-specific demand as well as global demand shocks. The results of Artami and Hara (2018) showed that the effect on Indonesia's GDP as a consequence to changes in the prices of oil was asymmetrical, as the drop in oil prices lowered GDP, while the hike in the prices of oil insignificantly affected the country's GDP. In addition, changes in oil prices had been shown to affect the Indonesian rupiah asymmetrically over the long term. Invariably, the Indonesian rupiah appeared to be more vulnerable to rising oil prices than otherwise (Baek & Choi 2018).

## METHODOLOGY

This part of the article presents the descriptive statistics of the variables corresponding to the data set used in this study. A description of the underlying Hansen's (1996, 2000) econometric method for estimating the threshold is also provided. The estimation follows three steps. First, the paper ascertains the integrational properties of the data. Secondly, the paper tests for cointegration relationship using Pesaran et al. (2001) bounds testing method and Enders and Siklos (2001) test for symmetry. Finally, the paper estimates the threshold regression of the impacts of oil price shocks on real GDP using Hansen's (2000) threshold estimation technique.

## DATA DESCRIPTION

The study used quarterly data derived from the International Finance Statistics (IFS) for both Malaysia and Indonesia, spanning 1990Q1–2018Q1 which included the oil price crisis in 2008 and the recent price decline since 2014Q3. The macroeconomic variables for the study, namely real effective exchange rate (REER), government expenditure (GOVT), total exports (EXPORT), gross domestic product (RGDP) were quoted in national currency per US dollar. As for oil price (OIL), the Brent Crude price quoted in the US dollar was used. All variables were deflated using the national consumer price index and transformed into natural logarithm. The construct of oil price shock variables was discussed further in the next section.

TABLE 2 and 3 provide some summary statistics on the variables used in the paper. Malaysia's average RGDP was approximately RM149 billion between 1990 and 2018, while Indonesia's average RGDP was RP110 billion over the same period. While Indonesia's OIL ranged from a maximum of USD247 and a minimum of USD25 for the same period, Malaysia had maximum and minimum OIL of USD126 and USD14 respectively.

### OIL PRICE SHOCK VARIABLES

For the asymmetrical effects of oil price, this paper adopts, respectively a widely applied, the non-linear transformations methods of Mork (1989), Hamilton (1996) and Lee et al. (1996) of oil prices (Mork, Hamilton and Lee hereafter). Mork (1989) distinguishes between positive and negative oil price shocks and finds that rising oil prices reduce GDP, while falling prices have little impact. In his work, Mork (1989) characterizes the positive rate of change in the price of oil, +, and its negative rate of change, − in the specification of asymmetry as follows:

$$MORK_t^+ = \max\left(0, \left(REALOIL - REALOIL_{t-1}\right)\right) \quad (1)$$

$$MORK_t^- = \min\left(0, \left(REALOIL_t - REALOIL_{t-1}\right)\right) \quad (2)$$

where REALOIL is calculated using $REALOIL_{i,t} = \log(OIL*E_{i,t})$, where $E_{it}$ is the exchange rate against US dollar for country $i$ at time $t$. Adjusting global oil prices for domestic exchange rates and inflation effects is common practice in this literature (see, for example, Mork et al., 1994 and Abeysinghe, 2001) in order to

TABLE 2. Summary statistics of variables for Malaysia

| Variables | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|
| RGDP (billion RM) | 149 | 67.7 | 53.3 | 282 |
| EXPORT (billion RM) | 121 | 50.4 | 31.9 | 203 |
| REER (index) | 102.45 | 11.33 | 85.62 | 128.51 |
| GOVT (billion RM) | 18.5 | 10.1 | 5.44 | 43.7 |
| OIL (US dollar) | 51.48 | 29.40 | 14.04 | 126.68 |

TABLE 3. Summary statistics of variables for Indonesia

| Variables | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|
| RGDP (billion Rupiah) | 1100000 | 599000 | 412000 | 2330000 |
| EXPORT (billion Rupiah) | 276000 | 112000 | 79000 | 473000 |
| REER (index) | 88.05 | 13.99 | 41.67 | 112.82 |
| GOVT (billion Rupiah) | 95100 | 62800 | 34300 | 297000 |
| OIL (US dollar) | 80.75 | 37.032 | 25.29 | 247.59 |

obtain a more accurate measurement of the price of oil (i.e the perceived domestic price).

Hamilton (1996) introduces a variant to the Mork's non-linear transformation. It uses net oil price increase ($HAMILTON^+$) as the explanatory variable. The $HAMILTON^+$ is the amount by which oil prices in quarter t, $REALOIL_t$, traverses the highest value of the preceding four quarters, and zero otherwise. In the same spirit as that of Hamilton (1996), the paper includes both net oil price increase ($HAMILTON^+$) and net oil price decrease ($HAMILTON_-$) defined as follows:

$$\text{HAMILTON}_t^+ = \max\left\{ \begin{array}{l} 0,\ \text{REALOIL}_t \\ -\max\left\{ \begin{array}{l} \text{REALOIL}_{t-1},\ \text{REALOIL}_{t-2}, \\ \text{REALOIL}_{t-3},\ \text{REALOIL}_{t-4} \end{array} \right\} \end{array} \right\} \quad (3)$$

$$\text{HAMILTON}_t^- = \min\left\{ \begin{array}{l} 0,\ \text{REALOIL}_t \\ -\min\left\{ \begin{array}{l} \text{REALOIL}_{t-1},\ \text{REALOIL}_{t-2}, \\ \text{REALOIL}_{t-3},\ \text{REALOIL}_{t-4} \end{array} \right\} \end{array} \right\} \quad (4)$$

In their study, Lee et al. (1995) adjusted the increase in oil prices by a standard deviation in price volatility in order to capture a better forecast of GDP. Thus, they concurred that the impact on the real GDP of an oil price shock is likely to be greater than otherwise in a stable oil price context. The AR (4)-GARCH (1,1) model is determined on the basis:

$$\Delta\text{REALOIL}_t = \beta_0 + \beta_1\Delta\text{REALOIL}_{t-1} + \beta_2\Delta\text{REALOIL}_{t-2} + \beta_3\Delta\text{REALOIL}_{t-3} + \beta_4\Delta\text{REALOIL}_{t-4} + \varepsilon_t \quad (5)$$

where $\Delta\text{REALOIL}_t$ is the change in REALOIL.

$$\varepsilon_t \mid I_{t-1} \sim N(0,\ h_t)$$

$$h_t = \gamma_0 + \gamma_1 e_{t-1}^2 + \gamma_2 h_{t-1} \quad (6)$$

$$LEE_t^+ = max\left(0, \hat{e}_t / \sqrt{\hat{h}_t}\right) \quad (7)$$

$$LEE_t^- = min\left(0, \hat{e}_t / \sqrt{\hat{h}_t}\right) \quad (8)$$

where $LEE_t^+$ signifies an increase in scaled oil price, and $LEE_t^-$ represents the opposite of it.

## THRESHOLD MODEL SPECIFICATION

This paper adopts Hansen's (2000) threshold estimation procedure (which his was an extension of Tong's (1983) threshold regression) and its variants to examine the non-linearity properties of the oil price-GDP nexus for Malaysia and Indonesia. Essentially, the estimation is carried out using STATA 15 that allows the presence of more than one threshold. The specification model for a single threshold is as follows:

$$y_t = \begin{cases} x_t\beta + z_t\delta_1 + \varepsilon_t & if\ -\infty < w_t < \gamma \\ x_t\beta + z_t\delta_2 + \varepsilon_t & if\ \gamma < w_t < -\infty \end{cases} \quad (9)$$

where $y_t$ is a dependent variable, RGDPt; $x_t$ is a $1 \times k$ covariate vector, β is a $k \times 1$ region-invariant parameter vector. There are three region-invariant parameters, β that they may have influences upon the $RGDP_t$, which are $EXPORT_t$, $REER_t$ and $GOVT_t$. $z_t$ is exogenous variables' vector with the region-specific vector coefficients $\delta_1$ and $\delta_2$. They consist of three separate positive (increase) and negative (decrease) oil prices measures by Mork (1989), Lee et. al. (1995) and Hamilton (1996). $w_t$ is the threshold variable, real crude oil price in US dollar, that is determined when the coefficient on region-specific variables changes. The errors $\varepsilon_t$ is identical and independently distributed with zero mean and finite variance $\sigma^2$ ($\varepsilon_{it} \,\tilde{}\, iid\left(0, \sigma^2\right)$).

The original Hansen (2000) model is designed for a single threshold. Considering a threshold model with *m+1* regions, as to allow the presence of more than one threshold. Next, let an index for region $j$ = 1,…., $m$+1. The model is written as;

$$y_t = x_t\beta + z_t\delta_1 I_1\left(\gamma_1, \omega_t\right) + \;.....+ z_t\delta_{m+1} I_m\left(\gamma_{m+1}, \omega_t\right) + \epsilon_t \quad (10)$$

$$y_t = x_t\beta + \sum_{j=1}^{m+1} z_t\delta_j I_j\left(\gamma_j, \omega_t\right) + \epsilon_t \quad (11)$$

where $\gamma_1 < \gamma_2 < .... < \gamma_m$ are ordered thresholds with $\gamma_0 = -\alpha$ and $\gamma_{(m+1)} = \alpha$ . $I_j(\gamma j, \omega_t) = I(\gamma_{(j-1)} < \omega_t \leq \gamma_j)$ serves for the jth region as an indicator. The threshold regression model is linear, conditional upon all estimated thresholds ($\gamma^1 \ldots \gamma^m$). Least squares estimation is then used to estimate the parameters that remain in the system. In equation (10), in the order of estimation, accordingly, the $\gamma^1$*…….. $\gamma^m$* denote the m thresholds. With the assumption, as to begin with, a model with two regions (refer equation (9)), is then estimated for its first threshold ($\gamma^1$*) value. Consecutively, the second threshold is next estimated, conditional upon the first threshold value. The newly generated threshold number is the one that yields the minimum sum of squared residual (SSR) overall observations in $\omega_t$ (the first threshold number excluded). In principal, the conditional (upon the first estimated threshold $\gamma^1$*) least- squares estimation technique, now with three regions, is used to estimate the second threshold $\gamma^2$*∗. In relation to the BIC criterion the optimal number of thresholds is apparently picked up. Essentially, the selection criterion is subjected to the SSR from the fitted model as BIC = T ln(SSR=T) + k ln(T) with k parameters of the model.

## RESULTS AND DISCUSSION

The standard practice in the co-integration modelling literature is to investigate the related variables' integration properties. This paper explores the variables

TABLE 4. Unit root tests for Malaysia

| Variable | GDP | Export | Government Expenditure | Real Effective Exchange Rate |
|---|---|---|---|---|
| Series in level | | | | |
| ADF[a] | -2.197 | -1.644 | -0.766 | -2.145 |
| KPSS[b] | 1.218*** | 1.126*** | 1.143*** | 0.828*** |
| PERRON[a] | -1.389 | -2.041 | 0.536 | -1.844 |
| Series in first difference | | | | |
| ADF[a] | -6.095*** | -6.306*** | 0.041 | -7.947*** |
| KPSS[b] | 0.249 | 0.447 | 0.386 | 0.062 |
| PERRON[a] | -9.522*** | -10.721*** | -19.696*** | -7.878*** |

*Notes:* 1. All variables are in natural log and real value
2. [a] signifies that the null hypothesis is unit root
[b] signifies that the null hypothesis is no unit root
3. *** denotes the statistical significance at 1% level

TABLE 5. Unit root tests for Indonesia

| Variable | GDP | Export | Government Expenditure | Real Effective Exchange Rate |
|---|---|---|---|---|
| Series in level | | | | |
| ADF[a] | -2.352 | -2.937 | -2.024 | -2.651 |
| KPSS[b] | 1.214*** | 1.065*** | 0.942*** | 0.244*** |
| PERRON[a] | -1.963 | -2.971 | -1.525 | 2.488 |
| Series in first difference | | | | |
| ADF[a] | -3.711** | -8.043*** | -2.024 | -7.320*** |
| KPSS[b] | 0.099 | 0.154 | 0.300 | 0.105 |
| PERRON[a] | -11.139*** | -11.161*** | -12.578*** | -9.349*** |

*Notes:* 1. All variables are in natural log and real value
2. [a] signifies that the null hypothesis is unit root
[b] signifies that the null hypothesis is no unit root
3. *** denotes the statistical significance at 1% level

TABLE 6. Bound co-integration test for Malaysia

| Test statistic | Value | Significance level | Bound Critical values* (restricted intercept and trend) | |
|---|---|---|---|---|
| | | | I(0) | I(1) |
| *F*-statistic-Mork | 5.271*** | 10% | 2.08 | 3 |
| *F*-statistic-Hamilton | 5.843*** | 5% | 2.39 | 3.38 |
| *F*-statistic-Lee | 9.63*** | 1% | 3.06 | 4.15 |

*Note:* *** denotes statistical significance at the 1% level

TABLE 7. Bound co-integration test for Indonesia

| Test statistic | Value | Significance level | Bound Critical values* (restricted intercept and trend) | |
|---|---|---|---|---|
| | | | I(0) | I(1) |
| *F*-statistic-Mork | 5.558*** | 10% | 2.08 | 3 |
| *F*-statistic-Hamilton | 8.878*** | 5% | 2.39 | 3.38 |
| *F*-statistic-Lee | 5.821*** | 1% | 3.06 | 4.15 |

*Note:* *** denotes statistical significance at the 1% level

for data stationarity through the unit root test (ADF) of Dickey and Fuller (1979), the PP test (Phillips and Perron, 1988) and the stationary test (KPSS) of Kwiatkowski et al. (1992). The results as in TABLE 4 for Malaysia and TABLE 5 for Indonesia suggest that real GDP, real exports and real effective exchange rates are found to be first-differenced stationary despite level non-stationary. On the contrary, real Government Expenditure is integrated of the order zero via both the KPSS and Perron tests. As far as oil price shocks measures (MORK, LEE and HAMILTON) are concerned, they are stationary at level or I(0) due to the construction of the variables themselves. Therefore, the unit root tests results are not presented in the paper but are available upon request from the authors.

In the next step of the analysis, the paper used the Pesaran et al. (2001) co-integration technique, which provides two sets of values for both the series of I(1) and I(0). Values for the I(1) series denote the critical upper bound whereas for the I(0) series, the values signify the critical lower bound. The golden rule is that the rejection of the no co-integration null hypothesis is valid only if the computed F-statistics exceeds its respective critical value. The computed F-statistics for the co-integration test is summarised in TABLE 6 and TABLE 7. In all cases, invariably, at a 5 per cent significance level, the computed F-statistics exceeds the critical bound value. As a consequence, the dismissal of the non-co-integration hypothesis is warranted. Essentially, the macroeconomic variables and the oil prices are found to be co-integrated, both for Malaysia and Indonesia.

To date, the presence of possible asymmetrical relationships in the adjustment process has yet to be explicitly accounted for, using the Malaysian and Indonesia data, despite significant evidence of co-integration among the series. Thus, sharing the spirit of Enders and Siklos (2001), the paper estimates the threshold autoregressive (TAR) model. More specifically, the paper tests the hypothesis of symmetrical presence among the co-integrated series as the null. The results in TABLE 8 highlight the rejection of the symmetry hypothesis for both cases (Malaysia and Indonesia). This is so, after 10 thousand simulations, at 5 per cent significance level, as the computed F-equal statistics for the TAR model were found to be greater than its critical value. These results validate the asymmetrical effects of oil price change, both on Malaysian and Indonesian GDP, reported in previous studies such as Aziz (2010), Balasubramaniam (2017), Mansur (2015) and Artami and Hara (2018).

TABLE 8. Enders and Siklos (2001) test for symmetry (TAR model)

| Asymmetric Specification | F-equal | Critical Value | Lags |
|---|---|---|---|
| Malaysia | | | |
| Mork | 3.492 | 1.956* | 4 |
| Hamilton | 4.117 | 1.929* | 10 |
| Lee | 3.082 | 2.011* | 4 |
| Indonesia | | | |
| Mork | 2.606 | 2.000* | 5 |
| Hamilton | 1.910 | 1.330* | 10 |
| Lee | 1.374 | 1.364* | 5 |

*Notes:* 10000 simulations for 5% significance level's critical values
* denotes statistical significance at 5% level

Having identified the asymmetrical relation between the macroeconomic variables and the price of oil, the paper continues to evaluate the possibility of a threshold effect between the co-integrated variables. It is a critical step before the long-run Threshold regression can be estimated. To this end, the paper uses the Lagrange Multiplier (LM) test (adopted

TABLE 9. LM test of linearity for oil price-GDP relationship for Malaysia and Indonesia

| Test of null of no threshold against alternative of threshold allowing heteroskedastic errors (white corrected) | Malaysia | Indonesia |
|---|---|---|
| Number of bootstrap replications | 5000 | 5000 |
| Trimming percentage | 15% | 15% |
| Threshold estimate | 37.8 US dollar | 47.5 US dollar |
| LM-test for no threshold | 18.6 | 29.9 |
| Bootstrap p-value | 0.003* | 0.000* |

*Note:* * denotes statistical significance at 1% level

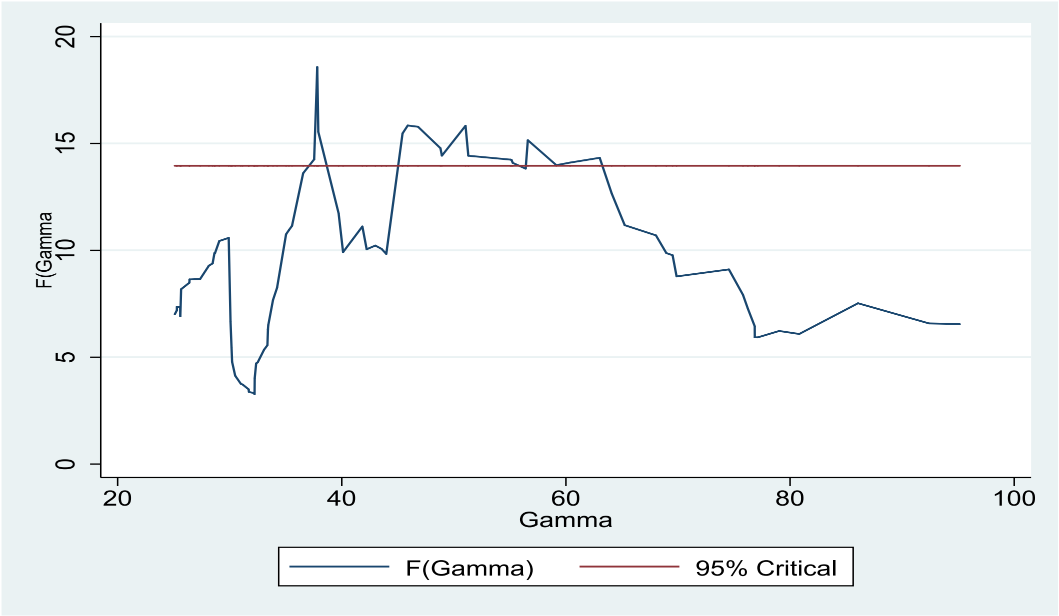


FIGURE 5. F-test for threshold presence-Malaysia

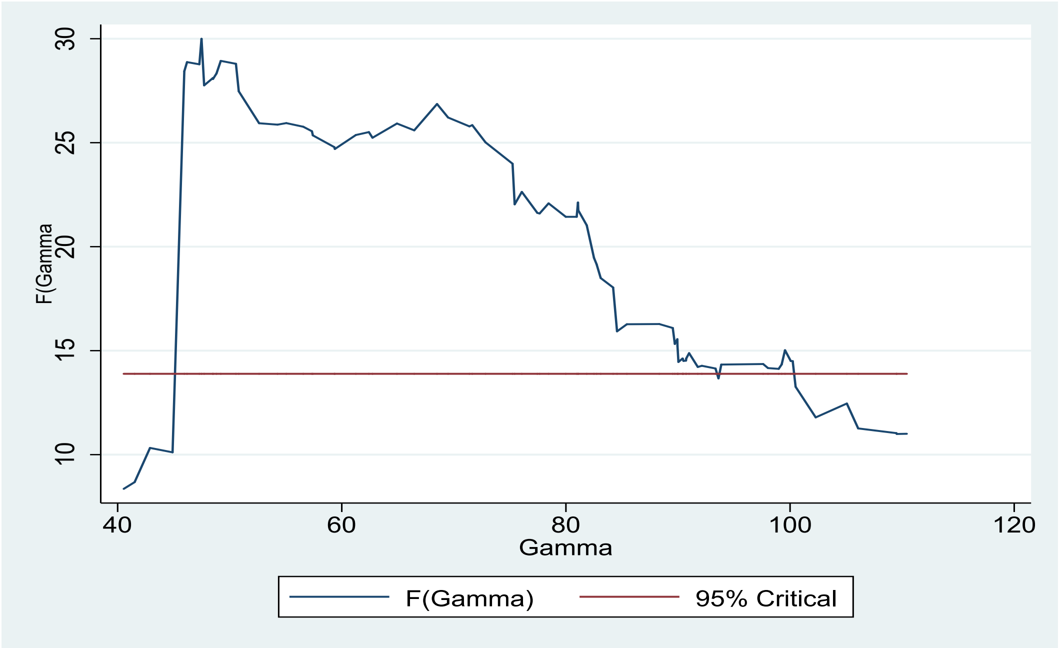


FIGURE 6. F-test for threshold presence-Indonesia

from Hansen, 1996, 2000) to check the presence of a threshold effect between co-integrated variables. Using 5000 replications of bootstrap and real oil price (in US dollar) as the threshold variable, the p-value of bootstrap for Malaysia and Indonesia is significant at 1% (see TABLE 9). The LM tests are equivalent to 18.6 for Malaysia and 29.9 for Indonesia which surpassed the critical value of 5.99 for the Chi-squared distribution table. The estimated optimum threshold value from the LM test is USD 37.8 for Malaysia and USD 47.5 for Indonesia. The null hypothesis (there is no threshold) is therefore rejected, implying at least one threshold. Similarly, the presence of threshold effect can also be assessed by plotting F (Gamma) values for each country in the LM test against the Gamma values. Results from FIGURE 5 and FIGURE 6 show that the computed F-sequence statistics allows for the rejection of the null of no threshold, for both, Malaysia and Indonesia, as the value exceeds the critical value of 95 per cent. In order to determine the possibility of the existence of more than one threshold, the paper adopts the modified Hansen (2000) threshold regression model (TREG) which allows for more than one threshold.

## THE OIL PRICE-ECONOMIC GROWTH RELATIONSHIP

TABLE 10 and 11 provide TREG estimates for Malaysia and Indonesia from 1990Q1 to 2018Q1. Columns (1) to (3) show estimates for two- and three-regime TREG models using non-linear oil price measures of Mork's, Hamilton's and Lee's. For comparative purposes, the fourth column presents estimates of linear oil price metrics using REALOIL as a regime-dependent regressor. For all the estimates, the BIC criterion that minimises the residual square sum (SSR) serves for the selection of the thresholds optimal number. For

TABLE 10. Threshold regression results for Malaysia

| Specification | Mork | Hamilton | Lee | Linear model |
|---|---|---|---|---|
| *Threshold* | Estimated Real Oil Price Threshold (US Dollar) | | | |
| 1st Ω | 37.8 | 24.2 | 37.8 | 37.8 |
| 2nd Ω | 55.3 | | 55.3 | 51.04 |
| | Impact of regime-dependent regressors | | | |
| | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* |
| Regime 1 | | | | |
| Increase | -0.637 (0.002)*** | -1.462 (0.177) | -0.093 (0.002)*** | 0.092 (0.067)* |
| | *(MORK$^+$)* | *(HAMILTON$^+$)* | *(LEE$^+$)* | *[REALOIL]* |
| Decrease | 0.105 (0.530) | -0.808 (0.013)** | -0.026 (0.280) | |
| | (MORK$_-$) | (HAMILTON$_-$) | (LEE$_-$) | |
| Regime 2 | | | | |
| Increase | 0.568 (0.002)*** | -0.560 (0.009)*** | 0.094 (0.037)** | 0.144 (0.002)*** |
| | (MORK$^+$) | (HAMILTON$^+$) | (LEE$^+$) | [REALOIL] |
| Decrease | 0.957 (0.003)*** | 0.245 (0.159) | 0.221 (0.001)*** | |
| | (MORK$_-$) | (HAMILTON$_-$) | (LEE$_-$) | |
| Regime 3 | | | | |
| Increase | 0.087 (0.710) | | -0.005 (0.887) | 0.105 (0.014)** |
| | (MORK$^+$) | | (LEE$^+$) | *[REALOIL]* |
| Decrease | -0.478 (0.771) | | -0.009 (0.680) | |
| | (MORK$_-$) | | (LEE$_-$) | |
| | Impact of regime-independent regressors | | | |
| | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* |
| EXPORT | 0.718 (0.000)*** | 0.728 (0.000)*** | 0.706 (0.000)*** | 0.683 (0.000)*** |
| REER | 0.305 (0.000)*** | 0.173 (0.004)*** | 0.306 (0.000)*** | 0.693 (0.000)*** |
| GOVT | 0.255 (0.000)*** | 0.269 (0.000)*** | 0.268 (0.000)*** | 0.193 (0.000)*** |
| Observations | 112 | 109 | 108 | 113 |
| Max threshold | 4 | 3 | 3 | 4 |
| No. of threshold | 2 | 1 | 2 | 2 |
| BIC Criteria | -455.6 | -451.1 | -449.1 | -487.9 |

*Notes:* *, **, **** denote statistical significance at the 10% level, 5% level and 1% level, respectively.

Malaysia, the test procedure involves two thresholds for the use of Mork's and Lee's specifications and one threshold for the use of Hamilton's specifications, while for Indonesia, a single threshold for all non-linear estimates is chosen. With regard to the impact of the regime-independent regressors on the RGDP, all the coefficients for Malaysia and Indonesia have the expected signs from Eq. 9. Specifically, export-related coefficients, government expenditure and effective exchange rates are positive and significant at 1percent.

In TABLE 10, the empirical results obtained from Mork's and Lee's specifications show that under Regime 1, at below USD 37.8, a real oil prices hike has an adverse and significant effect on Malaysia's RGDP. However, when it is between USD 37 and USD 55, the results of Regime 2 show that the Increases and Decreases measures statistically exhibit a significant relationship with RGDP and it is positive. Conversely, the impact on the RGDP is again negative when Lee's specification exceeds USD55 but is statistically insignificant for both Increase and Decrease measures. Estimates using Hamilton's specification show consistent negative signs when the value is below USD37 but continues to be negatively correlated with the RGDP under Regime 2 when the value is between USD37 and USD55. Column (4) shows that the REALOIL has a significant and favourable effect on the RGDP for both thresholds (USD37 and USD55). TREG findings using linear oil price measurements contradict the empirical and theoretical findings of previous studies (Abeysinghe 2001; Aziz 2010); i.e., shocks in the price of oil bring about a different repercussion on Malaysia's economic growth when oil prices are low and high. However, estimates of non-linear oil price measures generally yield results that are in support of that of Jalil et. al. (2009) and Balasubramaniam (2017) respectively. Malaysia's economy benefits from high oil prices but is adversely affected by low prices. According

TABLE 11. Threshold regression results for Indonesia

| | Mork | Hamilton | Lee | Linear model |
|---|---|---|---|---|
| | | Estimated Real Oil Price Threshold (US Dollar) | | |
| 1st Ω | 47.7 | 47.7 | 42.9 | 45.9 |
| 2nd Ω | | | | 109.5 |
| | | Impact of regime-dependent regressors | | |
| | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* |
| Regime 1 | | | | |
| Increase | 1.482 (0.001)*** | 7.349 (0.000)*** | 0.297 (0.000)*** | 0.223 (0.000)*** |
| | *(MORK$^{+}$)* | *(HAMILTON$^{+}$)* | *(LEE$^{+}$)* | *[REALOIL ]* |
| Decrease | 0.274 (0.252) | 0.506 (0.058)* | 0.079 (0.081)* | |
| | (MORK-) | (HAMILTON$_{-}$) | (LEE$_{-}$) | |
| Regime 2 | | | | |
| Increase | -0.599 (0.009)*** | -0.387 (0.176) | -0.070 (0.120) | 0.197 (0.000)*** |
| | *(MORK$^{+}$)* | *(HAMILTON$^{+}$)* | *(LEE$^{+}$)* | *[REALOIL ]* |
| Decrease | -0.382 (0.089) * | -0.114 (0.725) | -0.041 (0.217 | |
| | (MORK-) | (HAMILTON$_{-}$) | (LEE$_{-}$) | |
| Regime 3 | | | | |
| Increase | | | | 0.175 (0.000)*** |
| | | | | *[REALOIL ]* |
| Decrease | | | | |
| | | Impact of regime-independent regressors | | |
| | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* | *Estimated Coeff* |
| EXPORT | 0.753 (0.000)*** | 0.680 (0.000)*** | 0.735 (0.000)*** | 0.683 (0.000)*** |
| REER | 0.508 (0.000)*** | 0.433 (0.004)*** | 0.570 (0.000)*** | 0.693 (0.000)*** |
| GOVT | 0.228 (0.000)*** | 0.314 (0.000)*** | 0.237 (0.000)*** | 0.193 (0.000)*** |
| Observations | 112 | 109 | 108 | 113 |
| Max threshold | 4 | 3 | 3 | 4 |
| No. of threshold | 1 | 1 | 1 | 2 |
| BIC Criteria | -350.2 | -362.2 | -336.1 | -399.2 |

*Notes:* *, **, **** denote statistical significance at the 10% level, 5% level and 1% level, respectively.

to Korhonen and Ledyaeva (2010), this impact is called the revenue effect. The effect states that a fall (rise) in oil prices, inevitably, worsens (improves) the oil-exporting nation's terms of trade. Invariably, this brings about a reduction (spike) in its oil revenues, a deterioration (improvement) in the balance of trade, together with a shrivelling up in both domestic consumption and nations' investment.

As for Indonesia, the impacts of higher oil prices do not always reflect those traditionally felt by oil exporters. The estimation results in TABLE 11 show that all three non-linear oil price specifications yield increase coefficients which are positively significant at 1 per cent when they (the Ω) are below USD47 (Regime 1). The impact is negative when these (the Ω) are above USD47 and statistically significant under the Mork's specifications but statistically insignificant under Hamilton's and Lee's specifications. The results of the linear model are similar to those of Malaysia; the real price of oil has a positive direct impact on Indonesia's RGDP at both thresholds (USD45 and USD109), thus contradicting the asymmetric price-GDP relationship established in previous studies (see Abeysinghe 2001 and Mansur 2015). On the contrary, the findings of the non-linear oil price specifications show that Indonesia is likely to gain more when oil prices are low (below USD47) than when oil prices are high (above USD47), which is inconsistent with the results of Artami and Hara (2018). This is not surprising, even though Indonesia is an exporter of oil. Rafiq et. al. (2016) argue that the oil exporters tend to benefit from the shrivelling oil prices provided that the quantity effect is higher than the price effect. This behavioural pattern in the oil exporters is further substantiated through robustness check. There exists a tendency for oil exports to grow significantly at times where the decline in oil price prevails. On the contrary, the negatively significant relationship between Indonesia's GDP and oil prices under the high oil price regime reflects the country's growing dependence on oil imports as local production declines, oil rents decline, and oil self-sufficiency deteriorates. These undoubtedly undermine Indonesia's ability to withstand the adversity of a positive shock in the oil price.

## CONCLUSION

This paper re-examines the non-linear oil price-GDP relationship for Malaysia and Indonesia using quarterly data for the period 1990-2018. The objective has been achieved in five steps. Firstly, all dependent and regime-independent variables are level non-stationary but first-difference stationary. Secondly, it shows the existence of a long-term relationship (i.e. a co-integrating relationship) between variables. Thirdly, the paper finds evidence of an asymmetric relationship among co-integrated variables for all nonlinear specifications. Fourthly, the F-test rejects the null hypothesis that there is no threshold, suggesting that there is at least one threshold. Fifthly, the effect on the GDP, of oil prices variability, in the long-run is estimated using Hansen's (2000) threshold regression allowing for more than one threshold. The asymmetry of oil prices' impact on GDP is examined by dividing the changes in oil prices into positive and negative changes according to each non-linear specification. The findings suggest two thresholds (or three regimes) for Malaysia when applying Mork's and Lee's specifications and one threshold (or two regimes) for Indonesia when using all three non-linear specifications. Regression results show that unanticipated changes in oil prices negatively affect Malaysia's GDP when oil prices are below USD 37 but positively affect GDP when oil prices are between USD 37 and USD 55. For Indonesia, GDP responds positively to changes in oil prices when oil prices are below USD47 but are negatively correlated with GDP when oil prices are above USD47.

Malaysia's GDP response to oil price shocks is consistent with the empirical conclusion commonly derived from oil-exporting countries. Malaysia's economy is growing as oil prices rise above USD 37, as oil price increases boost government revenue, leading to higher output. However, the effect of the price of oil on GDP is negative (though statistically insignificant) when oil prices exceed the USD55 threshold, suggesting that any government benefits are significantly offset by indirect export impacts as growth slows in major trading partners. TREG estimates for Indonesia reveal a fresh finding; Indonesia's GDP invariably benefits from low oil prices but is adversely affected as oil prices rise above the USD47 threshold. As an oil-exporting nation, this result is inconsistent with those reported in the literature. In fact, it reflects the effects that commonly prevailed among oil-importing nations that higher oil prices act antagonistically to output growth. Although it was Rafiq et. Al (2016) who provide valuable insight into how oil exporters can benefit from low oil prices, declining oil production and increased oil consumption appears to play a stronger role in reducing Indonesia's ability to shield itself from positive oil shocks. As the contribution of the oil and gas industry to state revenues fell sharply from 14 per cent in 2014 to 3 per cent in 2016, the Indonesian Government was forced to reduce domestic fuel subsidies over the period 2009-2014, while multiplying efforts to find renewable energy sources so as to reduce dependence on oil, hence the detrimental effect of oil price fluctuations to the economy.

A number of policy implications stem from the findings. Sensible public policy formulation is much needed to manage the adverse impact-effects on the Malaysian and Indonesian economies, due to oil price fluctuations, particularly, during unforeseen random events and crises. The financial development of nations is adversely affected by oil dependence (Badeeb et. al.

2016). It is therefore appropriate for both countries to foster the level of oil dependency at a manageable level low, while intensifying diversification efforts on their economic activities and initiating (multiplying) new sector (the contribution of other sectors) to GDP. For Malaysia, with its persistently low price of crude oil, the government has made efforts to reduce its dependence on oil-related revenues. Among others, these include the subsidy rationalization program started in July 2010 and the introduction of the Good and Service Tax (GST) scheme. Since its implementation in 2014, the collection of GST has contributed about 16.6 per cent of the total government revenue. Notwithstanding the recent abolition of GST in favour of Sales and Service Tax (SST), the forecast reduction in tax collection must be offset against other sources. The Malaysian Government should continue focussing on increasing the production of existing oil and gas fields as well as exploration and development opportunities in deep-sea areas. For example, in 2010, tax and investment incentives under the Petroleum Income Tax Act (PITA) were implemented to promote oil and gas exploration activities (Rahim and Liwan, 2012).

Despite its glorious past as a member of the OPEC, Indonesia has had the nation's resources allocated to the consolidation of its renewable energy industry. Currently, ranked third as the world's largest contributor of geothermal energy (International Energy Agency (IEA), 2015), the Energy Ministry of the Republic plans to raise the geothermal output potential to 5,000 MW by 2025. Essentially, the rise in the new energy potential effectively reduces Indonesia's oil dependence. In a 2017 report, the International Renewable Energy Agency (IRENA) also stated that, by 2025, Indonesia has set a target of achieving 23 per cent of its total energy supply from her prospective renewable energy sources and, by 2050, this will be raised to 31 per cent. IRENA also notes that the achievement of this goal could soon see economic benefits spilt over to the country. These include reducing the costs of energy systems, as well as the costs of air pollution and carbon dioxide emissions, which will help the country save up to USD 53 billion annually by 2030, or around 1.7 per cent of its estimated GDP by 2030 (IRENA 2017).

Finally, this study focuses on the impact of oil price shocks on GDP in both Malaysia and Indonesia from 1990 to 2018. Since then, both countries have undergone significant changes from net exporters of petroleum to net importing countries. These significant changes are however not included in the study and as such further research is therefore required to examine their effects. This will help to further analyse the important policy that needs to be addressed on the basis of this issue. In addition, factors that may contribute to a different link between the oil price shock and GDP shock for both countries should also be considered in the future analysis. The strength of government and financial institutions may also contribute to this relationship.

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APPENDIX

Shocks in Oil Price and Real Price of Oil (2017 USD/bbl)