Bulletin of Monetary Economics and Banking, Vol. 23 No. 2, 2020, pp. 253 - 268
p-ISSN: 1410 8046, e-ISSN: 2460 9196

ASYMMETRIC EFFECT OF CRUDE OIL AND PALM OIL PRICES ON INDONESIA'S OUTPUT

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ABSTRACT

This paper empirically examines the impact of the price of crude oil petrol and palm oil on Indonesia's output. Using quarterly data from 2000Q1 to 2019Q2 and both linear and non-linear autoregressive distributed lag approaches to cointegration, we find: 1) a significant non-linear effect of oil prices on the country's output; 2) a decline in prices of oil can have a greater impact on the country's output as compared to an increase in oil prices; and 3) the palm oil price changes have a bigger effect on the country's output compared to petroleum price.

Keywords: Oil price; Palm oil; Non-linear autoregressive distributed lag model.
JEL Classifications: C22; E30; E31.

Article history:
Received : November 21, 2019
Revised : March 31, 2020
Accepted : April 02, 2020
Available online : June 30, 2020

https://doi.org/10.21098/bemp.v23i2.1304

I. INTRODUCTION

This paper empirically examines the link between oil prices and economic activities in Indonesia. Oil prices have shown significant fluctuations in the international market over the last two decades. For instance, crude oil petroleum price oil has fallen from US$140 in July 2008 to US$32 in June 2016, per barrel[1]. As oil is one of the essential commodities used across the world, any changes in its price will have a severe repercussion on economic performance. Oil importers may benefit from a decline in prices by saving the energy import bill and an improvement in their current account position, which enhances economic activities and thus output (Garg and Prabheesh, 2017). In contrast, oil exporters may face an adverse effect due to the reduction in export earnings. In the case of oil-exporting countries, the adverse effect is multifaceted from output to external sector stability.

Indonesia, one of the members of Organization of the Petroleum Exporting Countries (OPEC), has undergone significant changes in its role in the international market. Historically, Indonesia has been active in the oil and gas sector after its first oil discovery in North Sumatra in 1885. Due to the decline in production of oil, the country suspended its membership from OPEC in 2008, reactivating it in 2016, and again suspending it in 2018 (OPEC, 2019). Moreover, increased consumption of oil in the country, along with a decline in production, has resulted in Indonesia being a net oil importer since 2004. These facts indicate that the country has experienced an adverse effect due to the fluctuations in oil prices in recent years.

Similarly, Indonesia is the largest exporter of palm oil and contributes 55% to the global palm oil exports. Similarly, the share of palm oil exports to total exports also increased from 12% in 1990 to 26% in 2019 (OECD, 2019). It is argued that palm oil satisfies more than 30% of global demand for vegetable oil (Pirker et al., 2016), and 61% comes from Indonesia (Saleh et al., 2018). In recent years, these vegetable oils have been increasingly used to make biodiesel, and hence the demand for palm oil has increased significantly (Purnomo et al., 2020). Figures 1 and 2 depict the trends in crude petrol and palm oil prices along with real GDP growth during the 1991-2019 period. It can be observed that both oil prices exhibit high fluctuations, and the GDP growth co-moves with the two oil price levels. For instance, the country's economic growth has decreased along with the decline in two oil prices in 2009, and in the post-2014 period. During the 2010-2019 period, the country's current account balance moved from a surplus to a deficit and the revenue from the oil and gas sector dropped considerably from 15.42% to 7.38% of total revenue (PWC, 2019). These observations indicate a country's exposure to oil price fluctuations or shocks, which is exogenous in nature[2]. Given this backdrop, the present study examines the effect of oil prices, such as crude petroleum and palm oil, on Indonesia's economic performance. More specifically, the study investigates the asymmetric response of Indonesia's output to oil prices; that is, we study the response of Indonesia's output to both an increase and a decrease in oil prices.

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[1] Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma. Source: U.S. Energy Information Administration.

[2] It is argued that in recent years oil price movements were mainly driven by demand factors rather than supply side disturbances. Furthermore, Garg and Prabheesh (2018) have argued that oil-importing EMEs show greater vulnerability to oil price shocks.

Figure 1.
Trends in Petrol Price and Output growth

The figure presents the trends in oil price along with real GDP growth of Indonesia. The crude oil price is proxied by the West Texas Intermediate (WTI) and measured in US$ per barrel The data come from the website of Bank Indonesia and U.S. Energy Information Administration.

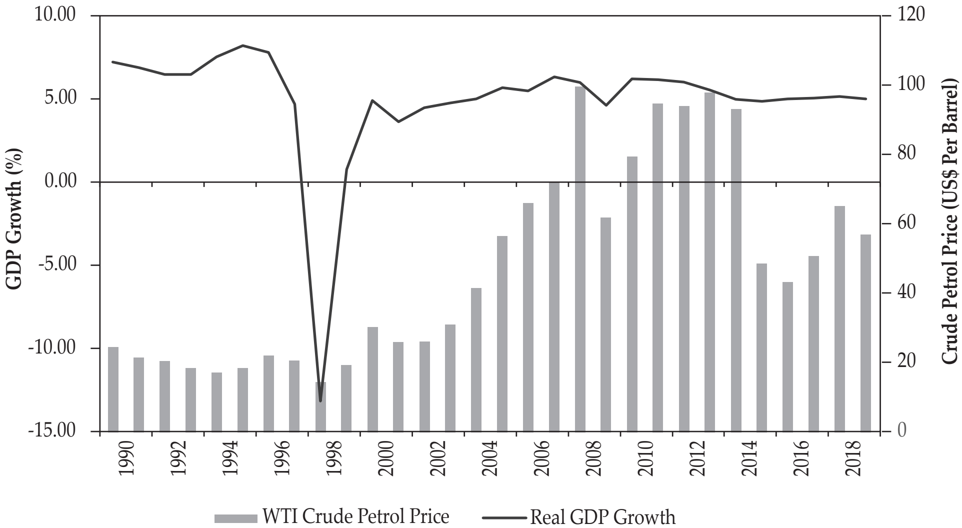
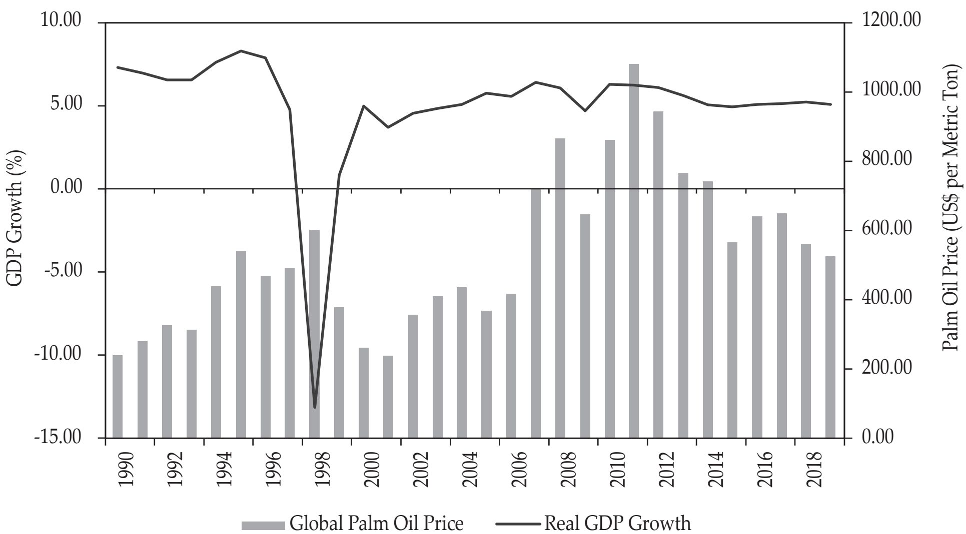


Figure 2.
Trends in Palm Oil Price and Output Growth

The figure presents the trends in global palm oil price along with real GDP growth of Indonesia. The palm oil price is measured in U.S. dollars per Metric Ton. The data come from the website of Bank Indonesia and International Monetary Fund.



The literature related to the impact of oil prices on economic activities is vast, and the key papers have found that the oil price fluctuations affect the macroeconomic performance of the oil-importing countries (See Hamilton,1983, 2008; Kilian, 2009; Narayan et al., 2014). However, the issues related to impact of oil prices on oil-exporting (and importing) countries is not given adequate attention in the literature. It is argued that any changes in oil prices would affect aggregate demand of an economy as it redistributes income between net oil importing and exporting countries (Ftiti et al.,2014). As the government's expenditure oil-exporting economies mainly depend upon revenue from the oil sector, any fluctuations in oil prices lead to variations in its spending and hence affect the output. Many studies find the evidence of pro-cyclical fiscal policy stance of the government in oil-exporting countries and a deterioration of budgetary positions during oil price booms owing to expansions in government expenditures and visa-verse (Villafouerte and Lopez-Murphy, 2009). Oriakhi and Osaze (2013) find that oil price fluctuations affect the growth of the Nigerian economy adversely through government expenditure level. Ebrahimi (2011) finds that uncertainty in oil shocks adversely affects GDP growth in oil-exporting countries, such as Algeria, Iran, Saudi Arabia, and Venezuela. Similarly, evidence also suggests that oil price has affected economic growth of Russia (Polbin et.al, 2019), Saudi Arabia (Aloui et.al, 2018) and emerging market economies (Kataryniuk and Martínez-Martín, 2019)[3].

Similarly, recent studies show evidence of asymmetric effects of oil price shocks on output growth; that is, adverse shocks have a higher impact on output growth compared to positive shocks, in economies such as Iran and Kuwait (Eltony and Al-Awadi, 2001; Delavari et al., 2008). Their results indicate that declining oil price decreases output growth severely, but rising oil price does not increase the economic growth by as much as the decline. Similarly, Iyke (2019) finds an asymmetric response of real output to oil price uncertainty in the case of Nigeria, i.e. a positive uncertainty leads to a decline in output, whereas negative uncertainty leads to a rise in output. Likewise, the asymmetric response of output to oil price is found to be in ASEAN five countries by Kisswani (2019) and in Brazil by De Oliveira et.al (2019).

There have been limited studies, which address the impact of oil prices on economic performance in the context of Indonesia. The existing studies analysed the oil petroleum price effect on exchange rate (Narayan et.al, 2019) and palm oil price effect on exchange rate (Aprina, 2014). Similarly, oil price is found to be an important determinant of domestic inflation (Ismaya and Anugrah, 2018). Sharma et al. (2019) find that the oil price predicts the movements of 31 macroeconomic variables, including economic growth for Indonesia. However, these studies did not consider the asymmetric impact of oil price fluctuations on Indonesia's output. Similarly, the effect of palm oil prices on economic activities is unknown from the existing literature. Hence, the present study addresses explicitly: 1) the role of petroleum crude oil and palm oil prices on Indonesia's output growth; and 2) any asymmetric effect of oil price changes on Indonesia's output growth. In order to address these issues, we test for a long-run relationship between oil price and output, using linear and non-linear Autoregressive Distributed Lag (ARDL and

[3] The recent studies specifically addressed the issues related to the Covid-19 pandemic and energy markets (Apergis, Apergis,2020; Fu and Shen, 2020; Gil-Alana and Monge, 2020; Qin et.al, 2020; Liu et.al, 2020; Narayan, P. K. 2020; Devpura and Narayan, 2020; Huang and Zheng, 2020; Prabheesh, Padhan, Salisu and Adediran , 2020; Garg, 2020; Iyke, 2020).

NARDL) models. Our findings show that the standard linear ARDL model fails to find a co-integration relationship between these two variables. When non-linearity in the relationship is accounted, we find evidence of a co-integrating relationship. We also find that palm oil price changes have a higher effect on the Indonesia's output compared to petroleum prices. Moreover, a decline in palm oil price in the international market leads to a higher adverse effect on the Indonesia's output compared to petroleum prices. Hence, our findings contribute to the existing literature on oil price and economic activities by being the first paper to compare the relative effects of palm and petroleum prices on output.

The following sections are structured as follows. Section 2 describes the empirical model and data. Section 3 discusses the empirical methodology, and section 4 presents empirical findings. Section 5 concludes.

II. EMPIRICAL MODEL AND DATA

We estimate the following four equations to examine the effect of oil price on output.

$$Y_t = \beta_0 + \beta_1 Wit\_Oil_t + \varepsilon_t \tag{1}$$

$$Y_t = \alpha_0 + \alpha_1 Palm\_Oil_t + \epsilon_t \tag{2}$$

$$Y_t = \beta^+ Wit\_Oil^+{}_t + \beta^- Wit\_Oil^-{}_t + \varepsilon_t \tag{3}$$

$$Y_t = \beta^+ Palm\_Oil^+{}_t + \beta^- Palm\_Oil^-{}_t + \varepsilon_t \tag{4}$$

where *Y* represents output, proxied by real gross domestic product (*GDP*); and *Wit_Oil* and *Palm_Oil* represent prices of crude petroleum oil and palm oil prices, respectively. Equations (1) and (2) represent the symmetric or linear effects of oil and palm oil prices on output. Equations (3) and (4) represent the asymmetric or non-linear effect of crude oil and palm oil prices on output, respectively. In Equations (3) and (4), the oil prices are decomposed into their cumulative sum of positive and negative shocks. Our choice of explanatory variables in these equations are influenced by the works of Kilian (2008), and Kilian and Vigfusson (2011a), who find that oil price is the key determinant of output growth. Similarly, oil price affects the output growth in a nonlinear way (Hamilton, 2003; Kilian and Vigfusson, 2011b).

Equations (1) and (2) are estimated using a linear ARDL technique whereas Equations (3) and (4) are estimated using a non-linear ARDL method. We used quarterly data from 2000Q1 to 2019Q2 for the analysis. The data are drawn from the website of the Bank Indonesia, the Federal Reserve Bank of St. Louis, and the International Monetary Fund. The oil prices are measure in real terms, i.e., deflated using the US consumer price index. All variables are converted into logarithmic form before estimation.

III. RESEARCH METHODOLOGY

A. BDS Test

Before employing the NARDL methodology, we examine whether there is any non-linearity present in the variables by employing the test for detecting non-linearity developed by Brock et al. (1987, 1996), known as BDS test (hereafter). The BDS test was designed to test the null hypothesis of independent and identical distribution (iid) in order to detect non-linearity and non-random chaotic dynamics and have power against a wide range of linear and nonlinear alternatives (Brock et al., 1991). When it is applied to the residuals from a fitted linear time series model, it allows the detection of remaining dependence and the presence of omitted nonlinear structure in the model. The use of BDS is advantageous because it is static, which does not require any distributional assumption on the data to be tested. The computational procedure of BDS can be written as follows:

Given a time series x_i for t = 1, 2, 3, 4 … … … . ,Z 2, 3, 4………, Z s m-history as $x_t^m = (x_t, x_{t-1}, \dots .. x_{t-m+1})$.

The *m* dimensional correlation integral can be estimated as follows:

$$C_{m,\in} = \frac{1}{Z_m(Z_m-1)} \sum_{m \le s < z \le Z} \sum I\left(x_t^m, x_s^m; \in\right)$$

Where, Z_m = Z_m + 1 and *I*(.) is the indicator function which is equal to 1 if $|x_{t-i} - x_{s-i}| < \in$ for I = 0, 1, ……, *m* - 11 and 0 otherwise.

It is estimated using the joint probability as follows:

$$\Pr(|x_t - x_s| < \in, |x_{t-1} - x_{s-1}| < \in, \dots \dots, |x_{t-m+1} - x_{s-m+1}| < \in)$$

The BDS test statistic can be stated as:

$$BDS_{m,\in} = \sqrt{Z}\,\frac{C_{m,\in} - C_{1,\in}^m}{s_{m,\in}}$$

Where, $s_{m,\in}$ is the standard deviation of $\sqrt{Z} C_{m,\in} - C_{1,\in}^m$. The BDS test is a two-tailed test and, under fairly moderate conditions, the test convergences in distribution to *N*(0,1).

B. Nonlinear ARDL (NARDL) test

The asymmetric ARDL or nonlinear ARDL model is proposed by Shin et al. (2014) for detecting nonlinearities and they focus on the long-run and short-run asymmetries among variables in the model. Nonlinear ARDL is an asymmetric extension of the linear ARDL approach to cointegration developed by Pesaran et al. (2001). The NARDL captures the asymmetric short-run and long-run dynamics through the distributed lag and single common cointegrating vector, respectively. It provides greater flexibility in relaxing the assumption of the same order integration of time series data and allows for a combination of I (0) and I(1) variables in the estimation. Besides the estimation simplicity, it is capable of distinguishing between the absence of cointegration, linear cointegration and nonlinear cointegration. Overall, the test provides better testing for cointegration in the small samples.

The general form of ARDL model can be defined as follows:

$$\Delta y_t = c + \delta y_{t-1} + \beta x_{t-1} + \sum_{i=1}^{m-1} \beta_i \, \Delta y_{t-i} + \sum_{i=0}^{m} \gamma_i \, \Delta x_{t-i} + \varepsilon_t$$

The non-linear regression can be interpreted as follows:

$$y_t = \gamma^+ x_t^+ + \gamma^- x_t^- + u_t$$

Where, γ^+ and γ^- are the long-run parameters and x_t is the k x 1 vector of regressors decomposed as:

Where, x_t^+ and x_t^- are the partial sum of positive and negative changes in the x_t.

$$x^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} \max\left(\Delta x_i \, , 0\right)\Bigg)$$

and

$$x^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} \min\left(\Delta x_i \, , 0\right)\Bigg)$$

By incorporating the x^+ and x^- to the ARDL(p, q) model, the non-linear error correction model can be obtained as follows:

$$\Delta y_t = c + \delta y_{t-1} + \beta^+ x_{t-1}^+ + \beta^- x_{t-1}^- + \sum_{i=1}^{m-1} B_i \Delta y_{t-i} + \sum_{i=0}^{m} \left(\varphi_i^+ x_{t-i}^+ + \varphi_i^- x_{t-i}^-\right) + \varepsilon_t$$

Where, Δ and ε_t are the first difference operator and the white noise term, respectively.

$$\varphi_i^+ = -\delta\gamma^+ \text{ and } \varphi_i^- = -\delta\gamma^-$$

The empirical analysis of the models follows various steps which can be summarized as follows:

I. Establishment of a long-run relationship between the levels of the variables i.e. y_t, x^+ and x^- with the use of a modified F tests and the bound-testing procedure developed by Pesaran et al. (2001) and Shin et al. (2014). This is referred to as the testing of joint null hypothesis $H_0: \delta = \beta^+ = \beta^- = 0$. The null hypothesis of no cointegration can be tested by the bounds test of Pesaran et al. (2001), which implies no long-run relationship among variables.

II. Using standard Wald tests, long-run symmetry, where, $\beta = \beta^{+} = \beta^{-}$) and short-run symmetry ($\varphi_i^{+} = \varphi_i^{-}$ or $\sum_{i=0}^{m} \varphi_i^{+} = \sum_{i=0}^{m} \varphi_i^{-}$) can be tested.
III. Finally, the use of asymmetric cumulative dynamic multiplier effects if a unit change in x^{+} and x^{-} on can be defined as $z_\rho^{+} = \sum_{i=0}^{\rho} \frac{ky_{t+i}}{kx_t^{+}}$ and $z_\rho^{-} = \sum_{i=0}^{\rho} \frac{ky_{t+i}}{kx_t^{-}}$, i = 0, 1, 2, ...0, 1, 2, …….asymmetric ARDL model.

If $\rho \to \infty$ then, $z_\rho^{+} = \gamma^{+}$ and $z_\rho^{-} = \gamma^{-}$. The asymmetric long-run coefficients are measured as $\gamma^{+} = -\beta^{+}/\delta$ and $\gamma^{-} = -\beta^{-}/\delta$.

IV. EMPIRICAL FINDINGS

A. Findings from unit root tests and BDS test

Before estimating the empirical models, we use augmented Dickey-Fuller (ADF) and Phillips–Perron (PP) tests to check the stationarity of the variables, and the results are reported in Table 1. The results indicate that all variables are non-stationary (i.e., I(1)) at levels, except *Palm_Oil* based on the ADF test, where it is found to be stationary (i.e., I(0)). In addition to these conventional tests, we employ the Narayan and Popp (2010) structural break unit root test that accounts for two endogenous breaks in the series[4]. Table 2 shows that the null of a unit root cannot be rejected in all variables, for models M1 (intercept) and M2 (intercept and trend). The evidence of a mixed order of integration of the variables, i.e., I(0) and I(1), from the above three unit root tests, allows us to employ the ARDL approach to cointegration for estimation. Similarly, the results obtained from the BDS test are reported in Table 3. This indicates that the null of linearity, i.e., independent and identical distribution, is rejected in all cases, showing evidence of non-linearity in these variables.

Table 1.
Results of Unit Root Test

The table shows the unit root test of the variables based on augmented Dickey-Fuller (ADF) and Phillips–Perron (PP). The null and the alternative hypotheses are that the series is non-stationary (contains unit root) and series is stationary (no-unit root), respectively. The test statistic of ADF and PP are compared with critical values tabulated by MacKinnon (1994) and MacKinnon (1996), respectively. Lags are selected automatically using Schwarz Information criterion (SBC). The sample period used is from 2000Q1 to 2019Q2. Where, *, ** denote rejection of unit root at 1% and 5% levels of significance, respectively. Finally, *Y*, *Wit_Oil*, *Palm_Oil* denote *output*, crude oil petrol price, and palm oil price, respectively.

Variables	ADF Test Statistic		PP Test Statistic	
	Levels	First Difference	Levels	First Difference
Y	-1.379	-6.714*	-1.326	-9.492*
Wit_Oil	-1.732	-9.336*	-1.480	-9.271*
Palm_Oil	-3.048**	-7.763*	-2.503	-7.604*

[4] The Narayan and Popp (2010) test is a superior test than the conventional structural break unit root tests in detecting the break dates more accurately. The Narayan-Popp test has better size and power properties and is invariant to the magnitude of the break and (Narayan and Popp, 2013). The test is widely implemented in recent empirical literature to accurately identify the structural breaks (Garg and Prabheesh, 2020; Narayan et al., 2019; Prabheesh and Rehman, 2019; Prabheesh et al. 2020, among many others).

Table 2.
Narayan and Popp Unit Root Test

The table 2 shows the unit root test with structural breaks based on Narayan and Popp (NP). M1 and M2 denote the two model used for the NP test: Model 1 allows for the two endogenous breaks in the intercept and Model 2 allows for two endogenous breaks in each of the intercept and the trend. The critical values are taken from Narayan and Popp (2010, pp. 1429) and *, ** and *** represent the 1%, 5%, and 10% significance levels. The sample period used is from 2000Q1 to 2019Q2. Finally, *Y, Wit_Oil, Palm_Oil* denote *output*, crude oil petrol price, and palm oil price, respectively.

Variables	**M1**				**M2**			
	Test stat	**TB1**	**TB2**	**K**	**Test stat**	**TB1**	**TB2**	**K**
Y	-0.343	2008Q4	2013Q3	5	-0.494	2008Q4	2013Q3	5
	(-4.074)				(-3.811)			
Wit_Oil	-0.182	2008Q4	2015Q1	0	-0.460	2008Q4	2015Q1	1
	(-1.999)				(-4.377)			
Palm_Oil	-0.097	2008Q4	2009Q3	1	-0.268	2008Q4	2009Q4	1
	(-2.350)				(-4.158)			
Critical values for unit root test								
1%			5%			10%		
Model M1 (Break in Intercept only)								
−4.958			−4.316			−3.980		
Model M2 (Break in Intercept and Trend)								
−5.576			−4.937			−4.596		

Table 3.
BDS Test Results Embedding Dimension (m)

The table shows the BDS test results of the variables following Brock et al. (1987, 1996). The null and the alternative hypotheses are independent and identical distributed (iid), and not independently and identically distributed at all dimension, respectively. As the BDS test is a two-tailed test, we should reject the null hypothesis if the BDS test statistic is greater than the critical values. The sample period used is from 2000Q1 to 2019Q2. Finally, *Y, Wit_Oil, Palm_Oil* denote *output*, crude oil petrol price, and palm oil price, respectively.

Dimension	**2**	**3**	**4**	**5**	**6**
Y	45.50 (0.00)	48.68 (0.00)	52.42 (0.00)	57.27 (0.00)	59.17 (0.00)
Wit_Oil	25.14 (0.00)	25.49 (0.00)	26.05 (0.00)	26.88 (0.00)	27.38 (0.00)
Palm_Oil	49.68 (0.00)	52.90 (0.00)	57.17 (0.00)	63.56 (0.00)	64.92 (0.00)

B. Findings from ARDL and NARDL

The findings from the *F*-test reported in Table 4 suggest that the null of no cointegration cannot be rejected in the case of Equations (1) and (2) based on the linear ARDL model. In these cases, the calculated *F*-statistics are much smaller than the upper limit of the critical values. Based on NARDL, on the other hand, the *F*-statistics are higher than the upper limit of the critical values in the case of Equations (3) and (4), indicating that there exists a long-run relationship. The lack of cointegration observed from the linear ARDL model suggests that the presence of non-linearity can affect the cointegration results. Having established the cointegration relationship from NARDL test, the next step is to estimate the long-run coefficients of the equation by using the NARDL specification. The estimated long-run coefficients of NARDL models suggested by Schwarz lag selection criteria (SBC) are shown in Table 5.

Table 4.
Results of *F*-Test

The table reports the results for cointegration test based on the Auto Regressive Distributed Lag (ARDL) and the Non-Linear ARDL procedure developed by Pesaran and Shin (1999) and Pesaran, Shin and Smith (2001), Shin et al. (2014). The null hypothesis of no cointegration is tested against an alternative of cointegration. The sample period used is from 2000Q1 to 2019Q2. In the models, *Y*, *Wit_Oil*, *Palm_Oil* denote *output*, crude oil petrol price, and palm oil price, respectively. Similarly, *Wit_Oil*$^+$ and *Wit_Oil*$^-$ represent decomposed cumulative sum of positive and negative shocks of crude oil petrol price. Likewise *Palm_Oil*$^+$ and *Palm_Oil*$^-$ denote decomposed cumulative sum of positive and negative shocks of palm oil price.

Models		Optimum lag (SBC)	Calculated F-statistic	Critical values 95% level	
				I(0)	I(1)
ARDL					
Equation 1	$Y_t = \beta_0 + \beta_1 Wit\_Oil_t + \varepsilon_t$	4	0.885	3.623	4.16
Equation 2	$Y_t = \alpha_0 + \alpha_1 Palm\_Oil_t + \epsilon_t$	4	1.110	3.623	4.16
NARDL					
Equation 3	$Y_t = \beta^+ Wit\_Oil^+{}_t + \beta^- Wit\_Oil^-{}_t + \varepsilon_t$	4	6.659	3.10	3.87
Equation 4	$Y_t = \beta^+ Palm\_Oil^+{}_t + \beta^- Palm\_Oil^-{}_t + \varepsilon_t$	4	11.153	3.10	3.87

Table 5 shows the long-run effect of both oil prices (*Wit_Oil* and *Palm_Oil*) by decomposing them into two partial sum series. Since the variables used in the model are measured in natural logarithmic form, the coefficients of these variables represent the elasticity of the dependent variable with respect to each independent variable. The long-run coefficients for *Wit_oil*$^+$ and *Wit_Oil*$^-$, associated with Equation (3), are found to be 0.114 and 0.175, respectively. This implies that a 1% increase in crude oil price leads to an increase in output by 0.114%, whereas a 1% decrease in oil price is associated with a reduction in output by 0.175%. This suggests that the decline in oil price has a greater impact on output as compared to an increase in oil price. A Wald test to examine the statistical significance of the difference in these coefficients, rejects the null of equality between these two coefficients. This implies the presence of asymmetry in the long-run relationship between oil price and output.

Likewise, the long-run coefficients obtained from Model 4, show that the palm oil price affects the output significantly. The coefficients associated with *Palm_Oil*$^+$ and *Palm_Oil*$^-$ are found to be 0.242 and 0.282, respectively. It can also be observed that the impact of a decline in palm oil price on output is higher than an increase in palm oil price. The Wald test further confirms the presence of asymmetry in the model. While comparing models 3 and 4, it can be observed that the size of the impact of the palm of price on output is larger than the crude petrol price. This finding implies the greater importance of the palm oil market in determining economic activities over the crude petrol market in Indonesia. As Indonesia is one of the largest exporters of palm oil in the global market, and its share to total exports is higher than crude oil, any changes in the prices of palm oil in the international market can significantly affect the economic activities in the country. Our findings suggest that the adverse shocks to palm oil prices in the international market affect the country more as compared to adverse shock to crude oil prices.

Table 5.
Long-run Coefficient Estimates by the NARDL Approach

The table reports the long-run coefficients estimated by Non-Liner Auto Regressive Distributed Lag (NARDL) approach to cointegration. The *, ** and *** denote statistical significance at 1%, 5 % and 10% levels, respectively and values in parenthesis indicate standard errors. The sample period used is from 2000Q1 to 2019Q2. In the regressions, *Y*, *Wit_Oil*, *Palm_Oil* denote *output*, crude oil petrol price, and palm oil price, respectively. Similarly, Wit_Oil^{+} and Wit_Oil^{-} represent decomposed cumulative sum of positive and negative shocks of crude oil petrol price. Likewise $Palm\_Oil^{+}$ and $Palm\_Oil^{-}$ denote decomposed cumulative sum of positive and negative shocks of palm oil price. Here, Wald test denotes the test for long-run symmetry. Equations (1) and (2) are not estimated as no cointegration is found between oil prices and output.

Regressor	Equation 3	Equation 4
Wit_Oil^{+}	0.114 (6.328)*	
Wit_Oil^{-}	0.175 (4.121)*	
$Palm\_Oil^{+}$		0.242 (8.530)*
$Palm\_Oil^{-}$		0.282 (5.142)*
Constant	10.372 (7.354)*	10.444 (5.343)*
Wald test	6.112*	8.836*

The short-run dynamics estimated by the error correction representation of the NARDL are reported in Table 6. The signs of the short-run coefficients are consistent with previous findings and the impact of a decline in palm oil price is found to be higher than that of crude petrol price. The error correction terms (ecm_{t-1}) are significant at 1 percent level in both models and have the expected sign. The estimated coefficient of error correction term ranges from -0.25 to -0.43 indicating that around 25% and 43% of the deviation from equilibrium is eliminated within one quarter. The diagnostics statistics reported do not show any serial correlation and ARCH effects in the residuals of the error correction model. Further, the models also confirm normality of the residuals. Moreover, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) on the recursive residuals do not show evidence of any instability of the coefficients across sample periods.

Table 6.
Error Correction Representation for the NARDL Model

The table report the short-run coefficients estimated by Non-Linear Auto Regressive Distributed Lag (NARDL) approach to cointegration. In these regressions, Y denote *output*. Similarly, Wit_Oil^{+} and Wit_Oil^{-} represent decomposed cumulative sum of positive and negative shocks of crude oil petrol price. Likewise $Palm\_Oil^{+}$ and Wit_Oil^{-} denote decomposed cumulative sum of positive and negative shocks of palm oil price. Equation 1 and 2 are not estimated as no cointegration is found between oil prices and output. Where Δ and ecm_{t-1} denote first difference and error correction term, respectively. Similarly χ^2_{AC} and χ^2_{Arch} are LM statistics for serial correlation and for ARCH effect at lag 4, respectively. Likewise χ^2_{Norm} are the LM statistic for normality in residual at lag 4. The * denotes statistical significance at the 1% level, respectively. Figures in square brackets show t-statistics and in parenthesis shows level of significance. CUSUM and CUSUMQ are tests for stability of the coefficients across sample periods.

Variables	Equation 3	Equation 4
	NARDL (1,0,3)	NARDL (1,0,2)
$\Delta\ Wit\_Oil^{-}$	0.055 (4.719)*	
	0.025 (0.424)	
$\Delta\ Wit\_Oil^{-}_{t-1}$	0.135 (2.430)*	
$\Delta\ Wit\_Oil^{-}_{t-2}$		0.174 (2.797)*
$\Delta\ Palm\_Oil^{-}$		0.184 (2.957)*
$\Delta\ Palm\_Oil^{-}_{t-1}$	-0.252 (-3.244)*	-0.435 (-6.823)*
ecm_{t-1}	0.35	0.45
χ^2_{AC}	0.613 [0.544]	0.345 [0.709]
χ^2_{Arch}	1.308 [0.256]	1.642 [0.174]
χ^2_{Norm}	0.619 [0.733]	1.942 [0.378]
CUSUM	Stable	Stable
CUSUMQ	Stable	Stable

V. CONCLUSIONS

The Indonesian economy has been dependent on crude oil and palm oil production over the last few decades. Fluctuations in these oil prices can affects Indonesia's economic activities. Given this, the present study examines the relative importance of crude oil WIT price and palm oil price on the Indonesian economy using data over the 2000 to 2019 period. The study addresses the asymmetric impact of these oil price changes on Indonesia's economic activities. Using the NARDL approach, our empirical findings suggest that both crude oil and palm oil price changes in the international market have a significant effect on the country's output. Since Indonesia is exports these oil, an increase in oil prices is found to be associated with an increase in output. However, the presence of asymmetry in the relationship reveals that a decline in prices of these oils can have a greater impact on output compared to an increase in oil prices. Moreover, our empirical findings support the vital role of palm oil prices in determining production. A reduction in palm oil price can adversely affect Indonesia's economic activities. It is, therefore, crucial to improve the efficiency and productivity of the palm oil sector to insulate the country's exposure to adverse oil price shocks.

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