Oil Palm Industry Economic Journal Vol. 24 (1) March 2024 p. 20-30
DOI: https://doi.org/10.21894/opiej.2024.03

THE IMPACT OF ASYMMETRIC RELATIONSHIP BETWEEN CRUDE OIL AND PALM OIL PRICES ON THE PALM OIL INDUSTRY

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ABSTRACT

The implementation of the palm biodiesel blend mandate in Malaysia has created new demand for palm oil, thus making the prices of both crude oil and palm oil move in tandem. Generally, the increase in demand for biodiesel products has resulted in a reduced supply of palm oil, which in turn has increased the price of crude palm oil (CPO) in the world market. However, the unpredictability of price movement which is highly influenced by the market situation and sentiment sometimes makes the relationship between both prices loosen. The motivation of this study is to analyse the relationship between Brent crude oil (BCO) and CPO using a non-linear autoregressive model (NARDL) for the period 2010-2019. By applying the Brock Dechert and Scheinkman (BDS), this study indicated the presence of the non-linearity relationship between BCO and CPO price. The bound tests with NARDL specification confirmed the asymmetric association between CPO price movements and their relation to positive and negative changes in BCO price. The estimated NARDL model confirmed the existence of an asymmetric relationship in the changes in CPO prices. This study found that in the long run, there is a significant relationship between the increase in BCO prices and CPO prices while no significant relationship between the decrease in BCO prices to CPO prices in the long run. In the short run, only the changes in BCO prices positively affect palm oil price inflation. The findings of this study are imperative to the industry players especially to the biofuel producers and exporters since changes in CPO price will directly affect their profitability and cost of production.

Keywords: asymmetry, crude oil prices, palm oil prices, NARDL.

Received: 8 December 2023**; Accepted:** 12 March 2024**; Published online:** 27 March 2024.

INTRODUCTION

Vegetable oils are plant-based oils. The consumption of vegetable oils can be divided into two categories which are edible oil for food and non-edible oil for non-food applications. In 2020, almost 132 of the total 235 million tonnes of vegetable oils produced in the world correspond to palm and soybean oils (Oil World, 2021). Malaysia is one of the major producers of world vegetable oil, namely crude palm oil (CPO). Vegetable oil prices move closely due to the substitutions of its applications with one another. Apart from that, a number of researchers have reported the correlation between vegetable oil prices and crude oil prices (Alam *et al.*, 2019; Campiche *et al.*, 2007; Cheng and Cao, 2019; Hanif *et al.*, 2021; Karakotsios *et al.*, 2021; Mokni and Youssef, 2020; Oluseun, 2021; Pal and Mitra, 2018; Priyati and Tyers, 2016). The usage of vegetable oil for biodiesel implementation mandate is one of the factors driving the relationship between vegetable oil prices and crude oil prices. Palm oil price is determined by the forces of supply and demand of vegetable oils thus making the producers an important role as price takers. Being a price taker is causing the CPO price volatile and uncertain.

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The main producers of biodiesel are the European Union, United States, Indonesia and Brazil, which represent 80% of world biodiesel production in 2022. Palm oil has great potential in producing biodiesel. Apart from the environmental and renewable benefits, palm oil-based biodiesel oil is more economically competitive than fossil fuels and other vegetable oil-based biofuels. However, it should be noted that the biodiesel mandate has been largely supported by government subsidies. This is necessary because the price of biodiesel is generally higher than the price of diesel oil.

This mandate would not happen without government intervention. It should be emphasized that government interventions have different effects in influencing the price of palm oil and other vegetable oils, whether they are positive, negative or have no effect at all. In other words, the uncertainty of this kind of situation increases the probability of non-linear relationships between markets especially as the study observed that the price of vegetable oil shows a significant increase in recent years.

The biodiesel policy has implications for the price of palm oil. For example, the level of biodiesel production in Indonesia has a direct effect on the global market of palm oil and vegetable oil prices. It is well known that Indonesia is the world's leading producer and exporter of palm oil, and palm oil is the vegetable oil most consumed by the world's population. Therefore, the biodiesel policy set by the Indonesian government to support the local biodiesel industry has put pressure on the availability of palm oil supply in the global market and subsequently affects the price of palm oil and other vegetable oils.

Figure 1 shows the evolution of the biodiesel implementation for the transport sector in Indonesia which is regulated by the Ministry of Energy and Mineral Resources (MEMR). The biodiesel industry in Indonesia started in 2008 with a B1 blending mandate (content of 1% palm-based biofuel, 99% petroleum oil), followed by B2.5 in 2010 until 2014. However, this mandate changed in 2013 with a higher blend target which was B10 in 2013 compared to the initial target of B2.5 and increased to B20 starting in 2015. However, the bio-fuel blending target in 2015 was lowered from B20 to B15 due to the sudden drop in crude oil prices resulting in a significant increase in the gap between the two prices further threatening the competitiveness of the biodiesel industry in Indonesia. Currently, Indonesia has implemented the B35 blending mandate.

As mentioned before, there have been a number of researchers who have sought to determine the relationship between crude oil prices and vegetable oil prices. However, there are only a few studies concerning the volatility movement factor (Chowdhury *et al.*, 2021; Ibrahim, 2015; Olasunkanmi and Oladele, 2018). This has given a different view and interpretation of the relationship between crude oil and agricultural commodity prices, particularly palm oil prices. In short, this paper has studied the relationship between Brent crude oil prices and palm oil prices. At the same time, this study will also explain the important role of biodiesel in the price movement.

Oils and fats are extracted either from plants or animals or fish oil. According to Oil World, there are 17 types of oils and fats in the world market. Palm oil, soybean oil, sunflower oil and rapeseed oil are the most consumed and mainly traded oils and fats in the international market. *Figure 2* shows the trend of consumption of oils and fats in the world is increasing as the population increases year on year basis. Besides, the world consumption of oils and fats has remarkably increased by only 1.0 million tonnes in 2000 to 2.5 million tonnes in 2023. In other

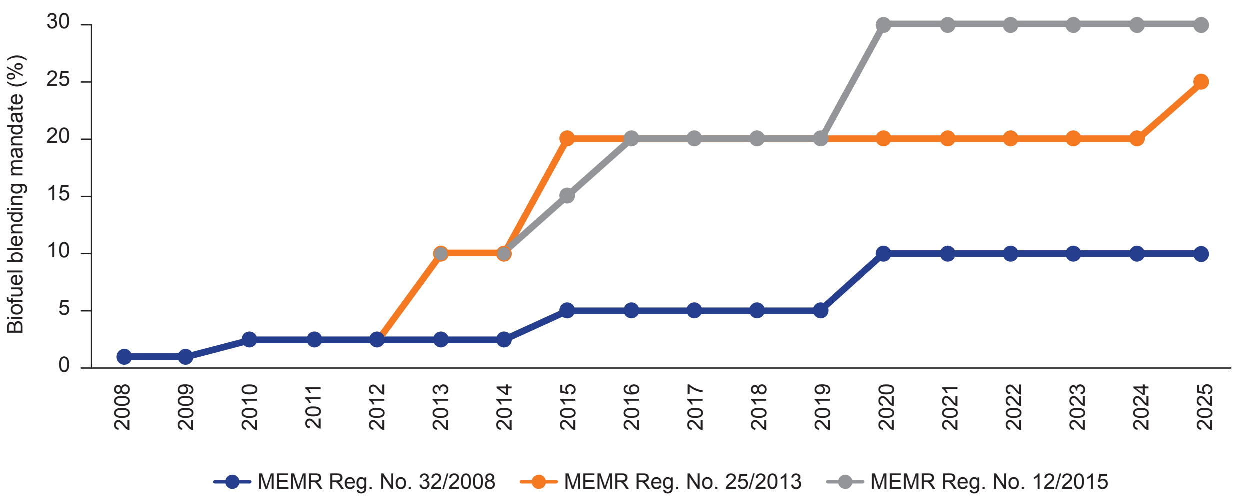
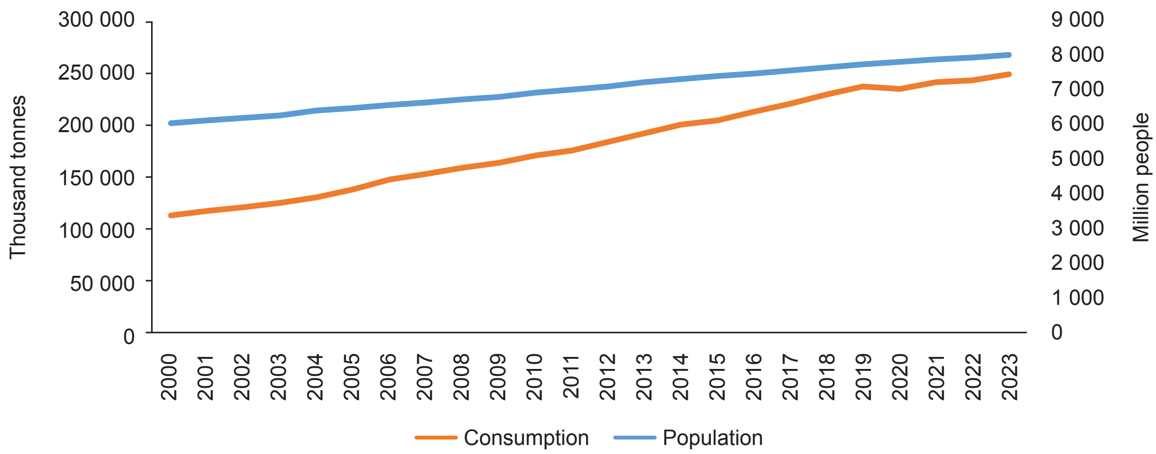


Figure 1. Biodiesel blending mandate for transportation sector in Indonesia.

words, the oils and fats consumption by one person in this world is twice as high in 2023 as compared to in 2000. The increasing trend especially for the four major oils is in line with the increasing number of world population. Thus, with the expectation that the world population will continue to increase exponentially, demand for these major oils is expected to continue to increase substantially in the future.

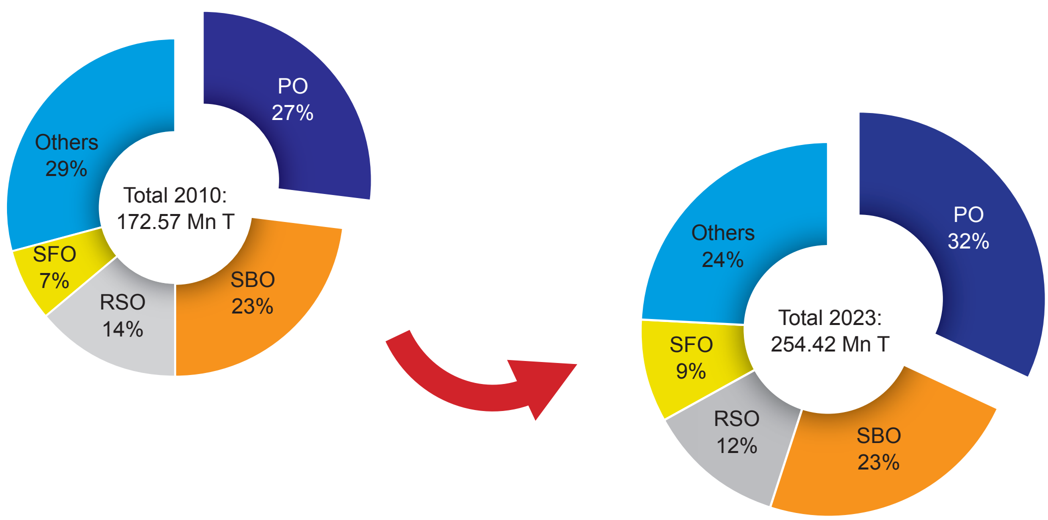
Figure 3 shows the breakdown of vegetable oil production in 2023 as compared to 2010. In 2023, 90.0% of the world's total vegetable oil production of 254 million tonnes are produced by the four main vegetable oils where palm oil (PO) is the main contributor (32.0%) followed by soybean oil or SBO (23.0%), rapeseed oil or RSO (12.0%) and sunflower oil or SFO (9.0%). Palm oil has become the leading vegetable oil, surpassing the production of soybean oil since 2003. Palm oil production has increased by 47.4% from year 2010-2023.

Malaysia's CPO industry is an export-oriented industry with at least 80% of palm oil exported compared to local consumption of only less than 20% (*Figure 4*). For 2022, the export of palm oil and other palm-based products has increased by 0.44 million tonnes or 1.8% to 24.72 million tonnes compared to 24.28 million tonnes in 2021. The five (5) main export markets for Malaysian palm oil are India, China, the European Union, Türkiye and Kenya, with a total export of 7.72 million tonnes or 49.1% of Malaysia's total palm oil exports (MPOB, unpublished data).



Source: World Bank (2024); MPOB (Unpublished data).

Figure 2. Oils and fats consumption vs. *world population 2000-2023.*



Source: MPOB (2021).

Figure 3. World production of 17 oils and fats, 2010 vs 2023.

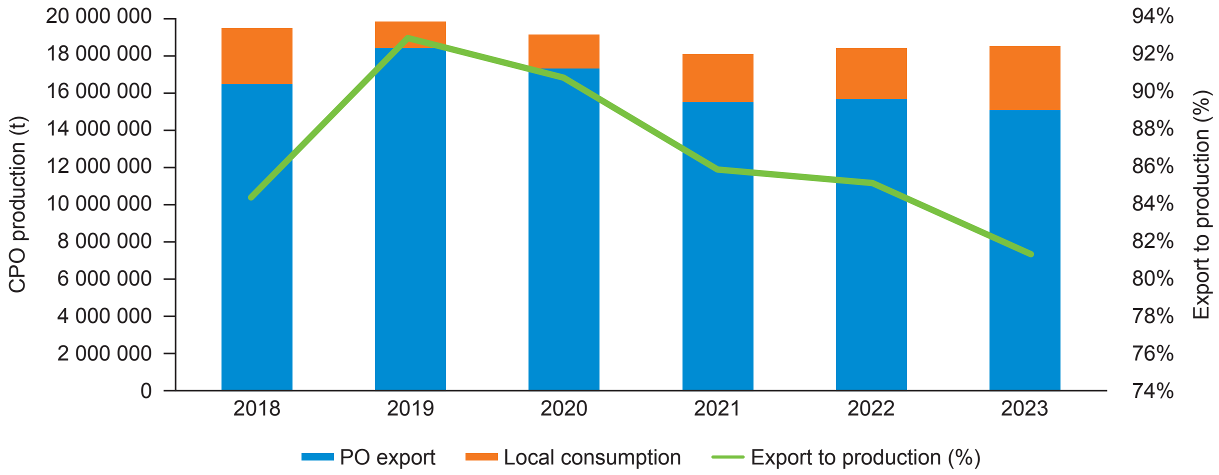


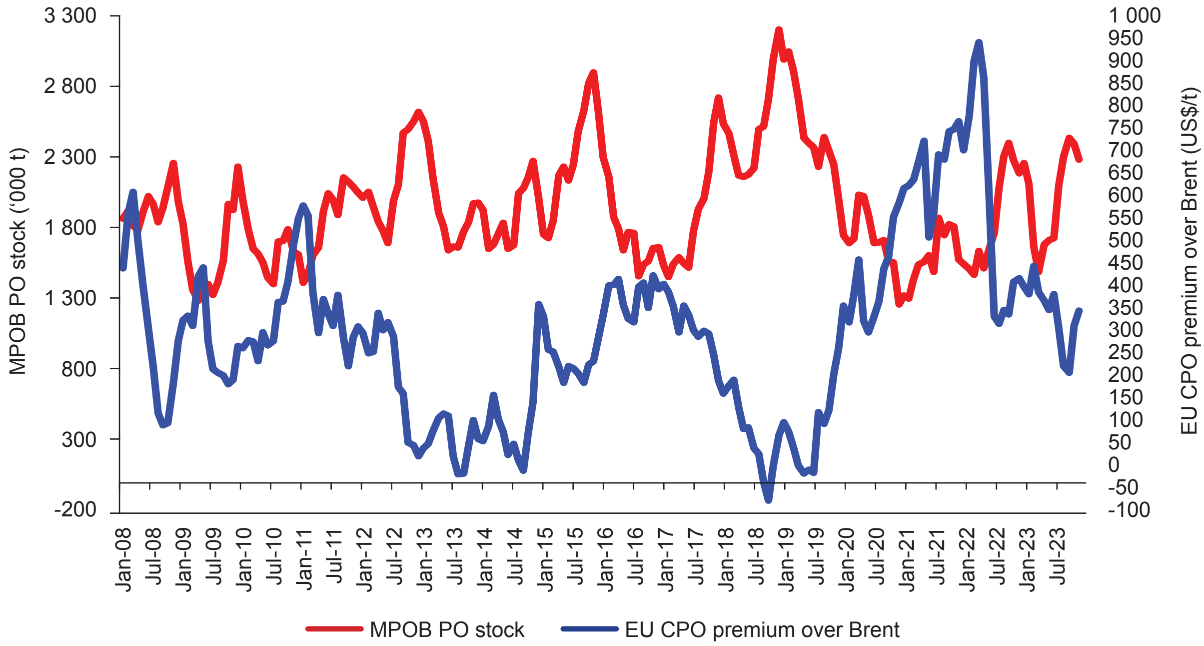
Figure 4. Export and local consumption of Malaysian palm oil.

The local demand for vegetable oils cannot be met due to the rapid increase in population thus most countries rely on trading activities. Changes in demand are also influenced by economic and political uncertainties as well as changes in the structure of import and export taxes. An increase (decrease) in demand will cause prices to increase (decrease). In addition, production, imports and net supply are important elements in determining supply. Production, imports and net supply are negatively affected by palm oil prices. High supply availability of palm oil and other vegetable oils in the market will influence a low palm oil price.

Furthermore, vegetable oil prices are also closely related to the world's crude oil prices. The argument on the relationship between vegetable oil price and the world crude oil price became stronger when the biodiesel programme was introduced in March 2006 voluntarily (Abdullah *et al.*, 2009). Since then, most of the time the movement of crude oil and other major vegetable oil prices are almost similar thus attracting the interest of researchers to understand the real relationship of these prices. There are a lot of arguments regarding the relationship between crude oil prices and major vegetable oil prices, which have led to many studies conducted on these topics. *Figure 5* below shows the relationship between the world's crude oil price and the Malaysian final stocks (closing stocks) of palm oil. The increase in world crude oil prices will be closely followed by vegetable oil prices, especially palm oil and soybean oil prices. However, the price of palm oil is found to be more competitive than that of other vegetable oils. As a result, palm oil consumption and trade were found to be higher, thus resulting in the final stocks of the oil being reduced as compared to the consumption and trade of other vegetable oils due to uncompetitive prices and *vice versa*.

There have been a number of longitudinal studies involving the relationship between crude oil and vegetable oil prices that have been reported, for instance, the study by Yu *et al.* (2006) stated that shocks in crude oil prices have a significant influence on the variation of edible oil prices. Campiche *et al.* (2007) examined the co-variability between crude oil prices and corn, sorghum, sugar, soybean, soybean oil, and palm oil prices in which the study found that soybean prices seem to be more closely correlated to crude oil prices rather than corn prices. Correspondingly, Wei and Chen (2016) also found that the changes in vegetable oil prices are significantly influenced by the changes in crude oil prices. Besides that, Songsiengchai *et al.* (2018) found that there is evidence for a causal relationship that runs from the world's crude oil price to the Thai CPO price, but not *vice versa*. Furthermore, Zafeiriou *et al.* (2018) which focused on the relationship between agriculture commodities and crude oil prices confirmed that crude oil prices affect the prices of agricultural products that are used in the production of biodiesel, as well as of ethanol, validating the interaction of energy and agricultural commodity markets. In general, most of the studies have indicated that there is a relationship between crude oil and vegetable oil prices.

Ayatollah *et al.* (2017) have explained that the use of palm methyl ester as a raw ingredient for palm-based biodiesel has resulted in world crude oil prices influencing CPO prices. The strength of the relationship between these two oils depends on the world market situation. Strong ties occur when the world crude oil prices are at a high level. Thus, biodiesel products are more competitive in the international market. However, the increase in demand for biodiesel products has resulted in a reduced supply of palm oil, which in turn has increased the price of CPO in the world market. In addition, the relationship between these two



Source: MPOB (Unpublished data).

Figure 5. Price of CPO and BCO vs. *Palm Oil Stocks.*

oils can be seen when the world crude oil prices are at low levels. This makes biodiesel products less competitive in the market as a result of the much cheaper diesel prices. Santeramo and Searle (2019) have agreed that a significant increase in the use of vegetable oils in biodiesel products has increased the demand for vegetable oils, and in turn, resulted in the increase in vegetable oil prices. Soybean oil and palm oil are substitutes or complementary oils. Changes in the demand for soybean oil for biofuel production have also resulted in changes in palm oil stocks. Subsequently, changes in the price of palm oil have also occurred in tandem. The implementation of the biodiesel programme has not only affected vegetable oil prices but has also influenced the food sector, for instance, Kochaphum *et al.* (2013) found that the implementation of the biodiesel programme from one angle has provided positive benefits to the vegetable oils industry. Nevertheless, the programme has encouraged farmers to prioritise the biofuel purpose rather than for food with the increased oil production indicating reduced local food production. Before this, Peri and Baldi (2010) also discussed the issue of the relationship between the vegetable oils market and biofuel policy, in which the surge in fuel prices increases the demand for biofuel, which subsequently decreases the supply and inventory of food. Besides, there was the depreciation of the USD Dollar that has led to a spike in the price of food. Even though biofuel improves the welfare of gasoline consumers and food producers, it has a significant negative effect on food consumers. Correspondingly, several studies have also found a similar indirect effect of the increasing fuel price on food prices through the demand for biofuel (Bentivoglio *et al.*, 2016; Ciaian, 2011; To and Grafton, 2015; Zhang *et al.*, 2010). Chungchild *et al.* (2012) have examined the factors influencing CPO pricing using the extreme value approach. The study showed that the growth rate of CPO and soybean oil prices have very extreme dependence. However, the growth rate between CPO and the world crude oil prices showed a weak interdependence or extreme non-dependence on each other. In contrast, the study by Shri *et al.* (2009) focused on the indirect effects between the biodiesel programme and the performance of the Malaysian palm oil trade. The study showed that biodiesel programmes indirectly have a significant impact on CPO prices.

Principally, the world crude oil prices are now one of the key elements in the CPO price equation of the impact of the biodiesel programme chain. Other than the demand and supply factors, the rise in CPO price movements is also influenced by market sentiments or price speculation. This factor can have a drastic impact on the price of CPO in a short period as compared to the basic factors of demand and supply. Besides that, the weather also influences the supply of palm oil, such as extreme *El Nino* and *La Nina* conditions, which bring extreme heat or excessive rainfall that also disrupts the supply, which in turn drives up prices of CPO.

MATERIALS AND METHODS

This section focuses on the framework of the study and the methodology of the data. A quarterly data set was collected from 2010 to 2022 to achieve the objective of the study. The data was sourced from the Monthly Oil World Reports 2010 to 2023. Variables used in the study were divided into three (3) elements, namely price, supply and demand elements. The data series were then transformed into natural logarithms. The technique used in this study was the Non-Linear Autoregressive Distributed Lag (NARDL) model. The functional framework of the study is as Equation (1):

$$CPO = f\ (price,\ supply,\ demand) \qquad (1)$$

CPO is the price of crude palm oil (CPO) traded internationally in USD per tonne. Meanwhile, the price element consists of Brent crude oil (BCO) price and soybean oil (SBO) price. The first implementation of the biodiesel programme back in June 2011 was B5 which consisted of 5% local refined, bleached and deodorised palm olein blended with 95% petrol diesel (Lim and Teong, 2010). In December 2014, the Government moved forward to implement the B7 programme. Then, in 2019 the B10 palm oil biofuel programme was implemented. Malaysia plans to implement the B20 palm oil biofuel programme by the end of 2022. Thus, this study will take into account these three programmes into the model to identify whether the BCO prices affected CPO prices in the same movement or not.

Supply-side elements that are believed to affect the price significantly are palm oil production (PROD) and palm oil closing stocks (POSTK). Finally, the demand elements consist of palm oil export (EXP) and soybean oil closing stocks (SBOSTK). The empirical framework of this study can be articulated as Equation (2):

$$CPO_t = \beta_0 + \beta_1 BCO_t + \beta_2 SBO_t + \beta_3 PROD_t + \beta_4 EXP_t + \beta_5 POSTK_t + \beta_6 SBOSTK_t + \varepsilon_t \qquad (2)$$

Based on Equation (2), the BCO price is expected to influence the CPO price positively. In other words, under a linear and symmetric setting as in Equation (2), CPO price responds to a change in BCO price during a soothing period and does not capture the downturn period. To achieve the objective, the asymmetric ARDL technique was employed following the method developed by Shin *et al.* (2014). The NARDL model is an advanced method from the ARDL model, which introduces the non-linearity of the series. For this study, the non-linear model can be articulated as Equation (3):

$$CPO_t = \alpha_0 + \alpha_1 BCO_t^+ + \alpha_2 BCO_t^- + \alpha_3 SBO_t + \alpha_4 PROD_t + \alpha_5 EXP_t + \alpha_6 POSTK_t + \alpha_7 SBOSTK_t + e_t \qquad (3)$$

Shin *et al.* (2011) improved ARDL developed by Pesaran and Shin (1999) to an advanced model; non-linear ARDL (NARDL). This model is capable of analysing asymmetric short and long-run relationships between variables. The concept of NARDL is to decompose the exogenous variable into a partial sum process. BCO^+ and BCO^- are the asymmetric long-run parameters in which the CPO price responds asymmetrically during up and down periods of BCO price as shown in Equation (4) and (5):

$$BCO_t^+ = \sum_{i=1}^{t} \Delta BCO_i^+ = \qquad (4)$$

and

$$BCO_t^- = \sum_{i=1}^{t} \Delta BCO_i^- = \sum_{i=1}^{t} min\ (\Delta BCO_i, 0) \qquad (5)$$

However, a few pre-tests need to be undertaken before conducting the NARDL model. Firstly, the stationary of the series will be determined by performing ADF and P-P unit root tests. Then to confirm the existence of non-linearity in the data series, the study conducts the Brock, Dechert and Scheinkman (BDS) test (Brock, *et al.,* 1996). BDS is a powerful tool that researchers frequently use for detecting serial dependence in a time series and is also often used as a diagnostic tool for the residual. The underlying null hypothesis is independent and identically distributed.

After confirming the existence of non-linear dependence, the study will then formulate the ARDL model. The optimum lag structure will be determined by reducing the highest insignificant lag, one by one until a minimum value of AIC and SIC (indication of optimum lag number) is reached. Next is to check for the robustness of the model and adequacy of the data, especially serial correlation and stability tests. A good estimation model needs to pass the diagnostic test for normality, heteroskedasticity and functional form by performing the LM test. In addition, the study will also do the CUSUM stability test.

The study then proceeds to estimate the extent of the impact of BCO price volatility on the price of palm oil using a non-linear framework by using Equation (6). It will then estimate the existence of cointegration in non-linearity by comparing the F-statistics with the lower and upper critical values by Pesaran *et al.* (2001) and Shin *et al.* (2011). The null hypothesis (no cointegration) will be rejected if F-statistics exceeds the upper bound. Shin *et al.* (2011) estimates from Equation (3) to ARDL procedure following Pesaran and Shin (1999) also Pesaran *et al.* (2001) as Equation (6):

$$\Delta CPOt = \alpha_0 + \alpha_1 BCO_t^+ + \alpha_2 BCO_t^- + \alpha_3 SBO_t + \alpha_4 PROD_t + \alpha_5 EXP_t + \alpha_6 POSTK_t + \alpha_7 SBOSTK_t + \sum_{i=1}^{p} \varnothing_i \Delta CPO_{t-i} + \sum_{i=1}^{q} (\theta_i^+ + \Delta BCO_{t-i}^+ + \theta_i^- \Delta BCO_{t-i}^-) + \sum_{i=1}^{r} \vartheta_i \Delta SBO_{t-i} + \sum_{i=1}^{s} \tau_i \Delta PROD_{t-i} + \sum_{i=1}^{t} \sigma_i \Delta EXP_{t-i} + \sum_{i=1}^{v} \rho_i \Delta POSTK_{t-i} + \sum_{i=1}^{w} \pi i \Delta SBOSTK_{t-i} + u_t \quad (6)$$

RESULTS AND DISCUSSION

Table 1 presents the results of the commonly used unit root test: ADF (Dickey & Fuller, 1979) and P-P test (Phillips and Perron, 1988). In order to comply with the bound testing procedure in which no I(2) variables are involved, the study first runs each time series to the ADF and P-P unit root tests. SIC is employed for the optimal lag order and constants with trend were included for testing "at level", meanwhile the study only included constants for the 1st difference unit root test. Based on ADF and P-P unit tests, all-time series are integrated of order 1 or I(1).

Table 2 shows the test of BDS to confirm the existence of non-linearity. The null hypothesis in the BDS approach is rejected as the test statistics are far bigger than the critical values. In other words, the series is linearly dependent and was rejected. The results suggested that Brent crude oil price is non-linearly dependent. Thus, the study is valid to imply NARDL for achieving the objective.

The study discovered the robustness and stability of the estimation model by performing some diagnostic statistical tests on the residuals. This is important to see the adequacy of the model specification. The result is stated in *Table 3*. The residual tests showed that the estimation was free from serial correlation by employing the LM test. The Jarque-Bera (J-B), which tests the error term, were also distributed normally. Meanwhile, the Breusch-Pagan-Godfrey (BPG) test is for detecting heteroscedasticity in the model. The result shows a score of 0.6199 with a probability value of 0.8125, which is greater than 0.5 of the value of the BPG test at a 95% confidence level. This showed the absence of heteroscedasticity or means that residuals are normally distributed. Estimation of the model's stability was investigated by applying a residual recursive residual test as proposed by Pesaran *et al.*, (2001), which is CUSUM and CUSUMSQ statistics for testing structural stability (*Figure 6*).

TABLE 1. UNIT ROOT TEST

Variable	At level		1st difference	
	ADF	PP	ADF	PP
CPO	-4.0986**	-2.9504	-4.3318***	-4.0944***
BCO	-1.7291	-1.8692	-5.2944***	-5.2944***
SBO	-2.4315***	-2.4950	-4.2609***	-4.2890***
POSTK	-4.7870	-2.4298	-3.3049**	-6.2042***
SBOSTK	-2.4753	-2.4804	-3.928***	-8.6671***
B5	-2.4968	-2.4758	-5.9161***	-5.9161***
B7	-0.8380	-0.8820	-5.9161***	-5.9161***

Note: CPO - Crude palm oil; BCO - Brent crude oil; SPO - Soybean oil; POSTK - Palm oil closing stocks; SBOSTK - Soybean oil closing stocks.

TABLE 2. NON-LINEARITY TEST

Dimension	LBCO				Residuals of LBCO (AR (1))			
	BDS Stat	Std. Error	Z-Stat	Prob.	BDS Stat	Std. Error	Z-Stat	Prob.
2	0.1264	0.0080	15.8100	0.0000	0.0382	0.0145	2.6280	0.0086
3	0.2184	0.0128	17.0322	0.0000	0.0808	0.0236	3.4241	0.0006
4	0.2453	0.0154	15.9281	0.0000	0.1029	0.0287	3.5876	0.0003
5	0.2521	0.0162	15.5643	0.0000	0.0813	0.0305	2.6634	0.0077
6	0.2619	0.0158	16.5953	0.0000	0.0917	0.0301	3.0506	0.0023

TABLE 3. STABILITY TEST

Variable	Coefficient	P-Value
Constant	8.7387	0.0000
CPO(-1)	-0.6819	0.0000
BCO+(-1)	0.0584	0.0678
SBO(-1)	0.2530	0.0436
POSTK(-1)	-0.4592	0.0001
SBOSTK(-1)	-0.2152	0.1010
B5(-1)	0.1314	0.0003
B7(-1)	0.0254	0.2864
ΔBCO+	0.3003	0.0118
ΔBCO+ (-1)	0.3185	0.0109
ΔSBO	0.9331	0.0000
ΔPROD	-0.4860	0.0000
ΔPROD(-1)	-0.2474	0.0001
ΔB5(-1)	-0.0617	0.0465
J-B	0.0757	0.9629
LM	1.6835	0.2085
Breusch-Pagan-Godfrey	0.6199	0.8125

Note: CPO - Crude palm oil; BCO - Brent crude oil; SBO - Soybean oil; POSTK - Palm oil closing stocks; SBOSTK - Soybean oil closing stocks; PROD - Palm oil production.

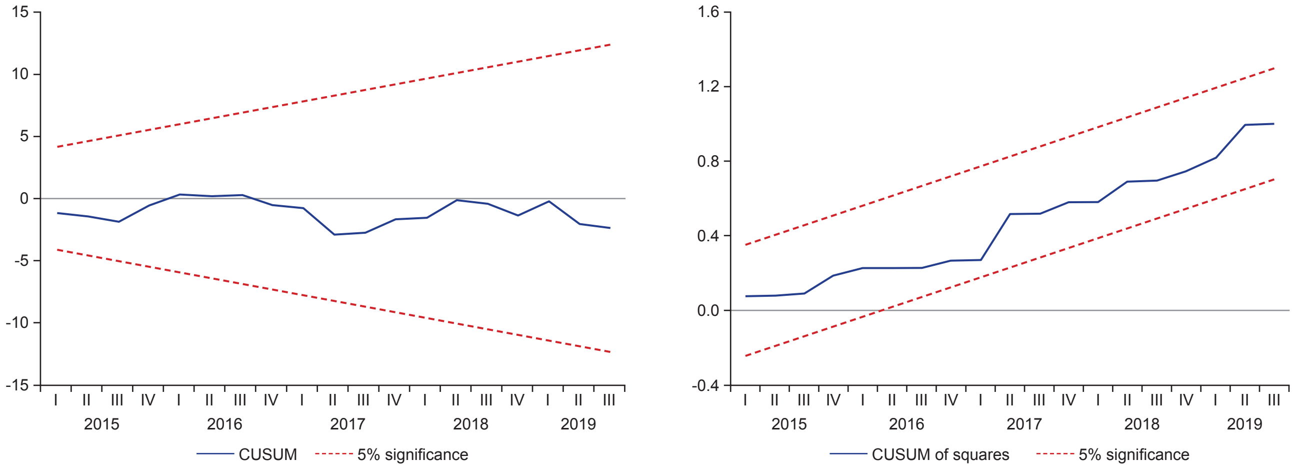


Figure 6. CUSUM and CUSUMSQ statistics.

From the bound test shown in *Table 4*, we conclude that in favour of asymmetric association between examined variables, the statistics 6.7707 exceed the critical upper bound. With this finding, we are in a position to assess crude palm oil price movements and their relation to positive and negative changes in BCO prices.

TABLE 4. BOUND TEST FOR NON-LINEAR

F-Statistics	95% lower bound	95% upper bound	Conclusion
6.7707	2.797	4.211	Cointegration

Notes: The critical values are from Narayan (2005), given the small sample size.

Table 5 discusses the empirical result of long-run nonlinear ARDL. As SBO and CPO are substitute oils, price changes in one oil will influence demand for the other. The study suggests that a 1.00% increase in SBO price will increase CPO price by 0.37%. Stocks are one of the supply elements. The lower the stocks, the better (higher) the price. Implementation of B5 in 2011 had a positive effect on CPO prices in the following year by 0.19%. In line with the main objective of this study, it showed that there is a significant asymmetric long-run relationship between CPO price and the increase in BCO price. Positive BCO price has a positive significant relationship with CPO price in the long run. The study suggests that a 1.00% increase in

BCO price will lead to a 0.09% increase in CPO price. Meanwhile, there is no significant relationship between the decrease in BCO prices and the changes in CPO prices.

In addition, the short-run nonlinear ARDL test is shown in *Table 6*. There is evidence of the presence of asymmetric. The study observed the significance of the positive change in BCO price. The change in the BCO price significantly influenced the CPO price to increase. A 1.00% increase in BCO price will immediately impact CPO price to increase by 0.32%.

CONCLUSION

This study provides conclusive evidence of the asymmetric relationship between crude oil and palm oil prices and how the asymmetric relationship impacts the palm oil industry. For this purpose, the study employed a nonlinear autoregressive methodology to confirm the asymmetric impact. To check the stationary properties of the variables, the study used ADF and P-P unit root tests. The result confirmed that all series were stationary at level I(0) and some after the first differencing I(1), concluding that no series is stationary at the second difference I(2). The BDS test applied rejected linearity of the examined variable. Next, to assess the magnitude of Brent crude oil price volatility in the non-linear framework, the study applied NARDL, breaking down the variable into positive and negative shocks. The estimated NARDL model confirmed the existence of an asymmetric relationship in the changes in palm oil prices. This study found that in the long run, there is a significant relationship between the increase in BCO prices and CPO prices while no significant relationship between the decrease in BCO prices to CPO prices in the long run. The study suggested that a 1.00% increase in BCO price will lead to an increase of 0.09% in CPO price. In the short run, only the changes in BCO prices positively affect palm oil price inflation. We anticipate our finding is vital for industry players especially to the biofuel producers and exporters since the changes in CPO price will directly affect their profitability and cost of production. This paper has shown that CPO price reacts significantly to an increase in BCO price, compared to a decrease in BCO price. Thus, it suggested that when Brent crude

TABLE 5. LONG RUN RELATIONSHIP

Variable	Coefficient	P-Value
Constant	8.7387	0.0000***
BCO+	0.0857	0.0614*
SBO	0.3710	0.0077***
POSTK	-0.6734	0.0000***
SBOSTK	-0.3156	0.0825*
B5	0.1928	0.0012***
B7	0.0372	0.2640

Note: ***, ** and * signify statistically significant at 1%, 5%, and 10%, respectively.
BCO - Brent crude oil; SBO - Soybean oil; POSTK - Palm oil closing stocks; SBOSTK - Soybean oil closing stocks.

TABLE 6. SHORT RUN RELATIONSHIP

Variable	Coefficient	P-Value
Constant	8.7387	0.0000
CPO(-1)	-0.6819	0.0000
BCO+(-1)	0.0584	0.0678
SBO(-1)	0.2530	0.0436
POSTK(-1)	-0.4592	0.0001
SBOSTK(-1)	-0.2152	0.1010
B5(-1)	0.1314	0.0003
B7(-1)	0.0254	0.2864
ΔBCO+	0.3003	0.0118**
ΔBCO+ (-1)	0.3185	0.0109**
ΔSBO	0.9331	0.0000***
ΔPROD	-0.4860	0.0000***
ΔPROD(-1)	-0.2474	0.0001***
ΔB5(-1)	-0.0617	0.0465**

Note: ***, ** and * signify statistically significant at 1%, 5%, and 10%, respectively.
CPO - Crude palm oil; BCO - Brent crude oil; SBO - Soybean oil; POSTK - Palm oil closing stocks; SBOSTK - Soybean oil closing stocks; PROD - Palm oil production.

oil increases, investors and biofuel producers should react to that positive shock to optimize higher profit from it.

The findings of this study benefit the stakeholders on the existence of a nonlinear relationship that revealed the question of 'why do palm oil prices surge even when there is a significant drop in crude oil prices especially during COVID-19?'. This is because the impact of positive change in crude oil price is higher than the effect of negative changes. Therefore, from a policy implication perspective, producing countries like Indonesia and Malaysia need to emphasise more local industries through increased efficiency and reduced production costs. This should reduce the impact of crude oil price shocks in the long run and act as a buffer to the impact of oil price fluctuations. Besides, in terms of monetary policy, the government is advised to monitor the policy changes in Indonesia, especially for their development of the biodiesel industry as it will not continue to rely on non-renewable energy sources for their country. This is important because Indonesia's action will have an impact on the fluctuation of palm oil prices and other vegetable oil prices. For future research, this is more beneficial if more empirical studies into similar agri-commodities in other producing countries with different biodiesel policy structures would link these results with market power and international trade policy.

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