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Factors affecting for sustainable improvement of palm oil industry in the world market: Ex-post forecast approach

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ABSTRACT
Currently, there is significant political and economic dependence on the palm oil industry in Malaysia, Indonesia, and Thailand. They are the most significant world producers and exporters. The objective of this study is to investigate the factors affecting the sustainable improvement of world production, consumption, and price in the palm oil market. This study employed a vector error correction model (VECM) along with an ex-post forecast approach. The data used monthly data from January 2014 to December 2019, covering 72 observations of pre-COVID-19 periods for analysis purposes. The study found that there were significant long-term relationships among the variables representing palm oil consumption, world population, and soybean oil price for palm oil price. Additionally, there were short-term relationships among exchange rates, palm oil production, and consumption for price. Changes in world total palm oil production are based solely on changes in world palm oil price. Moreover, changes in world total palm oil consumption are also based on world population, soybean oil price, and changes in world palm oil price. In summary, companies and governments that proactively implement sustainable measures will be better positioned to navigate regulatory challenges, maintain market access, and ensure long-term industry stability.

Contribution/Originality: The originality of this study provides insights to policymakers in devising short- and long-term strategies for the sustainable improvement of the increased global demand. The paper also supports comparable and unbiased results from testing the macro levels together with micro levels to learn about the prospective effects of the world palm oil industry.

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1. INTRODUCTION
Sustainability employs three interrelated 'pillars' encircling economic, social, and environmental factors or 'goals' (Purvis, Mao, & Robinson, 2019). Therefore, sustainable development has three dimensions: economic, social, and environmental, which are co-associated with each other if sustainable economic growth is achieved (Alaimo, Ciacci, &

Ivaldi, 2021). Among all three dimensions, the economic dimension is the most influential factor toward sustainable development (Holmberg & Sandbrook, 2019) and Khan, Zhang, Kumar, Zavadskas, and Streimikiene (2020). Amid the challenges from the post-pandemic recovery, strengthening economic development has become ever more important.

Palm oil remains robust in terms of its contribution to national economic development and the societal well-being of the palm oil-producing countries. Around 43.5 million metric tonnes (MT) were produced in Indonesia, making it the world's top producer and exporter in 2020–21 (Statista, 2021). Malaysia and Thailand were the second and third largest producers and exporters. Unsurprisingly, Indonesia and Malaysia have the largest certified palm tree areas (Figure 1).

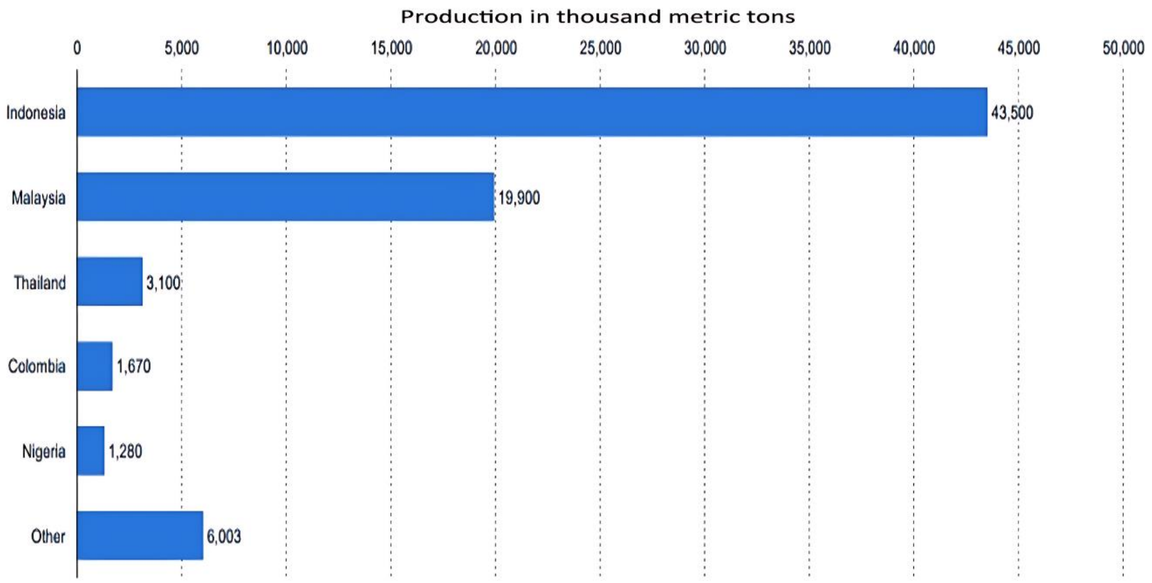

Figure 1. Palm oil top global producers 2020/21 (In 1,000 metric tons).
Source: Statista (2021).

Nevertheless, the Malaysian palm oil sector continues its struggle with the issue of sustainability. The continuous and recent remarks of the European Union (EU) remain one of the key distractors to the sector's global achievement. The Malaysian government has embarked on the Malaysian Sustainable Palm Oil (MSPO) Certification Scheme initiative to combat negative allegations and sentiments such as deforestation, unfriendly environmental approaches, and labor discrimination towards the local palm oil sector. These initiatives represent nationwide efforts in Malaysia aimed at endorsing palm oil plantations, independently managed smallholdings, and palm oil processing facilities according to the MSPO Standards. The ultimate aim of the initiative is;

> "To strengthen the global market's confidence in the sustainability of the country's palm oil industry and actively promote good agricultural practices among palm industry players, especially for oil palm smallholder farmers (particularly independent smallholders), this approach is essential in the sustainable management of the oil palm industry, particularly for small oil palm farmers, to meet the global certification requirements established by the Roundtable on Sustainable Palm Oil (RSPO)" (Siti-Dina, Er, & Cheah, 2023).

Malaysia's palm oil industry is going through a difficult time compared to Indonesia's. The main issue in Malaysia's palm oil industry is the fluctuating production of palm oil. According to Index Mundi, data shows that palm oil production in Malaysia has remained below 21 million MT for an extended period (Figure 1). In contrast, Indonesia's palm oil production reached 43.5 million MT in 2021 (Figure 1). The second issue Malaysia is currently facing in the palm oil market is labor exploitation. In December 2020, the United States (US) government announced that it was banning the importation of palm oil due to the involvement of a major producer in labor exploitation. The US-related department stated that the US will only lift the ban if any problem-solving remedies are taken or a reasonable explanation is provided.

Today, there are a lot of palm oil-based institutions organized by different parties from different countries. In Malaysia, the Malaysia Palm Oil Council (MPOC) and the Malaysia Palm Oil Board (MPOB) are palm oil institutions' delegates mainly used for research purposes. The Forum of Kelapa Sawit Berkelanjutan Indonesia (FoKSBI) and the Indonesian Palm Oil Association (IPOA) are the Indonesian versions of MPOB and MPOC. Besides that, in terms of global perspective, the Roundtable on Sustainable Palm Oil (RSPO) has about 4,000 members around the world, which encompass the entire supply chain of the palm oil industry from different countries to develop and implement global standards for sustainable palm oil.

Production is an action of manufacturing by converting an input material into an output to fulfill the demand of the consumer. These inputs could be raw materials or the labor force. It is a process of creating a physical item or services that intend to achieve the utility of the buyer (Kotler, Armstrong, Brown, & Adam, 2006). On the other hand, consumption refers to an action in which an individual or household purchases an item or service that the supplier provides to achieve utility. Consumption is the source of every economic activity that people produce for people to consume, according to mainstream economists (Carroll, 2021). According to Britannica (2018), price refers to a specific amount of money used to define what a product is worth. In today's economics, prices are typically expressed in different types of countries' currencies according to the money issued by the central bank. In economics, the neoclassical theory of price is the demand and supply theory, in which the demand and supply of the commodity determine the price. Figure 2 shows the global production and consumption volume of palm oil for the years from 2012/13 to 2020/21 and from 2015/16 to 2020/21, respectively.

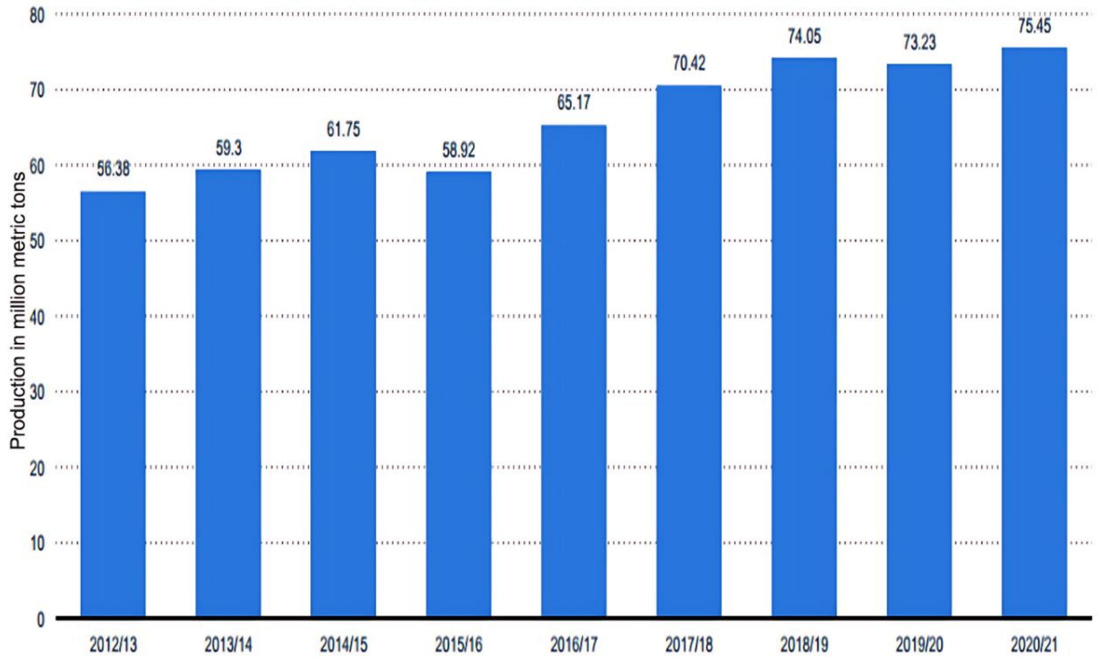

Figure 2 (a). Palm oil global production volume (1,000 metric tons).

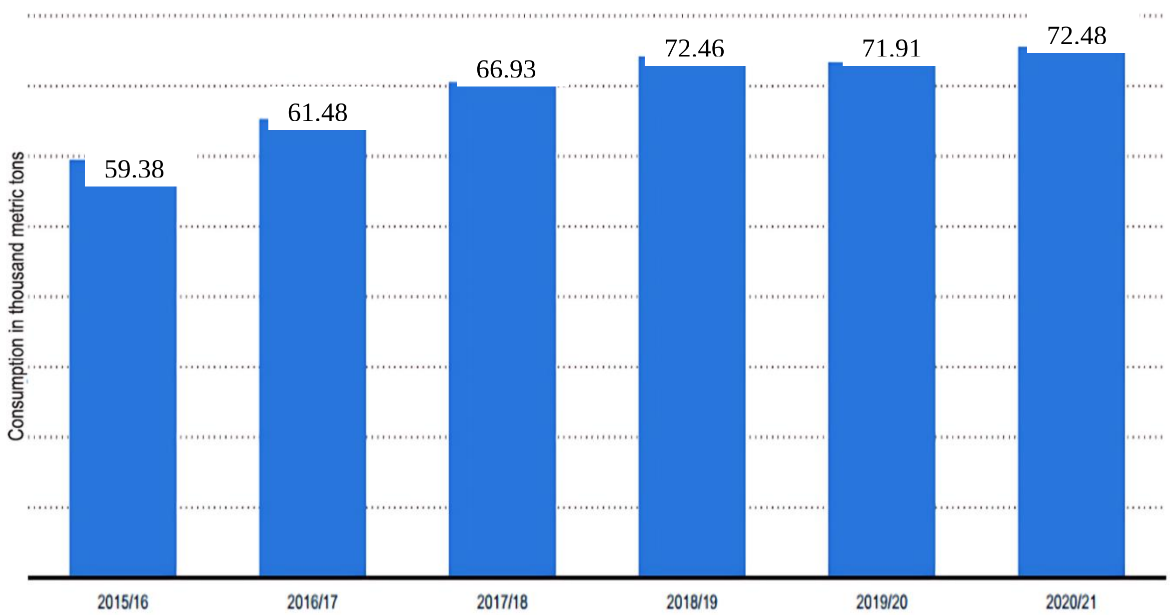

Figure 2 (b). Palm oil global consumption volume (1,000 metric tons).

Figure 2. Palm oil global production and consumption comparison.

Source: United State Department of Agriculture. USDA (2021).

The world production of palm oil was higher than the world consumption, as shown in Figure 2, indicating that the supply of palm oil was sufficient to cover the demand for palm oil in the world market. The world's highest palm oil consumption level was recorded at nearly 72 million MT in 2020/21, while the highest palm oil production level was recorded at nearly 75 million MT in 2020/21. Accordingly, the world population grew from 7.2 billion people to 7.7 billion people in 2019. In terms of world Gross Domestic Product (GDP) per capita in 2014, the world GDP per capita was recorded at 10,954 USD. After 2014, it went through a streak of decline for 2 years and increased again after 2016. In 2019, it recorded the highest GDP per capita among the years, which was at 11,417 USD.

Figure 3 shows the average world palm oil prices from 2014 to 2025. Before COVID-19, palm oil prices recorded their lowest price (601 USD/MT) in 2019 and increased to 749 USD/MT in 2023. The prediction for world palm oil prices is that they will increase from 763 to 777 USD/MT from 2024 to 2025 (World Bank, 2023). Figure 4 explains the comparison of world palm-oil price, soybean-oil price, and crude-oil price from 2014 to 2019 (Index Mundi, 2021).

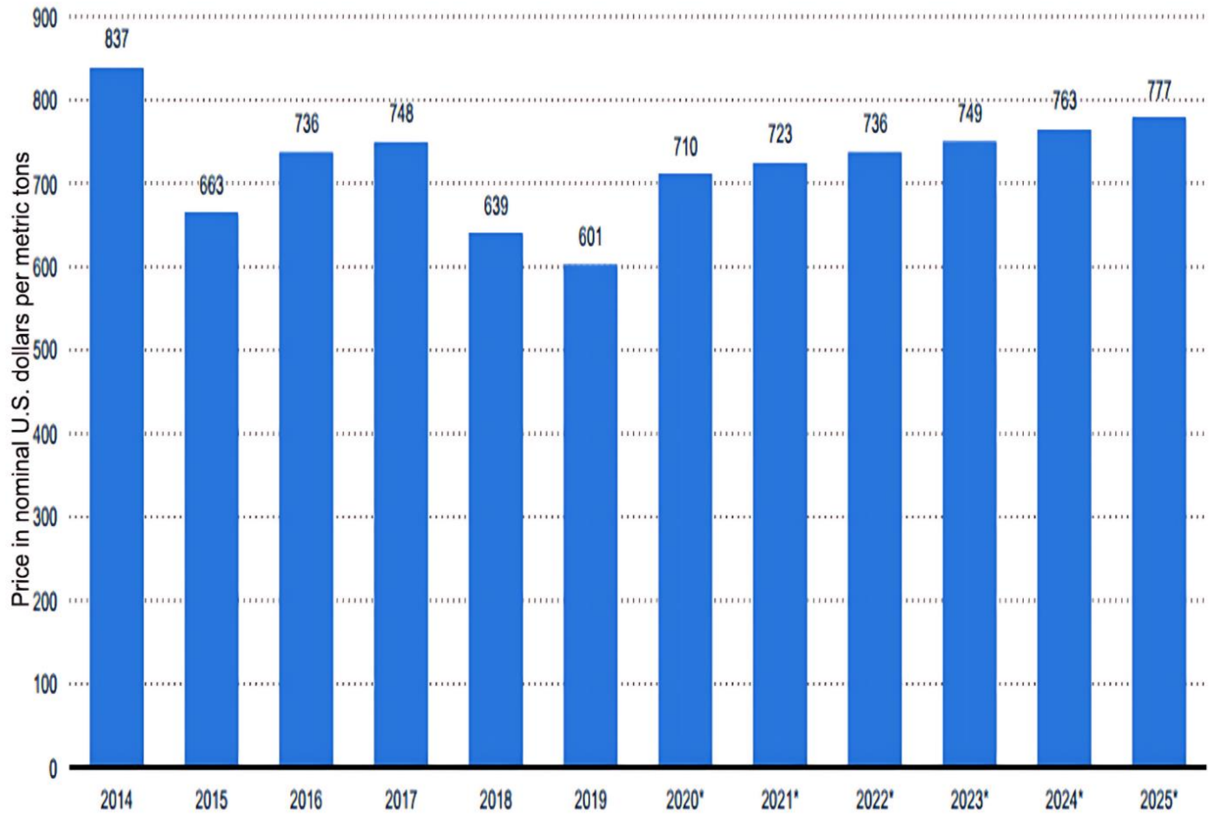

Figure 3. Worldwide average prices of palm oil (In nominal USD per metric tons).

Source: Statista (2023).

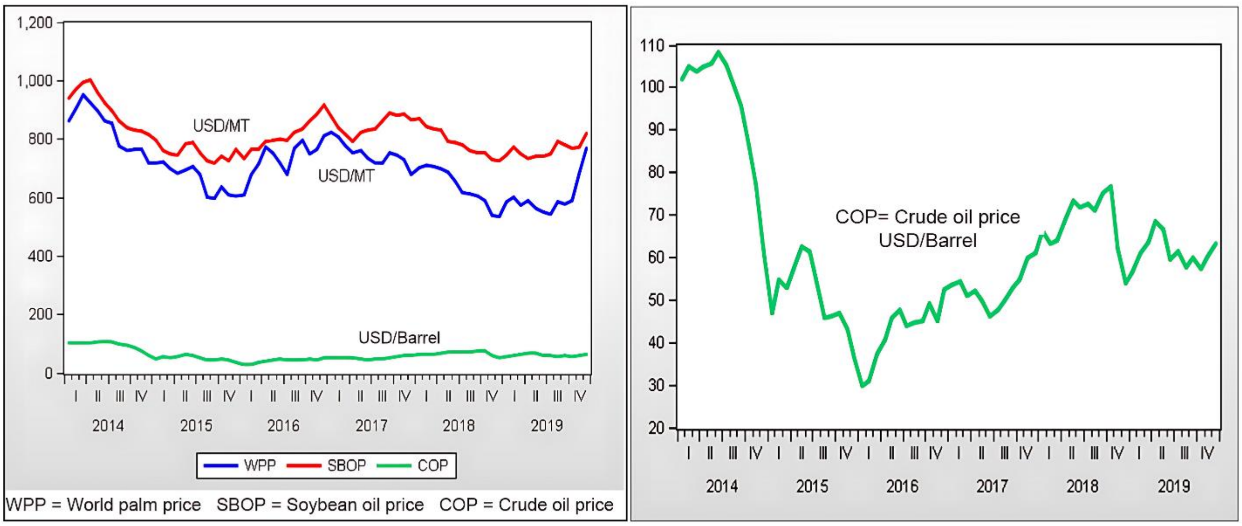

Figure 4. World palm oil, soybean oil and crude oil price (2014 to 2019).

Source: Index Mundi (2021).

Looking at the dynamics of palm oil and soybean oil prices over the years, these two commodities have demonstrated relatively stable trends compared to the fluctuating and declining trend observed in crude oil prices, which dropped from approximately $120 to $60 per barrel between 2014 and 2019. Among these three types of oils, crude oil prices exhibit the highest volatility. Overall, soybean oil has the highest price rate among the three types of oil, while crude oil has the lowest price rate during the major period. Moreover, the palm oil price has relatively lower price rate than soybean oil because palm oil production is more efficient compared to other vegetable oils, but not compared to crude oil.

Research on palm oil contributes significantly to human health and the longevity of people (Odia, Ofori, & Maduka, 2015). According to Muljaningsih (2019), the European Parliament defined Malaysian palm oil as a product that is environmentally unfriendly and ceased importing Malaysian palm oil into Europe by 2020. From the various issues surrounding this palm oil study, many useful results may have the potential to assist government policies on the sustainable development of the agriculture sector. Before implementing any policies, the government can assess the impact on palm oil production, consumption, and prices, and can tailor a suitable policy by referring to this study.

Moreover, this study also provides a general review and can serve as a reference for other researchers who want to examine the explanatory variables of palm oil production, consumption, and price. Due to the lack of studies that combine palm oil production, consumption, and price models, this study may be useful in filling these research gaps. However, much research still needs to be conducted in this palm oil-related field, such as a study on the non-Asian countries' palm oil production situation, as their palm oil production technology may improve. Therefore, this study aims to undertake an econometric analysis of global palm oil production, consumption, and pricing mechanisms by employing a vector error correction model (VECM) along with an ex-post forecast approach.

From a normal perspective, people will think that the relationship between the plantation area and production quantity is positively correlated. Yes, according to Syahza and Irianti (2021), when there is an increase in the plantation area of palm oil trees, even if it does not reflect technological progress or scientific advancements in related agricultural production, there is an increase in palm oil production. This indicates a rise in the yield of harvested palm oil fruits, which highlights a positive association between the planted area and the production quantity of palm oil. Essentially, if the palm oil plantation area in a specific region increases, the harvests of palm oil fruits lead to an uptick in overall production.

In the study of Indhushree and Shivakumar (2020), it was stated that the volatility of domestic production has a positive relationship with the tariff and import price of palm oil. If both producers and processors of palm oil benefited from the increased prices of palm oil, they increased their production and expanded their production scale to gain more profit following the rise in palm oil prices.

In the article by Rathour, Kumari, and Kumar (2021), they found that factors influencing oil consumption include income and population in India. They stated that in 2016, oil consumption by Indians had increased by 18 kg per annum due to the increase in population and income per capita. The study conducted by Dutta, Bouri, Saeed, and Vo (2021) stated that the crude oil volatility index (OVX) impacted the palm oil market. It mentioned that in 2014, the decrease in oil market prices had a negative impact on palm oil prices. Furthermore, the COVID-19 pandemic caused the OVX to decrease, implying a change in the palm oil price market.

Guei and Choga (2021) stated that when the exchange rate was at equal to or above 4.6%, it affected the prices of a commodity. Besides, they also found that when there was an increase in the real exchange rate, the commodity prices were positively affected. Syamni (2021) conducted a study on the effects of the COVID-19 pandemic on the palm oil industry. The research revealed that despite the depreciation of the Indonesian Rupiah caused by the pandemic, there was a surge in palm oil exports. This increase in export activity was attributed to the heightened price competitiveness of Indonesian palm oil. Consequently, the escalating export of palm oil drove up the price of palm oil.

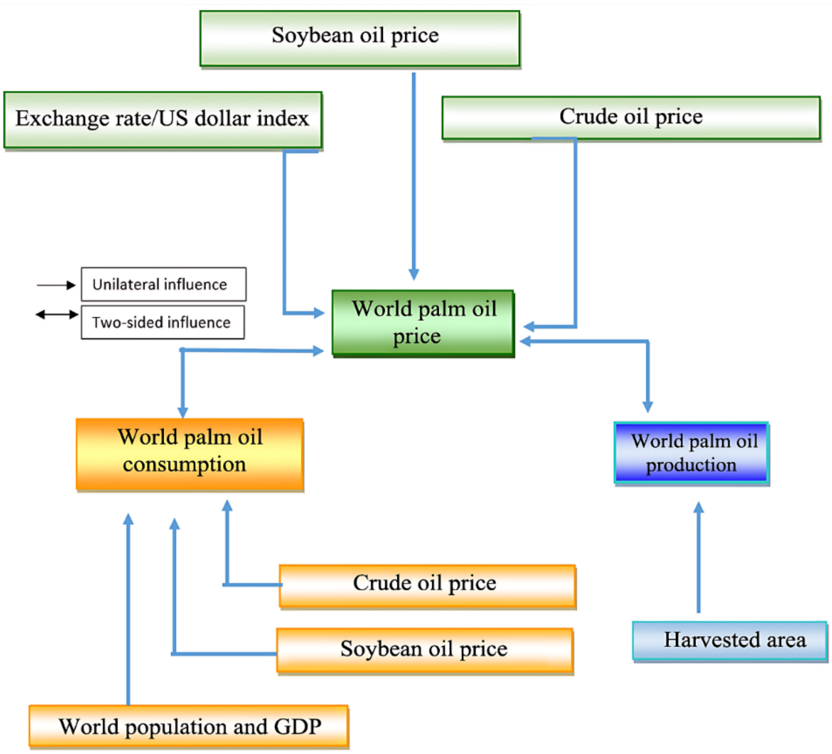

Figure 5. Conceptual framework of the study.

2. MATERIALS AND METHODS

2.1. Conceptual Framework

World Palm Oil Total Production: World's total production, Equation 1, is below:

$$WPOP_t = f(AHW_{t-1}, WPP_{t-1}, t, \varepsilon_{1t}) \tag{1}$$

Where:

$WPOP_t$ = World Palm Oil Total Production ('000 Metrics Tons, MT).

AHW_{t-1} = Palm Oil Harvested Area of World (Hectare).

WPP_t = World Palm Oil Price (USD/MT).

t = Time trend 2014 to 2019 monthly data (72 observations); ε_{1t} = Error Terms.

World Palm Oil Total Consumption: World's total consumption, Equation 2, is below:

$$WTC_t = f(SBOP_{t-1}, WGDPI_{t-1}, WP_{t-1}, WPP_{t-1}, COP_{t-1}, t, \varepsilon_{2t}) \quad (2)$$

Where:

WTC_t = World Palm Oil Total Consumption ('000 Metrics Tons).

$SBOP_{t-1}$ = Soybean Oil Price (USD/MT).

$WGDPI_{t-1}$ = World Gross Domestic Product (GDP) per Capita Index (In Current US Dollar).

WP_{t-1} = World Population (Billion People).

WPP_t = World Palm Oil Price (USD/MT).

COP_{t-1} = Crude Oil Price (USD/barrel).

t = Time trend 2014 to 2019 monthly data (72 observations); ε_{2t} = Error Terms.

World Palm Oil Price: World palm oil price Equation 3 is below:

$$WPP_t = f(SBOP_{t-1}, EXC_{t-1}, WTC_{t-1}, WPOP_{t-1}, COP_{t-1}, t, \varepsilon_{3t}) \quad (3)$$

Where:

WPP_t = World Palm Oil Price (USD/MT).

$SBOP_{t-1}$ = Soybean Oil Price (USD/MT).

EXC_{t-1} = Exchange Rate/US Dollars Index.

WTC_{t-1} = World Palm Oil Total Consumption ('000 Metrics Tons).

$WPOP_{t-1}$ = World Palm Oil Total Production ('000 Metrics Tons).

COP_{t-1} = Crude Oil Price (USD/ barrel).

t = Time trend 2014 to 2019 monthly data (72 observations); ε_{3t} = Error Terms.

Based on Figure 5, the world palm oil total production, consumption, and price models' equations are Equations 1, 2 and 3 above. The collected data used in these models are secondary data. The sources of this data come from the Malaysia Palm Oil Council (2021), Index Mundi, USDA Data, Investing, United Nations FAO Stat, and the World Bank database. The period of these secondary data is from 2014 to 2019, with monthly data and 72 observations for each model. Data were also collected monthly, including all price type data (soybean oil price, palm oil price, and crude oil price) and the exchange rate for the US dollar Index. The data include world palm oil total production, world palm oil total consumption, world palm oil harvested area, world income (GDP per capita index), and world population.

3. RESEARCH METHODS

3.1. Unit Root Test

The unit root test serves as a decisive tool for assessing the presence of a unit root in a time series dataset. Using this test, the null hypothesis (H0) postulates the existence of a unit root in the data, rendering it non-stationary, while the alternative hypothesis (HA) suggests stationarity. Stationary time series data maintain consistent statistical properties over time (Patterson, 2012), which makes the unit root test essential for determining the feasibility of employing the Vector Error Correction Model (VECM) method for model estimation. This study applied the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test to examine the unit root (Gujarati & Porter, 2009).

3.2. Vector Error Correction Model (VECM) Method

The Vector Autoregression (VAR) model estimates relationships involving two or more variable quantities in a time series. A VECM model is a restricted version of the VAR model that is only used for cointegrated series, and the series must not be stationary. Cointegration indicates that the variables have a long-run relationship. This model is formed to estimate the series' long-run and short-run dynamics. Lag length criteria suggest estimating VECM based on how many lags there are. In this study, the VECM model will be used to analyze the world palm oil production, consumption, and price model after sufficient tests are conducted to determine if the production, consumption, and price models are suitable for applying the VECM method (Gujarati & Porter, 2009).

3.3. Cointegration Analysis

The cointegration test is used to identify non-stationary time series datasets that move similarly and fluctuate within a long-run equilibrium (zero mean/equal to zero). It is crucial to clarify whether the series is appropriate for applying the VECM method. When there is cointegration between variables, they will have a long-run equilibrium relationship. They move similarly, and their linear relationship has been found to be non-stationary in terms of time series (Gujarati & Porter, 2009).

3.4. Residual Diagnosis

Two residual diagnosis detection tests were conducted: multicollinearity and normality tests. Multicollinearity refers to the presence of relationships between some or all independent variables. Certainly, multicollinearity consistently poses a challenge when variables in the model are highly correlated. In cases of perfect multicollinearity, the coefficients of explanatory variables become highly correlated, leading to infinite standard errors, thereby hindering the model estimation process (Gujarati & Porter, 2009). The detection of multicollinearity is typically achieved through the calculation of the Variance Inflation Factor (VIF), where a VIF value exceeding 5 indicates significant multicollinearity. In econometrics, a normality test assesses whether a dataset has a normal distribution and evaluates the degree of regularity within the data for model-fitting purposes. The assumptions underlying normality testing include the normal distribution of the dependent variable for each population as defined by different levels of the factor, uniform variances of the dependent variable across all populations, and the representation of random samples from the populations, with test variable scores being independent of each other (Hair, Anderson, Tatham, & Black, 2019).

3.5. Model Estimation Procedure of Palm Oil Global Production, Consumption and Price

Figure 6 shows the model estimation procedures step by step for palm oil global production, consumption, and price models, which are referred to by Pindyck and Rubinfeld (1998) and Ord and Fildes (2012) procedures, such as data collection, unit root test, and VECM to interpret the results.

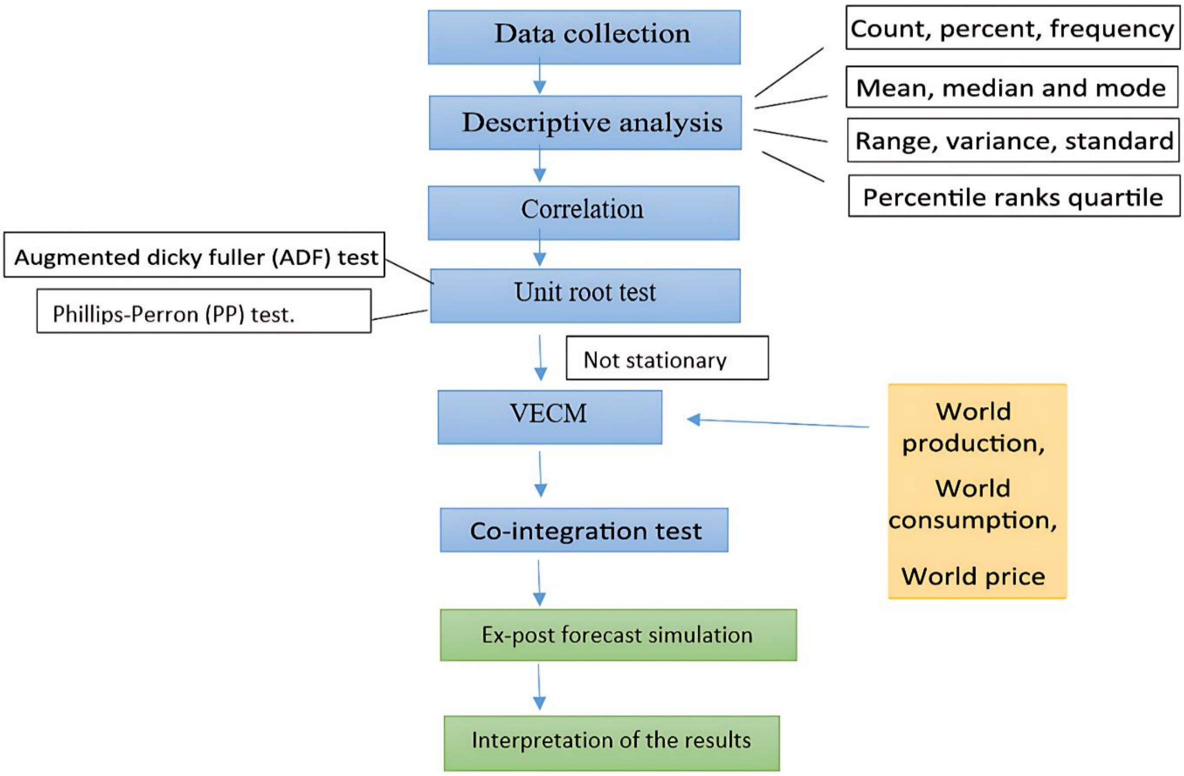

Figure 6. Model estimation procedure.

4. RESULTS AND DISCUSSION

4.1. Unit Root Test

The outcomes of the unit root test are presented in Table 1. SBOP and COP exhibit stationarity at I(0), indicating no need for further differencing. Conversely, WPOP, AHW, WPP, WTC, WGDPI, WP, and EXC initially display non-stationarity at their levels, yet become stationary after undergoing first differencing, indicating integration at I(1). The p-values obtained depict that first differencing led to the rejection of the null hypothesis of nonstationary time series. This suggests that the variables lack a unit root and are integrated at order 1. Both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests confirm the integration of the study's variables at I (1).

Table 1. Unit root test of world total palm oil production.

Variables	ADF statistics			PP statistics		
	Level data	1st Diff	2nd Diff	Level data	1st Diff	2nd Diff
WPOP	-0.915	-9.273***	-10.051***	-0.805	-9.331***	-71.401***
AHW	-0.636	-8.622***	-9.874***	-0.591	-8.640***	-68.637***
WPP	-2.577	-6.112***	-9.734***	-1.987	-5.998***	-15.624***
WTC	-0.453	-8.064***	-9.627***	-0.424	-8.059***	-51.615***
SBOP	-2.800*	-6.331***	-12.837***	-2.088	-6.322***	-24.533***
WGDPI	-0.796	-8.269***	-9.874***	-0.805	-8.269***	-68.637***
WP	-0.656	-8.907***	-9.874***	-0.504	-9.384***	-68.637***
COP	-2.622*	-5.690***	-7.837***	-2.203	-5.671***	-27.331***
EXC	-2.267	-4.434***	-17.039***	-2.279	-8.321***	-44.959***

Note: *** and * means stationary at level of significance 0.01, and 0.10, respectively.

4.2. World Total Palm Oil Production Model

Co-Integration Equation:

$$0.739\ \triangle WPOP_{t-1} - 15.295 \triangle AHW_{t-1} - 23.968 \triangle WPP_{t-1} = 0 \quad (4)$$

t-stat:[4.42081***] [-1.173] [-4.951***][1]

Based on the world total palm oil production (WPOP) cointegration Equation 4, the variables of world total palm oil production (WPOP) and world palm oil price (WPP) are cointegrated between the variables. A long-term relationship exists between world total palm oil production (WPOP) and world palm oil price (WPP) is statistically significant at the α 0.01 level. Therefore, in the long term, total palm oil production (WPOP) changes are based only on changes in world palm oil price (WPP).

VECM Equation:

$$\Delta WPOP_t = 0.01 + 0.011 \triangle WPP_{t-1} + 0.001 \triangle AHW_{t-1} + 0.159 \triangle WPOP_{t-1} \quad (5)$$

t-stat:[2.5996***] [0.9251] [-1.2612]

R^2 =0.4579 Adjusted R^2 = 0.424006

According to the VECM Equation 5 concerning the world's total palm oil production (WPOP), the explanatory variables explained approximately 45.79 per cent of the variance in the WPOP equation. Analysis indicates that among these explanatory variables, the world palm oil price (WPP) stands out as significant at the $\alpha < 0.01$ level. Moreover, a USD 1 per metric ton increase in the world palm oil price corresponds to an average positive impact on increasing world total palm oil production (WPOP) by 2.5996 thousand metric tons, which is also statistically significant at the 0.01 level, while holding other variables constant. Consequently, results state that, in the short term, fluctuations in world total palm oil production (WPOP) are primarily influenced by changes in the world palm oil price (WPP).

4.3. World Total Palm Oil Consumption Model

Co-Integration Equation:

$$-0.028 \triangle WTC_{t-1} - 1.725\ \triangle SBOP_{t-1} + 0.294\ \triangle WGDPI_{t-1} - 3264658\ \triangle WP_{t-1} + 0.05367\ \triangle WPP_{t-1} + 0.4973 \triangle COP_{t-1} = (6)$$

t-stat:[-0.919] [-2.6946***] [0.9071] [-5.4570***] [-3.4307***] [0.69913]

In the world total palm oil consumption (WTC) cointegration Equation 6, the variables of soybean oil price (SBOP), world population (WP), and world palm oil price (WPP) are cointegrated among the variables. There is a long-term relationship among soybean oil price (SBOP), world population (WP), and world palm oil price (WPP) that is statistically significant at the α 0.01 level. Based on this result, it contributes to the world total palm oil consumption (WTC) changes based on the world population (WP), a substitute product of soybean oil price (SBOP), and world palm oil price (WPP) changes in the long term.

VECM Equation:

$$\triangle WTC_t = -0.001 + 0.005 \triangle SBOP_{t-1} - 0.009 \triangle WGDPI_{t-1} + 0.0982 \triangle WP_{t-1} - 0.001 \triangle WPP_{t-1} + 0.0592 \triangle COP_{t-1} - 0.438 \triangle WTC_{t-1} \quad (7)$$

t-stat:[0.8311] [-0.7962] [-1.5646*] [-0.3152] [1.8545**] [-3.8754***]

R^2 = 0.2662 Adjusted R^2 = 0.1820

The VECM Equation 7 results regarding world total palm oil consumption (WTC) indicate that the explanatory variables explain around 26.62 percent of the variation in the WTC equation. Among these variables, the world population (WP), crude oil price (COP), and world total palm oil consumption in the lag period (WTC_{t-1}) emerge as significant factors with statistical significance. Notably, the world's total palm oil consumption in the lag period (WTC_{t-1}) holds the most importance in the model. Consequently, an increase of 1 billion people in the world population (WP) leads to an average positive effect on the world total palm oil consumption (WTC) by 0.0982 thousand metric tons, with statistical significance at the 0.10 level, while other variables remain constant. Similarly, a USD 1 per barrel increase in crude oil price (COP) results in an average positive impact on the world total palm oil consumption (WTC) by 0.0592 thousand metric tons, statistically significant at the 0.05 level, holding other variables constant. Conversely, a 1000 metric tons increase in world total palm oil consumption in the lag period (WTC_{t-1}) has a negative effect on the world total palm oil consumption (WTC) by 0.438 thousand metric tons, with statistical significance at the 0.05 level, keeping other variables constant. Based on the findings of this study, it is evident that changes in world total palm oil consumption (WTC) primarily stem from alterations in world population (WP) and crude oil price (COP) in the short term.

4.4. World Palm Oil Price Model

Co-integration Equation:

$$-0.9561\Delta SBOP_{t-1} - 0.0091\Delta EXC_{t-1} - 0.0137\Delta WTC_{t-1} - 0.0266\Delta WPOP_{t-1} - 0.0275\Delta COP_{t-1} - 0.9561\Delta WPP_{t-1} = 0 \quad (8)$$

t-stat:[-2.8368***] [-0.9740] [-2.5767***] [-4.6575***] [-1.0444] [-5.9011***]

In the world palm oil price (WPP) cointegration Equation 8, the variables of soybean oil price (SBOP), world total palm oil consumption (WTC), world palm oil total production (WPOP), and world palm oil price (WPP) are cointegrated among the variables. There is a long-term relationship among soybean oil price (SBOP), world total palm oil consumption (WTC), world palm oil total production (WPOP), and world palm oil price (WPP) variables statistically significant at the α 0.01 level. Based on this result, it provides the world palm oil price (WPP) changes

[1] Note: (***, ** and * here and hereafter means level of significance 0.01, 0.05 and 0.10, respectively)

based on the substitute product of soybean oil price (SBOP), world palm oil total production (WPOP), and world total palm oil consumption (WTC) changes in the long term.

VECM Equation:

$$\Delta WPP_t = 0.1317 - 0.3262\,\Delta SBOP_{t-1} + 4.5119\,\Delta EXC_{t-1} - 10.7092\Delta WTC_{t-1} + 20.9704\,\Delta WPOP_{t-1} + 0.1792\,\Delta COP_{t-1} + 0.2285\,\Delta WPP_{t-1} \quad (9)$$

t-stat: = [-1.7419**] [2.0937***] [-1.7132**] [3.5746***] [0.2365] [1.5906*]

$R2 = 0.4141$ Adjusted $R2 = 0.3469$

Based on the world palm oil price (WPP) VECM Equation 9 results, the explanatory variables accounted for about 41.41 percent of the variation in the world palm oil price (WPP) equation. Estimations reveal that the explanatory variables, namely the world palm oil total production (WPOP), world total palm oil consumption (WTC), US Dollar Index (EXC), soybean oil price (SBOP), and world palm oil price in the lag period (WPPt-1), were the important explanatory variables with statistical significance at the 0.01 level, 0.05 level, and 0.10 level respectively. However, the total production of world palm oil (WPOP) was the most important variable in the model. Therefore, a 1 USD/MT increase in soybean oil price (SBOP), on average, has a negative effect on decreasing the world palm oil price (WPP) by 0.3262 USD/MT with statistical significance at the 0.05 level, holding constant with other variables. Besides, a 1 US Dollar increase in the US Dollar Index (EXC), on average, has a positive effect on increasing the world palm oil price (WPP) by 4.5119 USD/MT with statistical significance at the 0.01 level, holding constant with other variables.

Thus, a 1000 MT increase in world total palm oil consumption (WTC), on average, has a negative effect on decreasing the world palm oil price (WPP) by 10.7092 USD/MT with statistical significance at the 0.05 level, holding constant other variables. Moreover, a 1000 MT increase in world palm oil total production (WPOP), on average, positively impacts the world palm oil price (WPP) by 20.9704 USD/MT with statistical significance at the 0.01 level, holding constant other variables. Finally, a 1 USD/MT increase in world palm oil price in the lag period (WPPt-1), on average, has a positive effect on increasing the world palm oil price (WPP) by 0.2285 USD/MT with statistical significance at the 0.01 level, holding constant other variables. Based on this result, it is important information provided that the world palm oil price (WPP) changes are based on the world palm oil total production (WPOP), world total palm oil consumption (WTC), exchange rate of the US Dollar Index (EXC), and changes in the substitute product of soybean oil price (SBOP) in the short term.

4.5. Residual Analysis

Table 2 shows the residual diagnosis results of each model. The residuals of the world palm oil total production (WPOP), world total palm oil consumption (WTC), and world palm oil price (WPP) models are normally distributed, and there is no multicollinearity problem.

Table 2. Results of residual diagnostics of world palm oil total production, consumption, and price models.

Residual diagnosis tests	Decision and conclusion
World palm oil production	
Normality test	P-value is 0.945 > 0.05, do not reject H0, the residuals are normally distributed
Multicollinearity	VIF= 1/(1- 0.054988) = 1.0582 <5, do not reject H0, there is no multicollinearity
World palm oil total consumption	
Normality test	P-value is 0.0785> 0.05, do not reject H0, the residuals are normally distributed
Multicollinearity	VIF= 1/(1-0.261846) = 1.35473<5, do not reject H0 there is no multicollinearity
World palm oil price	
Normality test	P-value is 0.136 > 0.05, do not reject H0, the residuals are normally distributed
Multicollinearity	VIF= 1/(1-0.178520)= 1.2173<5, do not reject H0 there is no multicollinearity

Source: EViews output.

4.6. Ex-Post Forecast

Model simulation for a study can be performed for several reasons, including (1) model testing, (2) evaluation, (3) historical policy analysis, and (4) forecasting. The ex-post forecast method is carried out by simulating the model forward in time beyond the estimation period. Under this kind of simulation method, the observation of endogenous and exogenous variables must be well-known and should not have uncertainty in the estimating period (Pindyck & Rubinfeld, 1998).

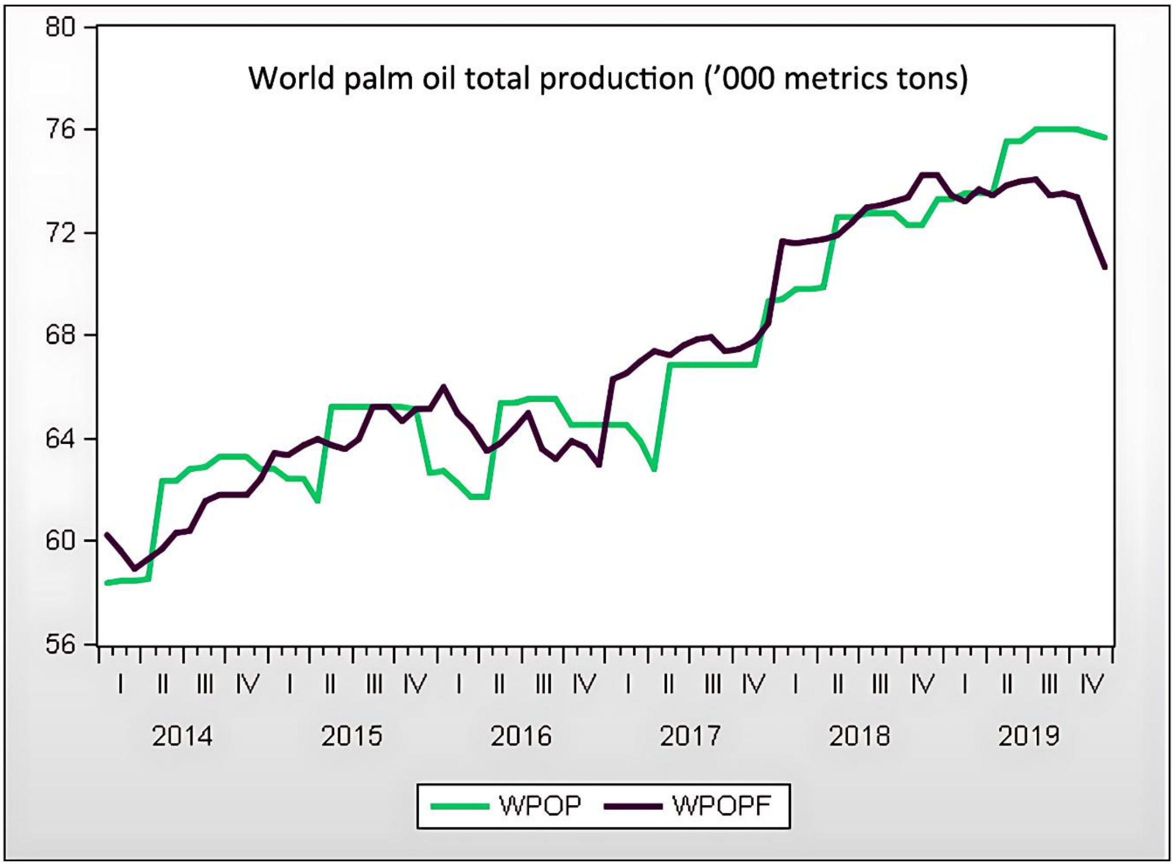

Figure 7. Ex-post forecast trend for world palm oil total production from 2014 to 2019.

Figure 7 shows the ex-post forecast value for world palm oil production from 2014 to 2019. It can be observed that world palm oil production increased significantly throughout 2019; however, the ex-post forecast of world palm oil production is expected to decrease significantly in the near future.

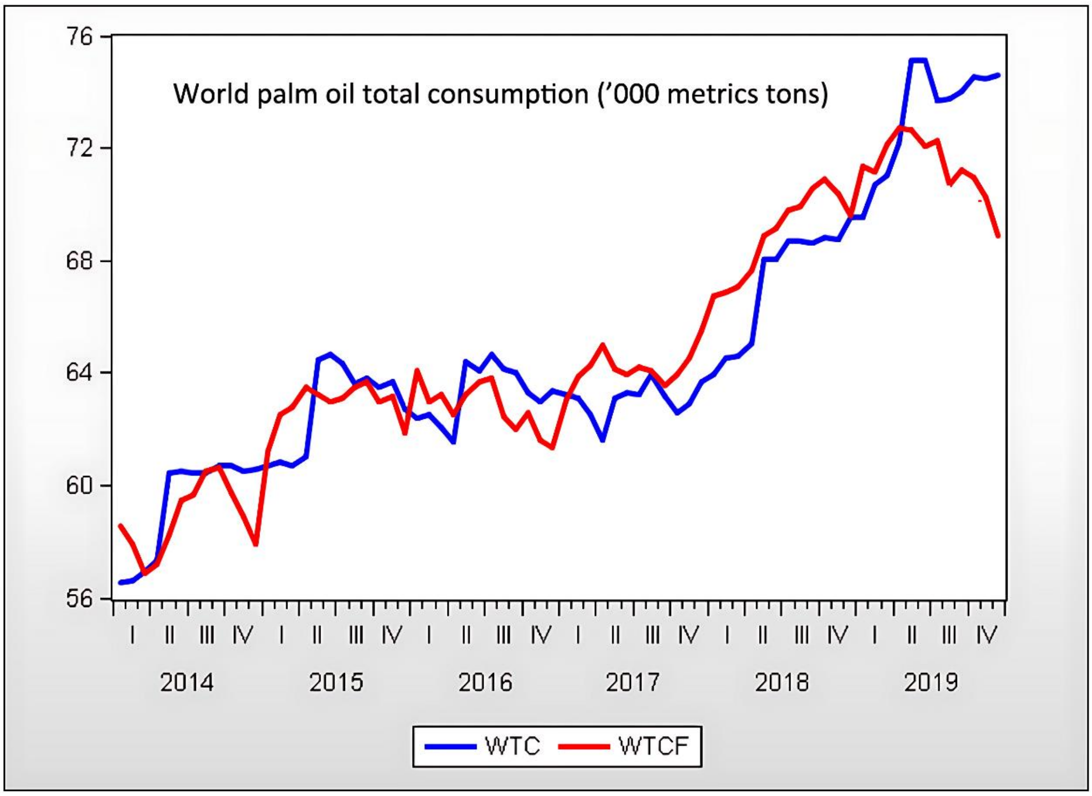

Figure 8. Ex-post forecast trend for world palm oil total consumption from 2014 to 2019.

Figure 8 shows the ex-post forecast value for world palm oil consumption from 2014 to 2019. It can be observed that world palm oil consumption increased significantly throughout 2019; however, the ex-post forecast of world palm oil consumption will significantly fall until it reaches 68.87 ('000 Metric Tons).

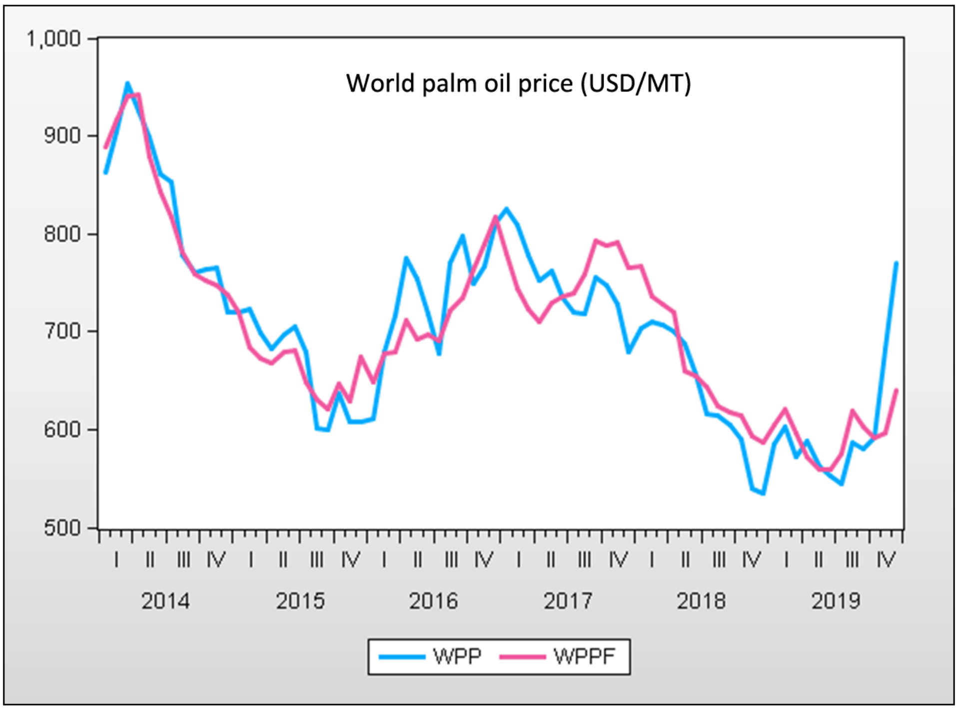

Figure 9. Ex-post forecast trend for world palm oil price from 2014 to 2019.

Figure 9 shows the ex-post forecast for the world palm oil price from 2014 to 2019. Generally, it fluctuates and decreases. It can be observed that the world palm oil price increased significantly throughout the year 2019. At the same time, the ex-post forecast predicted that it would still increase, but not as much as the actual.

5. CONCLUSION

From the estimation of the world palm oil production model, this study found that there is no significant relationship between the area harvested for palm oil and palm oil production in the world market. According to a study conducted by Alabi, Famakinwa, and Akinnawonu (2020), they stated that the area harvested in Nigeria was among the world's top three palm oil plantations, but its production level is still below that of Thailand. This indicates that a higher area harvested may not necessarily lead to higher palm oil production. The results of estimating the production model indicated that palm oil production has a direct relationship with palm oil prices, whether in the long term or short term. This aligns with the theory of supply. The higher the price level of palm oil, the more it will encourage producers to increase palm oil production to yield excess profits, while a lower price level of palm oil will cause producers to reduce production, as they find that producing palm oil yields a lack of profits.

According to the results of the world palm oil consumption model, there is no significant relationship between world GDP per capita and world palm oil consumption. The reason for these findings may be due to the unspecified nature of palm oil-importing countries during the estimation of data, while this is also due to the purpose of conducting this study. One aim of this study was to address a research gap concerning the influence of global income on worldwide palm oil consumption, a departure from conventional research focusing solely on specific major importing countries such as China, India, or the USA. For instance, prior studies like that of Iswandrik (2021) only considered India's GDP as an explanatory variable for palm oil consumption, while Pratiwi (2021) restricted their analysis to the GDPs of the United States, China, India, the Netherlands, and Spain in assessing their contribution to global palm oil consumption. However, according to Index Mundi (2021), palm oil consumption spans more than 100 countries worldwide, prompting this study to examine world GDP per capita as an independent variable affecting global palm oil consumption. The findings indicate that world GDP per capita does not exhibit statistical significance concerning world palm oil consumption. Interestingly, the findings indicate that world GDP per capita does not exhibit statistical significance in relation to world palm oil consumption. This discovery represents a notable contribution to palm oil research, shedding light on the complex dynamics between global economic indicators and the consumption patterns of this widely used commodity.

The results also show that the relationship between world population and world palm oil consumption is significant in both the long term and the short term. This finding aligns well with most other palm oil research findings. The study by Purba (2020) stated that from 1975 to 2016, the population of China increased rapidly, accompanied by an increase in vegetable oil consumption. This has caused China to import a massive amount of palm oil from palm oil-producing countries like Indonesia and Malaysia to meet the high demand for vegetable oil in the domestic market. Furthermore, the outcome indicates that palm oil prices impact palm oil consumption in the long run but do not affect it in the short run. On the other hand, world consumption of palm oil has resulted in a significant relationship with world palm oil prices. When palm oil prices are higher, the demand for palm oil decreases, as consumers are always seeking lower prices for products. Moreover, when demand for a product increases, it drives the price of that product, which is known as demand-driven inflation (Cochrane & Poot, 2021).

The results show that the soybean oil price will impact world palm oil consumption in the long term, while the soybean oil price will impact the world palm oil price in the long term or the short term. This result is consistent with the study by Hassan and Balu (2016), which found that an increase in the soybean oil price will lead to an increase in palm oil consumption, which will consequently pull up the price of palm oil. The results also showed that the crude oil price only impacted palm oil consumption in the short term, while there seems to be no relationship between crude oil price and palm oil price. These results are consistent with the outcomes of the studies by Destiarni and Jamil (2021) and Songsiengchai, Sidique, Djama, and Azman-Saini (2018), where no long-run relationship was shown between crude oil price and vegetable oil, including world palm oil price.

From the world palm oil price model results generated, the US dollar index is proven to have a significant relationship with the world palm oil price in the short term but does not relate in the long term. In terms of the long term, this result is consistent with the study by Chansuchai (2017). He researched the exchange rate of the local currency to the US dollar, and he found that the appreciation or depreciation of the currency rate against the US dollar had no impact on the palm oil price in Thailand. From this study, we can see that even in the market of the third-largest palm oil-producing country, the impact of the exchange rate on the palm oil price is next to nothing.

In conclusion, according to the results generated by this study and most other researchers' studies, there is still much room for improvement when constructing sustainable development for the global palm oil economy. Therefore, based on the results, the total changes in world palm oil production are based only on world palm oil price changes in both long-term and short-term periods. Moreover, it contributes to the world's total palm oil consumption changes, which are also based on the world population, substitute products of soybean oil price, and world palm oil price changes in the long term, as well as crude oil price changes in the short duration. This is critical information for this study. Furthermore, it indicates that the world palm oil price changes are based on the substitute product of soybean oil price, world palm oil total production, and world total palm oil consumption changes in the long-term periods. However, it is also based on the total production of palm oil, total palm oil consumption, the exchange rate of the US Dollar Index, and the substitute product of soybean oil price changes in the short-term periods. These are also important information for the policy implications of this study.

Future research needs to apply more specific and higher representative variables to generate more accurate results compared with Indonesia, Malaysia, Thailand, and the world market for four regions of production, consumption, and price models. For example, it was found that the exchange rate has a very low or almost no relationship with the price of palm oil in the long term. This point might be doubted as palm oil is a commodity that plays an important role in the international market; theoretically, the exchange rate will indeed have an impact on its price. Negative results generated by this study and most other researchers' studies might be due to a suitable currency rate plugged in to estimate the long-term model. Even though this study tried to plug in another type of exchange rate of the US dollar index, it still shows a weak relationship between palm oil prices and exchange rates. In the future, different currency rates may be used to estimate their relationship with palm oil prices by different researchers to develop the best-fitted explanatory exchange rate index to the palm oil price. The findings are helpful in the national priority areas of sustainable development goals SDG8 and SDG12 of decent work and economic growth and responsible consumption and production for sustainable development goals. The novelty of this research paper supports comparable and unbiased results from testing the macro-levels together with micro-levels to learn about prospective effects and improve the case for the sustainable growth of the world palm oil sector.

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