Jejak Vol 18 (1) (2025): hlm 50-67. DOI: https://doi.org/10/15294/jejak.v18i1.16008

JEJAK

Journal of Economics and Policy

http://journal.unnes.ac.id/nju/index.php/jejak

Energy Transition and The Impact of Biodiesel Development Policy on CPO Prices

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Permalink/DOI: https://doi.org/10.15294/jejak.v18i1.16008

Received: November 2024 ; Accepted: January 2025; Published: March 2025

Abstract

Biodiesel is a renewable fuel with great potential to support energy transition in Indonesia. This research aims to analyze the impact of the policy of developing biodiesel on CPO prices. Time series and secondary data from January 2015 to December 2023 were used in this research with the Autoregressive Distributed Lag (ARDL) method. The dependent variable was the domestic CPO prices and the independent variable were the price of CPO in the international market, biodiesel production volume, exports of CPO and its processed products, price of palm cooking oil, export levies, export duties, CPO production volume, and the Rupiah exchange rate against the United States Dollar. The results in the short run was the domestic CPO prices were influenced positively and significantly by the volume of biodiesel production, the export volume of CPO and its processed products, and the price of palm cooking oil. In the long run, domestic CPO prices were significantly and positively influenced by international CPO prices and palm cooking oil prices. At the same time, export levy, CPO production volume, and the Rupiah exchange rate are significantly and negatively influenced. These results indicate that biodiesel production impacts the prices of biodiesel raw materials and cooking oil in the short run.

Keywords : Biodiesel Development, CPO Prices, Energy Transition, Mandatory, Policy

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p-ISSN 1979-715X
e-ISSN 2460-5123

INTRODUCTION

Energy transition refers to a major shift in how a country or region produces, distributes, stores, and consumes energy, moving from fossil fuels to sustainable energy sources (Solomon and Krishna, 2011; Gallo *et al.*, 2016; Chen *et al.*, 2019). This transition is essential to reduce greenhouse gas (GHG) emissions since fossil fuel use generates substantial GHG emissions (Kovač, Paranos and Marciuš, 2021).

The energy transition in Indonesia represents a strategic effort to reduce reliance on fossil fuels and enhance national energy security. A key initiative within this transition is the utilization of palm oil-based biofuels, commonly known as biodiesel. Biodiesel is a type of bioenergy or biofuel derived from vegetable oils, including fresh or used cooking oil, which undergoes a transesterification process (Supraniningsih, 2012). Biofuels are categorized into biogas, bioethanol, and biodiesel and are produced from biomass or renewable biological materials and typically require specialized processes to be converted into fuel (Ahmad *et al.*, 2011; (Hirani *et al.*, 2018).

In line with Indonesia's commitment to reduce GHG emissions, the government has begun developing more environmentally friendly renewable energy. In 2006, the government initiated palm oil-based biofuel production, and in 2008, it officially implemented a mandatory biodiesel program under the Minister of Energy and Mineral Resources Number 32 Regulation concerning the Provision, Utilization and Trade of Biofuels as Other Fuels. This mandate aims to produce environmentally friendly fuels while also enhancing Indonesia's energy resilience and independence, stabilizing domestic CPO prices, increasing the added value of Indonesian palm oil, meeting the renewable energy target of 23% by 2025, substituting fossil fuels to reduce fuel imports, and lowering GHG emissions.

Markard (2018) stated that every energy transition process will produce winners and losers. Cantarero (2020) explained that developing countries face challenges in the energy transition. Biodiesel development has an impact on increasing employment opportunities in Indonesia and gross domestic product (Dharmawan *et al.*, 2020; Sahara *et al.*, 2022). Biodiesel also can help Indonesia to tackle unstability of oil prices (Suhara *et al.*, 2024; Wirawan *et al.*, 2024). While the increasing of the biodiesel blending rate has the potential to cause losses in CPO exports due to increased demand for biodiesel raw materials (Halimatussadiah *et al.*, 2021).

Indonesia still relies on fuel imports to meet its domestic consumption. Increasing oil import can encourage for biodiesel production (Timilsina, Mevel and Shrestha, 2011; Koizumi, 2015). Ewing and Msangi (2009) stated that the energy market can affect agriculture directly and indirectly. The direct impact is that increasing energy prices will increase the cost of agricultural inputs such as fertilizers. The indirect impact causes an increase in household spending on fuel purchases.

Biofuel production in 2007-2008 was stated to contribute to increasing food prices (Mueller, Anderson and Wallington, 2011; Zilberman *et al.*, 2012). However, Ajanovic (2011) and Staab and Duffield (2019) stated that the development of biofuels in the European Union and America in 2008 did not affect the increase in food prices. Sahara *et al.* (2022) stated that the development of B30 could potentially increase the price of agricultural food products.

Increased biofuel production will increase the demand for raw materials. Zilberman *et al.* (2012) stated that ethanol production from corn significantly increases the price of food commodities. Tanaka *et al.* (2023) stated that the use of soybean oil as biodiesel in America could impact soybean prices and influence international soybean prices. However, Shrestha et al., (2019) stated that biodiesel production does not necessarily cause an increase in corn and soybean prices in America.

CPO is an essential raw material for Indonesia's food industry especially cooking oil, oleochemical and biodiesel industries. Indonesian Palm Oil Association (IPOA) projects that the Indonesian palm oil industry will significantly increase production, domestic consumption, and exports from 2020 to 2045. Production of CPO and PKO (Palm Kernel Oil) is estimated to increase from 51,502 thousand tons in 2020 to 92,440 thousand tons in 2045. Domestic consumption, which includes the food industry, oleochemicals, and the use of fatty acid methyl ester (FAME) as a raw material for biodiesel, has also experienced a significant increase. In 2020, domestic consumption was recorded at 19,438 thousand tons and is projected to reach 43,768 thousand tons in 2045. In addition, palm oil exports are also expected to grow from 32,064 thousand tons in 2020 to 48,672 thousand tons in 2045.

Although domestic demand is increasing, export projections also show a stable growth trend. This shows that the Indonesian palm oil industry will remain a major player in the global market, although most of the production is also allocated for domestic consumption. The projected increase in production capacity to 92,440 thousand tons by 2045 ensures that Indonesia can meet domestic demand while maintaining large exports.

This study aims to analyze the impact of the policy of developing biodiesel on CPO prices. The research is expected to provide deeper insight into how the development of the biodiesel energy transition affects CPO prices. With the increasing demand of CPO for biodiesel as an alternative fuel, especially in policies such as the mandatory B20 to B50 in Indonesia, this study highlights the direct relationship between the increase in the biodiesel blending rate and the fluctuation of CPO prices in the domestic and global markets. With the increase in domestic biodiesel consumption, pressure on CPO export supplies may increase, directly affecting the commodity's price. This study contributes to understanding how Indonesia's energy transition policy can affect CPO's prices. This study also contributes to the literature on the impact of energy policies, especially the mandatory biodiesel policy, on the palm oil industry. By mapping the impact of biodiesel policies on CPO prices, this study can be a reference for policymakers in designing policies that support price stability and the welfare of farmers and all the stakeholders in the palm oil industry.

RESEARCH METHODS

This research used secondary data in time series from January 2015 to December 2023. Data sources were obtained from the Ministry of Agriculture, Ministry of Finance, Ministry of Energy and Mineral Resources, World Trade Organization, Bank Indonesia, and the Indonesian Palm Oil Entrepreneurs Association (GAPKI). All the varieables were presented on Table 1.

Table 1. Variables and operational definition

Variables	Definition
International CPO price (CPOI)	Average monthly price of CPO in the Rotterdam market average monthly (c.i.f. price, i.e. cost, insurance and freight price) USD/MT

Domestic CPO price (CPOD)	Average monthly price of CPO in the Indonesian domestic market average monthly (IDR/kg) Cooking oil price : Average monthly price of national bulk cooking oil (IDR/kg)
Biodiesel production volume (BIO)	Total of monthly production of palm oil biodiesel (thousand litres)
Export duty (ED)	Average nominal CPO export duty stipulated in the Regulation of the Minister of Finance each month (USD/MT)
Export levy (EL)	Average nominal CPO export levy stipulated in the Regulation of the Minister of Finance each month (USD/MT)
Export volume of CPO and its derivatives (CPOX)	Total of monthly CPO exports volume and its derivatives (HS codes 15111000 and 15119000 consisting of 15119020, 15119031, 15119032, 15119036, 15119037, 15119039, 15119041, 15119042, and 15119049) (thousand tons)
Cooking oil price (COP) CPO Production (CPOP)	monthly average price of cooking oil (IDR/kg) Total of monthly production volume of national CPO (thousand tons)
Rupiah exchange rate (IDR)	Average monthly nominal exchange rate of Rupiah against the US Dollar

The Autoregressive Distributed Lag (ARDL) model is a versatile econometric tool that estimates the relationship between variables over time, accommodating both short-run and long-run dynamics. This model can be used for testing using time series data (Kripfganz and Schneider, 2023). Short run model equation is:

$$D(LNCPOD)_t = \alpha + \sum_{i=1}^{p} \beta_i D(LNCPOD_{)t-i} + \sum_{j=0}^{q_1} \gamma_j D(LNCPOI)_{t-j} + \sum_{j=0}^{q_2} \delta_j D(LNBIO)_{t-j} + \cdots + \sum_{j=0}^{q_n} \zeta_j D(IDR)_{t-j} + \epsilon_t \quad (1)$$

The ARDL model also can predict for the long run analysis. The aim is to identify and estimate the long-run equilibrium relationship between independent and dependent variables in an econometric model, even though the data used has different integration properties (I(0), I(1), or a combination of both). The equation for the long run model is written as :

$$LNCPOD_t = \alpha + \beta_1 LNCPOI_t + \beta_2 LNBIO_t + \beta_3 LNCPOX_t + \beta_4 LNCPOP_t + \beta_5 EL_t + \beta_6 ED_t + \beta_7 LNIDR_t + \epsilon_t \quad (2)$$

The purpose of a stationary test in time series analysis is to check whether the time series data is stationary, that is, whether its statistical characteristics are constant over time. These statistical characteristics include mean, variance, and autocovariance. Stationarity testing is crucial because most classical time series analysis methods, such as ARDL, assume that the data being analyzed is stationary.

$$D(LNCPOD)_t = \alpha + \beta t + \gamma LNCPOD_{t-1} + \sum_{i=1}^{P} \delta_i D(LNCPOD_{t-i}) + \epsilon_t \quad (3)$$

Where $D(LNCPOD)_t$ is the first differentiation form of the natural logarithm of

CPO consumption at time. First differentiation ensures data stationarity (unit root test) in time series analysis. α is constant or intercept in the model. This constant value describes the average value of the change (differenced) in LNCPOD when all other variables in the model are zero. β is coefficient of the time variable t. γ is the coefficient of the first lag of the LNCPOD variable at time t-1. $\sum_{i=1}^{P} \delta_i D(LNCPOD_{t-i})$ is summation of the LNCPOD difference lag values up to the p-th lag. ϵ_t is error term orrandom disturbance that describes factors not explained by the model or stochastic variations of the model.

The main objective of lag length selection in the ARDL model is to ensure that the model can capture the dynamics of the short-run and long-run relationships between the variables analyzed. ARDL Lag equation (general ARDL model):

$$LNCPOD_t = \alpha + \sum_{i=1}^{p} \beta_i LNCPOD_{t-i} + \sum_{j=0}^{q} \delta_i x_{t-j} + \epsilon_t \tag{4}$$

Where $LNCPOD_t$ is the dependent variable, X_{t-j} is the independent variable, *p* and *q* are lagged for the dependent and independent variables, respectively, and ϵ_t is the error term.

ARDL Bounds Test is used to test the cointegration relationship between variables. The hypothesis is:

H_0: There is no cointegration.

H_1: There is cointegration.

The equation model is:

$$\Delta LNCPOD_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta LNCPOD_{t-i} + \sum_{j=0}^{q} \delta_j \Delta X_{t-j} + \phi LNCPOD_{t-1} + \psi x_{t-1} + \epsilon_t \tag{5}$$

In linear regression, the residuals of the model must be normally distributed to ensure that the dependent variable does not have a wrong functional form (Khatun, 2021). One of the most common methods used for testing data distribution or normality is Jarque–Bera test (Ghasemi and Zahediasl, 2012). This research, used Jarque–Bera test for normality test. The aim of this test is to see whether the model's residuals are normally distributed.

The hypothesis is:

H_0: Residuals are normally distributed.

H_1: Residuals are not normally distributed.

Jarque-Bera Test Equation:

$$JB = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \tag{6}$$

Where n is the sample size, S is the skewness and K is the kurtosis of the residuals.

Heteroscedasticity comes from the words hetero and scedasticity. Scedasticity or scedasticity means spread (variance) (Gujarati, 2003). This research used Breusch-Pagan Test test to check whether there is heteroscedasticity in the model (Halunga et al., 2017).

The hypothesis was:

H_0: Homoscedasticity (no heteroscedasticity).

H_1: There is heteroscedasticity.

The equation for the Breusch-Pagan Test:

$$\epsilon_t^2 = \alpha + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \cdots + \beta_n x_{n,t} + u_t \tag{7}$$

Figure 1. Development of biodiesel blending rate from 2006 to 2025

Source : Indonesian Palm Oil Association (IPOA), Directorate General of New, Renewable Energy and Energy Conservation - Ministry of Energy and Mineral Resources

This test was conducted using Breusch-Godfrey test (Edgerton and Shukur, 1999). This test is used to check whether there is autocorrelation in the residuals. The hypothesis was:
H_0: There is no autocorrelation.
H_1: There is autocorrelation.
The equation for the Breusch-Godfrey Test:

$$\epsilon_t = \alpha + \sum_{i=1}^{p} \beta_i \epsilon_{t-i} + u_t \quad (8)$$

The main function of the CUSUM (Cumulative Sum of Recursive Residuals) and CUSUM of Squares (Cumulative Sum of Squares of Recursive Residuals) tests is to evaluate the stability of parameters in a regression model over time. This test is useful in detecting changes in model parameters that may occur due to structural instability. The following are the equations of each test:

$$CUSUM_t = \sum_{i=k+1}^{t} \omega_i \quad (9)$$

$$CUSUMQ_t = \sum_{i=k+1}^{t} \frac{\omega_i^2}{\Sigma_{i=k+1}^{T} \omega_i^2} \quad (10)$$

Where ω_i is the recursive residual, k is the number of parameters, and T is the total observations.

RESULTS AND DISCUSSION

Indonesia's journey in biodiesel production reflects a strategic shift towards renewable energy, driven primarily by the need to reduce reliance on fossil fuels, support domestic palm oil industry, and reduce GHG emissions. When Indonesia started producing biodiesel in 2006, the initial blending level was set at 2.5%, meaning biodiesel only comprised 2.5% of the diesel blend, while the remaining 97.5% came from fossil-based diesel. Since then, Indonesia has gradually increased the blending level in line with government mandates and environmental goals. In 2023 and 2024, Indonesia's biodiesel policy has reached the B35

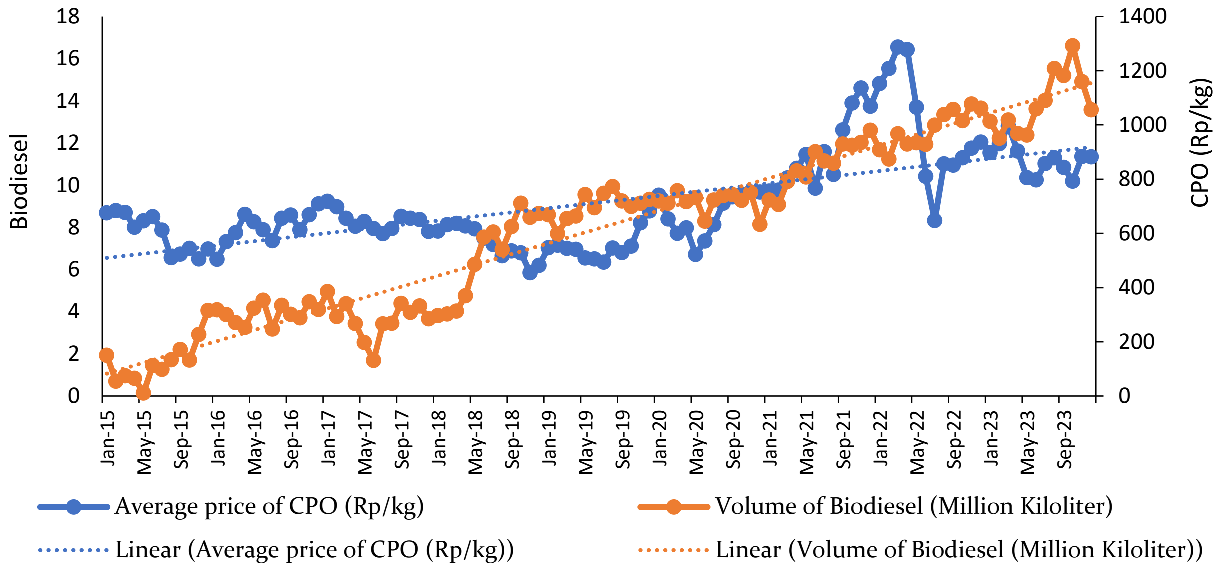

Figure 2. Development of biodiesel production volume and average domestic CPO price monthly from January 2015 to December 2023

Source : Ministry of Trade, Ministry of Agriculture

blending level (Figure 1). This change represents significant progress, making Indonesia one of the global leaders in biodiesel use and producer.

In 2007, the government launched a downstream program for the palm oil industry to increase its added value. By 2010, the Ministry of Industry expanded this initiative, specifically targeting the palm oil sector. Downstreaming represents a government-led effort for structural transformation, aimed at modernizing the CPO processing industry and promoting the export of higher-value derivative products (Berlian, 2015). The goal of the palm oil downstream program is to enhance the added value of processed palm oil through its application in food, non-food, and biofuel industries. Here, value refers to the quality of a product, determined by its necessity, usefulness, or perceived importance, as well as its monetary worth in trade or sale (Rutner and Langley, 2006).

In 2024, the biodiesel blending rate is at B35 and by 2025 will be B40. Biodiesel development can reduce the negative impact of international CPO prices on Indonesian domestic CPO prices (Prananta and Kubiszewski, 2021). Energy transition in Indonesia also an essential strategic step in facing the challenges of climate change and reducing dependence on fossil fuels. As a developing country with a large population, Indonesia is committed to balancing increasing energy needs and the environmental sustainability agenda. In the global context, energy transition means shifting from an energy system dominated by fossil resources, such as coal, oil, and gas, to the use of more environmentally friendly energy, such as renewable energy, energy efficiency, and low-carbon technology.

The dynamics of biodiesel production development in Indonesia are greatly influenced by government policies. Along with the increasing biodiesel blending mandate (from B2.5 to B35 in 2023), domestic biodiesel production volume has increased rapidly. Figure 2 shows the relationship between the average price of CPO (Crude Palm Oil) in Rupiah per kilogram and the volume of biodiesel production in kiloliters from January 2015 to December 2023. The average price of CPO increases gradually from early 2015 to 2023. There are price fluctuations at some points, especially around 2020-2021, where the price of CPO experienced a sharp increase. The volume of biodiesel production also shows a sharp increase over time, although there are fluctuations at some points, especially after 2021. There is a sharp increase in the volume of biodiesel produced in 2020-2021, followed by a brief decline, then increasing again until 2023. A correlation between the increase in biodiesel volume and CPO prices can be seen. For example, when the volume of biodiesel increases significantly, the price of CPO also tends to increase, especially in 2020-2021. The increase in biodiesel volume may contribute to the increase in CPO prices because increased biodiesel production requires more palm oil as a feedstock, thereby reducing the supply of CPO for other markets and increasing prices.

Table 2. Stationarity test results on all variables

Variable	*Level*	*First Difference*
LNCPOI	0.3735	0.0000**
LNBIO	0.1571	0.0000**
LNCPOX	0.0000**	0.0000**
LNCOP	0.8040	0.0000**
PE	0.0792	0.0000**
LNCPOP	0.0906	0.0000**
EL	0.2017	0.0000**
LNIDR	0.5711	0.0000**

*** significant at level of α=5%*

Table 2 presents the results of stationary tests. For variables international CPO price, domestic CPO price, biodiesel production volume, export duty, export levy, cooking oil price, CPO production and Rupiah exchange rate the p-values at the Level are above common significance levels (α=5%), indicating that these variables are non-stationary at their levels. For Export volume of CPO and its derivatives, stationary in the level. However, after taking the first difference, the p-values drop to zero (0.0000), suggesting that these variables become stationary after differencing once.

The nesxt step was to determine optimal lag length. The purpose is to determine the appropriate number of lagged terms (or past values) of both the dependent and independent variables to include in the model. Based on the Akaike Information Criteria (AIC) plot in Figure 1, the selected lag corresponds to the model with the lowest AIC value, which is visually identifiable as the lowest point on the curve. From the x-axis labels in Figure 3, the optimal model appears to be ARDL(2, 1, 3, 2, 0, 4, 1, 4, 4). This represents the selected lag structure for each variable in the ARDL model, indicating the number of lags for each variable that minimizes the AIC value.

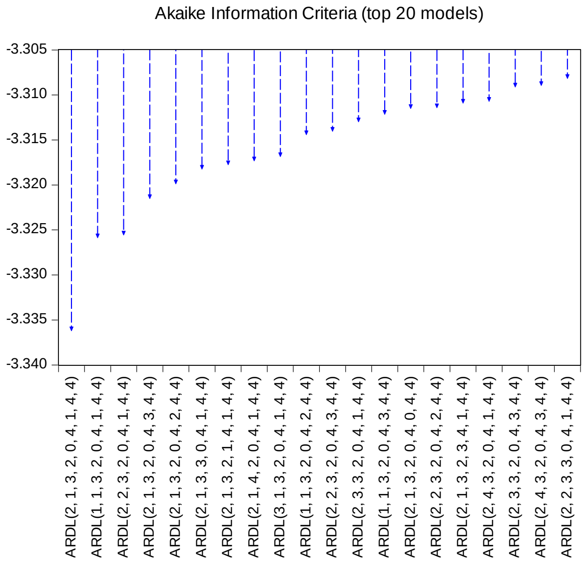

Figure 3. Optimal lag length selection

The results of this research show that in the short run (Table 3), the domestic CPO price is positively and significantly influenced by the volume of biodiesel production (3 previous lags), the export volume of CPO and its processed products (2 previous lags), and the price of palm cooking oil. Meanwhile, domestic CPO prices (1 to 2 lags previously), export duties (3 to 4 lags previously), export levies (currently, 1 to 2 lags previously), CPO production (1 lag previously), and the Rupiah exchange rate against other currencies. The American dollar (2 lags and four lags previously) has a significant negative effect. In the long run, domestic CPO prices are significantly and positively influenced by international CPO prices and palm cooking oil prices. At the same time, export demand, CPO production volume, and the Rupiah exchange rate were significantly and negatively influenced.

The negative coefficient on the variable CPO domestic prices D(LNCPOD(-1)) indicates that domestic CPO prices at lag 1 (previous period) have a significant negative effect on changes in domestic CPO prices in the current period. In commodity markets, prices tend to fluctuate in response to excess or shortage of supply and demand. If the CPO price increases in the previous period (lag 1), this may decrease demand because the higher price reduces consumption or increases supply because producers want to take advantage of the high price. As a result, prices decrease in the next period. This can explain the negative relationship between the CPO price in the previous period and the current price change.

CPO prices significantly influenced Indonesia's domestic CPO prices on the international market (Yanita and Suandi, 2023). The increase in CPO prices in the global market will increase the amount of CPO exports and reduce the amount of domestic supply (Winardi et al.., 2017; Irawan and Soesilo, 2021).

Purba and Hartoyo (2010) stated that increasing CPO prices on the international market would increase CPO exports by 0.182%. The increase in international CPO prices can reduce of domestic CPO supply due to excessive exports, thereby increasing the price of derivative products such as cooking oil (Siregar, et al., 2014).

Biodiesel production is closely related to the demand for CPO because palm oil is the primary raw material of biodiesel. When biodiesel production increases, the demand for CPO also increases. Over time, this increase in demand will cause a decrease in the supply of CPO in the domestic market, ultimately driving up CPO prices. The results in Table 3 show that biodiesel production volume significantly positively affects domestic CPO prices in the previous lag 3. This indicates that there is a time lag required for increased biodiesel production, which will impact CPO prices. Domestic market adjustment to increased demand for CPO takes time because the market may initially have sufficient stock. However, in the longer term, demand increases due to the continued growth of biodiesel production.

The increase in export volume will impact reducing domestic CPO stocks, which could encourage an increase in domestic CPO prices (Irawan and Soesilo, 2021). Hartoyo *et al.* (2011) stated that the development of the biodiesel industry would disrupt the availability of raw materials for cooking oil. The impact of increasing CPO export volumes may not be immediately felt in domestic prices. There is a time lag between increased exports and their impact on prices in the domestic market. This lag can be caused by various factors such as previously agreed export contracts, logistics processes, or domestic stock adjustments. Therefore, the effect of increasing export volumes is only seen significantly at lag 2.

An export levy is imposed to support the mandatory biodiesel program and the development of the downstream palm oil industry. Although this levy can help increase state revenue, the high burden can encourage producers to prefer selling CPO in the domestic market, especially when international prices are unfavourable. The significant negative effect of the export levy current up to lag 2 indicates that the export levy policy immediately lowers domestic CPO prices, as exporters reduce exports due to the additional burden of the levy, which causes an increase in domestic supply. The absence of a significant effect of export levy lag 3 indicates that after three periods, the impact of the export levy on domestic CPO prices fades because the market has adjusted to the policy. The significant positive effect of export levy lag 4 indicates that after several periods, the market recovers, and exporters increase exports so that supply in the domestic market decreases, eventually increasing domestic CPO prices.

Setting CPO export duties is considered effective in maintaining domestic palm cooking oil supply and prices (Susila and Setiawan, 2001). Rifin (2010) stated that the implementation of a CPO export tax will reduce the competitiveness of Indonesian CPOs in the international market. If the price of CPO in the international market is high, but the export tax imposed is also high, then the export volume will decrease (Susila and Setiawan, 2001; Prasetyo et al., 2017; Nugroho and Lubis, 2020).

Wahyudi *et al.* (2023) stated that the Rupiah exchange rate against the US Dollar significantly positively affects Indonesian CPO prices in the short run. The exchange rate is one of the determinants of domestic commodity prices (Aprina, 2014). The Rupiah exchange rate against the US Dollar also plays a vital role in the volume of Indonesian CPO exports.

Export duty is imposed on CPO exports to prevent too much CPO from being exported when international prices are high, to maintain stable domestic supply. This duty varies based on the global CPO reference price. When international CPO prices rise above a certain threshold, the government increases the export duty to reduce exports and maintain domestic price stability.

Table 3. Short run results

Variable	Coefficient	t-Statistic	Prob.
D(LNCPOD(-1))	-0.285771	-3.061225	0.0031***
D(LNCPOD(-2))	-0.117389	-1.484863	0.1419
D(LNCPOI)	0.542584	7.143721	0.0000***
D(LNCPOI(-1))	0.224442	1.956085	0.0543*
D(LNBIO)	-0.006559	-0.331839	0.7410
D(LNBIOL(-1))	-0.003567	-0.194730	0.8461
D(LNBIO(-2))	-0.013828	-0.801587	0.4254
D(LNBIO(-3))	0.033758	2.155247	0.0344**
D(LNCPOX)	-0.013313	-0.846927	0.3998
D(LNCPOX(-1))	0.015716	0.899672	0.3713
D(LNCPOX(-2))	0.066160	3.608805	0.0006***
D(LNCOP)	0.700466	4.169088	0.0001***
D(EL)	-0.000394	-2.168967	0.0333**
D(EL(-1))	-0.000445	-2.745064	0.0076***
D(EL(-2))	-0.000573	-3.152387	0.0023***
D(EL(-3))	-1.60E-05	-0.094977	0.9246
D(EL(-4))	0.000442	2.650347	0.0099***
D(LNCPOP)	-0.041133	-0.783481	0.4359
D(LNCPOP(-1))	-0.093965	-1.814472	0.0737*
D(ED)	0.000401	1.587541	0.1167
D(ED(-1))	-0.000278	-1.086191	0.2810
D(ED(-2))	0.000370	1.400447	0.1656
D(ED(-3))	-0.000767	-3.148943	0.0024***
D(ED(-4))	-0.000599	-2.708066	0.0084***
D(LNIDR)	-0.489069	-1.701382	0.0931*
D(LNIDR(-1))	0.391067	1.437480	0.1549
D(LNIDR(-2))	-1.186589	-4.041879	0.0001***
D(LNIDR(-3))	-0.106419	-0.399349	0.6908
D(LNIDR(-4))	-1.002431	-3.922887	0.0002***
C	0.002839	0.634346	0.5278
R-squared	0.813556		
Adjusted R-squared	0.739489		
F-statistic	10.98407		
Prob(F-statistic)	0.000000		

**significant at the α=10% level; **significant at the α=5% level; ***significant at the α=1% level.*

The weakening of the Rupiah against the US Dollar can have positive and negative impacts. The positive impact is that it can increase export profit margins. The depreciation of the Rupiah exchange rate will increase the price of CPO exports to the world market, increasing export volumes while domestic supply will decrease. Meanwhile, the negative impact of the weakening of the Rupiah is an increase in the price of imported goods, mainly imported industrial raw materials. The weakening of the Rupiah will impact the prices of CPO (Khin *et al.*, 2013). The weaker the Rupiah against the US Dollar, the higher the CPO export volume (Pradina and Adhitya, 2023). This will reduce domestic supply, potentially increasing CPO prices on the domestic market.

Indonesia and Malaysia are one of the world's largest CPO exporters (Novindra *et al.*, 2019; Hidayat *et al.*, 2023). Indonesia has a comparative advantage in palm oil due to its high production and export volumes (Utsaha, Suharno and Utami, 2022). Since most of Indonesia's CPO production is intended for export, prices in the international market are the primary reference for producers in setting prices in the domestic market. When international CPO prices rise, producers in Indonesia tend to increase prices in the domestic market because they can gain greater profits from the export market.

Global supply and demand dynamics, including production in palm oil-producing countries, trade policies, and climate conditions greatly influence CPO prices in the international market. When global CPO production declines, international prices rise. This price increase causes prices to rise in the domestic market because producers choose to export their CPO to more profitable international markets rather than selling it domestically.

The R-squared value obtained is 0.813556. This value shows how much variability of the dependent variable can be explained by the model. In this case, 81.36% of the variation in the dependent variable can be explained by the independent variables in the model. The higher the R-squared value, the better the model explains data variation. The Adjusted R-squared value is 0.739489. This value is an adjustment of R-squared to account for the number of independent variables in the model. A value of 0.739 indicates that the adjusted model explains about 73.95% of the data variability.

Table 4 shows the results of a Cointegration Test (Bounds Test). This test helps determine if there is a long-run equilibrium relationship between the dependent and independent variables in an ARDL. The calculated F-statistic for the Bounds Test is 19.78190. This value will be compared to the critical values listed under columns I(0) and I(1) at various significance levels to determine whether cointegration exists. The F-statistic (19.78190) is much larger than the critical value of 3.77 for the I(1) bound at the 1% significance level. Since the F-statistic exceeds the upper bound at the highest significance level (1%), there is strong evidence of cointegration. This means the variables in the model have a long-run equilibrium relationship.

Table 4. Cointegration Test (Bounds Test)

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	19.78190	10%	1.85	2.85
k	8	5%	2.11	3.15
		2.5%	2.33	3.42
		1%	2.62	3.77

The results of the long-run test are presented in Table 5. These results show that in the long run, domestic CPO prices are significantly and positively influenced by CPO prices in the international market and cooking oil prices, while those that significantly and negatively influence are export levy, CPO production, export duty, and the Rupiah exchange rate against the US Dollar. In the long run, biodiesel production volume does not significantly affect domestic CPO prices. These results indicate a spillover impact from biodiesel production on raw materials and cooking oil prices in the short run. If CPO stocks are abundant, CPO prices can fall and vice versa (Limbong and Halimatussadiah, 2022).

CPO prices in the international market significantly positively affect domestic CPO prices (a=1%). Indonesia is the world's leading producer and exporter of CPO, so domestic CPO prices are greatly influenced by global market conditions. When international CPO prices rise, producers in Indonesia prefer to export CPO because they can get higher prices in the global market.

Export levies have a significant negative effect (α=5%) on domestic CPO prices in Indonesia because they change the dynamics of supply and demand in domestic and international markets. Export levies increase exporters' costs when they sell CPO to the international market. With higher export levies, the total cost of exporting becomes greater, so the profit margin from selling CPO abroad is reduced. As a result, producers are more likely to hold back or reduce export volumes and increase sales in the domestic market to avoid the burden of these levies. This decrease in exports increases the availability of CPO in the domestic market, potentially lowering domestic prices due to increased supply.

CPO production significantly negatively affects (α=10%) on domestic CPO prices in the long run. High CPO production causes an increase in CPO supply in the domestic market. When production increases significantly and more CPO is available in the market than can be absorbed by domestic demand, CPO prices will fall. In economic principles, when the supply of a commodity exceeds demand, the commodity's price will fall to balance the market. Therefore, increased CPO production can cause excess supply in the domestic market, ultimately depressing CPO prices in the long run.

The rupiah exchange rate significantly negatively affects domestic CPO prices (α=1%). If the Rupiah weakens, CPO producers may be more tempted to export their products because the price in Dollars is more attractive. This could reduce supply for the domestic market. However, suppose the government or local policies impose export restrictions, implement high export taxes to protect domestic CPO supplies, and the implementation of Domestic Market Obligation (DMO). In that case, producers will be forced to sell in the domestic market even though global demand is more favourable. This could create excess domestic supply, which depresses domestic CPO prices.

Biodiesel production does not significantly affect domestic CPO prices because of government policies that regulate CPO supply for biodiesel, biodiesel dependence on subsidies and crude oil prices, and the abundance of CPO supply in the domestic market. In addition, domestic CPO prices tend to be more influenced by global market conditions, so increasing domestic biodiesel production is not enough to cause significant changes in domestic CPO prices in the long run.

Table 5. Long-run result

Variable	Coefficient	t-Statistic	Prob.
D(LNCPOI)	0.546643	5.717417	0.0000***
D(LNBIO)	0.006987	0.189188	0.8505
D(LNCPOX)	0.048864	1.619788	0.1096
D(LNCOP)	0.499206	4.225394	0.0001***
D(EL)	-0.000703	-2.501555	0.0146**
D(LNCPOP)	-0.096282	-1.715676	0.0905*
D(ED)	-0.000621	-1.228718	0.2231
D(LNIDR)	-1.705752	-3.283643	0.0016***
C	0.002023	0.637592	0.5257

The development of the biodiesel program increases domestic demand for CPO and will impact domestic palm oil prices (Purba and Hartoyo, 2010; Joni *et al.*, 2011). However, (Rambe, Kusnadi and Suharno, 2019) stated that the development of biodiesel has not had much impact on the increase in domestic CPO prices. One of the main challenges in using CPO for biodiesel is the competition between two major sectors that use CPO for the food industry (cooking oil) and energy (biodiesel). When the demand for biodiesel increases along with mandatory policies such as B20 and B30, the volume of CPO allocated for cooking oil production can decrease. This puts pressure on the supply of CPO for food needs, ultimately increasing the cooking oil price. Corley (2009) stated that population growth will increase CPO consumption. Mueller et al. (2011) stated that biofuel production could increase the prices of food commodities. The increase in CPO prices needs to be anticipated because it can potentially increase the price of cooking oil.

Increasing the biodiesel blending rate, as implemented in Indonesia, can worsen the situation when the supply of CPO is limited or disrupted. As a result, the price of domestic cooking oil can increase, considering that CPO is the main ingredient in its production (Tety, Hutabarat and S, 2009).

The dynamics of global supply and demand greatly influence the price of CPO in the international market. When the demand for CPO-based biodiesel increases in the global market, the price of CPO is automatically pushed up. This increase in CPO price will directly impact the production costs of cooking oil, considering that producers must adjust prices to compensate for the increase in raw material prices. At the same time, CPO export policies such as export duties or export levies imposed by the government can affect the supply of CPOs in the domestic market. If the government encourages CPO exports to benefit from high prices in the international market, this could reduce domestic supply and cause cooking oil prices to increase.

Using used cooking oil as an alternative biodiesel feedstock can help reduce pressure on CPO, which can stabilize cooking oil prices. If more biodiesel is produced from used cooking oil, then the demand for CPO for biodiesel can be reduced, and a larger supply of CPO can be allocated for food needs such as cooking oil. This can potentially reduce or stabilize cooking oil prices, especially in the domestic market.

Nuva *et al.* (2019) stated that the benefits of biodiesel development do not directly impact the community because palm oil produced by farmers is not only used to produce biodiesel. The Indonesian government has implemented mandatory biodiesel policies such as B20 and B30 as part of its energy transition and carbon emission reduction efforts. However, this policy also has an impact on the cooking oil market. When the biodiesel blending rate increases, the demand for CPO for fuel also increases, causing a reduction in the supply of CPO for cooking oil and an increase in prices. On the other hand, if the government can introduce regulations that support the use of used cooking oil as a biodiesel feedstock on a large scale, this can help reduce demand for CPO, stabilize CPO prices, and ultimately lower cooking oil prices.

Policies such as export levies and export duties imposed on CPO and its derivatives also play an important role in determining cooking oil prices. High export duties can reduce CPO exports and increase domestic supply, which can depress cooking oil prices. However, if export levies are low, producers may be more encouraged to export CPO, which can reduce domestic supply and increase cooking oil prices.

In linear regression, the R-squared value is commonly used as an assessment of Goodness of Fit (Pas, 1987). The R-squared value obtained is 0.813556 indicating that approximately 81.36% of the variability in the observed data can be explained by the model. This means that the model has a good ability to explain the relationship between the independent and dependent variables. The result of the probability value for normality test was 0.5124, this value is greater than significance level (α=5%), meaning we fail to reject the null hypothesis of normally distributed residuals.

The next tests were the autocorrelation and heteroscedasticity test to test the robustness of the model used (Jegadeesh and Karceski, 2009; Vogelsang, 2012). The results for these test are shown in Table 6. The Breusch-Godfrey Serial Correlation LM Test, shows probability value (Prob. F(2,71) = 0.1519) is greater than 0.05, so we fail to reject the null hypothesis, meaning there is no evidence of serial correlation in the residuals. Heteroskedasticity test using Breusch-Pagan-Godfrey test shows Prob. F(29,73) = 0.6554. Since this probability is greater than 0.05, we fail to reject the null hypothesis of homoscedasticity, indicating no evidence of heteroskedasticity.

Table 6. Autocorrelation and heteroskedasticity test result

Breusch-Godfrey Serial Correlation LM Test	Prob. F(2,71)	Prob. Chi-Square(2)
	0.1519	0.0698

Heteroskedasticity Test: Breusch-Pagan-Godfrey	Prob. F(29,73)	Prob. Chi-Square(29)
	0.6554	0.6021

Figure 4 shows a CUSUM (Cumulative Sum) test plot, which is commonly used to check the stability of coefficients in a time series regression model, such as ARDL. If the CUSUM line (blue line) stays within these bounds, it indicates that the model's coefficients are stable over time. These lines show the 5% significance level. If the line crosses these boundaries, it suggests a structural break or instability in the model's parameters. Since the CUSUM line stays within the critical bounds, we can conclude that the coefficients of the model are stable over time.

The CUSUM of Squares (CUSUMQ) test is shown in Figure 5. These lines show the 5% significance level. If the CUSUMQ line remains within these boundaries, it suggests that the variance of the residuals is stable over time.

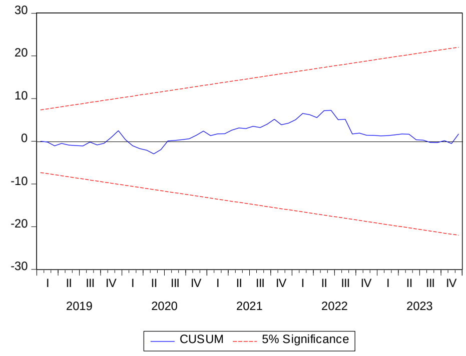

Figure 4. Result of CUSUM

If the line crosses these boundaries, it indicates a potential structural break or instability in the model's variance. Since the blue CUSUMQ line stays within the 5% significance boundaries, this implies that there is no significant change in the variance of the residuals over time. The model appears to be stable in terms of variance.

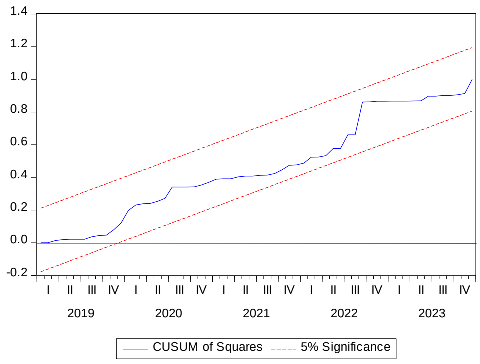

Figure 5. Result of CUSUMQ

Together, the CUSUM and CUSUMQ tests provide strong evidence that your model is stable, both in terms of the coefficients and the variance of the residuals.

CONCLUSION

The research results show that in the short term, the domestic CPO price is influenced positively and significantly by the volume of biodiesel production, the export volume of CPO and its processed products, and the price of palm cooking oil. Meanwhile, domestic CPO prices, export duties, export levies, CPO production, and the Rupiah exchange rate against the US Dollar have a significant negative effect. In the long term, domestic CPO prices are significantly and positively influenced by international CPO prices and palm cooking oil prices, while export demand, CPO production volume, and the Rupiah exchange rate are significantly and negatively influenced. Government policies need to consider the complexity caused by various factors including the biodiesel development policy itself. Increasing the biodiesel blending rate must consider domestic CPO prices so that it does not impact the increase in CPO prices in the domestic market so that it does not cause an increase in the price of CPO derivative products in the domestic market.

REFERENCES

Ahmad, A. L. *et al.* (2011) "Microalgae as a sustainable energy source for biodiesel production: A review," *Renewable and Sustainable Energy Reviews*, 15(1), pp. 584–593.

Ajanovic, A. (2011) "Biofuels versus food production: Does biofuels production increase food prices?," *Energy*, 36(4), pp. 2070–2076. doi: 10.1016/j.energy.2010.05.019.

Aprina, H. (2014) "The impact of crude palm oil price on Rupiah's rate," *Buletin Ekonomi Moneter dan Perbankan*, 16(4), pp. 295–314.

Berlian, G. S. (2015) "Politik Hilirisasi Kelapa Sawit Indonesia," *Jurnal Ilmiah Transformasi Global*, 2(2), pp. 80–100.

Cantarero, M. M. V. (2020) "Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries," *Energy Research and Social Science*, 70, pp. 1–15. doi: 10.1016/j.erss.2020.101716.

Chen, B. *et al.* (2019) "Pathways for sustainable energy transition," *Journal of Cleaner Production*, 228, pp. 1564–1571. doi: 10.1016/j.jclepro.2019.04.372.

Corley, R. H. V. (2009) "How much palm oil do we need?," *Environmental Science and Policy*, 12(2), pp. 134–139. doi: 10.1016/j.envsci.2008.10.011.

Dharmawan, A. H. *et al.* (2020) "Bioenergy Policy: The Biodiesel Sustainability Dilemma in Indonesia," *International Journal of Sustainable Development and Planning*, 15(4), pp. 537–546.

Edgerton, D. and Shukur, G. (1999) "Testing autocorrelation in a system perspective testing autocorrelation," *Econometric Reviews*, 18(4), pp. 343–386. doi: 10.1080/07474939908800351.

Ewing, M. and Msangi, S. (2009) "Biofuels production in developing countries: assessing tradeoffs in welfare and food security," *Environmental Science and Policy*, 12(4), pp. 520–528. doi: 10.1016/j.envsci.2008.10.002.

Gallo, A. B. *et al.* (2016) "Energy storage in the energy transition context: A technology review," *Renewable and Sustainable Energy Reviews*, 65, pp. 800–822. doi: 10.1016/j.rser.2016.07.028.

Ghasemi, A. and Zahediasl, S. (2012) "Normality tests for statistical analysis: A guide for non-statisticians," *International Journal of Endocrinology and Metabolism*, 10(2), pp. 486–489. doi: 10.5812/ijem.3505.

Gujarati, D. N. (2003) *Basic Econometrics*. 4th ed, *The Economic Journal*. 4th ed. Edited by L. Sutton and A. Bright. Gary Burke.

Halimatussadiah, A. *et al.* (2021) "Progressive biodiesel policy in Indonesia: Does the Government's economic proposition hold?," *Renewable and Sustainable Energy Reviews*, 150, pp. 1–11.

Halunga, A. G., Orme, C. D. and Yamagata, T. (2017) "A heteroskedasticity robust Breusch–Pagan test for Contemporaneous correlation in dynamic panel data models," *Journal of Econometrics*, 198(2), pp. 209–230. doi: 10.1016/j.jeconom.2016.12.005.

Hartoyo, S. *et al.* (2011) "Dampak kenaikan harga minyak bumi terhadap ketersediaan minyak goreng sawit domestik," *Jurnal Ekonomi dan Pembangunan Indonesia*, 11(2), pp. 169–179. doi: 10.21002/jepi.v11i2.188.

Hidayat, A. *et al.* (2023) "Competitiveness, Market Structure, and Energy Policies: A Case Study of the World's Largest Crude Palm Oil Exporter," *International Journal of Energy Economics and Policy*, 13(3), pp. 111–121. doi: 10.32479/ijeep.14199.

Hirani, A. H. *et al.* (2018) "A review on first- and second- generation biofuel productions," *Biofuels: Greenhouse Gas Mitigation and Global Warming*, pp. 141–154.

Irawan, B. and Soesilo, N. I. (2021) "Dampak kebijakan hilirisasi industri kelapa sawit terhadap permintaan cpo pada industri hilir," *Jurnal Ekonomi & Kebijakan Publik*, 12(1), pp. 29–43.

Jegadeesh, N. and Karceski, J. (2009) "Long-run performance evaluation: Correlation and heteroskedasticity-consistent tests," *Journal of Empirical Finance*, 16(1), pp. 101–111. doi: 10.1016/j.jempfin.2008.06.002.

Joni, R. *et al.* (2011) "Dampak pengembangan industri biodiesel dari kelapa sawit terhadap perkebunan kelapa sawit dan industri minyak kelapa sawit di indonesia," *Jurnal Teknologi Industri Pertanian*, 20(3), pp. 143–151.

Khatun, N. (2021) "Applications of Normality Test in Statistical Analysis," *Open Journal of Statistics*, 11(01), pp. 113–122. doi: 10.4236/ojs.2021.111006.

Khin, A. A. *et al.* (2013) "Price forecasting methodology of the Malaysian palm oil market," *The International Journal of Applied Economics and Finance*, 7(1), pp. 23–36.

Koizumi, T. (2015) "Biofuels and food security," *Renewable and Sustainable Energy Reviews*, 52, pp. 829–841. doi: 10.1016/j.rser.2015.06.041.

Kovač, A., Paranos, M. and Marciuš, D. (2021) "Hydrogen in energy transition: A review," *International Journal of Hydrogen Energy*, 46(16), pp. 10016–10035. doi: 10.1016/j.ijhydene.2020.11.256.

Kripfganz, S. and Schneider, D. C. (2023) "ardl: Estimating autoregressive distributed lag and equilibrium correction models," *Stata Journal*, 23(4), pp. 983–1019. doi: 10.1177/1536867X231212434.

Limbong, N. F. and Halimatussadiah, A. (2022) "The link between crude palm oil and crude oil price in various periods of the biodiesel mandatory policy in Indonesia," *Jurnal Ekonomi Pembangunan*, 20(2), pp. 115–124.

Markard, J. (2018) "The next phase of the energy transition and its implications for research and policy," *Nature Energy*, 3(8), pp. 628–633. doi: 10.1038/s41560-018-0171-7.

Mueller, S. A., Anderson, J. E. and Wallington, T. J. (2011) "Impact of biofuel production and other supply and demand factors on food price increases in 2008," *Biomass and Bioenergy*, 35(5), pp. 1623–1632.

Novindra, N. *et al.* (2019) "Impact of increasing in production capacity of CPO downstream industries on competitiveness and welfare of oil palm farmers in Indonesia," *International Journal of Oil Palm*, 2(2), pp. 61–73. doi: 10.35876/ijop.v2i2.33.

Nugroho, S. and Lubis, A. F. (2020) "Pengaruh pajak ekspor terhadap produksi crude palm oil di Indonesia," *Forum Ekonomi*, 22(1), pp. 138–151.

Nuva *et al.* (2019) "Ekonomi politik energi terbarukan dan pengembangan wilayah: persoalan pengembangan biodiesel di Indonesia," *Sodality: Jurnal Sosiologi Pedesaan*, 7(2), pp. 110–118.

Pas, E. I. (1987) "Intrapersonal variability and model goodness-of-fit," *Transportation Research Part A: General*, 21(6), pp. 431–438. doi: 10.1016/0191-2607(87)90032-X.

Pradina, Y. B. A. and Adhitya, D. (2023) "Effect of international cpo prices, substitution goods prices, and exchange rates on crude palm oil (cpo) export volume in Indonesia," *Jurnal Ekonomi Pembangunan*, 21(1), pp. 1–12. doi: 10.29259/jep.v21i1.19447.

Prananta, W. and Kubiszewski, I. (2021) "Assessment of Indonesia's future renewable energy plan: a meta-analysis of biofuel energy return on investment (eroi)," *Energies*, 14(10), pp. 1–15.

Prasetyo, A., Marwanti, S. and Darsono (2017) "The influence of exchange rate on CPO exports of Indonesia," *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi* *dan Pembangunan*, 18(2), pp. 159–174. doi: doi.org/10.23917/jep.v18i2.4233.

Purba, J. H. V. and Hartoyo, S. (2010) "Dampak kenaikan harga minyak bumi terhadap permintaan CPO untuk biodiesel dan beberapa aspek pada industri kelapa sawit Indonesia," *Jurnal Ilmiah Ranggagading*, 12(2), pp. 37–49.

Rambe, K. R., Kusnadi, N. and Suharno, S. (2019) "Dinamika Kebijakan Pengembangan Biodiesel Berbahan Baku Kelapa Sawit Indonesia," *Jurnal Sosial Ekonomi Pertanian*, 15(3), p. 239.

Rifin, A. (2010) "The effect of export tax on Indonesia's crude palm oil (cpo) export competitiveness," *Asean Economic Bulletin*, 27(2), p. 173.

Rutner, S. M. and Langley, C. J. (2006) "Logistics value:Definition, process and measurement," *The International Journal of Logistics of Logistics Management*, 11(2), pp. 73–82.

Sahara *et al.* (2022) "Economic impacts of biodiesel policy in Indonesia : a computable general equilibrium approach," *Journal of Economic Structures*, 11, pp. 1–22.

Shrestha, D. S., Staab, B. D. and Duffield, J. A. (2019) "Biofuel impact on food prices index and land use change," *Biomass and Bioenergy*, 124(August 2018), pp. 43–53. doi: 10.1016/j.biombioe.2019.03.003.

Siregar, M. A., Sembiring, S. A. and Ramli (2014) "The price of palm-cooking oil in indonesia: antecedents and consequences on the international price and the export volume of CPO," *Journal of Economics and Sustainable Development*, 5(23), pp. 227–235.

Solomon, B. D. and Krishna, K. (2011) "The coming sustainable energy transition: History, strategies, and outlook," *Energy Policy*, 39(11), pp. 7422–7431. doi: 10.1016/j.enpol.2011.09.009.

Staab, B. and Duffield, J. A. (2019) "Title Biofuel Impact on Food Prices Index and Land Use Change Author names and affiliations." Available at: https://www.elsevier.com/open-access/userlicense/1.0/.

Suhara, A. *et al.* (2024) "Biodiesel Sustainability: Review of progress and challenges of biodiesel as sustainable biofuel," *Clean Technologies*, 6(3), pp. 886–906. doi: 10.3390/cleantechnol6030045.

Supraniningsih, J. (2012) "Pengembangan kelapa sawit sebagai biofuel dan produksi minyak sawit serta hambatannya," *WIDYA*, 29(321), pp. 10–16. Available at: https://media.neliti.com/media/publications/218718-pengembangan-kelapa-sawit-sebagai-biofue.pdf.

Susila, W. R. and Setiawan, I. D. (2001) "Dampak pajak ekspor cpo terhadap beberapa aspek industri cpo Indonesia: simulasi model ekonometrik," *SOCA: Jurnal Sosial Ekonomi Pertanian*, 1(2), pp. 1–21.

Tanaka, T., Guo, J. and Wang, X. (2023) "Price interconnection of fuel and food markets: Evidence from biodiesel in the United States," *GCB Bioenergy*, 15(7), pp. 886–899. doi: 10.1111/gcbb.13055.

Tety, E., Hutabarat, S. and S, A. N. (2009) "The factors influencing on consumption of palm cooking oil in Indonesia," *Economic Journal of Emerging Makerts*, 1(2), pp. 137–146.

Timilsina, G. R., Mevel, S. and Shrestha, A. (2011) "Oil price, biofuels and food supply," *Energy Policy*, 39(12), pp. 8098–8105. doi: 10.1016/j.enpol.2011.10.004.

Utsaha, A., Suharno and Utami, A. D. (2022) "Perbandingan daya saing crude palm oil (cpo) antara Indonesia dan Malaysia di pasar internasional," *Jurnal Penelitian Kelapa Sawit*, 30(2), pp. 95–108.

Vogelsang, T. J. (2012) "Heteroskedasticity, autocorrelation, and spatial correlation robust inference in linear panel models with fixed-effects," *Journal of Econometrics*, 166(2), pp. 303–319. doi: 10.1016/j.jeconom.2011.10.001.

Wahyudi, H. *et al.* (2023) "Analysis of oil price and exchange rate in Indonesia," *International Journal of Energy Economics and Policy*, 13(2), pp. 27–33.

Winardi, W., Susanto, H. and Martana, K. (2017) "The impact of world cpo price change towards prices, economic activities, and income distribution in Indonesia," *Buletin*

Ilmiah Litbang Perdagangan, 11(2), pp. 207–226. doi: doi.org/10.30908/bilp.v11i2.66.

Wirawan, S. S. *et al.* (2024) "Biodiesel implementation in Indonesia: Experiences and future perspectives," *Renewable and Sustainable Energy Reviews*, 189(PA), p. 113911. doi: 10.1016/j.rser.2023.113911.

Yanita, M. and Suandi, S. (2023) "Determinant export volume of crude palm oil (cpo) in Indonesia and Malaysia in The European Union market," *Agricultural Socio-Economics Journal*, 23(1), pp. 19–24. doi: 10.21776/ub.agrise.2023.023.1.3.

Zilberman, D. *et al.* (2012) "The impact of biofuels on commodity food prices: Assessment of findings," *American Journal of Agricultural Economics*, 95(2), pp. 1–7. doi: 10.1093/ajae/aas037.