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BIODIESEL REALIZATION IN INDONESIA: DO PRICES, DEMAND, AND LAND MATTER?

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Abstract

This study analyzes the determinants of biodiesel realization in Indonesia during the period 2009-2025. Using annual time-series data, the study employs the Error Correction Model (ECM) based on the Engle-Granger two-step procedure to examine both long-run and short-run dynamics. The variables examined include world palm oil prices, world crude oil prices, active palm oil plantation area, and domestic biodiesel consumption as independent variables, against biodiesel realization as the dependent variable. The Augmented Dickey-Fuller test confirms that all variables are integrated of order I(1), and the cointegration test confirms a long-run equilibrium relationship. Results indicate that: (1) world palm oil prices have a significant negative effect on biodiesel realization in both the short and long run, consistent with production cost theory; (2) world crude oil prices have a significant positive effect, reflecting the substitution effect between biodiesel and fossil-based diesel; (3) active palm oil plantation area does not significantly affect biodiesel realization; and (4) domestic biodiesel consumption has a significant positive effect, confirming the demand-pull and policy-driven nature of Indonesia's biodiesel industry. The ECT coefficient of -1.08 indicates rapid adjustment toward long-run equilibrium. These findings provide strategic policy implications for sustaining Indonesia's biodiesel mandatory blending program and achieving energy independence targets.

Keywords: Biodiesel Realization, Palm Oil Price, Crude Oil Price, Error Correction Model, Mandatory Blending Policy

INTRODUCTION

Energy security has become a central challenge for resource-rich developing nations. Indonesia, the world's largest palm oil producer, has strategically leveraged its comparative advantage by developing a biodiesel program based on crude palm oil (CPO). Since 2009, the Indonesian government has implemented a mandatory blending policy and progressively increasing the biodiesel-to-fossil-solar ratio from B7.5 (7.5%) to B40 (40%) by 2025 as a key instrument to reduce fossil fuel dependency, conserve foreign exchange, and accelerate the share of new and renewable energy (EBT) in the national energy mix.

Based on data from the Ministry of Energy and Mineral Resources (ESDM), Indonesia's primary energy mix in 2024 was still dominated by coal (40.56%), petroleum (28.14%), and natural gas (16.62%), with EBT contributing only 14.47% which is well below the national target of 19.5%. Biodiesel, as the primary instrument for EBT acceleration, has demonstrated consistent growth in realization, from 379 million kL in 2009 to 30,594 million kL projected in 2025. The program has cumulatively saved Rp720 trillion in foreign exchange between 2015 and 2025, and reduced CO2 emissions by 38.8 million tons in 2025.

Despite these achievements, biodiesel realization exhibits significant volatility influenced by multiple determinants. From the supply side, world palm oil prices as the dominant input cost create direct pressure on producer margins. From the demand side, world crude oil prices determine the relative competitiveness of biodiesel versus fossil solar. Domestic palm oil plantation area represents the feedstock supply capacity, while domestic biodiesel consumption, driven by mandatory blending regulations, constitutes the primary market for producers.

This study aims to examine the determinants of biodiesel realization in Indonesia during 2009-2025 by analyzing the effects of world palm oil prices, world crude oil prices, active palm oil plantation area, and domestic biodiesel consumption on biodiesel realization.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

This study is grounded in the Cobb-Douglas production theory, which posits that total output(Q) is a function of capital (K), labor (L), and technological efficiency (A): Q = $AK^{\alpha}L^{\beta}$ Applied to the biodiesel industry, production volume is determined by the availability and cost of key inputs (palm oil as raw material), the price of substitute goods (fossil diesel), and market demand. When input prices rise, marginal costs increase and producers tend to reduce output, ceteris paribus. Conversely, when the price of the substitute good rises, demand for and production of biodiesel strengthens (Angelo & Gina, 2015).

Multiple studies confirm the critical role of commodity price dynamics and policy in shaping biodiesel output. Siregar et al. (2024) found that crude oil price movements positively affect Indonesia's biodiesel industry through the substitution mechanism. Limbong & Halimatussadiah (2023) established a conditional linkage between palm oil prices and biodiesel production under varying policy regimes. Sahara et al. (2022) demonstrated that the B30 mandate positively impacted real GDP and real wages. Puspitawati et al. (2024) confirmed through a Dynamic CGE model that biodiesel downstream industry generates positive economic spillovers. Syahputra et al. (2023) found that diesel prices and the number of diesel vehicles significantly affect biodiesel demand. Widyaningrum et al. (2024) showed that B35 exerts pressure on palm oil export stocks while strengthening domestic energy security.

Drawing from production theory and prior empirical evidence, the following hypotheses are proposed:

H1: World palm oil prices have a significant negative effect on biodiesel realization in Indonesia.
H2: World crude oil prices have a significant positive effect on biodiesel realization in Indonesia.
H3: Active palm oil plantation area has a significant positive effect on biodiesel realization in Indonesia.
H4: Domestic biodiesel consumption has a significant positive effect on biodiesel realization in Indonesia.
H5: World palm oil prices, world crude oil prices, active palm oil plantation area, and domestic biodiesel consumption simultaneously have a significant effect on biodiesel realization in Indonesia.

RESEARCH METHODS

This study employs a quantitative explanatory approach using annual time-series data from 2009 to 2025 (17 observations). The data sources are: (1) Biodiesel realization (BIOPROD, million kL) from the Directorate General of New, Renewable Energy and Energy Conservation (EBTKE), Ministry of ESDM; (2) World palm oil price (CPO, USD/ton) and world crude oil price (CRUDE, USD/ton) from the World Bank Commodity Price Data (Pink Sheet); (3) Active palm oil plantation area (LAND, ten-thousand hectares) from the Ministry of Agriculture; and (4) Domestic biodiesel consumption (CONSUM, terajoule) from the FAOSTAT database.

First, a unit root test is conducted to confirm that all variables are I(1). Second, the Engle-Granger cointegration test checks for a long-run equilibrium relationship by testing stationarity of the residuals from the OLS long-run regression. The long-run model is:

$BIOPRODt = \beta_0 + \beta_1 CPO_t + \beta_2 CRUDE_t + \beta_3 LAND_t + \beta_4 CONSUM_t + \varepsilon t$ .... (1)

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The residuals (ECT) from equation (1) are saved and incorporated into the short-run ECM:

$$D(BIOPROD)t = \alpha_0 + \alpha_1 D(CPO)_t + \alpha_2 D(CRUDE)_t + \alpha_3 D(LAND)_t + \alpha_4 D(CONSUM)_t + \gamma ECT(t-1) + \mu t \quad \text{..} (2)$$

Classical assumption tests include normality, multicollinearity, heteroscedasticity, and autocorrelation are conducted on the short-run model to ensure BLUE estimator properties. All estimations are performed using EViews

RESULTS AND DISCUSSION

Stationarity and Cointegration Tests

Table 1 presents the ADF unit root test results. All five variables are non-stationary at level (probability > 0.05) but become stationary at first difference (probability < 0.05), confirming they are all I(1).

Table 1. Unit Root Test Results

Variable	Level (Prob.)	Stationarity	1st Diff. (Prob.)	Stationarity	Order
BIOPROD	0.9400	Non-Stationary	0.0009	Stationary	I(1)
CPO	0.2684	Non-Stationary	0.0324	Stationary	I(1)
CRUDE	0.3131	Non-Stationary	0.0228	Stationary	I(1)
LAND	0.7121	Non-Stationary	0.0032	Stationary	I(1)
CONSUM	0.9908	Non-Stationary	0.0372	Stationary	I(1)

Source: Processed data by EViews, 2026

The Engle-Granger cointegration test yields an ADF t-statistic of -4.2992 (p = 0.0059), significantly below the 5% critical value of −3.0989. This confirms that BIOPROD, CPO, CRUDE, LAND, and CONSUM are cointegrated, justifying the use of the ECM framework.

Classical Assumption Tests

Classical assumption tests on the short-run ECM confirm model validity: (1) Normality: Jarque-Bera probability = 0.1344 > 0.05, residuals are normally distributed; (2) Multicollinearity: all VIF values are below 10 (D(CPO) = 2.81, D(CRUDE) = 1.69, D(LAND) = 2.80, ECT(-1) = 1.75), indicating no multicollinearity; (3) Heteroscedasticity (ARCH test): F-statistic probability = 0.4053, no conditional heteroscedasticity; (4) Autocorrelation (Breusch-Godfrey LM): Chi-Square probability = 0.5716, no serial correlation. The model satisfies all classical assumptions.

Long-Run Estimation Results

Table 2 presents the OLS long-run regression results. The R^2 of 0.9398 indicates the model explains 93.98% of variation in biodiesel realization. The F-statistic of 38.995 (Prob. = 0.000005) confirms simultaneous significance of all regressors, supporting H5.

Table 2. Long-Run OLS Regression Results

Variable	Coefficient	t-Statistic	t-Table (5%)	Prob.
Constant	6355.097	0.9727	±2.179	0.3536
CPO	−14.9042	−3.2729	−2.179	0.0084

Variable	Coefficient	t-Statistic	t-Table (5%)	Prob.
CRUDE	123.133	3.1616	2.179	0.0101
LAND	−1.2520	−0.2412	−2.179	0.8143
CONSUM	0.0695	5.0749	2.179	0.0005

Source: Processed data by EViews, 2026

The ECT(−1) coefficient of -1.0829 is significant (Prob. = 0.0403), confirming a valid error correction mechanism. The magnitude ($|\gamma| > 1$) indicates fast over-correction, meaning the system slightly overshoots equilibrium before converging, which is consistent with the highly policy-driven nature of Indonesia's biodiesel market.

Effect of World Palm Oil Price (H1)

World palm oil prices have a significant negative effect on biodiesel realization in both the short run (coefficient = -16.31, p = 0.0100) and long run (-14.90, p = 0.0084), supporting H1. This finding aligns with production theory: since palm oil constitutes approximately 75-80% of biodiesel production costs, an increase in input prices directly raises marginal costs and depresses output. Although the BPDPKS incentive mechanism is designed to offset this price pressure, the results suggest that extreme price spikes such as those observed in 2021-2022 when CPO reached USD 1,275.99/ton can overwhelm the incentive budget and constrain production. This finding is consistent with Limbong & Halimatussadiah (2023) and Panjaitan (2025).

Effect of World Crude Oil Price (H2)

World crude oil prices have a significant positive effect on biodiesel realization in both the short run (133.10, p = 0.0069) and long run (123.13, p = 0.0101), supporting H2. This is consistent with the theory of substitute goods: as crude oil prices rise, fossil solar becomes more expensive, narrowing the price spread and making biodiesel more competitive. The large coefficient magnitude reflects the leverage effect a USD 1/ton increase in crude oil price translates to a 133 million kL increase in biodiesel realization in the short run. This aligns with Siregar et al. (2024) and Soesanto et al. (2025).

Effect of Active Palm Oil Plantation Area (H3)

Active palm oil plantation area does not significantly affect biodiesel realization in either the short run (p = 0.3689) or long run (p = 0.8143), failing to support H3. The negative coefficient in the short run (-10.99) may reflect the temporary effects of replanting programs initiated since 2017, where land under rejuvenation is counted as inactive area without reducing long-run productive capacity (Hasbullah et al., 2025). The insignificance suggests that within the 2009-2025 period, supply-side constraints from land capacity have not been the binding constraint on biodiesel output. Rather, demand-side policies (mandatory blending mandates) and price signals dominate production decisions.

Effect of Domestic Biodiesel Consumption (H4)

Domestic biodiesel consumption has a significant positive effect in both the short run (0.063, p = 0.0340) and long run (0.070, p = 0.0005), supporting H4. This finding confirms the policy-driven and demand-pull character of Indonesia's biodiesel industry. The mandatory blending policy effectively creates a captive market which each successive increase in blending percentage compels producers to scale up output to meet the regulated quota. This is consistent with Wirawan et al. (2024) and Kurniadi et al. (2021), who found that policy-mandated demand is the primary growth driver of biodiesel production.

CONCLUSION

This study examined the determinants of biodiesel realization in Indonesia using annual time-series data from 2009 to 2025 and the Error Correction Model framework. The key findings are: First, world palm oil prices negatively and significantly affect biodiesel realization in both the short and long run, confirming that input cost pressures constrain output when price increases outpace the BPDPKS incentive mechanism. Second, world crude oil prices positively and significantly affect biodiesel realization, reflecting the substitution dynamics between biodiesel and fossil-based solar. Third, active palm oil plantation area does not significantly affect biodiesel realization, suggesting that feedstock supply capacity is not the binding constraint in this period; replanting program dynamics may partly explain the non-significance. Fourth, domestic biodiesel consumption positively and significantly drives biodiesel realization, confirming that the mandatory blending policy is the strongest determinant of production volume.

The policy implications are: (1) the BPDPKS incentive formula should be dynamically adjusted to remain viable during commodity price spikes; (2) government should strengthen mandatory blending targets (B45-B50 roadmap) during periods of low crude oil prices to compensate for weakened market incentives; (3) investment should shift from land expansion to yield intensification and replanting, consistent with sustainability objectives; and (4) regulatory consistency and predictability are paramount to sustaining investor confidence in the biodiesel sector.

Limitations include the small sample size of 17 annual observations, the exclusion of variables such as the Rupiah exchange rate, BPDPKS incentive disbursements, and the installed capacity of biodiesel plants. Future research should consider higher-frequency data, structural break tests (e.g., Gregory-Hansen cointegration), and provincial panel analysis to capture heterogeneity across producing regions.

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