

CPO Price Dynamics Amid Geopolitical Turmoil in the Strait of Hormuz: A Vector Error Correction Model (VECM) Approach

Muhammad Yazid Irfani^{1*}, Dian Artika², Evana Justine Nur Aisyah³, Ahmad Ahmad Djalaluddin⁴, Ahmad Tibrizi Soni Wicaksono⁵

Faculty of Economics, State Islamic University of Maulana Malik Ibrahim
Malang, Indonesia

Corresponding Author: Muhammad Yazid Irfani 240503110082@student.uin-malang.ac.id

ARTICLE INFO

Keywords: CPO Prices, Strait of Hormuz, VECM, Exchange Rate, Inflation

Received : 12, July

Revised : 14, August

Accepted: 30, September

©2026 Irfani, Artika, Aisyah, Djalaluddin, Wicaksono : This is an open-access article distributed under the terms of the [Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

This study analyzes the dynamics of CPO prices amid the geopolitical turmoil in the Strait of Hormuz, taking into account exchange rates, inflation, and economic growth. The research uses daily data and the Vector Error Correction Model (VECM) method to examine short- and long-term relationships, causality, responses to shocks, and the contribution of variables to changes in CPO prices. The results show a long-term equilibrium among the variables, while inflation plays a role in short-term dynamics. CPO prices respond to macroeconomic shocks, with economic growth contributing more over longer horizons. These findings highlight the importance of macroeconomic conditions and global energy in managing CPO price risks, as well as strengthening downstream development and biodiesel policies.

INTRODUCTION

The geopolitical turbulence in the Strait of Hormuz has become a source of uncertainty in global energy trade because the area is a strategic route for transporting crude oil and energy products. The geopolitical escalation in March–April 2026 heightened concerns about energy supply and increased volatility in global energy markets. This situation shows that geopolitical conflicts can act as external shocks affecting commodity markets and macroeconomic conditions simultaneously. For Indonesia, this situation is relevant because Crude Palm Oil (CPO) is one of the strategic commodities linked to the global energy market, particularly through its use as a raw material for biodiesel (Verduzco-Bustos, Guillermo Zanetti, 2026). Changes in energy market conditions can affect vegetable oil demand, while CPO price movements can also interact with trade, export revenues, exchange rates, inflation, and economic activity (Dutta & Vinh, 2021).

The relationship between CPO prices, exchange rates, inflation, and economic growth can be dynamic in both the short and long term. Changes in exchange rates can affect export competitiveness and CPO producers' revenues, while commodity price movements may also relate to foreign exchange earnings (Sumarno et al., 2026). Changes in CPO and energy prices can also contribute to inflationary pressures through production and distribution costs, which may subsequently relate to economic activity. Previous studies have shown a connection between energy markets and vegetable oil prices through the use of vegetable oil as a raw material for biodiesel (Alam & Singagerda, 2019). Geopolitical risks can also influence commodity markets through changes in expectations, potential supply disruptions, and trade uncertainty (Ramadhani et al., 2024).

Research that specifically integrates CPO price dynamics with exchange rates, inflation, and economic growth in the context of geopolitical turmoil in the Strait of Hormuz remains limited. Previous studies tend to focus on crude oil or broader energy markets when examining the effects of geopolitical risks. This study therefore positions CPO as the main variable and uses daily data to capture the dynamics among variables more closely during the observation period. In addition to identifying long-term and short-term relationships, this study examines temporal relationships through Granger causality, CPO price responses to shocks through the Impulse Response Function (IRF), and the contribution of variables to CPO price variations through Variance Decomposition (VDc) (Zou, 2018). This approach provides a more comprehensive view of CPO price dynamics under energy market uncertainty and changing macroeconomic conditions.

Based on the background and research gap, this study aims to analyze the dynamics of CPO prices amid geopolitical turmoil in the Strait of Hormuz by considering exchange rates, inflation, and economic growth. The analysis uses the Vector Error Correction Model (VECM) to identify long-term equilibrium relationships and short-term dynamics among variables. The study also examines temporal causality, analyzes CPO price responses to macroeconomic

shocks, and measures the contribution of each variable to CPO price variations across different daily time horizons.

THEORETICAL REVIEW

Geopolitical Theory and Commodity

Geopolitical risk is an external factor that can influence commodity market dynamics through increased uncertainty, changes in market participants' expectations, and potential disruptions to energy distribution and supply (Tao et al., 2025). Tensions in strategic energy trade regions can increase risk perception and contribute to greater commodity price volatility. The Strait of Hormuz has an important position in global energy trade, so geopolitical unrest in the region can create uncertainty in energy markets and related commodities. These conditions may operate through changes in energy prices, production and distribution costs, demand, and market participants' decisions. In this study, the geopolitical unrest in the Strait of Hormuz is positioned as the external context for examining CPO price dynamics during the observation period. Because geopolitics is not included as a direct variable in the VECM model, this study does not estimate the causal effect of the conflict itself on CPO prices. Instead, the empirical model focuses on the dynamic relationship between CPO prices and the exchange rate, inflation, and economic growth as the main macroeconomic variables.

CPO and Energy Market

Crude Palm Oil (CPO) is a vegetable oil commodity connected to the energy market through its use as a raw material for biodiesel. Increased biodiesel utilization can raise demand for CPO, meaning that changes in energy market conditions can affect vegetable oil prices (Dutta & Vinh, 2021). This relationship becomes more relevant during energy market fluctuations because changes in oil prices can influence the relative competitiveness of biofuels. The relationship between CPO and the energy market can therefore occur through demand, substitution, and cost mechanisms. A rise in energy prices, under certain conditions, can increase the attractiveness of biofuels and consequently support demand for CPO as a biodiesel feedstock. At the same time, changes in energy prices can affect CPO production, transportation, and distribution costs. Therefore, CPO's role as both a food commodity and an energy raw material provides a theoretical basis for examining its price dynamics amid uncertainty in global energy markets.

CPO Prices and Macroeconomic Variables

The price of CPO as an internationally traded commodity is influenced by the interaction of demand, supply, and global economic conditions (Awaliyah et al., 2023). The exchange rate is an important variable because CPO trade is largely conducted in US dollars. Exchange rate movements can affect export competitiveness, exporter earnings, and the value of producers' income in domestic currency. Conversely, changes in export commodity prices can affect foreign exchange earnings and exchange rate conditions. This reciprocal

relationship provides a basis for examining the exchange rate together with CPO prices in the empirical model.

Inflation and economic growth are also related to CPO price dynamics. Changes in CPO and energy prices can contribute to inflationary pressures through production, transportation, and distribution costs, while inflation can influence business operating expenses. Economic growth reflects changes in production activity and demand that may be associated with commodity price movements. These relationships indicate that CPO prices, exchange rates, inflation, and economic growth can interact dynamically rather than operate independently. Therefore, their relationships need to be examined in both the short and long term.

Vector Error Correction Model (VECM)

The Vector Error Correction Model (VECM) is a development of the Vector Autoregression (VAR) used to analyze dynamic relationships among time-series variables that have a long-term equilibrium relationship (Ana et al., 2023). When variables are cointegrated, they may experience short-term changes while maintaining a long-term equilibrium. VECM captures both short-term dynamics and the adjustment process when deviations from long-term equilibrium occur.

In this study, VECM provides the main analytical framework for examining the dynamic relationship between CPO prices, exchange rates, inflation, and economic growth. The model is used to identify long-term relationships, short-term adjustments, and the process through which variables respond to deviations from equilibrium. The analysis is complemented by Granger causality, Impulse Response Function (IRF), and Variance Decomposition (VDc) to examine temporal relationships, responses to shocks, and the contribution of each variable to CPO price variations.

Previous Research and Hypothesis Development

Previous research indicates relationships among energy markets, vegetable oil prices, and macroeconomic conditions. The relationship between crude oil prices and vegetable oils can occur through the use of vegetable oil as an alternative energy raw material, particularly biodiesel. Geopolitical risks can also influence commodity markets through changes in market participants' expectations, potential supply disruptions, and increased trade uncertainty (Ramadhani et al., 2024). These findings provide a basis for considering CPO price dynamics together with broader energy-market and macroeconomic conditions.

Research that specifically integrates CPO price dynamics with exchange rates, inflation, and economic growth in the context of geopolitical turmoil in the Strait of Hormuz remains limited. This study therefore positions CPO as the main variable and uses daily data to examine the dynamic relationships among the variables. Based on the theoretical relationships and previous research discussed above, the study proposes five analytical hypotheses: a long-term relationship among the variables (H1), short-term dynamic relationships (H2), temporal causality between variables (H3), responses of CPO prices to macroeconomic

shocks (H4), and contributions of exchange rates, inflation, and economic growth to CPO price variations across different time horizons (H5).

Conceptual Framework

The conceptual framework of this study illustrates the dynamic relationship between Crude Palm Oil (CPO) prices as the main variable and exchange rates, inflation, and economic growth within the context of geopolitical turmoil in the Strait of Hormuz. Geopolitical turmoil is positioned as an external context that may increase uncertainty in energy and commodity markets, while the empirical relationships are analyzed through the macroeconomic variables used. Since geopolitical factors are not included as separate variables in the model, this study does not claim a direct causal effect of geopolitical turmoil on CPO prices.

The analysis begins with stationarity and lag length tests, followed by cointegration testing to identify long-term equilibrium relationships. VECM is then used to examine long-term relationships and short-term dynamics, complemented by Granger causality, Impulse Response Function (IRF), and Variance Decomposition (VDC) to examine temporal relationships, responses to shocks, and the contribution of each variable to CPO price variations (Zou, 2018). This framework forms the basis for the five hypotheses concerning long-term relationships (H1), short-term dynamics (H2), temporal causality (H3), CPO responses to shocks (H4), and variable contributions to CPO price variations (H5).

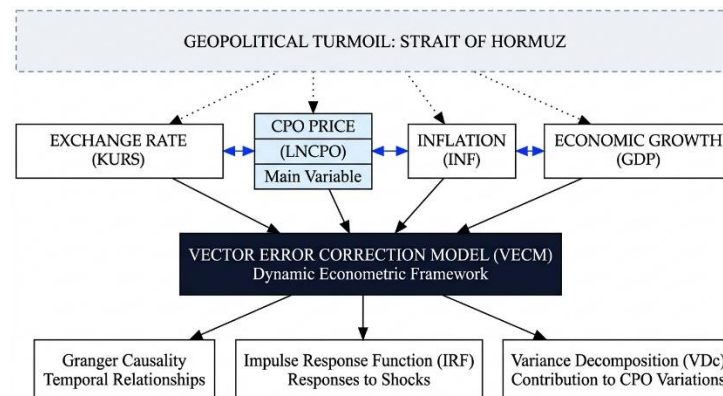


Figure 1. Conceptual Framework

METHODOLOGY

This study uses a quantitative approach with a time series research design to analyze the dynamics of Crude Palm Oil (CPO) prices and their relationship with exchange rates, inflation, and economic growth. The data used are secondary data with daily frequency for the period from August 9, 2025, to April 15, 2026, obtained from the Ministry of Trade of the Republic of Indonesia, the Palm Oil Plantation Fund Management Agency (BPDPKS), the Central Statistics Agency (BPS), and the World Bank. The research variables include CPO prices transformed into natural logarithms (LNCPO), exchange rates (KURS), inflation (INFLATION), and economic growth (GDP). Using daily data is intended to capture changes and responses between variables more closely in relation to

market dynamics. Because inflation and economic growth data are available at a lower frequency compared to CPO prices and exchange rates, these two variables are adjusted to daily frequency through linear interpolation. This process is done so that all variables have a uniform observation frequency, making them usable consistently in daily-based VECM model estimation.

The data analysis was carried out step by step. The initial testing was done using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to identify the stationarity characteristics of each variable (Sugiyono, 2022). Then, the optimal lag length was determined based on information criteria. A Johansen cointegration test was carried out to identify the existence of long-term equilibrium relationships between the variables. Based on the cointegration test results, the estimation continued using the Vector Error Correction Model (VECM) to analyze the adjustment mechanisms as well as the short-term and long-term relationships.

The analysis is then supplemented with Granger causality tests to identify the direction of temporal relationships between variables, Impulse Response Function (IRF) to observe how CPO prices respond to shocks in macroeconomic variables, and Variance Decomposition (VDC) to see the contribution of each variable in explaining the variations in CPO prices over several time horizons. The stability of the model is tested through the root modulus values, with the model considered stable if all modulus values are below one.

RESULTS

The analysis of the dynamic relationship between CPO prices, exchange rates, inflation, and economic growth started with a series of tests to determine the appropriate model specification. These steps included stationarity tests, selecting the optimal lag, and the Johansen cointegration test. The results from these initial tests served as the basis for using the Vector Error Correction Model (VECM) to analyze both short-term and long-term relationships between the variables.

Stationarity Test

Tabel 1. Augment Dickey Fuller (ADF) dan Philip Peron (PP)

Variabel	<i>Tahap level</i>			
	<i>ADF (Level)</i>		<i>PP (Level)</i>	
	<i>t-Statistic</i>	<i>Prob.*</i>	<i>Adj. t-Stat</i>	<i>Prob.*</i>
LN_CPO	-1.365592	0.5987	-1.554994	0.5039
GDP	-14.85097	0.0000	-15.45197	0.0000
INFLATION	-0.681608	0.4962	-2.253298	0.1883
KURS	-1.817271	0.0706	-1.817271	0.3715

The results in Table 1 show different stationarity characteristics among the variables. GDP is stationary at the level because its ADF and PP probability values are both 0.0000, which are below the 5% significance level. In contrast, LN_CPO, INFLATION, and KURS have probability values above 5% in both tests. This means that these three variables are not stationary at the level and may contain time-dependent trends or fluctuations that have not yet returned to a stable statistical pattern. Therefore, the analysis for these variables was continued at the first difference level (Aktivani, 2020).

Tabel 2. Augment Dickey Fuller (ADF) dan Philip Peron (PP)

<i>Tahap 1st Different</i>				
Variabel	<i>ADF (1st Different)</i>		<i>PP (1st Different)</i>	
	<i>t-Statistic</i>	<i>Prob.*</i>	<i>Adj. t-Stat</i>	<i>Prob.*</i>
LN_CPO	-15.03551	0.0000*	-15.10921	0.0000*
GDP	-24.30786	0.0000*	-151.8429	0.0000*
INFLATION	-1.932756	0.0546	-2.783703	0.0623
KURS	-16.28028	0.0000*	-16.20658	0.0000*

At the first difference, LN_CPO and KURS become stationary based on both ADF and PP tests, with probability values of 0.0000. GDP also remains stationary after differentiation. Meanwhile, INFLATION still has probability values above 5%, namely 0.0546 in the ADF test and 0.0623 in the PP test. Thus, INFLATION does not meet the strict 5% stationarity criterion at the first difference based on either test.

Overall, the stationarity results show that the variables do not have identical statistical properties. GDP is already stationary at the level, while LN_CPO and KURS become stationary after first differencing. INFLATION remains marginally above the 5% threshold at the first difference. These results are important for interpreting the subsequent cointegration and VECM analysis because the model must account for the different time-series characteristics of the variables rather than treating all variables as having the same order of integration.

Tabel 3. Lag Criteria Test

Lag	LogL	LR	FPE	AIC	SC
0	-2067.958	NA	3623.742	19.54677	19.6101
1	-884.6869	2310.727	0.059804	8.534782	8.851441

2	-560.8575	620.1639	0.003278	5.630731	6.200717
3	-492.7818	127.8024	0.002006	5.139451	5.962765*
4	-466.2696	48.77252	0.001818	5.040279	6.11692
5	-443.667	40.72729*	0.001711*	4.977991*	6.307959
6	-430.3741	23.45071	0.001758	5.003529	6.586825
7	-421.6455	15.06926	0.001888	5.072127	6.90875
Lag	-412.1489	16.03658	0.002014	5.133481	7.223431

The results of determining the lag length show that there are differences in recommendations among the information criteria used. The Likelihood Ratio (LR) criterion gives an optimal value at lag 5, as do the Final Prediction Error (FPE) and Akaike Information Criterion (AIC), both of which also give the best value at lag 5. Meanwhile, the Schwarz Information Criterion (SC) recommends lag 3. These differences indicate that each criterion has different sensitivity in considering model complexity and the loss of information due to adding more lags. Nonetheless, lag 5 is supported by three main criteria, namely LR, FPE, and AIC, so it was chosen as the optimal lag length in this study.

Choosing a 5-lag gives a consistent foundation for the next stages of analysis because it can capture the dynamics of relationships between variables by taking into account information from several previous periods. Using five lags allows changes in CPO prices to be analyzed not just based on current period conditions, but also considering the responses formed from developments in exchange rates, inflation, and economic growth in previous periods. Therefore, the 5-lag is later used in testing cointegration relationships, Granger causality analysis, as well as in estimating the Vector Error Correction Model (VECM). This result becomes an important step before identifying whether the relationships between variables only last in the short term or also form long-term equilibrium.

Tabel 4. Cointegration Rank Test

Hypothesized No. Of CE(s)	Cointegration Rank Test (Trace)			Cointegration Rank Test (Maximum Eigenvalue)		
	Trace Statistic	0.05 Critical Value	Prob.**	Max- Eigen Statistic	0.05 Critical Value	Prob.**
$r = 0$	53.49159	47.85613	0.0135	32.80181	27.58434	0.0097
$r < 1$	20.68978	29.79707	0.3773	14.32908	21.13162	0.3386
$r < 2$	6.3607	15.49471	0.6529	5.62599	14.2646	0.6616

$r < 3$ 0.73471 3.841465 0.3914 0.73471 3.841465 0.3914

The test results in Table 4 show that there is a cointegration relationship between LNCPO, EXCHANGE RATE, INFLATION, and GDP. Based on the Trace Statistic approach, for the hypothesis that there is no cointegration relationship ($r = 0$), the statistic value obtained is 53.49159, which is higher than the critical value of 47.85613, with a probability of 0.0135. This condition indicates that the null hypothesis is rejected, meaning there is a long-term relationship among the analyzed variables (Yusoff & Masih, 2021). For the hypothesis $r \leq 1$, the Trace Statistic value is 20.68978, which is lower than the critical value of 29.79707, with a probability of 0.3773. Similar results are also shown for the hypotheses $r \leq 2$ and $r \leq 3$, suggesting there is not enough evidence to declare any additional cointegration relationships after the first one.

The results were reinforced through the Maximum Eigenvalue approach. For the hypothesis $r = 0$, the Maximum Eigenvalue value of 32.80181 was higher than the critical value of 27.58434, with a probability of 0.0097. On the other hand, for the hypothesis $r \leq 1$, the test statistic of 14.32908 was below the critical value of 21.13162 and had a probability of 0.3386. The same pattern was seen for the hypotheses $r \leq 2$ and $r \leq 3$, where the test statistics were still below the critical values. The consistency of both approaches indicates that there is one cointegration relationship in the system consisting of LNCPO, EXCHANGE RATE, INFLATION, and GDP.

The presence of a cointegration relationship shows that the price movements of CPO, exchange rates, inflation, and economic growth are interconnected in the long run, even though each variable can still fluctuate in the short term (Shrestha & Bhatta, 2018). In other words, changes in one variable are not completely independent of the developments in the other variables over a longer horizon. This finding provides an empirical basis for using the Vector Error Correction Model (VECM) approach to identify adjustment mechanisms when there are deviations from long-term equilibrium (Shrestha & Bhatta, 2018). So, the next analysis is aimed at seeing how this relationship unfolds both through adjustment mechanisms and short-term dynamics between variables.

Granger Causality Test

The Granger causality test was conducted to identify whether changes in one variable contain temporal information that helps explain changes in another variable (Sasongko, 2020). The test examines the direction of temporal relationships among CPO prices, exchange rates, inflation, and economic growth. A probability value below the 5% significance level indicates a statistically significant Granger causality relationship.

Tabel 5. Granger Causality Test

Null Hypothesis:	Obs	F-Statistic	Prob.
GDP does not Granger Cause LNCPO	215	1.98335	0.0825
LNCPO does not Granger Cause GDP	215	0.61888	0.6855

INFLATION does not Granger Cause LNCPO	215	1.18153	0.3194
LNCPO does not Granger Cause INFLATION	215	0.27466	0.9266
KURS does not Granger Cause LNCPO	215	1.17934	0.3205
LNCPO does not Granger Cause KURS	215	0.64144	0.6683
INFLATION does not Granger Cause GDP	215	0.65995	0.6543
GDP does not Granger Cause INFLATION	215	5.23383	0.0002
KURS does not Granger Cause GDP	215	1.27788	0.2748
GDP does not Granger Cause KURS	215	1.02505	0.4039
KURS does not Granger Cause INFLATION	215	1.99772	0.0804
INFLATION does not Granger Cause KURS	215	0.98415	0.4285

The results show that most variable pairs do not exhibit a statistically significant temporal relationship at the 5% level. For the CPO variable, GDP does not Granger cause LN_CPO because the probability value is 0.0825, while LN_CPO does not Granger cause GDP with a probability of 0.6855. Similarly, neither inflation nor exchange rates show a significant temporal relationship with CPO prices, as their probability values in both directions are above 0.05.

A significant relationship is found between GDP and inflation. The null hypothesis that GDP does not Granger cause inflation is rejected because the probability value is 0.0002. In contrast, inflation does not Granger cause GDP, with a probability value of 0.6543. This indicates a one-way temporal relationship from economic growth to inflation during the observation period.

Vector Error Correction Model (VECM) Test

The Vector Error Correction Model (VECM) is used to analyze the relationships between variables when there is a long-term equilibrium relationship. This model allows researchers to see how variable changes occur in the short term while also showing the adjustment process toward long-term equilibrium. In this study, VECM is used to analyze the dynamics of CPO prices by considering EXCHANGE RATE, INFLATION, and GDP on a daily basis. The error correction term coefficient is used to see how the system adjusts when there is a deviation from long-term equilibrium.

Tabel 6. Vector Error Correction Model (VECM) Speed of Adjustment Test

VARIABEL	KOEFISIEN	T	T	KET
		STATISTIK	TABEL	
D(LNCPO)	-0.012804	[-2.51898]	1.97101	<i>Significant</i>
D(KURS)	-22.61946	[-1.50778]	1.97101	<i>Insignificant</i>
D(INFLATION)	0.000346	[3.49553]	1.97101	<i>Significant</i>
D(GDP)	841.8999	[2.44406]	1.97101	<i>Significant</i>

Based on Table 6, the variable LNCPO has a coefficient of -0.012804 with a t-statistic of -2.51898, which is statistically significant because the absolute value of the t-statistic is larger than the t-table value. The negative coefficient indicates that there is an adjustment mechanism when there is a deviation from the long-term equilibrium relationship (Drysdale et al., 1995). Thus, changes in CPO prices play a role in the system's return to equilibrium in the following period. Unlike LNCPO, the variable KURS has a coefficient of -22.61946 with a t-statistic of -1.50778. The absolute value of this t-statistic is smaller than the t-table value, so KURS does not show a significant adjustment mechanism toward long-term equilibrium. This result indicates that changes in the exchange rate have not been a factor that significantly drives the correction process when there is an imbalance in the relationship between the variables during the observation period.

Meanwhile, INFLATION has a coefficient of 0.000346 with a t-statistic of 3.49553, so it is considered significant. The same result is shown by the GDP variable, which has a coefficient of 841.8999 with a t-statistic of 2.44406 and is also considered significant. These findings indicate that INFLATION and GDP play a role in the adjustment mechanism towards long-term equilibrium. Overall, LNCPO, INFLATION, and GDP have a significant adjustment mechanism, while KURS does not show a significant adjustment mechanism in the model.

Tabel 7. Long Run Vector Error Correction Model (VECM) Test

VARIABEL	KOEFISIEN	T	T	KET
		STATISTIK	TABEL	
D(KURS)	-0.0000961	[-0.60474]	1.97101	<i>Insignificant</i>
D(INFLATION)	7.473155	[2.70142]	1.97101	<i>Significant</i>
D(GDP)	0.000374	[5.59038]	1.97101	<i>Significant</i>

The results show that the exchange rate does not have a significant long-term relationship with CPO prices. The coefficient of D(KURS) is -0.0000961 with a t-statistic of -0.60474, whose absolute value is lower than the t-table value. This indicates that exchange rate movements are not statistically associated with CPO price dynamics in the long-term equilibrium during the observation period.

In contrast, inflation has a significant long-term relationship with CPO prices. The coefficient of D(INFLATION) is 7.473155 with a t-statistic of 2.70142, exceeding the t-table value of 1.97101. This indicates that inflation is associated with CPO price dynamics in the long-term equilibrium.

GDP also shows a significant long-term relationship with CPO prices. The coefficient of D(GDP) is 0.000374 with a t-statistic of 5.59038, which is higher than the t-table value. This result indicates that economic growth is significantly associated with CPO price dynamics in the long term during the observation period.

Tabel 8. Short Run Vector Error Correction Model (VECM) Test				
VARIABEL	KOEFISIEN	T	T	KET
		STATISTIK	TABEL	
CointEq1	-0.012804	-2.518980	1.971010	Signifikan
D(LNCPO(-1))	-0.025439	-0.367790	1.971010	Insignifikan
D(LNCPO(-2))	-0.035676	-0.522450	1.971010	Insignifikan
D(LNCPO(-3))	0.063478	0.923150	1.971010	Insignifikan
D(LNCPO(-4))	0.091107	1.341920	1.971010	Insignifikan
D(KURS(-1))	0.000017	0.736700	1.971010	Insignifikan
D(KURS(-2))	0.000015	0.612200	1.971010	Insignifikan
D(KURS(-3))	0.000006	0.268630	1.971010	Insignifikan
D(KURS(-4))	-0.000043	-1.935180	1.971010	Insignifikan
D(INFLATION(-1))	8.104014	2.282960	1.971010	Signifikan
D(INFLATION(-2))	-15.703660	-2.391910	1.971010	Signifikan
D(INFLATION(-3))	15.835110	2.425060	1.971010	Signifikan
D(INFLATION(-4))	-9.127857	-2.628010	1.971010	Signifikan
D(GDP(-1))	-0.000003	-1.536310	1.971010	Insignifikan
D(GDP(-2))	-0.000002	-1.231870	1.971010	Insignifikan
D(GDP(-3))	0.000000	-0.152220	1.971010	Insignifikan
D(GDP(-4))	-0.000002	-1.947430	1.971010	Insignifikan

Based on Table 8, CointEq1 has a negative and significant coefficient, which indicates that there is a correction mechanism for imbalances in the relationship between the variables. So, when there is a deviation from long-term equilibrium, the system has a way to adjust back. These results support the Speed of Adjustment findings, showing that there is an adjustment process in the VECM model used.

In the short term, all lags of LNCPO do not show a significant relationship. The same also applies to all lags of KURS, meaning changes in LNCPO and KURS in several previous daily periods have not had a significant impact on changes in CPO prices in the short term. On the other hand, INFLATION shows a significant relationship from the first lag to the fourth lag. Its pattern also shows changes in the direction of influence between periods, reflected by alternating positive and negative coefficients. Meanwhile, all GDP lags do not show a significant relationship in the short term. Thus, the VECM results indicate that the short-term dynamics of CPO prices are more apparent through changes in INFLATION

compared to LNCPO, EXCHANGE RATE, and GDP. Overall, these findings show a difference in patterns between short-term and long-term relationships, where INFLATION and GDP have a significant connection in the long term, while in the short term, the significant impact is mainly seen in INFLATION.

VAR Stability Test

Stability testing is done to make sure that the model being used is stable before moving on to the Impulse Response Function (IRF) and Variance Decomposition (VDc) analysis. The model is considered stable if all the Root Modulus values are below one (Winarto & Beik, 2024).

Tabel 9. VAR Stability Test	
Root	Modulus
0.988614	0.988614
0.969143 - 0.096004i	0.973887
0.969143 + 0.096004i	0.973887
0.958289	0.958289
-0.477721 + 0.733032i	0.874959
-0.477721 - 0.733032i	0.874959
0.690376 - 0.057990i	0.692807
0.690376 + 0.057990i	0.692807
0.163062 + 0.646770i	0.667008
0.163062 - 0.646770i	0.667008
-0.166251 - 0.636511i	0.657864
-0.166251 + 0.636511i	0.657864
0.620184 + 0.181854i	0.646296
0.620184 - 0.181854i	0.646296
0.224771 - 0.541106i	0.585933
0.224771 + 0.541106i	0.585933
-0.539470 - 0.124801i	0.553718
-0.539470 + 0.124801i	0.553718
-0.100424 - 0.466747i	0.477428
-0.100424 + 0.466747i	0.477428

The test results show that all inverse roots of the AR characteristic polynomial are located inside the unit circle, with the largest root recorded at 0.988614. This indicates that the VAR model meets the stability condition because none of the roots lies outside the unit circle. The result shows that the dynamic

relationships among CPO prices, exchange rates, inflation, and economic growth remain within a stable system throughout the observation period.

The stability of the model provides a basis for interpreting the subsequent dynamic analyses. In particular, the stable VAR system allows the Impulse Response Function (IRF) to be used to observe the response of CPO prices to shocks in the macroeconomic variables and Variance Decomposition (VDC) to examine the contribution of each variable to CPO price variations over different time horizons.

Impulse Response Function (IRF) Test

The Impulse Response Function is used to see how CPO prices respond to shocks coming from macroeconomic variables over several days after the shock occurs (Kuru et al., 2024). In this study, the response of LNCPO is observed to shocks in GDP, INFLATION, and EXCHANGE RATE using the Cholesky One Standard Deviation Innovations approach.



**Figure 2. CPO Response to GDP
Response to Cholesky One S.D. Innovations**

Based on the IRF results, LNCPO's response to GDP shocks is positive throughout the observation period. In the first few daily periods, CPO prices increase, then reach a higher response around the middle of the observation horizon. After hitting that point, the response gradually decreases until it approaches a more stable condition by the end of the period.

This pattern shows that GDP shocks are followed by a rise in CPO price response. The changes in response from one period to the next reflect the process of CPO prices adjusting to economic growth shocks. So, the impact of GDP shocks

on CPO prices isn't just seen in the early periods, but unfolds over several daily periods before the response moves toward a more stable condition.

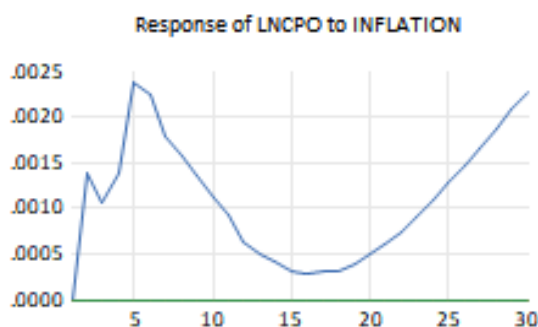


Figure 3. CPO Response to INFLATION
Response to Cholesky One S.D. Innovations

The IRF results show that LNCPO responds positively to INFLATION shocks throughout the observation horizon. In the first few days, CPO prices experience a fairly strong increase, then decrease before gradually showing an upward trend in the following periods. These movements indicate that the response of CPO prices to inflation shocks goes through some dynamics during the adjustment process.

This positive response means that inflation shocks are followed by an increase in CPO prices in the model. The changes in response over each period also show that the effect of INFLATION shocks on CPO prices is not direct or constant but develops as the system adjusts until the response moves toward a more stable condition.

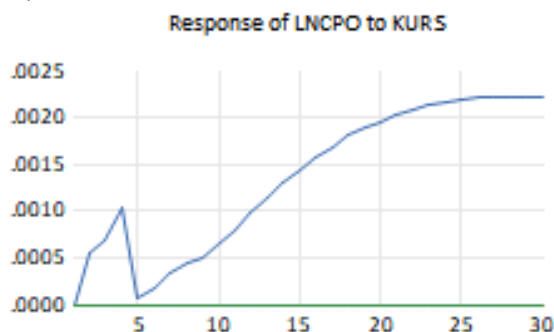


Figure 4. CPO response to EXCHANGE RATE
Response to Cholesky One S.D. Innovations

Based on the IRF results, LNCPO shows a positive response to EXCHANGE RATE shocks during the observation period. In the early daily period, CPO prices increased, then experienced a decrease before gradually rising again. Towards the end of the observation horizon, CPO price responses tended to stabilize.

This pattern indicates that EXCHANGE RATE shocks are followed by a positive response in CPO prices, although the magnitude of the response changes during some periods. This condition shows that there is an adjustment process in the system after changes in the exchange rate. Thus, CPO price responses to

the EXCHANGE RATE develop gradually and do not show a fully constant response pattern throughout the observation period.

Variance Decomposition Test (VDC)

Variance Decomposition is used to find out how much each variable's shocks contribute to explaining changes in CPO prices. This analysis shows how much of the variation in LNCPO can be explained by shocks to LNCPO itself, EXCHANGE RATE, INFLATION, and GDP in each period (Chan-lau, n.d.).

Tabel 10. CPO Price Variance Decomposition

Period	S.E	LNCPO	KURS	INFLATION	GDP
1	0.009736	100.0000	0.000000	0.000000	0.000000
5	0.021657	94.53393	0.396399	2.270431	2.799241
10	0.03093	89.35708	0.302935	2.570802	7.769187
15	0.036792	85.09154	0.708525	1.946499	12.25343
20	0.041173	80.70869	1.507407	1.593345	16.19056
25	0.044581	77.21802	2.421605	1.586772	18.7736
30	0.047285	74.66669	3.250399	2.214868	19.86804

The Variance Decomposition results show that the variation in CPO prices at the beginning of the period is almost entirely explained by the dynamics of LNCPO itself. As the time horizon increases, the contribution of LNCPO gradually decreases, indicating that CPO price variations are not only influenced by internal movements but start to get a bigger contribution from macroeconomic variables. This pattern shows that there is persistence in CPO price movements in the early period as well as an increasing connection with macroeconomic conditions over a longer horizon.

In the medium to long term, GDP becomes the external variable with the largest contribution in explaining CPO price fluctuations. Its contribution gradually increases until it reaches the most dominant position among external variables by the end of the observation period. This condition shows that changes in economic activity are increasingly related to CPO price variations as the analysis horizon is extended. INFLATION also contributes to CPO price variations, although relatively smaller and fluctuating between periods. Meanwhile, the contribution of EXCHANGE RATE tends to rise over a longer horizon, but still remains below that of GDP.

Overall, the VDC results show that CPO price dynamics remain the main source of price variation, while the contribution of macroeconomic variables increases as the time horizon gets longer. These findings support the IRF results that CPO prices respond to shocks in macroeconomic variables, with GDP playing an increasingly important role over longer horizons. In the context of geopolitical turmoil in the Strait of Hormuz, these results suggest that CPO price dynamics need to be understood not just from commodity market conditions, but also from broader economic developments that affect demand and market activity more widely.

DISCUSSION

Research results show that the dynamics of CPO prices during the geopolitical turmoil in the Strait of Hormuz have a complex relationship with macroeconomic conditions. The absence of a direct causal relationship between CPO prices and exchange rates, inflation, and economic growth suggests that daily price changes in CPO are not automatically influenced by changes in each of these variables. This situation can be understood because CPO is a global commodity affected by the interaction of supply and demand, international trade conditions, the energy market, and global uncertainties (Chiaramonte & Paltrinieri, 2025). Its connection with the energy market becomes increasingly important since CPO can be used as a raw material for biodiesel, so changes in energy conditions and geopolitics potentially affect the vegetable oil market indirectly (Gultom et al., 2025).

The long-term relationship found shows that CPO prices still have a connection with exchange rates, inflation, and economic growth, even though this relationship isn't always visible in the short term. These findings indicate that there is an adjustment process when deviations from balance between variables occur. In the context of the palm oil industry, this condition reflects that macroeconomic changes take time to be transmitted to the CPO market. Inflation has a relatively stronger link because changes in price levels can affect production costs, distribution, and commodity trading activities. Meanwhile, economic growth reflects the development of production activities and demand, which can eventually influence the need for commodities and energy (Prabheesh, 2020).

The exchange rate doesn't show a strong connection in the short or long term. Even though, in theory, changes in the exchange rate can affect CPO trade transactions since the commodity is largely traded in US dollars, that effect can be overshadowed by other, more dominant factors during periods of global uncertainty (Izraf et al., 2017). This shows that CPO market players don't just react to exchange rate changes but also consider supply conditions, demand, energy prices, and expectations about global economic developments. So, the impact of the exchange rate on CPO should be seen as part of a broader market mechanism, not as the sole factor determining prices.

The Impulse Response Function results show that CPO prices still respond to shocks coming from macroeconomic variables (Fuddin, 2014). This response changes over the observation period before moving toward a more stable condition. This pattern indicates that the impact of macroeconomic shocks on CPO prices happens through an adjustment process and doesn't always appear directly. The Variance Decomposition findings also show that initially, CPO prices are mostly explained by their own movements, while the contribution of macroeconomic variables becomes more noticeable as the time horizon extends. Among the macroeconomic variables used, economic growth shows an increasingly significant contribution to the variation in CPO prices.

In the context of geopolitical turbulence in the Strait of Hormuz, the findings show that uncertainty in energy trade routes can be an important factor in understanding changes in CPO prices. The Strait of Hormuz has a strategic position in global energy trade, so disruptions in the region can increase

uncertainty in energy markets and affect commodities linked to energy (Ramadhani et al., 2024). However, since geopolitical conditions are not included as a direct variable in the model, this study is not intended to measure the specific impact of conflicts. Instead, it treats geopolitical turbulence as an external environment that underlies market dynamics during the observation period.

Overall, the research results show that CPO prices have strong persistence, but they still interact with macroeconomic conditions through different mechanisms depending on the time horizon. These findings imply that risk management in the palm oil industry isn't just about keeping an eye on CPO price changes, but also needs to take into account inflation trends, economic growth, exchange rates, energy markets, and global geopolitical conditions. For the government, these results could be a consideration in strengthening downstream policies and developing biodiesel as an effort to increase the added value of CPO while also boosting energy resilience (Puspitawati et al., 2025).

CONCLUSIONS AND RECOMMENDATIONS

This study shows that the dynamics of CPO prices during the geopolitical turmoil in the Strait of Hormuz have a complex relationship with macroeconomic variables. Most causal relationships do not show a direct link, but there is a long-term equilibrium relationship between CPO prices, exchange rates, inflation, and economic growth. Inflation is one of the variables that has an important connection in the short-term dynamics, while economic growth increasingly plays a role in explaining CPO price variations over a longer horizon. These results indicate that changes in CPO prices are influenced by an adjustment process that takes place gradually.

For industry players, a risk management strategy is needed that takes into account the CPO market developments as well as the global macroeconomic and energy conditions. The government also needs to strengthen palm oil downstream processing and biodiesel development so that CPO isn't just reliant on the export market, but can also add value and support national energy security.

FURTHER STUDY

This study has some limitations because the geopolitical turmoil in the Strait of Hormuz was used as the research context and hasn't been directly included as a variable. Also, using daily data requires lower frequency data to be adjusted through interpolation. Future research could include geopolitical indicators, crude oil prices, or global uncertainty indexes to get a more specific picture of how geopolitical turmoil affects CPO prices.

ACKNOWLEDGMENT

The author would like to thank the Faculty of Economics at Maulana Malik Ibrahim State Islamic University Malang, the supervising lecturers, research colleagues, and everyone who has given guidance, support, and input during the research and writing of this article. Appreciation is also extended to the data providers who supported the implementation of the research.

REFERENCES

- Aktivani, S. (2020). *Uji Stasioneritas Data Inflasi Kota Padang Periode 2014-2019*. 20(2), 83-90.
- Alam, I. A., & Singagerda, F. S. (2019). *Price Determination Model of World Vegetable and Petroleum*. 9(5), 157-177.
- Ana, C. P., Lestari, T. E., & Permadi, H. (2023). TVECM TO ANALYZE THE RELATIONSHIP BETWEEN NET FOREIGN ASSETS AND CURRENCY CIRCULATION. *Jurnal Ilmu Matematika Dan Terapan*, 17(1), 113-124.
- Awaliyah, N. N., Iranto, D., & Mukhtar, S. (2023). ANALYSIS OF FACTORS AFFECTING INDONESIA'S CRUDE PALM OIL (CPO) EXPORTS IN THE GLOBAL MARKET 1992 - 2022. *Jurnal Pendidikan Ekonomi, Perkantoran, Dan Akuntansi*, 4(3), 115-125.
- Chan-lau, J. A. (n.d.). *Variance Decomposition Networks : Potential Pitfalls and a Simple Solution*.
- Chiaromonte, L., & Paltrinieri, A. (2025). *Geopolitical Risk and Energy Markets : Past , Present , and Future*. 2022, 2233-2253. <https://doi.org/10.1111/joes.12697>
- Drysdale, P., Gordon, J., Lowe, P., McKibbin, W., Okina, K., Pagan, A., Ryan, C., & Wells, G. (1995). *The Liberalisation and Integration of Domestic Financial Markets in Western Pacific Economies*.
- Dutta, A., & Vinh, X. (2021). *Crude oil volatility and the biodiesel feedstock market in Malaysia during the 2014 oil price decline and the COVID-19 outbreak Fuel price decline and the COVID-19 outbreak*.
- Fuddin, M. K. (2014). *Effectiveness of monetary policy transmission in Indonesia*.
- Izraf, M., Aziz, A., & Applanaidu, S. (2017). *Effects of Palm Oil Price on Exchange Rate : A Case Study of Malaysia and Indonesia*. 9(4), 71-87.
- Kuru, D., Banka, O., & Kanalını, K. (2024). *Does Exchange Rate Volatility Affect the Bank Lending Channel ?* 11(1), 51-61. <https://doi.org/10.26650/JEPR1343548>
- Prabheesh, K. P. (2020). *Bulletin of Monetary Economics and Banking Asymmetric Effect of Crude Oil and Palm Oil Prices on Economic Growth : Evidence from Indonesia*. 23(2).
- Puspitawati, E., Nurdianto, N. R., Pambudi, A., Alamsyah, M. R., Pakerti, K. A., & Maharani, N. D. (2025). *Economic Effect of Biodiesel Downstream Industry : An Analysis Based on a Dynamic CGE Model*. 15(1), 437-446.
- Ramadhani, R., Marzaman, A., Hasanuddin, U., Article, I., Stability, M., Security, G., Conflict, E., & Commons, C. (2024). *MARITIME STABILITY IN THE STRAIT OF HORMUZ : CHALLENGES , GLOBAL IMPACTS , AND*. 3(2), 81-96.
- Sasongko, G. (2020). *REVISITING KEYNES' INVESTMENT AND SAVING MODEL IN INDONESIA* Cheng-Wen Lee* , Andrian Dolfriandra Huruta** , Ramdani Putri Setyaningrum*** Gatot Sasongko****. XVIII(2), 45-58. <https://doi.org/10.51558/2303-680X.2020.18.2.45>
- Shrestha, M. B., & Bhatta, G. R. (2018). ScienceDirect. *The Journal of Finance and Data Science*, 4(2), 71-89. <https://doi.org/10.1016/j.jfds.2017.11.001>
- Sugiyono. (2022). *Metode Penelitian dan Pengembangan (Research and Development)*. Bandung: Alfabeta. 3, 94-104.
- Sumarno, W., Amelia, N., & Ramadhana, W. (2026). *Analysis of Indonesia ' s*

- Palm Oil (CPO) Export Volume Moderated by Inflation. *Formosa Journal of Science and Technology (FJST)*, 5(6), 1655–1666.
- Tao, Z., Li, T., Chen, Y., & Huang, X. (2025). *Does geopolitical risks drive the extreme spillovers of bulk energy and chemical commodity.* 1–22.
<https://doi.org/10.1371/journal.pone.0326268>
- Transition, E. (2025). *Energy Transition and The Impact of Biodiesel Development Policy on CPO Prices.* 18(1), 50–67.
- Verduzco-Bustos, Guillermo Zanetti, F. (2026). *The Effects of Geopolitical Oil Price Shocks.* April.
- Winarto, F. H., & Beik, I. S. (2024). *The effect of Sharia monetary policy instruments and Islamic bank financing on economic growth and inflation.* 10(1), 72–89.
- Yusoff, A., & Masih, and M. (2021). *Munich Personal RePEc Archive The impact of key industry-sectoral indices on islamic stock market : evidence from Malaysia.* 107907.
- Zou, X. (2018). *VECM Model Analysis of Carbon Emissions , GDP , and.* 2018.
<https://doi.org/10.1155/2018/5350308>