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Structural Break Analysis and Price Transmission of Bulk Cooking Oil in the Indonesian Palm Oil Agribusiness System

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Abstract: Volatility in Indonesia's bulk cooking oil market has increased since the COVID-19 pandemic, disrupting household consumption and threatening national food security. This study analyzes structural breaks in the price dynamics of Fresh Fruit Bunches (FFB), Crude Palm Oil (CPO), and bulk cooking oil, as well as asymmetric price transmission before and after key government interventions. Weekly data from 2020–2024 were examined using the Additive Outlier test, the NARDL model, the Hatemi-J asymmetric causality test, and the Wald test. The results reveal a significant structural break in April 2022, associated with the CPO export ban, DMO/DPO policies, and the implementation of a retail price ceiling (HET). Before the break, short-run price transmission was asymmetric but became symmetric in the long run. After the intervention, short-run transmission was symmetric, while long-run asymmetry persisted, indicating downward price rigidity and reduced market efficiency. These findings suggest that government intervention effectively stabilized short-term prices but created long-term structural distortions. Strengthening distribution efficiency, improving price transparency, and adopting more adaptive policies are essential to enhance market efficiency and economic food resilience.

Keywords: Bulk cooking oil; Food security; Palm oil policy; Price transmission; Structural break

Introduction

Since 2020, Indonesia has experienced significant economic dynamics as the COVID-19 pandemic triggered major disruptions to food stability and the prices of strategic commodities (Syafitri et al., 2022; Olivia et al., 2020). Bulk cooking oil has been one of the most affected commodities, as it is a necessity for households and micro-business actors, making price changes in this commodity highly influential on inflation and people's purchasing power (Mahaputra & Saputra, 2022; Mawardati et al., 2024). Disruptions to supply chains, distribution, and logistics efficiency during the pandemic sharply increased the volatility of bulk cooking oil prices (Yudha & Roche, 2023; Surni et al., 2021). This situation demonstrates that the price of bulk cooking oil is influenced not only by normal supply and demand mechanisms, but also by global external shocks and domestic policy factors (Yulianto et al., 2022; Widodo et al., 2023). Therefore, understanding the dynamics of commodity price formation is a strategic issue for maintaining economic stability and national food security (Mardianto et al., 2020; Aryanto et al., 2024).

From an agribusiness perspective, the price movement of bulk cooking oil is part of the palm oil value chain, which involves the relationship between the price of Fresh Fruit Bunches (FFB), the price of Crude Palm Oil (CPO), and the retail price of cooking oil (Judijanto & Pamungkas, 2024; Nesti et al., 2018). The concept of price transmission is used to explain how efficiently price changes at the upstream level are passed on to the downstream level (Bakucs et al., 2014; Rezitis & Tsionas, 2019). Under ideal market conditions, price changes at the producer level should be transmitted proportionally to consumer prices, both during price

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increases and decreases (Rezitis & Tsionas, 2019; Bareith et al., 2025). However, the bulk cooking oil market is characterized by complex industrial structures, price regulations, and distribution systems, which can cause price transmission to become asymmetric (Bakucs et al., 2014; Nesti et al., 2018). In this context, a fundamental change in the pattern of price formation can indicate a structural break, meaning a sudden shift in the price relationship that significantly differs from previous normal conditions (Ewing & Malik, 2017; Salisu & Fasanya, 2013).

The problem arose when the surge in bulk cooking oil prices in 2021–2022 was not followed by a commensurate price decline even though global CPO prices began to weaken (Nafisah & Amanta, 2022; Nendissa & Pellokila, 2025). The phenomenon of price increases moving very quickly followed by a slow decline shows that there is asymmetric price transmission that is detrimental to consumers (Pratomo et al., 2024). Government intervention policies such as the setting of the Highest Retail Price (HET), Domestic Market Obligation (DMO), and the ban on CPO exports also strengthen the allegation of structural changes in the price-setting mechanism along the palm oil agribusiness supply chain (Hermanto & Saragih, 2023). This condition raises a critical question in the agribusiness economics literature: whether the changes are temporary or have permanently changed the structure of price relationships (Sujarwo et al., 2019). Until now, empirical research that specifically identifies the time point of the structural break and its impact on the transmission of cooking oil prices in the Indonesian palm oil agribusiness system is still very limited (Purbawa et al., 2023).

Based on these conditions, the research entitled "Structural Break Analysis and Bulk Cooking Oil Price Transmission in the Indonesian Palm Oil Agribusiness System" is important to be carried out to provide a data-based scientific understanding of the dynamics of the formation of bulk cooking oil prices for the 2020–2024 period. This study aims to identify the point in time for structural breaks in the prices of FFB, CPO, and bulk cooking oil, as well as analyze price transmission patterns at various market levels both before and after the structural break. The results of the research are expected to be the basis for the formulation of more effective price stabilization policies, strengthening market integration, and improving distribution efficiency in the palm oil agribusiness system. Thus, this research makes an important contribution to efforts to maintain food security and national economic stability during global market dynamics.

Method

Data Types and Sources

This study uses secondary data in the form of a time series. The data used are in the form of weekly prices of Fresh Fruit Bunches (FFB), Crude Palm Oil (CPO), and bulk cooking oil at the level of producers, wholesalers, and traditional markets for the period from January 2020 to December 2024. FFB and CPO price data were obtained through the Superior Plantation Products Market Information System (SIPASBUN), while bulk cooking oil price data were sourced from the Bank Indonesia Strategic Food Price Information Center (PIHPS BI).

Data Analysis Methods

This study applies to the Additive Outlier (AO) approach to detect the existence of structural breaks in the price movements of FFB, CPO, and bulk cooking oil at various levels of the marketing chain. In addition, the Nonlinear Autoregressive Distributed Lag (NARDL) approach is used to identify and estimate short-term and long-term relationships between research variables, both symmetrically and asymmetrically. Data processing was carried out using Microsoft Excel 2016 and StataMP 17. The two main approaches used are descriptive analysis and inferential analysis.

Descriptive analysis is used to provide an initial understanding of commodity price movement patterns through the presentation of tables and graphs. This analysis aims to answer the first research objective, which is to identify the existence of structural breaks in the dynamics of monthly bulk cooking oil prices in Indonesia.

Inference analysis was used to test the existence of significant structural breaks and analyze the efficiency of price transmission and suspected price asymmetry in the bulk cooking oil marketing chain. The Additive Outlier (AO) approach was used to identify breaks at a given time, while the NARDL approach was used to test the dynamic relationship and price asymmetry between marketing agencies. The AO model is used to capture local breaks that affect data at only one specific period. Meanwhile, the NARDL model was developed to overcome the limitations of the traditional cointegration model through long-term relationship estimation even though the variables have different orders of integration (combination I (0) and I (1)). The Bound Testing procedure is used to test the existence of cointegration within the NARDL framework.

Stationarity Test

The stationarity test was carried out using the Phillips-Perron (PP) method to robustly detect root units against heteroscedasticity and autocorrelation at the error term. The basic hypothesis tested is:

$$\Delta Yt = \alpha + \beta_t + \rho Y_{t-1} + \varepsilon_t$$

H0 : ρ = 0 → non-stationary data
H1 : ρ < 0 → data stasioner

Decision making is made based on the probability value (p-value) and MacKinnon's critical value. If the p-value < 0.05 then H0 is rejected so that the data is declared stationary.

Outlier Additive Test (AO)

The AO method is used to identify structural breaks in time series data with the following model:

$$y_t = \beta_0 + \beta_1 X_t + \sum_{j=1}^{m} Y_i D_t + \varphi = D_t + PCPO_t + \omega(D_t.PTBS_t)\ldots$$

H0: γ = ψ = ω = 0 → no structural break effect
H1: γ ≠ ψ ≠ ω ≠ 0 → There is an influence of structural break

Determination of Optimal Lag

Optimal lag selection is performed with AIC, SIC/BIC, and HQC to avoid model bias and residual autocorrelation. The optimal lag is selected based on the smallest information value. In general, the form of the equation is:

$$SIC = -2\, ln_{(L)} + K ln_{(n)}$$
$$HQ = -2\, ln_{(L)} + 2K\,(ln_{(n)})$$
$$AIC = -2\, ln_{(L)} + 2K$$

Cointegration Bound Test

Cointegration tests are performed to determine whether variables in the model have long-term relationships. Decision based on the comparison of F-statistical values with cut-off values (lower and upper cuts).

$$\Delta PMGC_t = \alpha + \mathrm{i} = 1 \sum p - 1\beta i \Delta MGCt_{t-i} + k = 1 \sum 5_j = 0 \sum qk - 1\gamma kj \Delta Xk_{t-j} + k \sum 6\, \lambda k X k_t - 1 + \varepsilon t$$

With variable definition:
$X_1 = TBS, X_2 - CPO, X_3 - PRMGC, X_4 - PEMGC, X_5 - PBMGCX_6 - PMGC$

With variable definition:
$H_0 : \lambda_i = 0$ = No cointegration
$H_1 : \lambda_i \neq 0$ = No cointegration

Hatemi-J Causality Test (Asymmetric Granger Causality)

The causality test is used to understand the direction of the cause-and-effect relationship between variables in a dynamic system. After obtaining a long-term relationship through the Bound Test cointegration test, this study continues the analysis by testing the direction of causality between the prices of FFB, CPO, PRMGC, PEMGC, PBMGC, and PTMGC using the Asymmetric Granger Causality Test according to Hatemi-J (2012). In contrast to the conventional Granger test (Granger 1969) which assumes a symmetrical relationship, the Hatemi-J approach separates the response to positive shocks and negative shocks, making it more suitable for analyzing commodity price dynamics. This approach is important because the price of bulk cooking oil often shows different behavior when input prices increase compared to when they decrease.

Hatemi-J (2012) based his approach on the Vector Autoregressive (VAR) model, but with the decomposition of variables into two cumulative components, namely positive and negative. Mathematically, a change in a variable yt is defined as:

$$\Delta PTMGC_t = PTMGC_t - PTMGC_{t-1}$$

Then, the change is divided into two parts, namely the positive component and the negative component:

$$PTMGC_t^+ = \max(\Delta PTMGC, 0)$$
$$PTMGC_t^- = \min(\Delta PTMGC, 0)$$

Furthermore, Hatemi-J (2012) built a cumulative variable for each of these components:

$$y_t^+ = \sum_{i=1}^{t} \Delta y_i^+ \qquad y_t^- = \sum_{i=1}^{t} \Delta y_i^-$$

These two cumulative variables (positive and negative) are then used in the following VAR models:

$$\begin{bmatrix} y_t^+ \\ x_t^+ \end{bmatrix} = \alpha^+ \sum_{i=1}^{p} \beta_i^+ = \begin{bmatrix} y_{t-i}^+ \\ x_{t-i}^+ \end{bmatrix} + \varepsilon_t^+$$

$$\begin{bmatrix} y_t^- \\ x_t^- \end{bmatrix} = \alpha^- \sum_{i=1}^{p} \beta_i^- = \begin{bmatrix} y_{t-i}^- \\ x_{t-i}^- \end{bmatrix} + \varepsilon_t^-$$

The Hatemi-J causality test was then carried out through hypothesis testing as follows:
H0: $\beta^+ = 0$ (no causality of x_t wed y_t)
H1: $\beta^+ \neq 0$ (There is a causality of x_t wed y_t)
H0: $\beta^- = 0$ (no causality of x_t wed y_t)
H1: $\beta^- \neq 0$ (There is a causality of x_t wed y_t)

If the null hypothesis is rejected (Prob > chi^2 < 0.05), then there is a significant asymmetrical cause-and-effect relationship between independent and dependent variables on both positive and negative components. This method allows the analysis of whether the increase in the price of raw materials is transmitted to the price of bulk cooking oil faster than the price decrease. Thus, the Hatemi-J Test provides a deeper understanding of asymmetric Price Transmission, which often reflects market conditions that are not fully competitive or where there are structural barriers in the supply chain. The results of the Hatemi-J causality test are expected to be able to explain the direction and character of price transmission from the upstream level (FFB and CPO) and the distribution level (PRMGC, PEMGC, PBMGC) to the price of bulk cooking oil in the traditional market (PTMGC), both before and after the structural break.

Model NARDL

The Nonlinear Autoregressive Distributed Lag (NARDL) model is an extension of the ARDL model (Pesaran et al., 2001) introduced by Shin et al. (2014) to identify the asymmetric relationship between independent variables and dependent variables in the short and long term. In this study, the NARDL model was used to analyze the transmission of bulk cooking oil prices in the traditional market (PTMGC) in response to changes in the price of main raw materials, namely the price of Fresh Fruit Bunches (FFB) and the price of Crude Palm Oil (CPO), as well as the influence of bulk cooking oil prices at the producer (PRMGC), retail trader (PEMGC), and wholesaler (PBMGC) levels. In addition, this model includes a dummy variable (Dt) to capture the presence of structural breaks. The NARDL model used in this study is formulated as follows.

ΔPTMGCt =

$$\alpha_0 = \sum_{i=1}^{p} \beta_i \Delta PTMGC_{t-i} + \sum_{j=0}^{q} y_j^+ \, \Delta TBS_{t-1}^+$$

$$\sum_{j=0}^{q} y_j^- + \sum_{k=0}^{r} \delta_k^+ \Delta CPO_{t-k} \sum_{k=0}^{r} \delta_k^- \Delta CPO_{t-k}^- +$$

$$\sum_{m=0}^{s1} \int m \Delta PRMGC_{t-m} \sum_{n=0}^{s2} \theta \Delta PBMGC_{t-n} +$$

$$\sum_{o=0}^{s3} k_o \Delta PEMGC_{t-0} + \varphi PBMGC_{T-1} - \beta^+$$

$$TBS^+ - \beta TBS_{t-1} - \beta^+ CPO_{t-1}^+ + \beta^- CPO_{t-k}^- \, \beta PRMGC_{t-1} - \beta PBMGC_{t-1} - PEMGC_{t-1} + n^D t + \varphi 1 = (D_{t.} CPO_t) + \varphi = (D_{t.} TBS_t) + \mathcal{E}_t$$

Then it is carried out through hypothesis testing as follows:

$\gamma_j^+ \neq \gamma_j^-$ *or* $\delta_k^+ \neq \delta_k$	=	there is a short-term asymmetry
$\beta^+ \neq \beta^-$	=	there is a long-term asymmetry
$\psi 1, \psi 2 < 0.05$	=	There is a change in price transmission pattern after the *structural break*

Wald Test

The Wald Test, developed by Wald (1943), the Wald test is used to examine the joint significance of regression coefficients within an econometric model. In this study, the Wald test is applied to the Nonlinear Autoregressive Distributed Lag (NARDL) model to assess the asymmetric effects of Fresh Fruit Bunch (FFB/TBS) and Crude Palm Oil (CPO) price movements on bulk cooking oil prices in traditional markets (PTMGC). The NARDL framework separates positive and negative price changes, allowing increases and decreases to be analyzed distinctly, in accordance with the theory of asymmetric price transmission.

The Wald test is employed to examine the effects of the independent variables in both the short-run and long-run, as well as before and after the structural break, which reflects changes in the price transmission mechanism due to critical events or policy interventions. In the short run, the Wald test evaluates the influence of weekly changes in TBS and CPO prices on PTMGC, based on the hypothesis regarding the joint significance of the asymmetric coefficient parameters.

H_0 : $\Delta TBS^+, \Delta TBS^-, \Delta CPO^+, \Delta CPO^- > 0.05$ = no significant effect

H_1 : ΔTBS^+, ΔTBS^-, ΔCPO^+, $\Delta CPO^- < 0.05$ = have a significant effect

In the long run, the Wald test evaluates the coefficients of the independent variables together with the Error Correction Term (ECT), which reflects the long-run market equilibrium, with the following hypothesis:

H_0 : $TBS^+, TBS^-, CPO^+, CPO^-, PRMGC, PEMGC, PBMGC > 0.05$ = symmetries

H_1 : $TBS^+, TBS^-, CPO^+, CPO^-, PRMGC, PEMGC, PBMGC < 0.05$ = asymmetries

Result and Discussion

Stationarity Test

The stationarity test is an important early stage in time series analysis to ensure that the data are free of trends that can cause the relationships between variables to become spurious. The non-stationarity shown by changes in mean and variance over time has the potential to eliminate the economic significance of regression coefficients. This study uses the Phillips-Perron (PP) method because it can correct autocorrelation and heteroscedasticity in a non-parametric manner so that it provides higher flexibility than the Augmented Dickey-Fuller (ADF) method. Gujarati (2009) emphasized that the stationarity test is the main basis in building a price dynamics model to prevent bias in empirical conclusions. The results of the stationarity test are shown in Table 1.

The results of the optimal lag selection using the varsoc test in Table 1 show that almost all information criteria, i.e. LR, FPE, AIC, and HQ, chose the 4th lag, while SIC chose the shorter lag due to the large parameter penalty. The 4th lag has the lowest FPE and

AIC values, so the model with four lags has the best balance between model suitability and the number of parameters. The LR value also shows a significant increase in likelihood when the lag is added up to four. The combination of these indicators confirms that the 4th lag is the most consistent choice to capture the price dynamics of FFB, CPO, and bulk cooking oil at various market levels. Pesaran (2001) stated that adequate lag selection is crucial in the ARDL/NARDL model, especially when the relationships between variables are nonlinear and asymmetrical.

Table 1. Results of Selection of Optimal Lag for the Varsoc Test

Lag	LL	LR	FPE	AIC	HQ	SIC
0	-13727.5	-	8.0e+32	92,794	92,824	92,869
1	-12657.4	2140.3	7.4e+29	85,807	86,017	86,330
2	-12478.4	357.9	2.8e+29	84,841	85,230	85,813*
3	-12391.1	174.6	2.0e+29	84,494	85,063	85,915
4	-12285.1	212.1*	1.2e+29*	84,021*	84,770*	85,891

*Description: Lag Likelihood (LL); Likelihood Ratio (LR); Final Prediction Error (FPE); Akaike Information Criterion (AIC); Hannan-Quinn (HQ); Schwarz Information,Criterion (SIC)

The selection of the 4th lag aligns with the characteristics of the Indonesian cooking oil market, which features a long value chain from FFB (Fresh Fruit Bunches) to CPO (Crude Palm Oil), then to producers, distributors, retailers, and finally traditional markets, resulting in gradual price adjustments (Mahaputra & Saputra, 2022). The transmission of cooking oil prices in Indonesia is influenced by factors such as logistics, contracts, production, and stock management, which can cause delays in price adjustments along the supply chain (Nendissa & Pellokila, 2025). The structure of the palm oil market, where domestic CPO prices are closely linked to global markets and export-import policies, also supports the use of a longer lag in price transmission models (Manurung et al., 2019). Government policies such as Domestic Market Obligation (DMO), Domestic Price Obligation (DPO), and export bans have been shown to create additional delays in price transmission by disrupting supply chains and causing market distortions (Efendi et al., 2024).

The 2022 export ban and policy interventions (such as HET and MGCR) in Indonesia's cooking oil market created a structural break, leading to a slower and more gradual domestic price adjustment process. This disruption required market participants to reorganize distribution systems, resulting in delayed price transmission (Wibowo et al., 2023). The selection of a 4th lag in ARDL or NARDL models is methodologically justified, as it allows the model to capture these gradual, policy-induced dynamics and the asymmetric effects of positive and negative shocks (Demirhan, 2020).

Structural break analysis is essential in time series research because the relationships among economic variables may change abruptly due to policy interventions, external shocks, or supply disruptions. Sudden changes in price structures can affect farmers' welfare, processing industry performance, staple food price stability, and the effectiveness of government policies within Indonesia's palm oil sector. Therefore, identifying break points is crucial to avoid biased parameter estimates, particularly when the prices of TBS, CPO, and bulk cooking oil have experienced strong volatility driven by global market dynamics and rapidly shifting domestic regulations.

This study employs the Additive Outlier (AO) approach to detect structural breaks, as this method is specifically designed to capture sudden shocks that cause instantaneous level shifts in the data. Perron (1989) highlights that AO is highly suitable when structural change occurs in the form of sharp jumps rather than gradual transitions. This characteristic aligns with the nature of Indonesia's palm oil market, where government policies such as the export ban on CPO, Domestic Market Obligation (DMO), and the Highest Retail Price (HET) are often implemented abruptly and generate immediate effects. Enders (2015) reinforces that the AO method enables econometric models to avoid estimation bias arising from significant structural disruptions.

The AO test results indicate a significant structural break at observation 139, corresponding to April 2022, coinciding with the government's export ban on CPO and downstream palm oil products. This policy generated a major shock because palm oil exports constitute a critical component of Indonesia's national economy. The export suspension triggered a sharp domestic oversupply, driving TBS prices downward within a very short period. This finding is consistent with Santiago (2023), who reports that the export ban distorted price transmission due to the loss of international price signals, and with Wibowo (2023), who shows that farmers were the most affected group as palm oil mills substantially reduced TBS purchases. Meanwhile, bulk cooking oil prices remained elevated and did not decrease proportionally to the collapse in CPO and TBS prices, indicating price rigidity at the downstream level. The visual representation of both short-run and long-run structural breaks is presented in Figure 1.

The long-run visualization in Figure 1 clearly illustrates the changing relationship among the variables. TBS prices show a sharp decline in the period leading up to and during April 2022, reflecting the immediate impact of the export ban on raw material demand at the mill level. The export suspension caused stock accumulation and a rapid price drop when CPO could no longer be shipped to international markets. CPO prices also display strong volatility, indicating that the policy disrupted the linkage between domestic and global price dynamics. In contrast, bulk cooking oil prices in traditional markets increased significantly during the same period, demonstrating weak transmission of declining input costs to consumers.

operational factors such as logistics costs, seasonal demand, and DMO–HET regulations. Hamilton (1994) explains that sudden shocks trigger strong but temporary price reactions before the system reaches a new equilibrium. This behavior is evident in wholesale and retail prices, which remained elevated even after the decline in CPO prices. The phenomenon indicates that downstream price rigidity is stronger in the short run, as traders tend to maintain margins under conditions of supply uncertainty and shifting policy regimes. Ouma (2023) highlights that short-run price volatility in the cooking oil market is heavily influenced by distribution disruptions, delivery delays, and frequently changing government policies, particularly during the enforcement of HET, which pressured retailers to adhere to fixed selling prices regardless of acquisition costs.

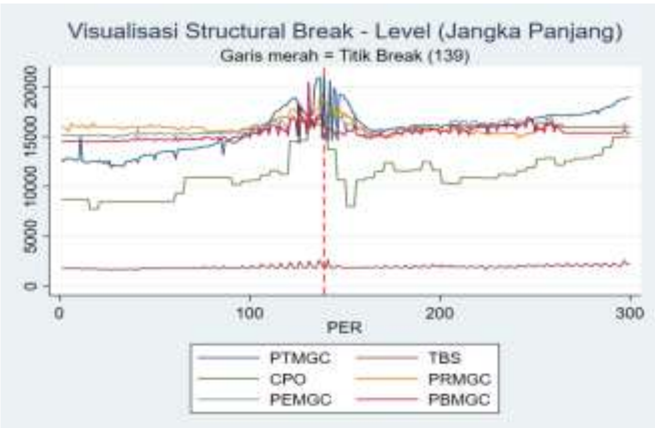

Figure 1. Structural breakdown visualization of FFB, CPO, and cooking oil prices long-term bulk in Indonesia (*Description: Traditional Market (PTMGC); Producer (PRMGC); Retail Trader (PEMGC); Wholesaler (PBMGC))

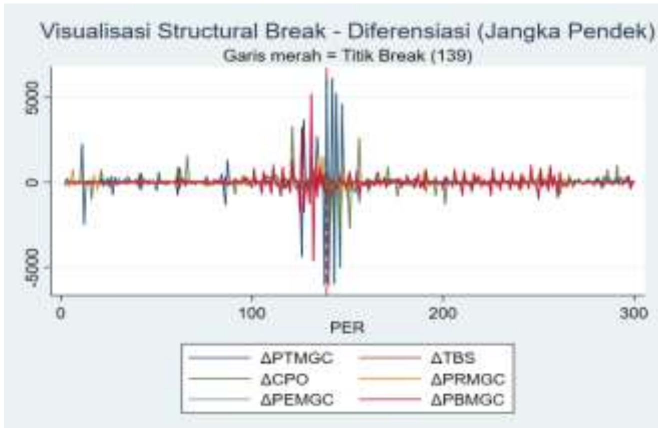

Figure 2. Visualization of structural breakdown of fresh fruit bunches (FFB), crude palm oil (CPO), and cooking oil prices bulk prices in Indonesia in the short term (*Description: Traditional Market (PTMGC); Producer (PRMGC); Retail Trader (PEMGC); Wholesaler (PBMGC))

Wholesale and retail prices remained rigid and did not follow the cost reduction occurring upstream. These findings are consistent with the Asymmetric Price Transmission (APT) theory proposed by Meyer and von Cramon-Taubadel (2004), which suggests that decreases in input prices are often not fully transmitted downstream due to market power, lengthy distribution chains, and rigid mark-up behavior among wholesalers and retailers. The Indonesian cooking oil market exhibits an oligopolistic structure, particularly at the producer and large-scale distributor levels, reinforcing strong price control and slow adjustment to upstream price changes. Mariyono et al. (2023) further confirms that the extensive distribution pathway in Indonesia is a key reason why market price adjustments at the consumer level occur much more slowly than changes experienced by mills or farmers.

Figure 2 illustrates more complex and volatile short-run price dynamics. The short-term pattern reflects market responses to policy shocks and

The comparison before and after the break provides critical insight into the Indonesian context. Prior to April 2022, price relationships along the supply chain were relatively stable, and transmission dynamics followed market equilibrium despite the COVID-19 effects and rising biodiesel demand (Olivia et al., 2020). After the break, price behavior changed sharply. TBS and CPO prices became highly sensitive to domestic policy, with excess supply driving TBS prices downward and increasing CPO volatility (Fitriani, 2023). In contrast, bulk cooking oil prices did not adjust proportionately, indicating strong downstream market power, long distribution channels, and price rigidity that obstruct effective transmission (Meyer & von Cramon-Taubadel, 2004).

This explanation provides a strong basis for subsequent NARDL-based asymmetric price transmission analysis, as the presence of a structural break implies that parameter constancy cannot be assumed. Models must incorporate regime changes to avoid biased estimates and ensure economically meaningful interpretation under real market conditions. The bound cointegration test is applied in this study to verify the existence of a long-run relationship among price variables within the bulk cooking oil supply chain. This approach is essential because commodity price data typically exhibit heterogeneous levels of stationarity. Prices of FFB, CPO, and bulk cooking oil at different market levels, producers (PRMGC), wholesalers (PBMGC), retailers (PEMGC), and traditional markets (PTMGC) show distinct fluctuation patterns influenced by market-specific conditions. The unit root results confirm that the variables are integrated at mixed levels, I(0) and I(1), rendering conventional cointegration techniques inappropriate.

The bound test is therefore the most suitable method, as it accommodates mixed integration orders provided no variable is I (2) (Pesaran et al., 2001). In the context of Indonesia's palm oil industry, the supply chain extends from plantations, CPO processing, and refining, to distribution and final retail sales. Price adjustments across these stages occur at different speeds: CPO producers respond rapidly to FFB price changes, distributors adjust after considering inventory and logistics, while retailers display the slowest response due to price rigidities and limited market information (Goodwin & Holt, 1999). These asymmetric adjustment dynamics justify the application of the bound test to confirm long-run equilibrium relationships and to evaluate the transmission of upstream price shocks to downstream consumer markets. The bound test results are presented in Table 2.

Table 2. Results of the Bound Test Cointegration Test

Dependent/Independent Variables	F-Statistic Value	Prob > F	Conclusion
PTMGC, TBS, CPO, PRMGC, PEMGC, PBMGC	5.04	0.0000	Reject H_0

*Description: Traditional Market (PTMGC); Producer (PRMGC); Retail Traders (PEMGC); Wholesale (PBMGC)

The bound test results demonstrate the presence of a statistically significant long-run relationship among the price variables in the bulk cooking oil supply chain. The computed F-statistic of 5.04 exceeds the upper critical value at the 5% significance level reported by Pesaran et al. (2001), thereby leading to the rejection of the null hypothesis of no cointegration. This finding confirms that the prices of FFB, CPO, and bulk cooking oil at various market levels are cointegrated. Although these prices may diverge temporarily in response to policy interventions or market disturbances, they exhibit a tendency to return to a long-run equilibrium through the adjustment mechanism captured by the error correction term, as explained by Enders (2014).

The presence of cointegration is consistent with the vertically integrated characteristics of Indonesia's palm oil industry, where upstream and downstream price movements are structurally interlinked. Price changes at the consumer level are ultimately influenced by variations in upstream production costs and market supply conditions (Daryanto, 2022; Arifin, 2023). The temporary disruption caused by the April 2022 export ban, marked by a sharp decline in FFB prices, volatility in domestic CPO prices, and persistently high retail cooking oil prices, illustrates short-run transmission rigidities arising from distribution constraints and regulatory uncertainty. However, subsequent price adjustment confirms that long-run price relationships remain intact despite short-run distortions.

These findings provide an important foundation for further asymmetric transmission analysis using the NARDL framework. The existence of long-run cointegration validates the separation of short-run and long-run coefficients and enables meaningful interpretation of price transmission dynamics. For policymakers, this evidence suggests that regulatory interventions may alter short-run price behavior but do not eliminate fundamental market linkages. Effective policy should therefore focus on improving distribution efficiency and transparency rather than attempting to disconnect upstream and downstream markets.

Hatemi-J Causality Test (Asymmetric Granger Causality Test)

The Asymmetric Granger Causality test of Hatemi-J is employed in this study to determine the direction of causal relationships between bulk cooking oil prices in traditional markets and key supply chain price variables, including FFB prices, CPO prices, and bulk cooking oil prices at the producer, wholesale, and retail levels. Developed by Hatemi-J (2012), this method accounts for asymmetric price adjustments by decomposing positive and negative shocks. This specification is essential, as markets do not respond to price increases and decreases with equal intensity, causing potentially biased inferences when applying symmetric causality models.

The application of this approach is highly relevant in the Indonesian context, where bulk cooking oil prices experienced substantial structural changes from 2020 to 2024 due to multiple shocks, including the COVID-19 pandemic, global CPO price surges, the 2022 export ban, and policy interventions such as HET, DMO, and DPO. These disruptions generated different behavioral responses before and after the structural break, resulting in asymmetric price transmission dynamics across supply chain levels. By distinguishing between positive and negative shocks, the Hatemi-J method provides a more accurate representation of causal relationships compared to conventional Granger tests. The empirical results of the Hatemi-J causality tests are presented in Table 3.

The Hatemi-J causality results presented in Table 3 reveal substantial differences in causal transmission patterns before and after the structural break in April 2022. Prior to the break, the price formation mechanism operated largely under competitive market dynamics with minimal policy intervention. Positive price shocks in FFB (TBS) significantly caused increases in bulk cooking oil prices in traditional markets (PTMGC), consistent with the vertical price transmission framework described by Meyer and von Cramon-Taubadel (2004). CPO prices also exerted strong causal influence on downstream markets, aligning with earlier empirical findings on the long-run integration of Indonesia's palm oil markets reported by Susila (2004). Retail (PEMGC) and wholesale (PBMGC) prices demonstrated causal leadership over traditional markets, supporting the price-leadership hypothesis proposed by Azzam (1999). Furthermore, the bidirectional causality observed among PTMGC, CPO, and TBS reflects a feedback adjustment mechanism, consistent with the dynamic interaction processes described by Enders (2014), indicating that the market functioned as a highly integrated and responsive system before the policy shock occurred.

Table 3. Hatemi-J Causality Test Results

Direction of Causal Relationships	Pra-Break ($PTMGC^{+}$) Prob < 0.05	Post-Break ($PTMGC^{-}$) Prob < 0.05
TBS → PTMGC	0.000	0.075
CPO → PTMGC	0.000	0.000
PRMGC → PTMGC	0.516	0.000
PEMGC → PTMGC	0.002	0.009
PBMGC → PTMGC	0.000	0.000
PTMGC → TBS	0.000	0.000
CPO ↔ TBS	0.027	0.000
PRMGC ↔ PEMGC	0.000	0.001
PBMGC ↔ PEMGC	0.098	0.007

*Description: Traditional Market (PTMGC); Producer (PRMGC); Retail Trader (PEMGC); Wholesaler (PBMGC)

After the structural break, the export ban and policy interventions such as DMO, DPO, and HET significantly altered price transmission patterns in the Indonesian palm oil sector. The causal influence of Fresh Fruit Bunches (TBS) on processed cooking oil prices (PTMGC) weakened, indicating that market adjustments became more restricted under direct policy control (Sabila et al., 2023; Wibowo et al., 2023). In contrast, Crude Palm Oil (CPO) prices maintained a strong causal influence, reflecting the persistent vertical integration and central role of CPO in the industry's price formation (Hidayat et al., 2023; Syahril et al., 2020).

Producer-level prices (PRMGC) gained greater causal significance for PTMGC, suggesting increased pricing power at the processing stage, likely due to tighter supply chain management and policy-driven market segmentation. Retail prices (PEMGC) continued to serve as the main reference in downstream markets, a trend amplified by transparent pricing mechanisms under HET regulations (Hermanto & Saragih, 2023). Additionally, the strengthened causality from wholesale prices (PBMGC) points to improved supply-chain coordination and stricter distribution monitoring following policy interventions.

Nonlinear Autoregressive Distributed Lag Test (NARDL)

The Nonlinear Autoregressive Distributed Lag (NARDL) model, developed by Shin et al. (2014), is employed in this study to capture asymmetric responses in the relationship between bulk cooking oil prices and key upstream and downstream market variables. The model allows price changes to be decomposed into positive and negative partial sums, enabling differential assessment of the effects of price increases and decreases. This approach is particularly relevant because price adjustments in agricultural commodity markets are rarely symmetric, especially within Indonesia's cooking oil sector, where supply chains are lengthy and market structures are highly concentrated.

The application of NARDL is appropriate in the context of Indonesia's palm oil industry, which has experienced substantial shocks and policy interventions, including the April 2022 export ban on CPO, DMO–DPO regulations, subsidies, and the enforcement of HET price controls. Such interventions create structural asymmetries that challenge linear modeling assumptions. NARDL further distinguishes between short-run and long-run effects, where the short-run component reflects dynamic adjustments across lagged price responses, and the long-run component captures equilibrium relationships among prices along the supply chain.

The estimated short-run and long-run nonlinear effects before and after the structural break are presented in Table 4 and Table 5, providing robust evidence of asymmetric price transmission within Indonesia's cooking oil market. Short-term analysis before the structural break showed that the price of bulk cooking oil (PTMGC) was significantly influenced by past prices, characterized by an LD coefficient (PTMGC) −0.542 at the level of 1%. The negative value indicates the existence of a price inertia mechanism, which is a slow process of price adjustment towards equilibrium due to a long distribution structure. The influence of FFB prices shows an asymmetrical pattern, where the increase in the price of FFB lag 2 decreases the price of bulk cooking oil, while the decrease in the price of FFB lag 3 increases the price. This phenomenon reflects downward price rigidity, where output prices do not necessarily fall when input costs decrease.

CPO prices had a significant positive influence on some lags, reflecting vertical price transmission, although not very strong due to loose export policies before 2022. Cooking oil prices at the producer (PRMGC), wholesaler (PBMGC), and retail trader (PEMGC) levels also showed significant influence, with wholesalers serving as shock absorbers and retail prices as the main determinants of final prices in traditional markets. In general, the market mechanism was still running before the break despite price rigidity. After April 2022, there was a significant change in the market structure. The interaction coefficient shows that the decrease in FFB prices increases the price of bulk cooking oil, due to domestic supply disruptions after the export ban policy and the implementation of the DMO that was not optimal. The variable of CPO price interaction was not significant, indicating that short-term price dynamics were more influenced by government policies than market mechanisms. This indicates that price stability after the break was achieved through regulatory intervention, but with a consequent weakening of efficiency and price transmission in the cooking oil value chain.

Table 4. Results of Short-Term NARDL Test on Bulk Cooking Oil Prices in Indonesia

Variable	Coefficient	Std. Err.	t-Statistics	Prob.
LD(PTMGC)	-0.542	0.070	-7.70	0.000
LD2(PTMGC)	-0.250	0.087	-2.86	0.005
LD3(PTMGC)	0.150	0.091	1.65	0.101
LD4(PTMGC)	-0.097	0.077	-1.26	0.210
LD2(TBS_pos)	-2.244	0.988	-2.27	0.024
LD3(TBS_neg)	1.862	0.862	2.16	0.032
LD4(TBS_neg)	1.112	0.570	1.95	0.052
LD2(CPO_pos)	0.351	0.161	2.18	0.030
LD4(CPO_pos)	0.322	0.120	2.70	0.008
LD1(PRMGC)	0.624	0.223	2.80	0.006
LD3(PRMGC)	-0.465	0.198	-2.35	0.020
LD1(PBMGC)	-0.350	0.153	-2.28	0.023
LD2(PBMGC)	-0.462	0.177	-2.60	0.010
LD3(PBMGC)	-0.536	0.180	-2.98	0.003
LD2(PEMGC)	0.475	0.234	2.03	0.044
ecm(-1)	-0.068	0.036	-1.89	0.060
inter_TBS_pos	0.357	0.801	0.45	0.656
inter_TBS_neg	2.118	0.895	2.37	0.019
inter_CPO_pos	-0.288	0.291	-0.99	0.324
inter_CPO_neg	-0.087	0.307	-0.28	0.777
_cons	-10.366	46.396	-0.22	0.823

*Source: Processed data (2025)

The results of the long-term NARDL test in Table 5 show that changes in the price of raw materials have not been the main determining factor in the price of bulk cooking oil before the structural break. The decrease in the price of FFB (L1(TBS_neg)) has a significant effect with a coefficient of 2.430 at the level of 5%, which means that the decrease in the price of FFB increases the price of bulk cooking oil in the long term. The pattern shows strong price rigidity in the structure of the domestic market. On the other hand, CPO prices do not show a significant influence on either the conditions of increase or decline, so price formation was still highly determined by the distribution structure and domestic policy. This result is in line with the FAO (2020) and Bank Indonesia (2021) reports, which stated that price stability before 2022 was still naturally formed due to the lack of administrative intervention.

Table 5. Long-Term NARDL Test Results on Bulk Cooking Oil Prices in Indonesia

Variable	Coefficient	Std. Err.	t-Statistic	Prob.
L1(TBS_pos)	0.343	0.904	0.38	0.705
L1(TBS_neg)	2.430	1.069	2.27	0.024
L1(CPO_pos)	0.304	0.288	1.05	0.292
L1(CPO_neg)	0.142	0.296	0.48	0.631
PRMGC	0.317	0.136	2.33	0.020
PBMGC	0.467	0.243	1.92	0.055
PEMGC	1.390	0.306	4.54	0.000
inter_TBS_pos	1.512	1.229	1.23	0.220
inter_TBS_neg	6.176	1.399	4.41	0.000
inter_CPO_pos	0.840	0.428	1.96	0.050
inter_CPO_neg	-0.528	0.322	-1.64	0.102
_cons	-19048.6	2724.9	-6.99	0.000

The price of bulk cooking oil at the producer level (PRMGC) has a significant effect with a coefficient of 0.317, indicating that producers have an important role in long-term price formation. The price of bulk cooking oil at the retail merchant level (PEMGC) shows the strongest influence with a coefficient of 1,390 at a significant level of 1%, which indicates the dominance of retail traders in determining final prices in traditional markets. Long-term conditions before the break describe a more symmetrical price movement and a return to equilibrium, according to the theory of the Law of One Price (Enders, 2014).

A significant change appeared after the break, marked by a significant inter_TBS_neg coefficient of 6.176 at 1%. This value shows the occurrence of extreme market distortions, where the decline in FFB prices triggered a large increase in the price of bulk cooking oil. This phenomenon shows the occurrence of asymmetric price transmission as explained by Meyer et al. (2004), which was influenced by the dominance of industry players and government regulatory intervention. The increase in CPO prices after the break (inter_CPO_pos) has a significant effect with a coefficient of 0.840, indicating that domestic prices are increasingly sensitive to global price increases (Manurung, 2019). Prices at the level of producers, wholesalers, and retail traders were again factors that shaped long-term prices, as also found in the research of Bulutay (2021) and the Bank Indonesia report (2024).

Wald test

The Wald test results provide a clearer understanding of the price transmission mechanism in Indonesia's bulk cooking oil market across two different market regimes: before and after the structural break in April 2022. This period division is essential because the government implemented major policy interventions, including the CPO export ban, DMO/DPO regulations, and the mandatory retail price cap (HET), which directly affected the market structure and supply chain of cooking oil. Empirical evidence from both periods indicates a substantial shift in price formation dynamics in both the short run and the long run. Overall, the Wald test confirms that price transmission patterns changed significantly following the intervention policies. The detailed Wald test results are presented in Table 6.

Table 6. Wald Test Results

	Short-term						Short-term	
	TBS	Prob>F	CPO	Prob>F	TBS	Prob>F	CPO	Prob>F
Before the break	7.46	0.0000	1.99	0.0352	3.21	0.0741	0.18	0.6750
After the break	2.90	0.0569	0.49	0.6102	7.53	0.0065	8.09	0.0048

*Source: Data processed (2025)

The Wald test results confirm the presence of asymmetric price transmission in Indonesia's bulk cooking oil market, particularly in response to changes in FFB (TBS) and CPO prices. Before the structural break, increases in input prices were transmitted more rapidly than decreases. The highly significant short-run F-statistic for FFB (Prob > F = 0.0000) indicates strong short-run asymmetry, demonstrating downward price rigidity, where retail prices adjust slowly when production costs decline. This condition reflects the influence of dominant market players and long distribution channels, as documented by Warr and Yusuf (2011), who highlight structural constraints and price-stickiness in Indonesian food markets. However, long-run results before the break reveal symmetric price transmission (Prob > F = 0.0741), implying that despite short-run distortions, the market continued to converge toward equilibrium consistent with the Law of One Price (Enders, 2014) and the asymmetric transmission mechanism described by Meyer et al. (2004).

After the structural break, caused by government interventions such as DMO/DPO regulations and the HET price ceiling, short-run transmission became symmetric, as indicated by non-significant F-statistics for FFB and CPO (Prob > F = 0.0569; 0.6102). These results indicate that administrative control successfully dampened short-term price responses by reducing volatility in raw material costs, consistent with evidence from Nafisah et al. (2022) on the stabilizing role of government intervention during periods of supply disturbance.

In contrast, the long-run results after the break exhibit significant asymmetry (FFB Prob > F = 0.0065; CPO Prob > F = 0.0048). Prices rise quickly when input prices increase but fall more slowly when production costs decline, reflecting deeper structural distortions and reduced market flexibility as a consequence of prolonged regulatory pressure. This pattern aligns with Shin et al. (2014), who emphasize nonlinear and asymmetric adjustment under policy-induced constraints, and with Bank Indonesia (2024), which reports that strict price stabilization policies may generate long-run inefficiencies and weaken competitive market responses. As a result, market participants tend to maintain higher margins to compensate for uncertainty and regulatory burdens, reinforcing long-run price stickiness.

Overall, Indonesia's cooking oil market shifted from a short-run asymmetric and long-run symmetric transmission structure before the policy shock to a short-run symmetric and long-run asymmetric pattern after the intervention period. This transition illustrates that although government intervention successfully reduced short-run volatility, it also created structural rigidities that amplified long-run price asymmetry.

Implementation of Government Policy

The Wald test results provide essential policy implications for the Indonesian government. Price control interventions such as HET, DMO, and DPO were effective in stabilizing short-term cooking oil prices, but they imposed long-term efficiency costs. Policymakers must balance short-term price stability with long-term market efficiency. As emphasized by Warr et al. (2011), price stabilization is necessary for welfare protection, yet it should not excessively restrict market mechanisms. Market distortions during the break period indicate that upstream producers, particularly palm farmers, received unfairly low prices, while consumers did not fully benefit from cost reductions when input prices declined.

The first proposed policy improvement concerns making DMO and DPO more adaptive to market dynamics. These policies should follow a formula that reflects global price volatility, domestic consumption needs, and production capacity. Excessively rigid export restrictions risk depressing farm-gate prices, as highlighted by Fitriani (2023), who reported that the 2022 export ban reduced FFB prices by more than 70%, while consumer prices remained high.

The second recommendation is to strengthen transparent price information systems throughout the value chain. Long-term distortions are often driven by information asymmetry. Goodwin et al. (1999) note that efficient price transmission requires complete market information. A digital integrated pricing platform for FFB, CPO, producer, wholesale, and retail markets would enhance competition and reduce opportunities for price manipulation.

The third implication involves reducing market concentration. The oligopolistic structure, where four large groups control more than 50% of the market (KPPU, 2022) drives asymmetric pricing behavior. Strengthening antitrust enforcement and supporting SME participation in the cooking oil industry would enhance competition and reduce long-run rigidity. This mechanism aligns with findings by Bakucs et al. (2014) and Meyer et al. (2004), who show that concentrated markets tend to exhibit stronger asymmetric price transmission.

Another recommended policy is revising the HET framework. A cost-based HET formula reflecting production costs, raw material prices, distribution expenses, and fair margins would prevent supply shortages. Nafisah et al. (2022) show that price ceilings led to scarcity in traditional markets because distributors could not operate profitably. Direct targeted subsidies would better protect low-income consumers without distorting price formation.

A key insight from the policy experience is that strong interventions successfully achieved short-term price stability but created long-term rigidities. After 2022, price transmission became less responsive to cost reductions, demonstrating structural price stickiness. Therefore, reforms should move beyond temporary price control to structural efficiency improvements, including logistics optimization, supply-chain digitalization, and stronger regulatory institutions. This aligns with Bank Indonesia (2024), which emphasizes that long-term food price stability requires complementary short- and long-term strategies.

Finally, policy design must balance the interests of both producers and consumers. The 2022 structural break demonstrated that excessive consumer-oriented stabilization can shift burdens upstream, harming palm farmers and reducing incentives for supply expansion. Efficient transmission ensures fair pricing throughout the supply chain, allowing both farmers and consumers to benefit from market adjustments.

Conclusion

The results of this study demonstrate a significant shift in the price formation mechanism of Indonesia's bulk cooking oil market, marked by a structural break in April 2022 following the CPO export ban and the implementation of DMO–DPO policies. The NARDL, Bounds Test, Hatemi-J, and Wald Tests confirm the presence of asymmetric price transmission, where increases in input prices (FFB and CPO) are passed through more rapidly than decreases, particularly after policy intervention, resulting in persistent price rigidity at the consumer level. These findings indicate that government intervention successfully reduced short-term price volatility but generated long-term structural distortions that weakened market efficiency and widened price disparities along the supply chain. Therefore, policy reforms must incorporate adaptive stabilization mechanisms, transparent price information systems, and enhanced competition to ensure fair value distribution across upstream and downstream market participants.

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