Jurnal Ekonomi Indonesia, 15(1) 2026, 056-074

Indonesian Economic Journal

P-ISSN 0854-1507 | E-ISSN 2721-222x
Available at https://jurnal.isei.or.id

Price transmission in Indonesia's CPO chain: An ARDL-UECM assessment

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Abstract

Purpose — This paper examines price transmission along Indonesia's crude palm oil (CPO) to cooking-oil value chain, focusing on identifying structural frictions between upstream and downstream markets.

Method — An ARDL model in its UECM form is applied using monthly data (2016–2023) to estimate both upstream (CPO to wholesale) and downstream (wholesale to retail) transmission, incorporating policy dummies for the 2022 intervention period.

Findings — Upstream transmission is rapid but incomplete, with moderate long-run pass-through and fast adjustment. In contrast, downstream transmission is slow, rigid, and amplifying, with larger long-run effects but delayed adjustment, reflecting significant market frictions at the retail level.

Implications — The results suggest that price instability is driven primarily by downstream rigidities. Policy interventions such as price controls may delay adjustment and distort transmission, while improving distribution efficiency and market transparency offers more effective solutions.

Originality — This study provides chain-consistent evidence of asymmetric price transmission within a unified framework, highlighting downstream markets as the key bottleneck.

Keywords: ARDL-UECM; price transmission; crude palm oil; price transmission; market frictions

JEL Classification: Q11;Q13;Q18

Recommended Citation
Kartawinata, M., Herawan, J. E., Komala, A., Susilo, Y. S., Tendean, V., Brata, A. G. (2026). Price transmission in Indonesia's CPO chain: An ARDL-UECM assessment. *Jurnal Ekonomi Indonesia.* 15(1) 2026, 056-074. DOI: https://doi.org/10.52813/jei.v15i1.788

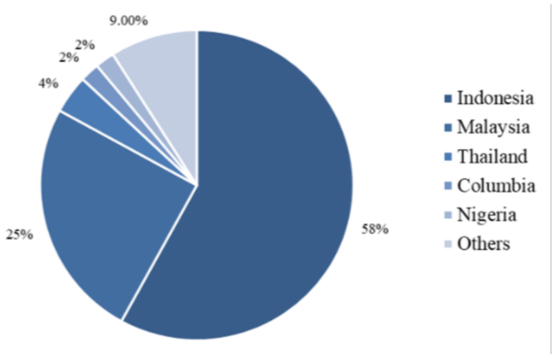
Introduction

Indonesia is the undisputed leader in crude palm oil (CPO), accounting for roughly 58% of global output, with 2024 production estimated at ~46 million tons. As Figure 2 shows, palm oil also dominates domestically, contributing 83.37% of national plantation output.

Submitted: 22 September 2025 – Revised: 21 Desember 2025 – Accepted: 28 April 2026

This scale translates into significant macroeconomic weight: GAPKI reports USD 27.76 billion in foreign-exchange earnings in 2024, while the Ministry of Finance notes the industry supports about 16 million jobs and contributed IDR 88 trillion to the 2023 state budget.

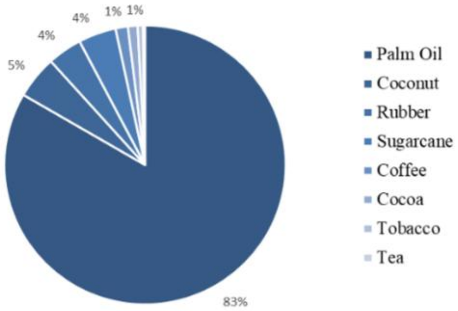
Figure 1. Share of global CPO production share (%) by country



Source: USDA, Processed by Author (2024)

Furthermore, Figure 2 stresses that palm oil dominates the national plantation sector, contributing 83.37% to total plantation output. Yet this strength rests on a maturing asset base. More than 40% of smallholder plantations are beyond the optimal 25-year lifecycle, depressing yields and raising harvesting costs. Replanting lags due to uneven access to quality seedlings, limited training, and restrictive eligibility for public funds, leaving many farmers, especially independents, unable to renew their stands.

Figure 2. Share of Indonesia's plantation crop production (%) by commodity



Source: BPS Statistics, Processed by Author (2024)

Resilience varies those linked to cooperatives or prior government programs fare better, while unorganized smallholders face institutional and financing gaps. These structural frictions also shape how price changes travel along the CPO–cooking-oil chain.

Later in the paper, we take a simple two-step look at that transmission, first from international CPO to domestic wholesale, then from wholesale to retail, using monthly, real and FX-adjusted data from January 2016 to May 2023, including the 2022 policy window. This lets us separate quick, short-run movements from longer-run shifts and see where the chain absorbs or amplifies shocks, especially during the export-ban/DMO period. Given its economic magnitude and the depth of these vulnerabilities, CPO production provides a compelling baseline case study for diagnosing structural bottlenecks in Indonesia's investment climate. Focusing on the cooking-oil segment highlights how these constraints manifest not only upstream (from plantation to bulk cooking-oil) but also downstream (wholesale to retail), influencing price stability, supply reliability, and overall market competitiveness.

This analysis will therefore serve as a microcosm for broader lessons in governance, capital allocation, and green transition pathways in one of Indonesia's most strategic industries. Indonesia's cooking-oil market is macro-critical: cooking oil is a staple input to household consumption, so its price volatility maps quickly into food inflation and welfare, making stability an explicit policy target rather than a purely market outcome.

Beyond headline CPI, spikes in cooking-oil prices compress real purchasing power for lower-income households and can trigger ad-hoc interventions (export controls, DMO/HET), which in turn alter normal transmission along the value chain, hence the need to understand both long-run linkages and short-run frictions. Global evidence frames why upstream energy and commodity shocks matter for food systems: oil prices co-move positively with broad food price indices in the long run, even when short-run impacts vary by period and regime, implying that energy-cost channels and expectations embed into food markets over time (Olayungbo, 2021). This long-run association motivates modeling designs that allow persistent trends while still capturing transitory deviations and partial adjustment.

Global evidence frames why upstream energy and commodity shocks matter for food systems: oil prices co-move positively with broad food price indices in the long run, even when short-run impacts vary by period and regime, implying that energy-cost channels and expectations embed into food markets over time. This long-run association motivates modeling designs that allow persistent trends while still capturing transitory deviations and partial adjustment. Focusing on edible oils, cross-commodity studies show crude oil and major vegetable oils, including palm, exhibit co-movement and measurable pass-through; impulse responses typically decay toward baseline within roughly ten months, indicating that shocks are material but not permanent once inventories, contracts, and arbitrage unwind (Destiarni and Jamil, 2021).

The implication is that both the scale (how much of a shock ultimately passes through) and the speed (how quickly the system re-equilibrates) are empirical questions, not assumptions. For Indonesia, market-integration work on cooking oil and olein finds cointegrated long-run relationships and adjustment speeds on the order of about five months, with downstream olein responding more strongly than upstream inputs, consistent with margin layering and retail-side rigidities that can amplify or delay pass-through (Nauly and Daulay, 2023). These estimates serve as practical priors for domestic chain dynamics: upstream links tend to correct faster, while downstream segments display slower and sometimes larger cumulative responses. Indonesia's 2022 cooking-oil episode exposed how shocks at the upstream palm-oil market can cascade through domestic supply chains and reshape the behaviour of wholesale and retail prices.

High-frequency evidence shows pronounced volatility spikes during early Q2-2022 across consumer and wholesale segments, consistent with a short-lived regime of elevated, tier-specific risk around the policy window that began in February 2022. This motivates an error correction framework that distinguishes short run disturbances from long run equilibrium adjustment along the value chain.

Evidence from the Indonesian food market further suggests that price transmission across market stages may be asymmetric and characterized by delayed adjustment (Laili et al., 2020).

Recent chain-level studies in food systems emphasise that even when a stable long-run relation exists, the path back to equilibrium can feature stickiness, overshooting, or asymmetric responses, especially under stress or when policies and margins bind (Panagiotou, 2021). Evidence from seafood markets further indicates that price transmission may be asymmetric and incomplete, particularly under conditions of structural change (Gizaw et al., 2021). In agricultural commodity chains, international-to-local transmission often reveals frictions and welfare risks (Emediegwu and Rogna, 2024). In this literature, a long-run elasticity near one indicates complete transmission, values between zero and one indicate partial transmission, and zero indicates no stable linkage (Waiswa and Yavuz, 2023).

Methodologically, estimating transmission is non-trivial because directionality must be justified (for example, through weak exogeneity tests or institutional ordering) and because prices are typically non-stationary. Dynamic specifications that combine levels and differences are required to avoid spurious inference (Pesaran et al., 2001). Recent applications in food systems adopt ARDL-type models precisely to accommodate these features and, where needed, allow for asymmetries (Asche et al., 2021).

Cross-country research further highlights the importance of separating long run pass through from short run dynamics when analysing how global commodity and exchange rate shocks transmit into domestic markets (Abbas & Lan, 2020). Against this background, we analyse Indonesia's CPO-to-cooking-oil chain using an Autoregressive Distributed Lag (ARDL) model expressed in its Unrestricted Error-Correction representation. The ARDL/bounds framework is attractive for three reasons. First, its cointegration test is valid regardless of whether regressors are I(0), I(1), or a mix, avoiding pre-testing uncertainty common in alternatives (Pesaran et al., 2001).

Second, once a levels relationship is supported, the ARDL can be written as a UECM that separates (i) the long-run pass-through elasticity (how large a shock ultimately is) from (ii) the error-correction speed (how fast deviations decay), while keeping short-run impact and cumulative multipliers explicit (Shin et al., 2014). Third, the approach is pragmatic in empirical work: it nests standard unit-root and cointegration logic and uses information criteria to pick lag orders, offering a transparent way to guard against over- or under-fitting (Pesaran et al., 2001).

Our contribution is twofold. Substantively, we provide chain-consistent estimates for Indonesia that quantify upstream global CPO to domestic wholesale bulk and downstream wholesale to retail packaged transmission before, during, and after the 2022 policy episode, thereby identifying where shocks are absorbed and where they persist (Pratiwi, 2022). Methodologically, we tailor an ARDL-UECM design to monthly data (2016–2023) with policy dummies for the export-ban/DMO transition and the post-June-2022 regime, reporting (a) long-run pass-through; (b) the error-correction parameter and implied half-lives; and (c) short-run multipliers over 1–6 months, metrics that map directly into stabilization and consumer-protection objectives.

This design follows best practice in the recent price-transmission literature and, where appropriate, connects to nonlinear ARDL/NARDL extensions used to study amplification or asymmetry in modern food chains (Shin et al., 2014). Findings from palm oil supply chains further highlight the persistence of asymmetric transmission and the vulnerability of smallholders (Nesti et al., 2025). Price transmission analysis focuses on how price changes at one stage of a market or value chain are transmitted to other stages, particularly from international to domestic markets or from upstream to downstream segments. In theory, the law of one price implies complete pass-through in integrated markets, but empirical evidence consistently shows that transmission is often incomplete, delayed, and asymmetric.

Factors such as transaction costs, trade policies, market power, inventory behavior, and adjustment frictions frequently prevent prices from adjusting proportionally and instantaneously, especially in food systems where policy intervention and structural rigidities are common (FAO, 2023). A growing body of literature emphasizes the role of energy prices, particularly crude oil, in shaping food price dynamics. Oil prices affect food prices through multiple channels, including production costs, transportation expenses, and expectations embedded in commodity markets.

Using linear and nonlinear ARDL frameworks, Zmami and Ben-Salha (2019) demonstrate that oil price shocks have a statistically significant long-run impact on global food prices, but the effect is asymmetric: positive oil price shocks are transmitted more strongly than negative shocks. Their disaggregated results further show that vegetable oils and other energy-intensive food categories are especially sensitive to oil price increases, highlighting the importance of commodity-specific analysis. Evidence on asymmetry is reinforced by Karakotsios et al (2021), who examine the dynamic linkages between oil and food prices and explicitly test whether asymmetric adjustment matters.

They find that food prices respond differently to oil price increases and decreases, both in magnitude and speed, implying that symmetric specifications may underestimate the persistence and welfare implications of commodity price shocks. These findings suggest that both the scale of pass-through and the speed of re-equilibration are empirical outcomes rather than theoretical constants. Beyond aggregate indices, recent studies stress the importance of analyzing price transmission along specific supply chains. Study from Kidane (2025), value chain using a nonlinear ARDL model, finds that while price transmission generally exists between export and retail markets, adjustment speeds and cumulative effects vary across product forms and processing stages. Even in relatively integrated markets, structural changes, such as consolidation among intermediaries, can modify how shocks propagate, potentially dampening or amplifying downstream price responses. This line of research underscores that price transmission is inherently chain-specific and shaped by institutional and structural characteristics.

Methodologically, the autoregressive distributed lag (ARDL) approach has become standard in price transmission studies because it accommodates variables integrated of different orders and allows for the joint estimation of long-run relationships and short-run dynamics. However, linear ARDL models impose symmetry by assumption. To address this limitation, the nonlinear ARDL (NARDL) framework decomposes explanatory variables into positive and negative changes, enabling separate estimation of responses to price increases and decreases. Using a NARDL framework, Chen and Chang (2025) show that the pass through of global oil price shocks to food prices in Hong Kong is asymmetric in the long run, whereas short run effects are not statistically significant.

They further find that negative oil shocks exert the larger long run impact. Their findings confirm that ignoring asymmetry can mask important dynamics, particularly during periods of market stress or policy intervention. Taken together, the literature establishes three core insights. First, price transmission in food markets is rarely complete or symmetric, especially when energy costs, policy measures, or market power intervene. Second, oil prices are a critical upstream driver of food price movements, with heterogeneous effects across commodities and value-chain stages. Third, ARDL-based models, particularly in their nonlinear form, offer a robust empirical framework for disentangling long-run pass-through from short-run adjustment. These insights motivate the present study's focus on Indonesia's CPO–cooking oil chain, where global commodity shocks and domestic policy regimes are likely to interact in shaping asymmetric price dynamics across upstream and downstream markets.

Methodology

To formally analyze price transmission along the cooking-oil value chain, we estimate two Autoregressive Distributed Lag (ARDL) models and report them in Unrestricted Error-Correction (UECM) form, which cleanly separates short-run dynamics from long-run equilibrium relationships (Pesaran, 2015). Before estimation, we diagnosed the order of integration of each monthly series (Jan-2016–May-2023) using a complementary battery of unit-root tests, Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and KPSS.

The results indicate a mixed integration order: some variables are I(1) in levels and become stationary after first differencing, while others are I(0) in levels; none is I(2) (Dickey and Fuller, 1979; Phillips and Perron, 1988; Kwiatkowski et al., 1992). This pattern motivates the ARDL–UECM framework, which is explicitly designed to accommodate regressors that are a combination of I(0) and I(1) and to model adjustment back to equilibrium via an error-correction mechanism (Hendry, 1995; Pesaran, 2015). Two single-equation models reflect the chain's structure: (i) an upstream link from international CPO benchmarks to domestic wholesale bulk cooking-oil prices, and (ii) a downstream link from wholesale to retail bulk prices.

This two-stage specification isolates where transmission is efficient and where bottlenecks arise, over a period that spans both stable conditions and the 2022 cooking-oil crisis. The analysis uses monthly data spanning January 2016 to May 2023, covering both stable market periods and the disruptions during Indonesia's 2022 cooking oil crisis. All series are expressed in logarithms and real terms to allow elasticity interpretation and comparability across variables. The dataset includes three main price series: the international CPO benchmark price (deflated by Indonesia's CPI and converted into rupiah using the JISDOR FX rate), the domestic wholesale bulk cooking-oil price, and the domestic retail bulk cooking-oil price.

To capture the effect of government intervention, two policy dummies are added: policy_window (equal to 1 during February–May 2022, the period of export bans and Domestic Market Obligation (DMO) transition), and post22 (equal to 1 from June 2022 onward, reflecting the MGKR/DMO regime). For robustness, all price series are CPI-deflated and exchange-rate adjusted, ensuring that the pass-through estimates are not biased by general inflation or currency fluctuations. This adjustment makes the estimates more reliable in identifying true transmission dynamics across the value chain. Table 1 summarizes the operational definitions, scales, and data sources of the variables employed in the analysis.

Despite its advantages, the ARDL framework is not without limitations. First, ARDL and its associated bounds testing procedure can be conservative in small to moderate samples, which may reduce the power to detect cointegration even when a stable long run relationship exists, particularly in applications with monthly data and complex dynamics (Jordan and Philips, 2018). Second, inference from ARDL models is sensitive to correct specification, as misspecified conditional or unconditional forms may lead to misleading conclusions regarding equilibrium relationships and adjustment dynamics (Bertelli et al., 2022).

In addition, the single equation nature of ARDL restricts the analysis to one conditional long run relationship and assumes weak exogeneity of regressors, which may not fully capture feedback mechanisms present in a fully simultaneous system (Kripfganz and Schneider, 2023). Nevertheless, these limitations are acceptable and well managed in the present study. The ARDL UECM framework is explicitly designed for settings with mixed orders of integration and none of the variables exceeding I(1), which matches the empirical properties of the data and avoids the need for potentially distortive pre differencing.

Moreover, the separation of short run dynamics from long run equilibrium adjustment provides a transparent structure for interpreting price transmission and policy effects across different stages of the value chain, while the conservative nature of the bounds test implies that detected long run relationships are unlikely to be spurious (Jordan and Philips, 2018). Recent methodological advances further suggest that bootstrap ARDL approaches with Fourier functions provide more reliable inference under structural shifts, supporting the use of the ARDL UECM framework for analysing price transmission during periods of policy intervention and market stress (Yilanci et al., 2020).

The study applies an Autoregressive Distributed Lag (ARDL) model, expressed in its Unrestricted Error-Correction Model (UECM) form, to investigate price transmission along Indonesia’s crude palm oil value chain. The ARDL framework is well suited to situations where regressors are a mixture of I(0) and I(1) processes, without requiring pre-differencing or strict stationarity (Pesaran et al., 2001). Monthly data from January 2016 to May 2023 are used to examine both upstream dynamics, linking CPO to wholesale prices, and downstream dynamics, linking wholesale to retail prices.

To determine the dynamic structure of each equation, we implement a compact information–criteria search over autoregressive and distributed-lag orders. For the dependent variable, we allow up to three lags while ensuring at least one lag to preserve the error-correction structure. For the main regressor, we consider up to three lags, with world CPO prices driving the upstream model and wholesale prices driving the downstream model. Policy indicators are entered contemporaneously only, without lags. Deterministic components are specified as Case III, an intercept without a deterministic trend, which is standard practice for logged real prices in ARDL applications.

Model selection relies on the Akaike Information Criterion (Akaike, 1974). For each admissible lag combination, we estimate the ARDL, calculate the residual-based AIC, and retain the specification with the lowest value. This balances in-sample fit with parsimony and allows the two market layers to display different degrees of persistence. Once the preferred lag orders are identified, we apply the Pesaran–Shin–Smith bounds F-test (Case III) to confirm the existence of a long-run levels relationship before reporting results in UECM form.

Table 1. Definition and Sources of Variables

Variable	Operational definition	Scale	Source
Global CPO price (lagged)	ln(global CPO benchmark), deflated by Indonesia CPI	Log index	World Bank Pink Sheet; CPI: BPS
Wholesale Price (lagged)	ln(national wholesale bulk cooking-oil price), CPI-deflated	Log index	Kemendag/PIHPS (compiled), CPI: BPS
Retail Price (lagged)	ln(national retail bulk cooking-oil price), CPI-deflated	Log index	PIHPS/Kemendag (compiled), CPI: BPS
2022 policy window	1 for Feb–May 2022 (HET/export ban/DMO transition), 0 otherwise	Dummy	Government regulations (2022)
Post-2022 regime	1 from June 2022 onward (DMO/MGKR regime), 0 before	Dummy	Government regulations (2022)
Consumer Price Index	National CPI (latest base)	Index	BPS
JISDOR FX rate	Monthly average IDR/USD	Level	BI

Source: Processed by Author

The selected specifications are ARDL(1,1) for the upstream relation between CPO and wholesale prices, and ARDL(3,2) for the downstream relation between wholesale and retail prices, both including contemporaneous policy dummies. Robustness checks using the Bayesian Information Criterion (BIC) and a wider lag grid yield identical specifications and confirm the stability of the results.

$$WH_t = a_0 + \sum_{i=1}^{p} \phi_i WH_{t-i} + \sum_{j=0}^{q} \theta_j CPO_{t-j} + \gamma_1 PW_t + \gamma_2 P22_t + \varepsilon_{ut} \quad (1)$$

$$\Delta WH_t = \lambda_u (WH_{t-1} - \beta_u CPO_{t-1}) + \sum_{i=1}^{p-1} \psi_i \Delta WH_{t-i} + \sum_{j=0}^{q-1} \delta_j \Delta CPO_{t-j} + \gamma_1 PW_t + \gamma_2 P22_t + \varepsilon_{ut} \quad (2)$$

Robustness checks using the Bayesian Information Criterion (BIC) and a wider lag grid yield identical specifications and confirm the stability of the results. Where WH_t denotes the logarithm of the domestic wholesale bulk cooking-oil price, expressed in CPI-deflated terms; CPO_t is the logarithm of the global crude palm oil benchmark price, CPI-deflated and adjusted to JISDOR; PW_t is a policy dummy that equals one during February–May 2022.

Capturing the export-ban and DMO transition period, and zero otherwise; $P22_t$ is a post-policy dummy that equals one from June 2022 onward, corresponding to the MGKR/DMO regime, and zero otherwise. The parameter a_0 represents the intercept, while ϕ_i are coefficients on the lagged dependent variable WH_{t-i}, capturing autoregressive dynamics for $i = 1, \ldots, p$.

The coefficients θ_j measure the contemporaneous and lagged effects of CPO_{t-j} on wholesale prices for $j = 0, \ldots, q$, and γ_1 and γ_2 capture the impacts of the policy dummies PW_t and $P22_t$, respectively. The error term is denoted by ε_t. The operator Δ indicates first differences. In the unrestricted error-correction specification, ψ_i represent short-run dynamics in changes of wholesale prices, while δ_j capture short-run effects of changes in CPO prices.

The coefficient λ_u is the speed-of-adjustment parameter associated with deviations from the long-run equilibrium, expected to be negative, and β_u denotes the long-run pass-through elasticity from global CPO prices to domestic wholesale prices. Finally, p and q indicate the optimal lag lengths selected using information criteria.

$$RT_t = a_0 + \sum_{i=q}^{p} \phi_i RT_{t-i} + \sum_{j=0}^{q} \theta_j WH_{t-j} + \gamma 1 PW_t + \gamma 2 P22_t + \varepsilon_{dt} \quad (3)$$

$$\Delta RT_t = \lambda_d (RT_{t-1} - \beta_d WH_{t-1}) + \sum_{i=1}^{p-1} \psi_i \Delta RT_{t-i} + \sum_{j=0}^{q-1} \delta_j \Delta WH_{t-j} + \gamma 1 PW_t + \gamma 2 P22_t + \varepsilon_{dt} \quad (4)$$

Where RT_t denotes the logarithm of the retail packaged cooking-oil price, expressed in CPI-deflated terms, and WH_t is the logarithm of the domestic wholesale bulk cooking-oil price, also CPI-deflated. The variable PW_t is a policy dummy equal to one during February–May 2022, capturing the export-ban and DMO transition period, and zero otherwise, while $P22_t$ is a post-policy dummy equal to one from June 2022 onward, representing the MGKR/DMO regime, and zero otherwise. The parameter a_0 denotes the intercept.

The coefficients ϕ_i capture autoregressive dynamics in retail prices through lagged values of RT_{t-i} for $i = 1, \ldots, p$, while θ_j measure the contemporaneous and lagged effects of wholesale prices WH_{t-j} on retail prices for $j = 0, \ldots, q$. The parameters γ_1 and γ_2 reflect the impacts of the policy dummies PW_t and $P22_t$, respectively, and ε_t is the error term.

The operator Δ denotes first differences. In the unrestricted error-correction specification, ψ_i represent short-run dynamics in changes of retail prices, while δ_j capture short-run effects of changes in wholesale prices. The coefficient λ_d is the speed-of-adjustment parameter associated with deviations from the long-run equilibrium, expected to be negative, and β_d denotes the long-run pass-through elasticity from wholesale to retail prices. Finally, p and q indicate the optimal lag lengths selected using information criteria.

This specification allows us to quantify both the speed and magnitude of pass-through from international CPO prices to wholesale and retail cooking-oil markets, while accounting for policy shocks and macroeconomic adjustments. The results from these models form the basis for identifying bottlenecks in Indonesia's cooking-oil value chain. From this representation, key quantities are derived as follows. Equation (5) defines the long-run pass-through elasticity. Equation (6) defines the error-correction coefficient (speed of adjustment). Equation (7) reports the implied half-life of adjustment.

Short-run cumulative multipliers are computed over horizons $h \in \{1,3,6\}$. Lag orders are selected by AIC and cointegration is assessed using the ARDL bounds test.

$$\beta = -\frac{\theta}{\rho} \quad (5)$$

Where θ is the coefficient on the lagged driver $L(x,1)(e.g., L(CPO,1)$ upstream or $L(WH,1)$ downstream) and ρ is the coefficient on the lagged dependent $(e.g., L(WH,1), L(RT,1))$. This is the elasticity that holds once the system returns to equilibrium.

$$\lambda \equiv \rho. \text{with } \lambda < 0 \quad (6)$$

Which reflects the monthly speed at which deviations from the long-run equilibrium are corrected (Wooldridge, 2016).

$$HL = \frac{\ln(0.5)}{\ln(1+\lambda)}, -1 < \lambda < 0 \quad (7)$$

Indicating the number of months required for half of a disequilibrium shock to dissipate. Short-run cumulative multipliers are computed as the sum of coefficients on first-difference terms of the driver over horizons $h \in \{1,3,6$, capturing near-term responses before long-run equilibrium is restored (Stock and Watson, 2019). Lag orders are chosen by AIC with p≥1, and cointegration is verified using the ARDL bounds test (Case III: intercept, no trend) of Pesaran, Shin, and Smith (2001).

Long-run pass-through elasticities from the UECM are reported with Newey–West HAC standard errors and delta-method transform (Newey and West, 1987; Wooldridge, 2016). Modeling the upstream global CPO to wholesale and downstream wholesale to retail links, with policy dummies for Feb–May 2022 and post-June 2022 regimes, aligns with the chain's sequencing and isolates structural breaks. Together, the reported β (long-run pass-through), λ (speed of adjustment), half-life, and short-run multipliers summarize how shocks transmit, are absorbed, or are dampened across Indonesia's cooking-oil value chain.

To assess the robustness of the ARDL estimates, several diagnostic and stability checks are conducted. First, residual diagnostics are performed using the Breusch–Godfrey test for serial correlation, the Breusch–Pagan test for heteroskedasticity, and the Jarque–Bera test for normality. Second, parameter stability is evaluated using the OLS-based CUSUM test to verify the absence of structural instability over the sample period. Finally, inference is re-evaluated using Newey–West heteroskedasticity and autocorrelation-consistent standard errors to ensure that statistical significance is not sensitive to residual dependence. Together, these checks confirm that the estimated pass-through coefficients and adjustment dynamics are robust and well specified.

Results and Discussion

Present Before presenting the detailed results, it is important to note a structural difference between the two stages of the value chain. The upstream model CPO to wholesale shows rapid and direct price transmission, with little evidence of lagged dynamics, reflecting the commodity nature of wholesale trade.

By contrast, the downstream model wholesale to retail exhibits slower and staggered adjustments, requiring multiple lags to capture inventory cycles, menu costs, and retail rigidities. In practice, this means wholesalers adjust quickly to global shocks, while retailers respond sluggishly, often with delays and partial reversals before reaching equilibrium.

Furthermore, Diagnostic and robustness tests indicate that the estimated ARDL–UECM models are well specified. The Breusch–Godfrey tests show no evidence of serial correlation, and CUSUM tests confirm parameter stability over the sample period. While the Breusch–Pagan and Jarque–Bera tests indicate the presence of heteroskedasticity and non-normal residuals, a common feature in monthly price data and during policy-shock episodes, this does not affect coefficient consistency.

Accordingly, statistical inference is based on Newey–West heteroskedasticity and autocorrelation-consistent standard errors. Under this robust inference, the estimated long-run pass-through elasticities and adjustment dynamics remain statistically significant, supporting the reliability of the main results. Unit-root tests indicate a mixed order of integration across series: CPO and retail prices are non-stationary in levels but stationary in first differences (I(1)), while wholesale is stationary in levels (I(0)). This I(0)/I(1) mix motivates the ARDL/UECM approach, which permits regressors with different integration orders without pre-differencing.

Using the Akaike Information Criterion with the constraint $p \geq 1$, the data select ARDL(1,1,0,0) for the upstream link CPO to wholesale and ARDL (3,2,0,0) for the downstream link wholesale to retail, the last two zeros indicate no extra lags on the Feb–May 2022 policy window and the post-June-2022 regime dummies. This choice already signals a structural difference across stages: upstream transmission is rapid and direct, with minimal lagged dynamics, consistent with the commodity nature of wholesale trade; downstream adjustment is slower and staggered, requiring multiple lags to capture inventory cycles, menu costs, and retail rigidities.

Table 2. Upstream ARDL/UECM Results

Series	ADF p	PP p	KPSS p	Decision
In CPO (level)	0.096	0.868	0.049	I(1)
In Wholesale (level)	0.047	0.759	0.056	I(0)
In Retail (level)	0.131	0.921	0.100	I(1)
Δ In CPO	0.001	0.010	0.100	I(0)
Δ ln Wholesale	0.000	0.010	0.100	I(0)
Δ ln Retail	0.000	0.010	0.100	I(0)

Source: Processed by Author

In practice, wholesalers react quickly to global shocks, whereas retailers respond more sluggishly, with delays and partial reversals before equilibrium is restored. Cointegration is supported in both links by the ARDL bounds test (Case III: intercept, no trend). For upstream, the test yields F = 8.862, p = 0.000, rejecting the null of no levels relationship. For downstream, F = 6.784, p = 0.002, likewise rejecting the null. These results justify reporting the UECM form and interpreting the long-run pass-through (β) and the speed of adjustment (λ).

Table 3. ARDL lag orders selected by AIC

Equation	Dependent Variable	Driver	Policy Window	Post 2022
Upstream	1	1	0	0
Downstream	3	2	0	0

Source: Processed by Author

The coefficient on Global CPO price (0.268, $p < 0.001$) is positive and highly significant, confirming that international CPO prices are transmitted to Indonesia's wholesale cooking-oil prices. The lagged dependent variable, Wholesale price (-0.639, $p < 0.001$), is negative and significant, providing the adjustment mechanism consistent with cointegration, wholesale prices adjust rapidly back to equilibrium when they deviate from the international benchmark.

Neither the 2022 policy window (Feb–May 2022 export ban/DMO) nor the Post-2022 regime (June 2022 onward, MGKR policy) dummies are significant, suggesting that government interventions in 2022 did not materially change long-run pass-through dynamics. This result aligns with Putra and Patunru (2024), who show that strong price linkages between international and domestic CPO prices limit the effectiveness of export-restricting policies in reducing domestic CPO and cooking-oil prices, reinforcing the conclusion that global market movements shape domestic price behavior in Indonesia.

Table 4. ARDL Bounds Test for Cointegration

Equation	Case	F-stat	P-value	Decision
Upstream	III	8.862	0.000	Cointegration
Downstream	III	6.784	0.002	Cointegration

Source: Processed by Author

Wholesalers continued to primarily follow global market signals rather than regulatory actions. In the short run, the coefficient on Δ Global CPO price (0.131, $p \approx 0.07$) is marginally significant, implying that around 13% of a monthly CPO price shock is passed on immediately to wholesale prices, with the remainder absorbed through the error-correction process.

The estimated half-life of deviations is only ~20 days, underscoring the rapid speed of adjustment. This finding is consistent with et al (2022), who show that external shocks such as global crude oil and substitute vegetable oils dominate internal shocks in explaining palm oil price movements in Malaysia.

Moreover, the broader theoretical literature on price transmission highlights that pass-through should be evaluated in terms of both magnitude and speed, with equilibrium displacement models predicting rapid yet incomplete adjustments to shocks (Antonova, 2014). Overall, the upstream model explains 44% of the variation in wholesale prices ($R^2 = 0.444$), with a strong overall F-statistic ($p < 0.001$), indicating a robust and well-specified model.

Table 5. Upstream ARDL/UECM Results

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.815	0.380	4.774	0.0000***
$Wholesale\ price_{t-1}$	-0.639	0.116	-5.510	0.0000***
$Global\ CPO\ price_{t-1}$	0.268	0.052	5.155	0.0000***
2022 policy window	0.053	0.038	1.409	0.165
Post-2022 regime	-0.005	0.014	-0.348	0.723
Δ Global CPO Price	0.131	0.071	1.852	0.069

Source: Processed by Author
Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; $p < 0.15$ (marginal significance)

Having established that upstream pass-through is fast and efficient, we now turn to the downstream stage wholesale to retail, where the results reveal slower, stickier, and more complex adjustment dynamics. The coefficient on lagged wholesale price (0.336, $p < 0.001$) is positive and highly significant, confirming that changes in wholesale prices are strongly transmitted to retail prices. Meanwhile, the lagged retail price (−0.143, $p < 0.05$) is negative, validating the cointegration condition and showing that retail prices gradually adjust back toward equilibrium when deviating from wholesale prices.

The Post-2022 regime dummy (−0.038, $p < 0.05$) is significant and negative, implying that retail prices were systematically lower under the MGKR/DMO regime, conditional on wholesale price movements. By contrast, the 2022 policy window dummy (−0.0530, $p > 0.1$) is statistically insignificant, indicating that temporary interventions during the export ban/DMO transition did not meaningfully alter retail price transmission.

The immediate effect of wholesale price change (0.104, $p > 0.3$) is statistically insignificant, but its lagged change (−0.533, $p < 0.001$) is negative and highly significant. This suggests that retail prices underreact in the same month but partially roll back in subsequent months before stabilizing. Additional lagged retail price changes (−0.475, $p < 0.001$ and 0.194, $p > 0.1$) further highlight sluggish and corrective adjustments at the retail level.

Such inertia is consistent with price transmission theory, which emphasizes that downstream stages tend to display greater stickiness and asymmetry due to market power, inventory management, and the complexity of jointly produced goods (Antonova, 2014). The estimated adjustment speed ($\lambda = -0.143$) indicates that deviations from the wholesale–retail equilibrium are corrected very slowly compared to the upstream stage. The half-life of shocks is approximately 4.5 months, reflecting persistent stickiness and inertia in retail pricing. The model explains around 50% of the variation in retail prices ($R^2 = 0.504$), with a strong F-statistic ($p < 0.001$), confirming that the downstream relationship is statistically well-identified.

The downstream model, which links wholesale bulk cooking-oil prices to retail packaged prices, highlights a slow but significant adjustment process in Indonesia's value chain. The lagged retail price is negative and statistically significant, showing that retail prices gradually return toward equilibrium after a disturbance. However, the adjustment speed is low, indicating that deviations persist for several months before being fully corrected. This reflects considerable inertia and stickiness in retail pricing compared to upstream adjustments.

Table 6. Downstream ARDL/UECM Results

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	−0.872	0.378	-2.308	0.025**
$Retail\ price_{t-1}$	−0.143	0.066	-2.176	0.034**
$Wholesale\ price_{t-1}$	0.336	0.087	3.880	0.000***
2022 policy window	−0.053	0.039	-1.349	0.183
Post-2022 regime	-0.038	0.016	-2.449	0.017**
$\Delta\ Retail\ price_{t-1}$	0.194	0.124	1.564	0.124.
$\Delta\ Retail\ price_{t-2}$	-0.475	0.128	-3.711	0.000***
Δ wholesale price	0.104	0.107	0.974	0.3340
$\Delta\ Wholesale\ price_{t-1}$	-0.533	0.123	-4.329	0.000***

Source: Processed by Author
Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; . $p < 0.15$ (marginal significance)

The lagged wholesale price enters with a positive and highly significant effect, confirming the existence of long-run pass-through from wholesale to retail markets. In practical terms, this means that persistent changes in wholesale costs are eventually transmitted to consumers, although not immediately. The elasticity is substantial, underlining that wholesale costs remain the main driver of retail pricing over time. Turning to policy interventions, the post-2022 regime dummy is negative and significant.

This suggests that during the MGKR/DMO regulatory framework, retail cooking-oil prices were systematically lower, even after accounting for wholesale price dynamics. In contrast, the short-lived 2022 policy window dummy is not statistically significant, implying that temporary interventions during the export ban and DMO transition period did not fundamentally alter the retail pricing mechanism.

The short-run dynamics further reveal how sluggish retail responses are. The immediate impact of wholesale price changes on retail prices is statistically insignificant, while the lagged effect is strongly negative and significant.

This pattern suggests that retail prices do not fully respond in the same month but instead display partial reversals in subsequent months before stabilizing. Additional lags of retail price changes also show that adjustments are not smooth: some months see significant rollbacks, while others exhibit minor corrections.

Taken together, these results point to a downstream market characterized by gradual adjustment, strong long-run linkages, but limited responsiveness in the short run. Consumers therefore experience delayed price pass-through, with retail markets showing persistent stickiness and inertia. This has important implications for policy: while long-run integration ensures eventual alignment between wholesale and retail prices, short-run rigidities mean that consumer relief or cost increases are felt only with significant delay.

Table 7. Summary of Long- and Short-run Estimates

Segment	Long-run PT (β)	Adjustment speed (λ)	Half-life (months)	Short-run multiplier (1m)	Short-run multiplier (3m)	Short-run multiplier (6m)
Upstream	0.420	−0.639 (fast)	0.68 (~20 days)	0.131	0.131	0.131
Downstream	2.34	−0.143 (slow)	4.49 (~4.5 months)	0.104	−0.429	−0.429

Source: Processed by Author

Conclusion

This study finds a clear structural asymmetry in Indonesia’s cooking oil value chain. Upstream, international CPO shocks are transmitted to domestic wholesale prices relatively quickly but only partially. The long run pass through estimate of 0.420 implies that a 10 percent increase in international CPO prices raises wholesale prices by around 4.2 percent in the long run, with adjustment occurring rapidly and a half-life of about 20 days. By contrast, downstream transmission is much weaker in speed but stronger in magnitude. Retail prices respond more than proportionally to wholesale prices, with a long run elasticity of 2.34, yet the adjustment is slow, with a half-life of about 4.49 months. The small initial retail response, followed by reversals and overshooting, suggests that inventories, menu costs, delayed repricing, and retail pricing behavior play a larger role downstream. In short, upstream markets appear relatively responsive, while the main bottleneck lies at the retail level where shocks persist longer for households.

These results imply that policy should not focus mainly on suppressing prices upstream. Since wholesale prices already adjust relatively quickly, interventions such as export restrictions, Domestic Market Obligation schemes, or other upstream controls are unlikely to solve the main transmission problem. They may temporarily compress upstream prices, but they do not necessarily ensure faster or fuller relief for consumers if retail adjustment remains slow. In that sense, the findings suggest that DMO style interventions are poorly targeted to the actual weak point in the chain. Blanket retail price ceilings are also risky, because they can compress margins, distort incentives, worsen supply frictions, and prolong the gap between wholesale and retail prices.

A more effective policy approach is to address downstream frictions directly. This includes improving distribution efficiency, reducing logistics bottlenecks, supporting inventory financing for distributors and retailers, and increasing transparency in wholesale to retail price spreads across regions.

When consumer protection is needed, targeted and temporary support such as vouchers or direct transfers is preferable to broad price controls, because it protects households without weakening market signals. Although this study is limited by the absence of direct data on inventories, margins, and policy intensity, the main implication is clear: the core problem is not weak upstream transmission, but slow and amplified downstream adjustment. Policy should therefore prioritize fixing retail and distribution frictions rather than relying on broad upstream controls.

AI declaration

The authors declare that artificial intelligence (AI) tools were used solely to assist in language refinement, grammar checking, and improving the clarity of writing. The use of AI did not influence the research design, data collection, data analysis, interpretation of results, or the development of conclusions. All intellectual contributions, including conceptualization, methodology, analysis, and final content, remain the full responsibility of the authors.

Conflict Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. The research was conducted independently without any financial, commercial, or personal relationships that could be construed as a potential conflict of interest.

References

[1] Abdlaziz, R.A., Rahim, K.A. and Adamu, P. (2016) 'Oil and food prices co-integration nexus for Indonesia: A non-linear autoregressive distributed lag analysis', *International Journal of Energy Economics and Policy*, 6(1), pp. 82–87.

[2] Adyanti, A.S. and Yafi, M.A. (2024) 'Market integration of Indonesia and Malaysia crude palm oil (CPO) export prices (A VECM approach)', *Buletin Penelitian Sosial Ekonomi Pertanian Fakultas Pertanian Universitas Haluoleo*, 26(2), pp. 177–188. doi:10.37149/bpsosek.v26i2.1607.

[3] Alvarez-Blaser, S., Cavallo, A., MacKay, A. and Mengano, P. (2025) *Markups and cost pass-through along the supply chain*. doi:10.3386/w34110.

[4] Antonova, M. (2015) *Theoretical analysis of price transmission: a case of joint production*. Christian-Albrechts-Universität zu Kiel. Available at: https://nbn-resolving.org/urn:nbn:de:gbv:8-diss-142124.

[5] Bertelli, S., Vacca, G. and Zoia, M. (2022) 'Bootstrap cointegration tests in ARDL models', *Economic Modelling*, 116, p. 105987. doi:10.1016/j.econmod.2022.105987.

[6] Destiarni, R. and Jamil, A. (2021) 'Price integration analysis of crude oil and vegetable oils', *HABITAT*, 32(2), pp. 82–92. doi:10.21776/ub.habitat.2021.032.2.10.

[7] Dickey, D.A. and Fuller, W.A. (1979) 'Distribution of the estimators for autoregressive time series with a unit root', *Journal of the American Statistical Association*, 74(366a), pp. 427–431. doi:10.1080/01621459.1979.10482531.

[8] Emediegwu, L.E. and Rogna, M. (2024) 'Agricultural commodities' price transmission from international to local markets in developing countries', *Food Policy*, 126. doi:10.1016/j.foodpol.2024.102652.

[9] Food and Agriculture Organization of the United Nations (FAO). (2023) *The State of Food and Agriculture 2023: Revealing the true cost of food to transform agrifood systems*. Rome: FAO.

[10] Gizaw, D., Myrland, Ø. and Xie, J. (2020) 'Asymmetric price transmission in a changing food supply chain', *Aquaculture Economics & Management*, 25(1), pp. 89–105. doi:10.1080/13657305.2020.1810172.

[11] Hendry, D.F. (1995) *Dynamic Econometrics*. doi:10.1093/0198283164.001.0001.

[12] Ibrahim, M.H. (2015) ‘Oil and food prices in Malaysia: A nonlinear ARDL analysis’, *Agricultural and Food Economics*, 3(1). doi:10.1186/s40100-014-0020-3.

[13] Jordan, S. and Philips, A.Q. (2018) ‘Cointegration testing and dynamic simulations of autoregressive distributed lag models’, *The Stata Journal: Promoting Communications on Statistics and Stata*, 18(4), pp. 902–923. doi:10.1177/1536867X1801800409.

[14] Kharisma, B. and Indrawan, Z.M.S. (2023) ‘Analysis of rice price transmission in West Java, Indonesia’, *Cogent Food & Agriculture*, 9(2). doi:10.1080/23311932.2023.2266198.

[15] Kripfganz, S. and Schneider, D.C. (2023) ‘ARDL: Estimating autoregressive distributed lag and equilibrium correction models’, *The Stata Journal: Promoting Communications on Statistics and Stata*, 23(4), pp. 983–1019. doi:10.1177/1536867X231212434.

[16] Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992) ‘Testing the null hypothesis of stationarity against the alternative of a unit root’, *Journal of Econometrics*, 54(1–3), pp. 159–178. doi:10.1016/0304-4076(92)90104-Y.

[17] Laili, F., Widyawati, W. and Budi Setyowati, P. (2020) ‘Asymmetric price transmission in the Indonesian food market’, *IOP Conference Series: Earth and Environmental Science*, 518(1), p. 012078. doi:10.1088/1755-1315/518/1/012078.

[18] Mallory, M.L., Peng, R., Ma, M. and Wang, H.H. (2025) ‘High-dimensional spatial-plus-vertical price relationships and price transmission: a machine learning approach’, *arXiv*. doi:10.48550/arXiv.2506.13967.

[19] Nendissa, D.R. and Pellokila, M.R. (2025) ‘Cooking oil price volatility in the consumer market and wholesalers market in Indonesia’, *Journal of Global Innovations in Agricultural Sciences*, pp. 61–70. doi:10.22194/jgias/25.1499.

[20] Nesti, L. (2025) ‘Price transmission in the supply chain of independent oil palm smallholders in West Sumatera, Indonesia: A case study in Dharmasraya district’, *Journal of Oil Palm Research* [Preprint]. doi:10.21894/jopr.2025.0005.

[21] Olayungbo, D.O. (2021) ‘Global oil price and food prices in food importing and oil exporting developing countries: A panel ARDL analysis’, *Heliyon*, 7(3), e06357. doi:10.1016/j.heliyon.2021.e06357.

[22] Panagiotou, D. (2021) ‘Asymmetric price responses of the US pork retail prices to farm and wholesale price shocks: A nonlinear ARDL approach’, *The Journal of Economic Asymmetries*, 23. doi:10.1016/j.jeca.2020.e00185.

[23] Pesaran, M.H., Shin, Y. and Smith, R.J. (2001) ‘Bounds testing approaches to the analysis of level relationships’, *Journal of Applied Econometrics*, 16(3), pp. 289–326. doi:10.1002/jae.616.

[24] Phillips, P.C. and Perron, P. (1988) ‘Testing for a unit root in time series regression’, *Biometrika*, 75(2), pp. 335–346. doi:10.1093/biomet/75.2.335.

[25] Putra, F.P. and Patunru, A. (2024) ‘Examining policies on controlling prices: Indonesian crude palm oil (CPO) and cooking oil’, *Southeast Asian Economies*, 41(2), pp. 125–151. doi:10.1355/ae41-2c.

[26] Putra, H.A. et al. (2023) ‘Understanding short-term and long-term price fluctuations of main staple food commodities in Aceh Province, Indonesia: An ARDL investigation’, *Ekonomikalia Journal of Economics*, 1(1), pp. 26–32. doi:10.60084/eje.v1i1.50.

[27] Sarma, N., Tiwari, P. and Rajib, P. (2024) ‘From fields to futures: connectedness among edible oil and oilseeds—where soybean leads, others follow’, *Asia-Pacific Financial Markets*, 32(2), pp. 447–463. doi:10.1007/s10690-024-09458-7.

[28] Scott, F., Lusompa, A., Rodziewicz, D., Cowley, C. and Dice, J. (2024) ‘The passthrough of agricultural commodity prices to food prices’, *Federal Reserve Bank of Kansas City Research Working Papers*. doi:10.18651/rwp2024-16.

[29] Shin, Y., Yu, B. and Greenwood-Nimmo, M. (2011) ‘Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework’, *SSRN Electronic Journal*. doi:10.2139/ssrn.1807745.

[30] Varela, G., Aldaz-Carroll, E. and Iacovone, L. (2013) ‘Determinants of market integration and price transmission in Indonesia’, *Journal of Southeast Asian Economies*, 30(1), pp. 19–44. Available at: http://www.jstor.org/stable/43264658.

[31] Waiswa, D. and Yavuz, F. (2023) 'Market integration and asymmetric price transmission in selected domestic markets for major staple foods in Uganda', *Future Business Journal*, 9(1). doi:10.1186/s43093-023-00281-6.

[32] Wibowo, H., Adam, H. and Fauziah, M. (2023) 'Changes in global, domestic, and stock price as a response to Indonesian CPO export ban: An opening door into a worldwide financial distress', *International Journal of Science and Society*, 5(5), pp. 66–84. doi:10.54783/ijsoc.v5i5.868.

[33] Widarjono, A. and Hakim, A. (2019) 'Asymmetric oil price pass-through to disaggregate consumer prices in emerging market: Evidence from Indonesia'. Available at: https://www.econjournals.com/index.php/ijeep/article/view/8287.

[34] Yilanci, V., Bozoklu, S. and Gorus, M.S. (2020) 'Are BRICS countries pollution havens? Evidence from a bootstrap ARDL bounds testing approach with a Fourier function', *Sustainable Cities and Society*, 55, p. 102035. doi:10.1016/j.scs.2020.102035.

[35] Zaidi, M.A.S., Karim, Z.A. and Zaidon, N.A. (2021) 'External and internal shocks and the movement of palm oil price: SVAR evidence from Malaysia', *Economies*, 10(1), p. 7. doi:10.3390/economies10010007.

Appendix 1. Residual diagnostics for ARDL–UECM models

Model	Test	Statistic	df	p-value	Conclusion
Upstream	Breusch–Godfrey (AR(12))	17.146	12	0.144	No serial correlation
	Breusch–Pagan	24.466	5	0.000	Heteroskedasticity present
	Jarque–Bera	17.079	2	0.000	Non-normal residuals
Downstream	Breusch–Godfrey (AR(12))	11.463	12	0.49	No serial correlation
	Breusch–Pagan	42.699	8	<0.001	Heteroskedasticity present
	Jarque–Bera	58.425	2	<0.001	Non-normal residuals

Appendix 2. CUSUM parameter stability tests

Model	Test Type	Test Statistic	p-value	Stability Conclusion
Upstream	OLS–CUSUM	1.378	0.240	Stable parameters
Downstream	OLS–CUSUM	1.194	0.67	Stable parameters

Appendix 3. Upstream model CPO to wholesale, Newey–West standard errors

Variable	Coefficient	Std. Error	t-stat	p-value
Intercept	1.815	0.561	3.234	0.002
L(WHt−1)	-0.639	0.177	-3.611	<0.001
Variable	Coefficient	Std. Error	t-stat	p-value
L(CPOt−1)	0.268	0.072	3.707	<0.001
Policy window	0.0528	0.0317	1.6688	0.101
Post-2022	-0.005	0.017	-0.29	0.773
ΔCPOt	0.131	0.036	3.611	<0.001

Appendix 4. Downstream model wholesale to retail, Newey–West standard errors

Variable	Coefficient	Std. Error	t-stat	p-value
Intercept	-0.872	0.396	-2.202	0.032
L(RTt−1)	-0.143	0.072	-1.987	0.053
L(WHt−1)	0.336	0.145	2.317	0.025
Policy window	-0.053	0.065	-0.816	0.419
Post-2022	-0.038	0.015	-2.651	0.011
ΔRTt−1	0.194	0.126	1.535	0.131
ΔRTt−2	-0.475	0.227	-2.092	0.042
ΔWHt	0.104	0.084	1.243	0.212
ΔWHt−1	-0.533	0.345	-1.545	0.129