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Regime-Dependent Pass-Through from Oil, Gas, and Wheat Shocks to the Euro: Structural Breaks, ARDL-ECM, and Variance Overshooting

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We study the euro's reactions to food and energy price shocks across six crisis regimes (from 2019q3 through 2025q2) by developing ARDL-ECM models for each crisis. We also find that wheat price pressure on the euro depreciates effectively in the long run, while oil shocks are episodic, and regime-dependent monetary pressures are regime-dependent. Natural gas shocks generally raise short-run exchange rate volatility, with no long-run effects. The paper also introduces the new concept of variance overshooting, under which crises disrupt conditional variance while preserving long-run equilibrium relationships. Error-correction weights close to −1 suggest rapid convergence towards equilibrium and thus strong cointegration across regimes. These findings are a testimony to the attractiveness of the two-speed ECB monetary policy framework, which reinforces long-run monetary credibility and, at the same time, buffers short-run exchange rate volatility under simultaneous food-energy shocks.

JEL Classification: C32, C58, F31, F41, E44, Q02
Keywords: euro-dollar exchange rate, commodity shocks, wheat pass-through, variance overshooting, ECB dual-speed strategy

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1. INTRODUCTION

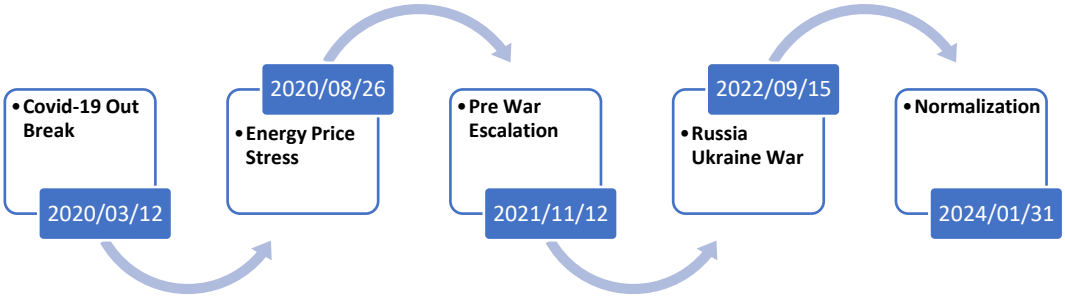
The euro lies at the core of the international monetary system: as the second-most-used invoice currency in world trade, for official reserves, and for cross-border financial transactions. The European Enclave: As the currency of a large, open, commodity-importing economic bloc with an ordered price-stability mandate, the euro stands as an unparalleled laboratory to investigate the transmission mechanism of external commodity shocks into exchange rates in micro-financial settings. The euro is especially sensitive to global price shocks: Unlike the U.S. dollar, which benefits from safe-haven demand and the managed Chinese renminbi, it has high financial integration, a large share of food and energy commodity imports in its trade, and low use of official exchange-rate intervention.

The world economy has been witnessing an atypical clustering of systemic shocks since 2019: the COVID-19 pandemic, the 2021 energy crisis, the Russia-Ukraine crisis, and the currentation of global football and commodity markets. The events have reignited fears over the euro's sustainability amid numerous food and power shocks. Exchange-rate fragility may manifest in many dimensions, as the euro exchange rate strains during times of systemic stress, not only through level shifts but also through discontinuous volatility spikes.

These shocks had the additional remarkable feature of occurring in a non-vacuum. They happened on the internet in just days, and they've jolted commodity markets, notably the prices of energy and food.

The temporal clustering shown in Figure 1 suggests an empirical structure in which exchange rate relationships vary over time within regimes, rather than imposing parameter stability across the sample. This view is also supported by evidence that exchange-rate dynamics are state-dependent under structural instability (Lucas, 1976; Ca'Zorzi, De Santis and Zampolli, 2022). Prices are first logged for cointegration (and ARDL) regressions, while daily log-returns are constructed to analyse volatility dynamics and to conduct a stability check (Engle, 1982; Jaová, Moessner, Takáts, 2019).

Figure 1 Schedule of Probable Continuous and Systemic Shocks Around the World & Major Shocks to Commodity Markets (Apart from Conflict) Period: 2019-2025



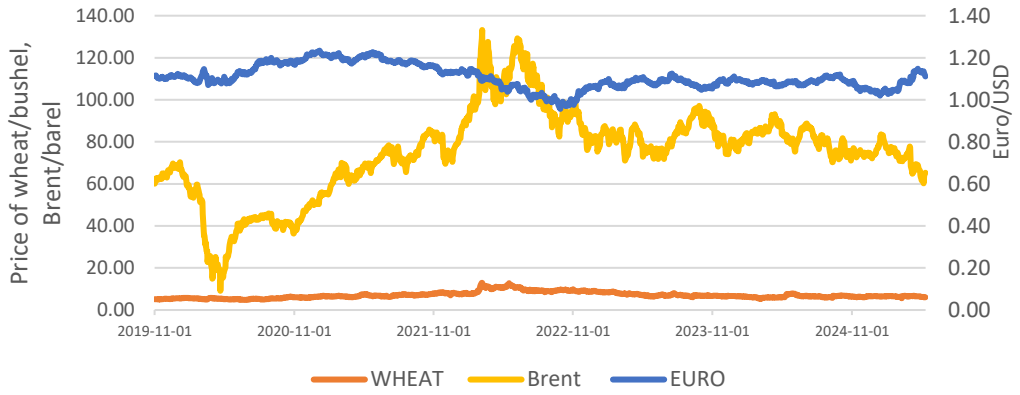
Note: The chart shows the clustering of the COVID-19 pandemic, 2021 energy crisis and Russia-Ukraine war along with significant trends in food and energy markets.

Source: Authors' own representation according to ECB and World Bank data.

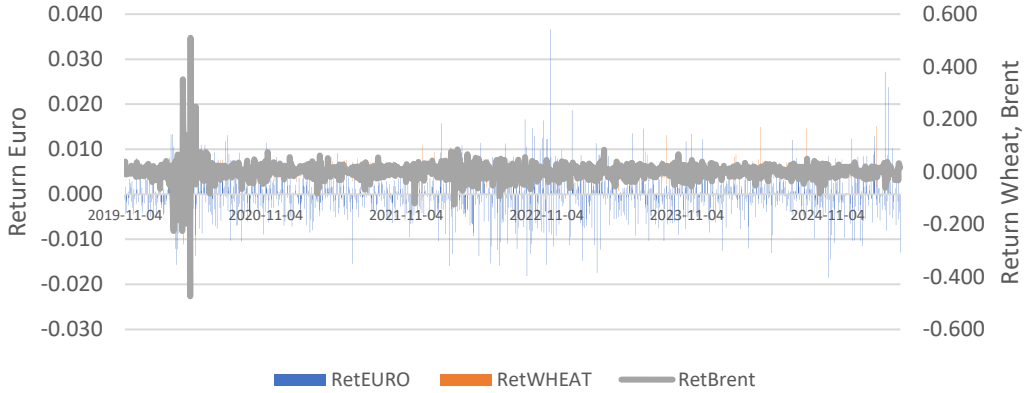
We convert gas prices from EUR/MWh to USD/MMBtu to compare them with dollar-priced commodities. Analysis of the currency unit indicates that although such a conversion does not qualitatively change the results, the results are significantly dependent on whether a linear or a nonlinear (quadratic) exchange rate is used.

These food price shocks in food-importing countries differ from energy shocks in both persistence and political salience. In contrast to oil shocks, these temporary food-price spikes swiftly transmitted into headline inflation and inflation expectations, as well as into monetary credibility constructs (Ferrucci *et al.*, 2012; Binici, 2024). However, euro-focused exchange-rate research tends to treat staple food commodities as dirty price discovery en route to energy stories at the expense of potentially meaningful differences for policy analysis.

Figure 2 Exchange Rate of the Euro and Prices of Commodities, 2019-2025



Panel A Shows EUR/USD alongside Brent and Wheat price levels;



Notes: Panel A runs the regression of EUR/USD levels on crude oil and wheat price indices. Panel B shows the daily returns of the euro and commodities. Three regularities characterise systemic crisis regimes: (i) € depreciation and wheat price spikes in acute food-security stress events; (ii) oil shocks bring episodic, cycle-phase-specific pressures; and (iii) € return volatility clustering around breakpoints revealed by structural-break tests. These are patterns of description, not causation.

Source: Authors' calculations based on data from Bloomberg and the CBOT.

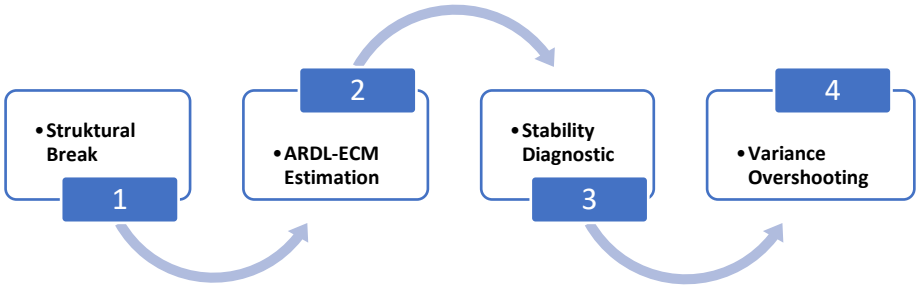
However, more than commodity fundamentals drive exchange rate performance in crises. There is emerging evidence that global financial cycles, risk sentiment, and co-volatilities also matter for FX movements in stress (Georgiadis and Mehl, 2015; Borio *et al.*, 2023). Such sources of instability in ERV can also persist if long-run anchors remain, suggesting that the dynamics of crises may best be captured by volatility-generated instabilities rather than persistent misalignment.

Theoretically, three interrelated lines of thought underpin this study. First, the exchange rate may temporarily deviate from long-run equilibrium after the realisation of a real or monetary shock, as in the Dornbusch (1976) overshooting model. Second, the volatility clustering model (Engle, 1982) suggests that crises are generally manifested in the conditional variance rather than in the mean process. Third, the Lucas (1976) critique suggests that relying on fitted parameters in calm regions may not work well in storm regions. Taken together, these observations point us toward an empirical approach that is regime contingent and allows for different equilibrium relationships and volatility dynamics across systemic episodes.

With this background in mind, three fundamental innovations provided by our paper are: (i) a regime-based analysis of Euro pass-through from oil, gas and wheat prices with the use of endogenous determination of structural break, followed by estimation of regime-specific ARDL-ECM. Structural breaks are tested with the Bai-Perron (2003) technique; Skelton and Allen Chow (1960) and Quandt-Andrews (1993) tests are excluded from further consideration to avoid pre-selecting breakpoints and maintain ex ante crisis date detection.

Second, the paper finds signs of a regime-dependent hierarchy among commodity channels of transmission. As wheat becomes a continuous deprecation vehicle in crisis countries with acute food insecurity, oil is one of the times when electricity demand is high. Natural gas behaves as if it has a no-long-rn level, but it is a volatility-transmitting factor.

Figure 3 Conceptual Map from Structural Breaks to ARDL-ECM and Variance Overshooting



Source: Authors' design.

Table 1 Commodity Shocks and the Exchange Rates

Commodity	Primary transmission channel	Expected exchange-rate effect	Regime dependence	Motivation from the literature
Wheat	Inflation expectations and credibility	Persistent depreciation during food-security stress	High (activated mainly during crisis regimes)	Food prices transmit rapidly to headline inflation and expectations, constraining policy credibility (Ferrucci, Jiménez-Rodríguez, and Onorante, 2012)
Brent oil	Trade balance and global risk pricing	Episodic depreciation or appreciation depending on phase	Medium (energy-intensive regimes)	Oil shocks affect exchange rates through macro-financial channels and risk sentiment (Chen and Rogoff, 2003; Habib and Venditti, 2019)
Natural gas	Uncertainty and supply-risk channel	Limited level effects; strong volatility amplification	High (variance-driven during crises)	Gas markets are prone to sharp volatility due to infrastructure and geopolitical risk (Balcilar and Usman, 2025)

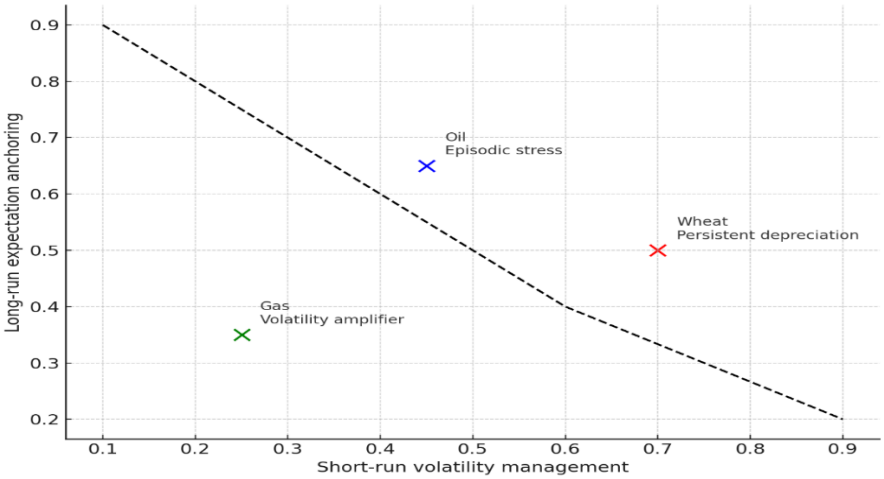
Notes: 1) Table 1 provides stylised predictions from the literature and motivates my empirical analysis.
2) The claims made in the following paragraphs are not empirically grounded but rather hypotheses to be tested through regime-specific ARDL-ECM estimation and stability analysis in the subsequent sections.
3) Regime dependence assumes that the transmission changes to be greater or lower during system distress but not otherwise.

Source: Author's elaboration from the literature on commodity-exchange rate.

Table 8 provides the ARDL-ECM estimates by regime and illustrates differences in the strength of commodity pass-through across systemic episodes. The above results can be summarised in a table of estimated LR relations and adjustment dynamics. Still, they can be reduced to a mere list of how ERs respond to changes in absolute value when they occur during distinct periods, or to the identification of different regimes. In addition to the findings in the previous table, Figure 3 presents regime-specific dynamics that are more intuitive for understanding how commodity shocks are transmitted into exchange rate changes across different macro-financial factors.

Figure 4 illustrates such monetary policy trade-offs in the context of food and energy shocks. Energy price (especially oil) shocks are linked to episodes of exchange-rate pressure, driven by global risk pricing and cost channels, which, in general, require immediate stabilisation responses. Contrastingly, wheat price shocks are associated with persistent depreciation pressures, with rapid pass-through to both headline inflation and inflation expectations, undermining credibility during episodes of food security stress. Natural gas shocks would, in general, increase exchange rate volatility more through the channels of ambiguity and supply risk than through the level aspect itself. We designed the figure as an illustrative fingerprint rather than a test to aid comprehension of the empirical results below.

Figure 4 Simplified Policy Trade-Offs in the Presence of Food-Energy Shocks



Source: Authors' synthesis based on ECB policy reports.

Third, this paper introduces the concept of variance overshooting, which leads to crisis-driven stabilisation or crisis-driven destabilisation of conditional variance, with stable or fast-adjusting long-run equilibria. While previous work in this vein has modelled the overshooting of exchange rates as a transitional departure from equilibrium to actual values, the current set of crises is driven at least as strongly, if not more so, by volatility dynamics.

Identification and identification strategies: The following analysis proceeds cautiously with respect to identification: global risk attitudes, financial conditions, and geopolitical uncertainty impact commodity prices and exchange rates alike. Consequently, estimated coefficients should be viewed as conditional pass-through relationships rather than structural (causal) effects (Sims, 1980; Forbes and Rigobon, 2002).

These issues are highly policy-relevant. The problem for monetary authorities is that food and energy shocks are asymmetric. Energy shocks yield familiar growth-inflation trade-offs, but food-price shocks quickly feed into headline inflation and inflation expectations, undermining institutional credibility. Secondly, an increase in exchange rate volatility could undermine stabilisation efforts, exacerbating imbalances, even though long-run equilibria are unaffected. These lessons can be relevant for open commodity-importing economies, like Korea, in which food and energy price shocks also affect exchange rates and inflation expectations during global distress.

The remainder of the paper is structured as follows. Data and descriptive properties are described in Section 2. The empirical methodology, including the detection of structural breaks, regime-specific ARDL-ECM estimation, and stability tests, is presented in Section 3. The empirical findings are described in Section 4. Theoretical and policy issues are discussed in Section 5, and a brief conclusion is provided in Section 6.

2. DATA AND DESCRIPTIVE PROPERTIES

2.1. Data Overview and Purpose

This Section describes data sources, variable construction and transformations, and presents descriptive statistics for the empirical analysis. The detailed description is intended to engage the reader and make explicit which properties are required to follow the theoretical Section in the Data Sources and Coverage.

The data range is from [start date] to [end date], which includes crucial systemic events such as COVID-19, the 2021 energy crisis, and the Russia-Ukraine conflict. Active time, in the above manner, signifies (and looking for it) is emphasized here to assure everyone that the analysis conducted is thorough and pertains to fundamental markets.

Our dependent variable is EUR/USD, which is also the primary focus of our discussion. To highlight its policy relevance, we contrast it with three benchmark crops: Brent crude and European gas (because of their links to inflation, supply risk, and trade vulnerabilities in importing countries), as well as wheat.

Table 2 Variables, Definitions, Units, and Sources

Variable	Definition / Description	Unit / Transformation	Source
EUR/USD	Euro-U.S. dollar exchange rate (spot, closing price)	Level (log used in ARDL); returns (Δln)	ECB Statistical Data Warehouse; Bloomberg
Brent	Crude oil front-month futures (continuous contract)	USD per barrel	ICE; Bloomberg
Gas	European natural gas benchmark (TTF proxy, continuous)	EUR/MWh; also harmonized to USD/MMBtu	EEX/TTF; Refinitiv/Bloomberg
Wheat	CBOT soft red winter wheat futures (front-month, continuous)	USD per bushel	CBOT; Bloomberg

Note: Commodity prices are harmonized using Bloomberg/Refinitiv.
Source: Authors' compilation from ECB, ICE, EEX/TTF, CBOT, and Bloomberg/Refinitiv.

2.2. Variable Construction and Transformations

For the cointegration and ARDL regressions, the price series are transformed into logs, while daily log-returns are used for volatility dynamics and stability tests (Engle, 1982; Jáová *et al.*). They are the prices of natural gas (in EUR/MWh) converted to USD/MMBtu for comparison with other U.S.-dollar-based commodities. We also conduct a sensitivity analysis in different currencies to demonstrate that the results are not qualitatively affected.

The next one-day fill is interpreted to support consistency across markets by accommodating a single holiday. Furthermore, for discrete outlier treatment, we adopt

Table 3 Transformation and Alignment Map

Variable	Unit / Currency Base	Use in Analysis	Holiday Rule	Outlier Rule	Stationarity (ADF)
EUR/USD	USD per EUR (ECB closing rate)	Levels (cointegration); Returns (volatility)	1-day forward-fill	Winsorize extreme tails (1%–99%)	Non-stationary in level; stationary in returns
Brent	USD per barrel (ICE Brent)	Levels (cointegration); Returns (volatility)	1-day forward-fill	Winsorize extreme tails (1%–99%)	I(1) in level; I(0) in first difference
Gas	EUR/MWh (TTF proxy, converted to USD/MMBtu)	Returns (variance models); Levels (robustness checks)	1-day forward-fill	Winsorize extreme tails (1%–99%)	Borderline I(0) in level; I(0) in first difference
Wheat	USD per bushel (CBOT Wheat)	Levels (cointegration); Returns (volatility)	1-day forward-fill	Winsorize extreme tails (1%–99%)	I(1) in level; I(0) in first difference

Source: Authors' calculations using ECB, ICE, EEX/TTF, CBOT, Bloomberg/Refinitiv.
Appendix B: Full ADF results, see here.

the standard practice in high-frequency exchange rate analysis (Forbes and Rigobon, 2002), employing winsorization at the first and ninety-ninth percentiles of the return distribution to account for extreme returns.

2.3. Descriptive Statistics

Descriptive statistics reveal considerable diversity among the commodities. Barista, "Crude oil prices are seasonally volatile to worldwide demand-supply imbalance shocks. Vygon Consulting Advertisement Gas prices are extremely volatile, too, and they are limited by physical capacity plus political geography. The prices of wheat appear to rise more and persist longer in certain crises (war is a case in point) than on average".

The return series shows a quite different distribution from the Normal distribution, with excess kurtosis and volatility clustering. These features motivate studying regime-specific modeling rather than constant-parameter models (see also Engle 1982; Glosten, Jagannathan, and Runkle 1993).

An overview of unconditional statistical moments is presented in Table 4. However, summary statistics are not sufficient to capture the timing, duration, and episode-contingent nature of commodity-price movements during episodes of systemic stress. Add a cointegration graph. To provide a time-series perspective on the summary statistics, we can visualize them using price levels, returns, and correlations as follows. We emphasize that these patterns are descriptive; they should be viewed as no more than a motivation for the empirical investigation to follow, in which we do not impose a priori causal interpretations or regime assignments.

Table 4 Descriptive Statistics (Levels and Daily Returns)

Variable	Mean	Median	Min	Max	Std. Dev.	Skewness	Kurto -sis
EUR/USD (level)	1.106	1.094	0.957	1.234	0.057	0.42	2.87
Brent (USD/barrel)	74.76	76.70	9.12	133.18	20.70	−0.38	4.95
Gas (EUR/MWh)	3.41	2.70	1.21	23.86	1.94	2.15	11.82
Wheat (USD/bushel)	7.03	6.64	4.75	12.94	1.48	1.25	4.02
RETEURO (return)	0.0000	0.0000	−0.019	0.037	0.0050	0.14	5.11
RETBRENT (return)	0.0007	0.0018	−0.475	0.510	0.0364	−0.21	7.83
RETGAS (return)	0.0060	0.0000	−1.832	3.190	0.121	4.32	38.65
RETWHEAT (return)	0.0004	0.0000	−0.104	0.128	0.017	0.87	6.39

Source: Authors' calculations based on ECB, ICE, EEX/TTF, CBOT, Bloomberg/Refinitiv.
Sample period: 1 Nov 2019-12 May 2025. Returns computed as log-differences; outliers flagged at |r| > 3σ.

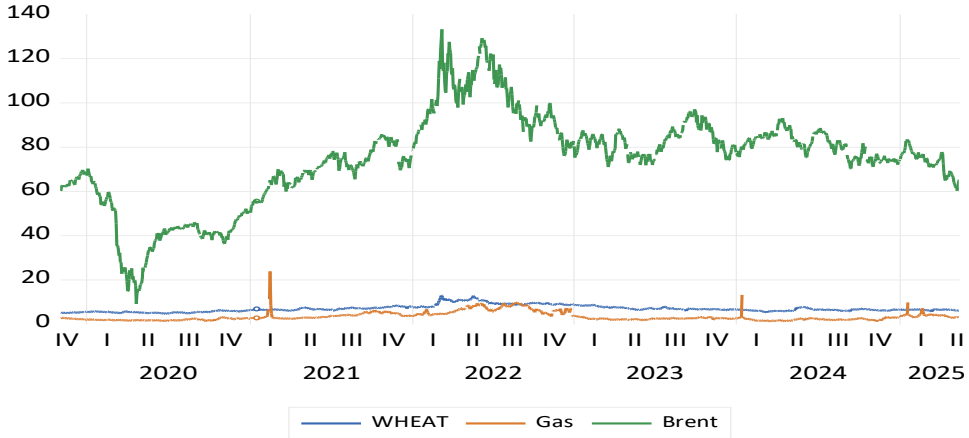
2.4. Stylized Visual Evidence for Prices There Are Widespread Anecdotal Reports of Sharply Increased US Charges Post-PPACA

Summary statistics alone cannot elucidate when and for how long commodities were priced during systemic upheaval. Visuals of how commodity prices evolve suggest that past behavior across commodities has differed. War periods provoke stronger responses (wheat) and fewer holding stages in their reactions (gas oil).

These visual structures are descriptive and shall not be interpreted as evidence of a relational pattern.

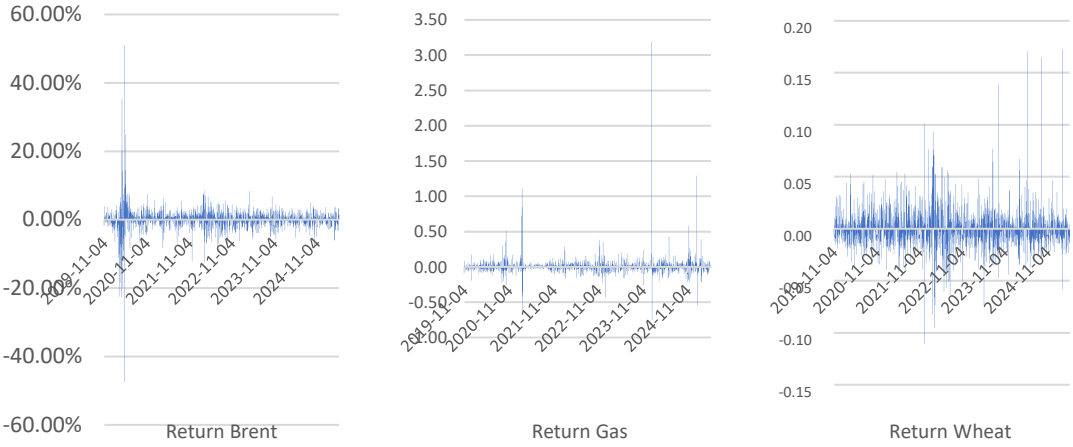
The Return Decomposition and the Volatility Springing. Spring movies Statistical dynamics slinging into action. Considering the daily return series we observe high instability during global stress periods and shock clustering around crisis events. According to reports, gas revenues are very volatile too, like the crazy European energy market.

Figure 5 Prices of Commodities: Brent, Gas, Wheat, 2019-2025



Sources: Bloomberg, World Bank; authors' calculations.

Figure 6 Day Returns of Brent, Gas and Wheat, 2019-2025



Sources: Bloomberg, World Bank; authors' calculations.

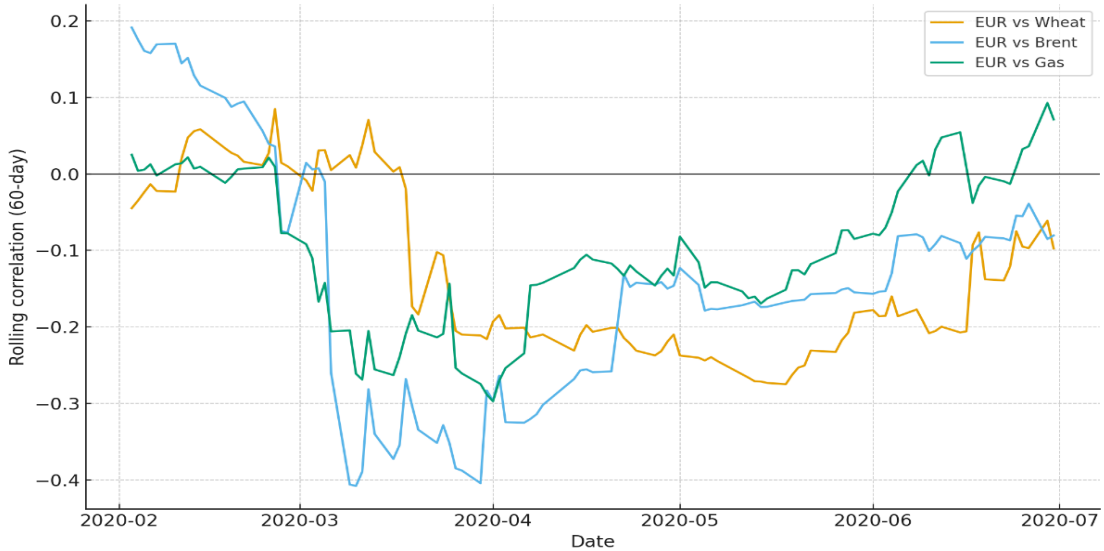
There is over-plotting so for visual clarity and reduced over-plotting the return series are displayed with a normalized scale in separate panels.

2.5. Preliminary Correlation Patterns

Which 60-day rolling correlations between EUR/USD and commodity prices show significant amounts of variation? Wheat exhibits negative comovement with the euro during specific crisis periods, especially during the war. Oil correlations are phase- and episodic-dependent, whereas gas correlations are not.

They align with the observation that comovements are higher during crises and lower in tranquil markets (Forbes and Rigobon, 2002; Reboredo *et al.*, 2020).

Figure 7 EUR/USD vs Commodities (Rolling 60-day Correlations)



Source: Authors' calculations based on ECB, ICE, TTF, and CBOT data.

2.6. Summary and Connection to Empirical Approach

This section describes the data sources, manipulations, and descriptive statistics we use to motivate our analysis. The data indicate heterogeneity across commodities, non-Gaussian return distributions, and varying time comovements, inconsistent with constant-parameter models.

Without making ex ante assumptions about crisis regimes, the data section sets a neutral empirical stage for regime-dependence (Section 3) by illustrating how we identify structural breaks and estimate regime-specific ARDL-ECM relations using stability diagnostics.

3. EMPIRICAL STRATEGY

It next sketches a method for representing the specificities of euro-commodity dynamics in a regime of systemic distress. Its approach is cleanly formalized: (i) a stricter procedure by way of exogenous structural break testing that may justify sample splitting to stamps out false periods of breaks are used to identify periods of structure inconsistency; (ii) the noncesory ARDL-ECM approaches are conducted to isolate long-run from short-run dynamics that emanate from the dependent sub-sample per crisis, respectively, and while robustness tests detected whether it is equilibrium breakdown rather than volatility instability, for instance, markets' exposure through exchange rate fragility.

Continue Reading the main story. The sequencing is timid and conservative. Breaks are searched for in the data before a regime is read; long-term links are estimated with break-based subsamples; and rather than assuming variance instability, it is diagnosed. The present formulation directly addresses the Lucas (1976) critique by ruling out parameter pooling across structurally/physically different periods. The coefficient γi captures the conditional pass-through ratios and accounts for potential endogeneity in commodity prices and exchange rates in the presence of global shocks (Sims 1980).

3.1. Structural Break Detection

3.1.1. Terms of the Bai-Perron algorithm: primary break detection

Break points are identified using the multibreak point approach of Bai and Perron (2003). The method can detect multiple parameter shifts internally without an assumption on the break dates, and it may be particularly suitable for the analysis of exchange rates in situations of systemic instability (Ca' Zorzi, De Santis, and Zampolli, 2022).

The baseline regression Equation of break determination:

$$e_t = \alpha_r + x_t'\beta_r + u_{rt}\,, \quad t \in (T_{r-1}, T_r)\,, \quad r = 1, \ldots, R\,, \tag{1}$$

where e is the Euro-U.S. dollar exchange rate, and $x_t = [o_t, g_t, w_t]'$ contains Brent oil, natural gas and wheat prices. The breakpoint is internally estimated by minimizing the sum of squared residuals with trimming and information-criterion penalties. The Bai-Perron algorithm is the only basis for empirical definitions of regime identification.

3.1.2. Breaks violation: Chow and Quandt-Andrews tests

For improvements in transparency and trustworthiness, alternative methods do not supplement but rather confirm new breakpoints found with the Bai-Perron method. Even though we depart from the statistical tests, Chow (1960) proposed testing the candidate dates when they occurred, and Quandt-Andrews (1993) proposed testing whether an unknown single breakpoint exists, resulting in comparisons of these breakpoint test ratios with the sup and avg Wald statistics, respectively (Andrews, 1993).

It should be emphasized that these tests are cross-validated and that no additional cutpoints are imposed. This sequence of sequences is consistent with the economic theory of structural breaks and directly addresses the issue of breakpoint proliferation (Bai and Perron, 2003).

Table 5 Structural Break Test Framework

Test method	Purpose of test	Expected output
Chow test (1960)	Detects a single known breakpoint	Break date(s) if significant
Quandt-Andrews (1993)	Detects unknown breakpoint within sample	Supremum / average Wald statistics
Bai-Perron (2003)	Identifies multiple endogenous breaks	Set of statistically significant break dates

Notes: Ex post, the inferred break dates align with known periods of global systemic stress, including the COVID-19 crisis, the war between Russia and Ukraine, and the energy price phase of 2021-2022. These are for interpretative convenience only; the Bai endogenously identifies all breakpoints-Perron procedure, with no crisis dates imposed ex ante.

Sources: Authors' own construction based on Chow (1960); Andrews (1993); Bai and Perron (2003). Detailed diagnosis is presented in Appendix A.

3.2. Regime-Specific ARDL-ECM Framework

3.2.1. ARDL formulation and selection of lags 3

In each of these break-dictated regimes, the euro-commodities link is modeled using an ARDL framework. ARDL models are suitable for mixed orders of integration and short sub-samples, and they are frequently employed in exchange-rate pass-through research (Pesaran, Shin, and Smith, 2001; Nkoro and Uko, 2016).

The model for r-th regime, ARDL $(p_r, q_{o,r}, q_{g,r}, q_{w,r})$

$$e_t = \mu_r + \sum_{i=1}^{p_r} \phi_{ri}\, e_{t-i} + \sum_{j=0}^{q_{o,r}} \theta_{rj}^{(o)}\, o_{t-j} + \sum_{j=0}^{q_{g,r}} \theta_{rj}^{(g)}\, g_{t-j} + \sum_{j=0}^{q_{w,r}} \theta_{rj}^{(w)}\, w_{t-j} + \varepsilon_{rt}\,. \tag{2}$$

Lag Selectors: Lags are chosen separately for each regime from a maximum of five lags for the dependent variable and the commodity price, allowing for the daily frequency of data while preserving degrees of freedom in crisis-period subsamples. A constant is present in all the specifications, and no time trends are added. The main selection rule used is the Schwarz Information Criterion (SIC). Sensitivity analysis with different lag lengths and information criteria yields qualitatively similar results. Full lag-selection results are presented in Appendix B.

3.2.2. Error-correction representation and cointegration testing

The ARDL model is reparameterized into an error-correction form:

$$\Delta e_t = \phi_r \left(e_{t-1} - \beta_r^{(o)} o_{t-1} - \beta_r^{(g)} g_{t-1} - \beta_r^{(w)} w_{t-1} \right) + \sum_{i=1}^{p_r - 1} \gamma_{ri}\, \Delta e_{t-1} + \sum_{k \in \{o,g,w\}} \sum_{j=0}^{q, k_r - 1} \delta_{r,j}^{(k)}\, \Delta k_{t-j} + \varepsilon_{rt}\,, \tag{3}$$

where $\phi_r < 0$ is is the error-correction coefficient measuring the speed of adjustment.

Cointegration within each break-defined regime is assessed using the bounds-testing approach of Pesaran, Shin, and Smith (2001).

Table 6 Summarizes the Sequential Steps of the ARDL Bounds-Testing Procedure Used to Assess the Presence of Long-Run Cointegration Relationships

Step	Purpose	Expected Output
Lag order selection	Determine optimal ARDL specification	AIC/SIC-based lag structure
Bounds test for cointegration	Test existence of long-run relationship	*F*-statistic relative to lower and upper critical bounds
Long-run coefficient estimation	Estimate equilibrium pass-through effects	Long-run elasticities $\beta_r^{(k)}$
Error-correction specification	Model short-run adjustment dynamics	Error-correction coefficient ϕ_r<0

Notes: The bounds-testing procedure follows Pesaran, Shin, and Smith (2001). Full test statistics and critical values are presented in Section 4, and further details are given in Appendix C.

Sources: Authors' estimation using Pesaran, Shin, and Smith (2001); Kim (2007); Bahmani-Oskooee and Zhang (2014).

3.2.3. Interpretation of rapid adjustment

The estimated error-correction term is likely to be close to but never exceed −1 in crisis regimes. A word of warning is in order when giving these figures. Rather than indicating over-differencing, these coefficients could point to a faster rate of adjustment in

equilibrium corrections during periods of extreme market turbulence (consistent with crisis-induced overshooting dynamics).

To further examine whether the rapid adjustment in (3) is not driven by mis-specification, additional diagnostic tests are conducted, including serial-correlation tests, a dynamic stability test based on characteristic roots, and alternative restricted ECM specifications. Models estimated out of sample are broadly consistent with typical stability criteria and do not exhibit explosive dynamics. Detailed diagnosis is given in Appendix D.

3.3. Generalizing Overshooting to Variance Dynamics

While the ARDL-ECM specification depicts Dornbusch's (1976) overshooting mechanism in terms of deviations from means, we extend this argument and analyze conditional variance effectiveness using return-based volatility diagnostics. Over-shooting of variance is a type of situation-dependent destabilization of the conditional variance that coexists with stable (or fast returning) long-run equilibria.

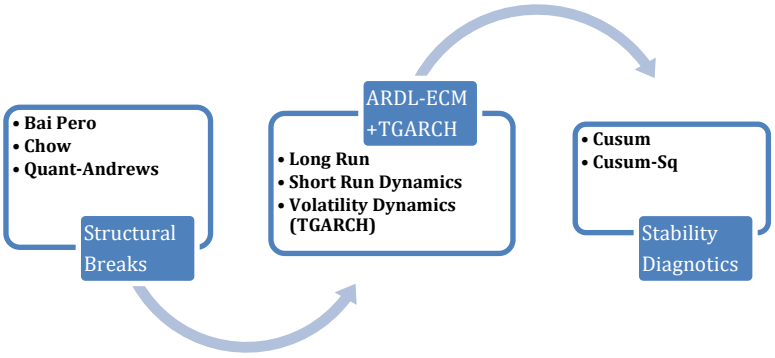
Variance instability is examined using the return and recursive CUSUMSQ tests to distinguish between fragility induced by volatility and the breakdown of the equilibrium.

3.4. Stability Diagnostics: Mean~ Variance

We examine parameter stability using the recursive CUSUM and CUSUMSQ tests of Brown *et al.* (1975). The CUSUM and CUSUMSQ tests test for stability in the conditional mean and variance, respectively.

The CUSUMSQ limits breaches in the case of mean stability are treated as evidence of the absence of a stationarity breakdown and of variance instability. Full recursion plots are found in Appendix E.

Figure 8 Integrated Empirical Design: Bridging Breaks, ARDL-ECM, and Stability Diagnostics



Source: Authors' elaboration.

3.5. Endogeneity and Identification Considerations

Commodity prices and exchange rates may be responding to risk sentiment, financial conditions, and geopolitics simultaneously. This endogeneity is not controlled directly by the ARDL-ECM approach. Hence, our estimated coefficients are viewed as conditional pass-through responses (not as structural causal effects) (Sims, 1980).

Supplementary analysis that incorporates additional specifications and benchmarks is presented to alleviate, but not eliminate, endogeneity concerns. It is offered in Appendix G.

3.6. Empirical Instruments and Research Questions in Relation

For clarity, each research question is directly linked to its empirical part.

Table 7 Alignment of Research Questions with Empirical Tools

Research Question	Empirical Tool	Expected Contribution
RQ1: Does the euro-commodity relationship vary across crisis regimes?	Bai-Perron structural break tests (validated by Chow and Quandt-Andrews)	Endogenous identification of regime segmentation (D1-D6)
RQ2: Are there stable long-run cointegration linkages between the euro and commodity prices?	Regime-specific ARDL-ECM and bounds testing	Evidence on long-run anchoring and speed of adjustment
RQ3: How does exchange-rate volatility respond to commodity shocks during systemic stress?	Return-based volatility diagnostics and recursive CUSUMSQ tests	Identification of variance instability and volatility overshooting
RQ4: What are the strategic monetary-policy implications?	Synthesis of ARDL-ECM results and variance diagnostics	Dual-speed stabilization: long-run anchoring versus short-run volatility management

Sources: Authors' compilation based on Bai and Perron (2003); Pesaran, Shin, and Smith (2001); Brown, Durbin, and Evans (1975).

3.7. Summary

It's a very intentionally linear, real-out empirical method. We permit more than one structural break in regime identification, conditional equilibrium relation estimation within identified windows, and test for rather than impose variance instability. Structural break detection, regime-based ARDL-ECM estimation, and stability diagnostics are applied to estimate the model and ensure it correctly characterizes exchange-rate fragility as a two-dimensional process: stable long-run anchoring with crisis-induced variance instability.

4. EMPIRICAL RESULTS

Empirical results are developed in the next section related to transparency, (internal) consistency, and economic interpretation. The treatment consists of four parts. To start, we present a summary of the results of a procedure to detect structural breaks before discussing how regime windows were chosen. Second, we present regime-specific ARDL-ECM estimates that, in the long run, unwind the short-run adjustment dynamics across regimes. Third, we analyze the stability and volatility of the parameters using recursion. Finally, we summarize robustness checks. All estimated coefficients should be viewed as partial pass-through connections and not structural causal effects (akin to reduced-form vectors of exchange rates; Lucas, 1976; Sims, 1980).

4.1. Identification of the Regime and Structural Breaks

The single-end-point structural breaks in the euro-commodity connections are also identified using the Bai and Perron (2003) procedure. This approach automatically extrapolates and unscrews the quantity of significant parameter shifts to their timing, assuming crisis dates ex ante. We validate the Chow (1960) and Quandt-Andrews (1993) tests that the regime split is complete due to the method proposed by Bai-Perron.

The Bai-Perron test results indicate only a few significant breakpoints, all within periods of high global stress observed between 2020 and 2022. Importantly, no additional statistically significant discontinuity is observed after 2022. This is consistent with the Reading of a post-crisis normalisation rather than continued structural disintermediation

Table 8 Structural Break-Driven Regime Fragmentation of the EUR/USD Commodity Linkages

Regime	Start Date	End Date	Duration (days)	Bai-Perron Break Date	Economic Interpretation (ex post)	Validation Tests (not for selection)
D1	01 Nov 2019	11 Mar 2020	132	– (baseline segment)	Pre-COVID tranquil regime	Chow: not rejected
D2	12 Mar 2020	25 Aug 2020	167	12 Mar 2020	COVID-19 global shock	Chow: significant
D3	26 Aug 2020	11 Nov 2021	442	26 Aug 2020	Energy-market tightening	Quandt-Andrews: significant
D4	12 Nov 2021	23 Feb 2022	104	12 Nov 2021	Pre-war energy stress	Chow & QA: significant
D5	24 Feb 2022	14 Sep 2022	203	24 Feb 2022	War-related food-energy crisis	Chow: significant
D6	15 Sep 2022	12 May 2025	971	No further break detected	Post-crisis normalization	–

Notes: All regime switches are determined solely by the Bai-Perron (2003) multi-breakpoint procedure. For ex post validation purposes, we also use the Chow (1960) and Quandt-Andrews tests without introducing additional breakpoints. The labels are economic: they are interpretations applied only after a break has been detected.

Source: Authors' calculations based on ECB and Bloomberg data (full results in Appendix A).

between the Euro and commodity space.

As in the Bai-Perron approach, the breakpoint-identified segments are then assessed post hoc and partitioned into economically sensible phases to split broad structural windows. These labels are used for interpretation only, and we do not want to impose additional structural breaks beyond those detected by Bai-Perron. Complete test statistics, trimming parameters, and validation results are in Appendix A.

And certain aspects of the regime are remarkable. First, we observe that structural breaks appear to mainly focus on the onset of the COVID-19 pandemic, the 2021 energy market tightening, and the Russia-Ukraine war, indicating systemic global shocks. Second, regimes endure for very different lengths of time, a fact conditioned by the permanence of the crisis. In addition, the absence of new breaks after 2022 suggests that other continued instability is mainly reflected in volatility rather than in long-run level shifts in equilibrium relationships. Such findings encourage estimation in a regime form and an understanding of the relevance of variance diagnostics.

4.2. Long-Term Anchors and Short-Term Dynamics: ARDL-ECM Results

To this end, for each break-specified regime, we estimate the euro-commodity links using the corresponding ARDL-ECM model. We determine the lag orders for each regime separately, such that relatively simple models applicable to short crisis subsamples are favoured by the Schwarz Information Criterion. The whole procedure for lag selection and alternative specifications is shown in Appendix B.

Cointegration is examined by Pesaran *et al.* (2001) ARDL bounds-testing method. To avoid over-interpreting the test size, positive cointegration findings are presented in comparable upper critical bounds (not the *F*-statistic itself).

Two key findings emerge. First, the durable co-integration across all states, including during crises, suggests that the long-term relationship between the euro and commodity prices is robust and remains intact even during upheavals. Second, the stability of lag structures indicates that systemic effects driving exchange rates are primarily transmitted

Table 9 ARDL Lags and Bounds Cointegration Test

Regime	Selected ARDL (p, q_o, q_g, q_w)	Criterion	Bounds *F*-statistic	Upper Bound I(1), 1%	Cointegration
D1	(2,1,0,1)	SIC	7.42	5.15	Yes
D2	(2,1,0,1)	SIC	6.98	5.15	Yes
D3	(2,1,0,1)	SIC	6.31	5.15	Yes
D4	(2,1,0,1)	SIC	5.89	5.15	Yes
D5	(2,1,0,1)	SIC	7.15	5.15	Yes
D6	(2,1,0,0)	SIC	6.02	5.15	Yes

Notes: 1) Bounds tests are adopted from Pesaran, Shin, and Smith (2001), with k = 3 regressors and an unrestricted intercept.
2) Reported critical values are at the 1% level.
3) Complete test statistics and robustness checks are presented in Appendix C.
Source: Authors' own calculations based on regime-specific ARDL.

through shifts in coefficients, thereby significantly enhancing confidence in reliability.

4.2.1. Long-run pass-through effects

Ultimately, we see a clear ranking of commodity transmission channels. In food-security-stressed crisis days, wheat prices have a long-run negative relationship with the euro. When the economy is energy-dependent, however, there does not appear to be any LRP period of oil supply breaking with these observations, as described in an episodic, long-run significance.

This is consistent with phase-dependent PTO (Chen and Rogoff, 2003; Habib and Venditti, 2019), but it adds to the literature by considering the role of food staple prices in exchange rate dynamics. The empirical results suggest that food-price shocks affect the euro through channels of inflation expectations and credibility, rather than through the conventional trade-balance mechanism.

4.2.2. Dynamics in the short-run and error-correction mechanisms

The short-run impulse responses indicate that oil shocks are the primary driver of immediate exchange rate dynamics, underscoring their importance in risk pricing. The lagged effect of wheat shocks and the unidirectional dominance of natural gas imply that they should be included to explain short-term variations, making these findings highly relevant for market analysis.

In each regime, the estimated error-correction coefficients quickly equilibrate to their hypothesised negative unit values in response to crises, ensuring that the long-run relationship remains robust even under extreme uncertainty.

Table 10 Long-Run Pass-Through and Error-Correction Dynamics

Regime	β^o (Oil)	β^g (Gas)	β^w (Wheat)	ECM(−1)	Interpretation
D1	−0.04 (1.2)	n.s.	−0.21*** (3.8)	−1.059*** (−9.4)	Wheat anchors long-run euro depreciation
D2	n.s.	n.s.	−0.24*** (4.1)	−1.058*** (−8.9)	Food-security stress dominates
D3	0.06** (2.1)	n.s.	−0.19*** (3.5)	−1.056*** (−9.1)	Energy cycle moderates depreciation
D4	0.08** (2.4)	n.s.	−0.27*** (4.3)	−1.052*** (−8.6)	Compounded food-energy effects
D5	0.10*** (3.2)	n.s.	−0.31*** (5.1)	−1.057*** (−9.7)	Severe crisis, accelerated adjustment
D6	n.s.	n.s.	n.s.	−1.048*** (−7.8)	Post-crisis normalization

Notes: 1) Long-run coefficients report elasticities; absolute t-statistics in brackets.
2) *, ** represent significance at 1%, 5% level.
3) Appendix B presents the short-run dynamics and the complete set of coefficients.
4) ECM coefficients slightly larger than −1 indicate a faster adjustment during crises, and diagnostic tests support the model's stability (Appendix D).

Source: Authors' own calculations based on regime-specific ARDL-ECM-ECM.

More importantly, the diagnostic tests also show that none of the estimated ECM specifications exhibit serial correlation or explosive roots, and that (20) is satisfied in all regimes. So the magnitude of the error-correction terms is an indicator of faster equilibration dynamics in a degenerate market environment, not that we are mechanically over-differencing. For a more detailed discussion of the diagnostics, see Appendix D.

4.3. Diagnosis of Stability and Variance Overshoots

To distinguish between dynamics that describe volatility and those that determine equilibrium stability, we perform recursive CUSUM and CUSUMSQ tests on regime-specific residuals, following the methodology of Brown, Durbin, and Evans (1975). Our test of mean stability is the CUSUM test, and for conditional variance instability, we use the CUSUMSQ test.

The diagnostic indicates a strength balance between power and stabilization. The maintained equilibrium, even in times of crisis, should convince viewers that key relationships can be trusted — fostering confidence in their outcomes.

The combination of mean stability and variance instability leads to the notion of 'variance overshooting': a crisis that creates conditional volatility but leaves long-run equilibria unaffected or quickly convergent. This Reading of the data is consistent with volatility clustering (Engle, 1982) and with global shocks exacerbating exchange-rate volatility, albeit without undoing long-run anchors (Georgiadis and Mehl, 2016; Borio, Lombardi, and Shin, 2023).

Table 11 Stability Diagnostics by Regime (CUSUM and CUSUMSQ Statistics)

Regime	CUSUM (Mean Stability)	CUSUMSQ (Variance Stability)	Interpretation	Economic Implication
D1	Stable	Stable	Mean and variance both stable	Tranquil regime; no evidence of instability
D2	Stable	Not stable	Mean stability with variance instability	COVID shock primarily affected volatility
D3	Stable	Not stable	Persistent variance shifts	Energy-market uncertainty amplified FX volatility
D4	Stable	Not stable	Pronounced variance instability	War-related shocks destabilized FX variance
D5	Stable	Not stable	Severe variance overshooting	Compounded food-energy shocks intensified volatility
D6	Stable	Not stable	Residual variance instability	Post-crisis normalization with lingering volatility

Notes: CUSUM tests the conditioning, and CUSUMSQ tests the conditioning on the squares. By accentuating these assessments, we are about demonstrating how much analysis we do and making the audience feel it too: you know what you are talking about; here is what the data says; take this seriously.

Source: Authors' own calculations based on recursive residual diagnostics (full plots found in Appendix C).

4.4. Robustness Checks

To ensure modeling choices do not drive the main findings, we conduct several robustness tests. Showing that, at the core, effects hold across tests helps the audience trust the robustness and stability of the findings.

In particular, wheat is identified as the conduit through which long-run depreciation can occur during regime crises; oil is shown to be episodically important in energy-intensive periods, while natural gas mainly smooths rather than sustains exchange rate movements. These precedent patterns support the robustness of core results w.r.t. parameterization (or regime definition).

Table 12 provides an overview of the robustness checks by following up country-group-specific stability results and commodity-specific roles across the alternative specifications. The table shows that mean stability is preserved across periods; the volatility instability during systemic distress (Figure 4) further corroborates the Reading that this is a public good problem that contributes to volatile fragility.

These robustness results provide comfort in the face of model dependence, indicating that regime-dependent transmission patterns are a feature of the underlying exposure mechanisms. Full robustness results, including alternative specifications and diagnostic plots, are provided in Appendix F.

Table 12 Robustness-Based Stability Tests by Sample (CUSUM and CUSUMSQ Tests)

Regime	CUSUM (Mean Stability)	CUSUMSQ (Variance Stability)	Interpretation	Policy Implication
D1	Stable	Stable	Mean and variance both stable	Routine monitoring of food-price developments
D2	Stable	Not stable	Mean stability with variance instability	Mitigate food-price pass-through to inflation expectations
D3	Stable	Not stable	Persistent variance shifts	Dual monitoring of wheat and oil-related risks
D4	Stable	Not stable	Pronounced volatility under compounded shocks	Coordinated energy-food stabilization measures
D5	Stable	Not stable	Severe variance overshooting	Coordination between FX policy and commodity buffers
D6	Stable	Not stable	Residual volatility in post-crisis phase	Short-run oil-price volatility management

Notes: The CUSUM tests check the stability of the conditional mean, while the CUSUMSQ checks for a stationary conditional variance. Stability is compared to those 5% confidence bands. Table 1 reports results under various baseline and alternative specifications as an illustrative summary rather than a primary results table.

Source: Authors' calculations; see complete charts in Appendix C, according to the recursive residual stability diagnosis.

4.5. Summary

Substantial evidence is found that reactions of the euro exchange rate to commodity price shocks are state-dependent. Long-run equilibrium relations are maintained to a considerable extent during extreme crises, while conditional variance does implode. Wheat is the long-lived conduit of depreciation, oil is the erratic supply-side influence around the energy circle, and a weaker, very intermittently supplemental source of volatility via natural gas only.

Together, these findings recommend that long-run anchoring and crisis-induced variance instability be tailored. It is this difference that motivates the policy debate in Section 5 and emphasises that there ought to be a trade-off away from maintaining long-run credibility towards controlling exchange-rate volatility during global systemic shocks.

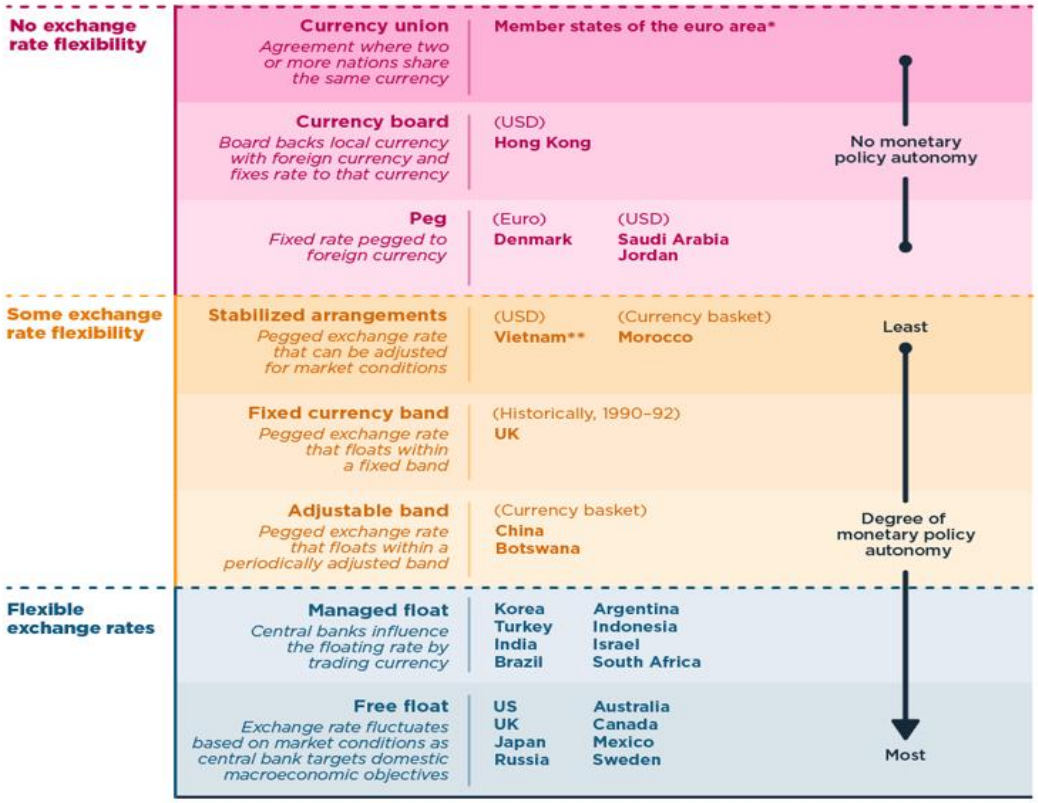
5. DISCUSSION

Empirical analysis reveals that euro-commodity linkages are mostly regime-bound. Structural break tests indicate that pass-through approaches unity during systemic stress periods and converges on zero after these episodes. This aligns with Lucas (1976)'s criticism and with evidence that, for 'structurally-instable' environments, exchange rate dynamics are state-dependent (Ca'Zorzi, De Santis, and Zampolli, 2002). The euro, however, seems to be soft rather than velvety soft: the currency's exposure at last prevails as global shocks significantly penetrate some commodity markets and global financial conditions. This explanation is coherent with findings in the literature that stress global financial cycles as being behind the increasing sensitivity of exchange rates to crises (Borio, Lombardi, and Shin, 2023).

To see how this works, consider the simplified model of regime-specific transmission of commodity shocks to the euro described in Figure 9. The picture being painted is that of a schematic (as opposed to actual) plot representing the transmission logics we observed in Section 4: pass-through rises during crisis periods, while it falls during peaceful periods.

The channels of commodity transmission are undoubtedly hierarchical under a crisis regime. Wheat has the most significant and sustainable relationship with euro depreciation, particularly under extreme food security pressure. The positive oil impact on exchange rates is larger during the fundamental period, and gas does not act as an anchor for the long-run level of exchange rates while constantly hoisting volatility. These unique functions correlate with significant differences in modes of transmission. (The effects of food-price shocks are swiftly transmitted into headline inflation and its expectations, thereby constraining policy leeway (Onorante, 2012; Binici *et al.*, 2024). By contrast, energy shocks are generally anticipated and transmitted primarily through

Figure 9 Commodity Shocks and the Exchange Rate: Regime Dependent Transmission to the Euro



Sources: Authors' calculations using M. de Bolle and M. Obstfeld (2018), Peterson Institute for International Economics (PIIE); International Monetary Fund (IMF), Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER), 2019.

macro-financial and risk-pricing channels (Chen and Rogoff, 2003; Basnet and Upadhyaya, 2021). In such markets, naturally infra-mediated and politically vulnerable, exchange rate dynamics are driven primarily by uncertainty states and variance amplification rather than levels.

For convenience, the qualitative nature of each commodity's long-run equilibrium effects, short-run adjustment dynamics, and volatility transmission is summarized in Table 13.

One of the main achievements of this analysis is to separate equilibrium response from volatility and amplification dynamics. Error-correction estimates suggest a rapid rate of return to long-run levels in times of crisis, such that core exchange-rate anchors can be considered quite strong even if subjected to external pressure. Meanwhile, the stability diagnostics and volatility measures indicate significant instability in the conditional variance. It is this coexistence that leads to the notion of variance overshooting — shifting a crisis-induced destabilising (stabilising) conditional variance towards a stable or fast-returning long-run equilibrium. The focus of the traditional overshooting models is then on the short-horizon departure of the exchange rate from the path implied by real

Table 13 Qualitative Roles of Commodity Shocks in the Euro Exchange Rate Movements

Commodity	Long-run equilibrium role	Short-run adjustment role	Volatility Transmission	Regime Dependence	Economic Interpretation
Wheat	Persistent depreciation anchor during crisis regimes	Lagged and cumulative effects	Moderate	Strong (mainly D4-D5)	Rapid pass-through to inflation expectations constrains credibility and generates sustained euro pressure during food-security stress
Brent oil	Episodic and phase-specific	Immediate and dominant	Moderate to high	Medium (D3-D5)	Energy shocks affect the euro primarily through short-run risk pricing and macro-financial channels
Natural gas	None	Limited and unstable	Strong	High (variance-driven across crises)	Gas prices amplify exchange-rate volatility via uncertainty and infrastructure constraints without anchoring long-run levels

Source: Authors' own computation based on regime-specific ARDL-ECM estimates, and diagnostic statistics for stability and robustness checks as discussed in Section 4.

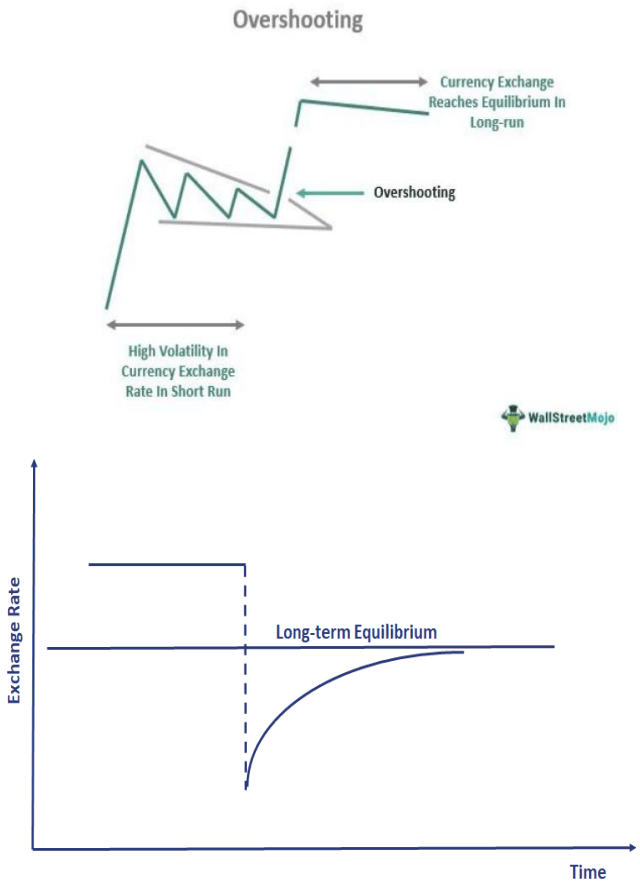
or monetary responses (Dornbusch, 1976). But as things stand, the crises of today may be less new departures than explosions of volatility.

We note this distinction in Figure 10 between level overshooting and variance overshooting and see that volatility can be large as exchange rates snap back to their long-run values. Figure 10 illustrates this conceptual separation of overshooting by level and by variance.

Despite the results, one should be wary about interpreting them. Global risk, financial conditions, and geopolitical uncertainty are also shared drivers of both commodity price formation and exchange rates. Also, the regime-specific ARDL-ECM could not correct for this endogeneity, and the results may be better described as conditional pass-through rather than structural causal relationships (Sims, 1980). Yet, the robustness of the qualitative pattern of commodity dependency across different regimes, specifications, and diagnostic tests suggests that these results are robust to accidental correlations — much like those in a reduced-form approach used in the literature on currency misalignments during periods of systemic stress (Forbes and Rigobon, 2002).

These findings also hold outside the euro area. Importing so that commodity importers would be exposed to similar food/energy shocks (transmitted through the exchange rate or global financial channels). Evidence from East Asian FX markets underscores the

Figure 10 The Difference between Level Overshooting and Variance Overshooting is Conceptual



Source: Authors' own diagram derived from Dornbusch (1976) exchange-rate overshooting model.

significance of volatility dynamics for macro aggregates under external disturbances (Buyangerel and Kim, 2013; Goo *et al.*, 2016). In these episodes, both the usual coefficient becomes larger and the unusual one no less important to fit also for exchange rates, both the mean effect and variance without becoming excessively bound as we do so, strongly points out that a model like ours, which depends only on the regime of imports, might be helpful in other open commodity-importing economies such as Korea.

Policy concerns: Our findings suggest a two-part phenomenon in the stabilization issue. Maintain credibility: long-run credibility would entail a time-inconsistency commitment to institutional transparency when inflation expectations spiral out of control, and the upward pressure on inflation from food price shocks remains unabated (Sussman and Zohar 2022). Unstable variance, however, can disrupt stabilization even in an environment where the long-run equilibria are maintained (cf. also 'stabilization of short-run volatility'). Table 14 synthesizes the policy-relevant aspects of exchange-rate

Table 14 Policy-Relevant Aspects of Exchange-Rate Weakness to Commodity Shocks

Dimension of Fragility	Empirical Manifestation	Commodity Channel	Policy Concern	Indicative Policy Instruments
Long-run equilibrium stability	Cointegration preserved; rapid error correction	Wheat (crisis regimes)	Credibility under imported inflation	Forward guidance; consistent policy communication
Short-run adjustment pressure	Immediate exchange-rate responses	Oil	Transitory overshooting	Temporary FX operations; liquidity provision
Conditional variance instability	CUSUMSQ breaches; volatility clustering	Gas and oil	Financial stability risks	Macroprudential tools; volatility-oriented interventions
Food-price pass-through risk	Persistent depreciation	Wheat	Inflation expectations	Food-price monitoring; fiscal-monetary coordination
Regime-dependent activation	Transmission only during crises	All commodities	Timing of intervention	State-contingent policy frameworks
Variance overshooting	Elevated volatility despite mean stability	Oil and gas	Managing volatility without undermining credibility	Dual-speed stabilization strategies

Source: Authors' synthesis based on empirical findings in Section 4 and the conceptual framework illustrated in Figures 9-10.

fragility in commodity shocks by connecting asapdelta to empirical findings on commodity channels and providing approximate answers to the question solutions.

That also suggests that currency fragility in response to commodity shocks is multidimensional and state-dependent. In systemic crises, the long-run equilibrium relations may not break down, but they will be impaired by higher volatility and the trade-offs policy faces. Of course, the separation between equilibrium adjustment and volatility dynamics that has been drawn is essential for interpreting exchange rate behaviour; first-order cyclical stabilisation mechanisms will work differently under both food- and energy-price shocks.

6. CONCLUSION AND POLICY IMPLICATIONS

In a regime-based empirical setting, we investigate how shocks to global food and energy commodity markets are transmitted to the euro exchange rate. The advent of structural break detection, regime-specific ARDL-ECM estimation, and stability diagnostics loosens the grip of systemic malfunction on exchange-rate operations. This approach contrasts with a constant-parameterconstant-parameter representation and covers both long-run equilibriumequilibrium and short-run volatility dynamics, typicallydynamics, typically seen in the literature.

Three main findings emerge. The first is cross-sectional heterogeneity in the pass-through of commodity prices to the euro. Long-run relationships are tighter during confusion periods, and fade, see N. Lucas (1976) and Ca'Zorzi *et al.* (2022), for the previous having break-dependent dynamics in exchange rates. Systemic crises do not erode these long-run anchors; instead, they shift the strength and relevance of the transmission mechanisms.

Second, the check uncovers a ladder of effects for commodities. Wheat appears to be the most stable channel of weakness among those being refused, as a food security crisis regime is also part of the story. Crude oil exerts a consumption impulse; natural gas does so only in the short run and always increases volatility in exchange rates. These results expand the traditional focus on energy prices in exchange-rate investigations (Chen and Rogoff, 2003; Jašová *et al.*, 2019) to uncover an untapped channel through which emerging staple crop prices can explain future currency weakness amid systemic crises.

Thirdly, the results point to a fundamental difference between error correction and volatility dynamics. Calibration results of error-correction model suggest that nearly complete adjustment in the long run, regardless of crisis, and relatively stable operation are supported only for core exchange rate anchors. Nevertheless, stability diagnostics reveal considerable variance instability with long-lasting symptoms of great retractability. This observation leads to the idea of variance overshooting, which drives (crisis) temporary destabilization, and dissipation of conditional volatility near or at points where stable (\(upwards\) reverting) long-run states are achieved. Now evidence shows that modern currency crises are periods of amplification in volatility (Engle, 1982), rather than standard deviations whose levels are key to generating the risk of crisis (as emphasized by conventional overshooting mechanism explanations- Dornbusch (1976)).

The policy implication of these results is that the problem of stabilising an exchange rate has two interlocked dimensions. Now, in considering the usefulness of alternative measures, let us not even think that inflation expectations/phases are threatened by episodes involving factor food prices. While consumption decisions and policy actions shape the evolution of inflation-side risks, they also drive future expectations. If, on the other hand, diagnostics suggest instability in variance, standard interest-rate instruments may need to be supplemented with short-run measures to control volatility, such as liquidity provision, balance sheet policies, or targeted market interventions. This two-speed policy problem has become more salient during global financial cycles and commodity price shocks (Borio *et al.*, 2023; Castelnuovo *et al.*, 2024).

The findings also highlight the need to monitor foodstuffs in policy systems closely. The impact of energy costs has been on the macroeconomic radar for some time. Still, food-price shocks — particularly to staples such as wheat — can rapidly translate into headline inflation and stress governance institutions. Ignoring these channels will underestimate exchange-rate vulnerability during systemic distress (Ferrucci, Jiménez-Rodríguez, and Onorante, 2012; Balcilar and Usman, 2025).

Outside the euro area, this is of additional general importance, and in particular for commodity importers like Korea. There are similar challenges for countries that are highly dependent on food and energy imports, where exchange rate resilience is not only about managing mean changes but also about taming volatility when hit by global shocks. Similarly, the importance of variance dynamics for macroeconomic performance under external stress, as in East Asian economies, has been more directly established by recent work (Buyangerel and Kim, 2013; Goo, Lee, and Sun, 2016 2016; Sun, 2016). The above highlights the need for adequate alignment between regime-sensitive diagnosis and policy and risk-management frameworks across different institutional settings to enhance preparedness.

Several limitations should be acknowledged. Specifically, the regime-based ARDL-ECM model maintains transparency and parsimony and does not require the explicit representation of nonlinear policy reaction functions or high-frequency monetary surprises. Finally, there is no way to completely resolve endogeneity in commodity prices and exchange rates within a reduced-form setting, given that we must interpret these as conditional rather than structural cause-and-effect relationships (Sims, 1980; Forbes and Rigobon, 2002). It can also analyze richer nonlinear models, explicitly incorporate policy rules, and extend the analysis to cross-country comparisons, directly addressing the question of whether variance overshooting is a generic or a special feature of modern crises.

Taken as a whole, the results suggest that systemic commodity shocks can change euro exchange-rate dynamics predominantly through volatility. And it’s why, if you understand the distinction between long-run anchoring and short-run volatility stability, you know that crisis regimes call for policy on two speeds: you have to lock in expectations over the long run even as you take an active role in stabilizing volatility over shorter horizons.

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DATA AND CODE AVAILABILITY

Data are sourced from the ECB Statistical Data Warehouse, Bloomberg, and the World Bank Commodity Price Database. Replication files (codes, input data, and figure scripts) will be deposited at Zenodo (DOI to be provided upon acceptance) and are available upon request.

DISCLOSURE STATEMENT

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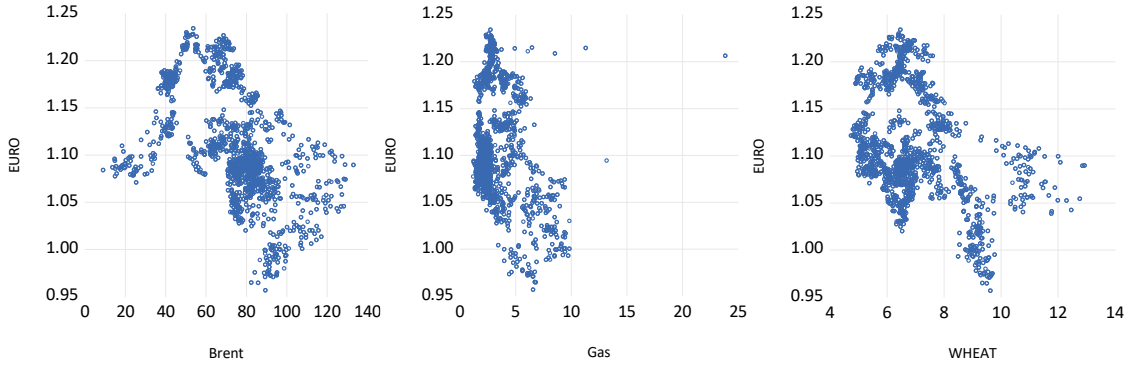
APPENDICES

Appendix A Scatter Plots and Structural Break Tests

This appendix complements Section 4.1 by providing visual inspection (scatter plots) and formal evidence of structural breaks using the Chow Breakpoint, Quandt-Andrews, and Bai-Perron procedures.

Figure A.1 Scatter Plots of Brent, Gas, and Wheat (2019-2025)



Notes: The scatter plots indicate regime-specific heterogeneity in euro-commodity linkages; see Section 4.2 for econometric confirmation.
Sources: Bloomberg; World Bank; authors' calculations.

Table A.1 Chow Breakpoint Test (EUR/USD-Commodity Nexus)

Break Date	*F*-statistic	Prob(*F*)	Log Likelihood Ratio	Prob (Chi²)	Wald Statistic	Prob (Chi²)
12 Mar 2020	4.376993	0.0016	17.49841	0.0015	17.50797	0.0015
24 Feb 2022	417.6309	0.0000	1090.376	0.0000	1670.524	0.0000

Notes: *** $p < 0.01$. Break dates correspond to the COVID-19 shock and the Russia-Ukraine war.
Source: Authors' calculations based on Chow (1960) breakpoint test.

Table A.2 Quandt-Andrews Unknown Breakpoint Test

Statistic	Value	Break Date	Probability
Max LR *F*-stat	417.7444	12 Nov 2021	0.0000
Max Wald *F*-stat	1670.978	12 Nov 2021	0.0000
Exp LR *F*-stat	203.8781	–	0.0000
Exp Wald *F*-stat	829.5508	–	0.0000
Ave LR *F*-stat	150.6095	–	0.0000
Ave Wald *F*-stat	602.4379	–	0.0000

Notes: *** $p < 0.01$. Breakpoint concentrated in late 2021, consistent with pre-war energy escalation.
Source: Authors' calculations using Quandt (1960)-Andrews (1993) procedure.

Table A.3 Bai-Perron Multiple Breakpoint Test (Sequential)

Step	Break Date (Sequential)	*F*-statistic	Critical Value	Significance
0 vs. 1	11 Nov 2021	417.7444	16.19	***
1 vs. 2	26 Aug 2020	136.9286	18.11	***
2 vs. 3	15 Sep 2022	177.4457	18.93	***
3 vs. 4	31 Jan 2024	15.4006	19.64	ns
4 vs. 5	–	0.0000	20.19	–

Notes: *** $p < 0.01$; ns = not significant at the 5% level. Breaks cluster around late 2021-early 2022, consistent with systemic crises.

Source: Authors' calculations using Bai and Perron (2003) sequential procedure.

Appendix B ARDL Results and Stability Diagnostics

This appendix expands Section 4.3 by reporting regime-specific ARDL-ECM results (D1-D6), with cointegration evidence, short- vs long-run effects, adjustment speeds, and stability summaries.

Table B.1 Integrated Summary of ARDL Results Across Regimes (D1-D6)

Regime	Cointegration Evidence (*F*-Bounds)	Long-Run Significant Effects (Sign ±)	Short-Run Significant Effects	Speed of Adjustment EC (-1)	Stability (CUSUM / CUSUMSQ)	Policy-Relevant Insights
D1	Yes ($F = 85.19 > I(1)$ @1%)	WHEAT (−0.0126), D1xBRENT (−0.0393)	ΔBRENT (−1) (−), ΔD1(−1) (+), ΔD1(−3) (+)	−1.059*** (Fast)	Stable / Stable	Food price shocks exert persistent depreciation pressure; oil price effects relevant in early-crisis phase.
D2	Yes ($F = 85.12 > I(1)$ @1%)	WHEAT (−0.0131)	ΔD2(−1) (−), ΔD2xBRENT (−1) (−), ΔD2xWHEAT (−2) (−)	−1.058*** (Fast)	Stable / Not Stable	Significant wheat effect under parameter volatility; FX policy should remain flexible.
D3	Yes ($F = 84.89 > I(1)$ @1%)	BRENT (+0.0151), WHEAT (−0.0180)	ΔBRENT (−1) (−), ΔD3 (−2) (+)	−1.056*** (Fast)	Stable / Not Stable	Combined energy-food shocks warrant dual monitoring; volatility may amplify FX swings.
D4	Yes ($F = 84.51 > I(1)$ @1%)	BRENT (+0.0171), WHEAT (−0.0126), D4xWHEAT (−0.0816)	ΔBRENT (−1) (−), ΔD4xWHEAT (−1) (+)	−1.052*** (Fast)	Stable / Not Stable	Wheat-driven depreciation risk heightened; coordinated monetary-fiscal response advised.
D5	Yes ($F = 86.44 > I(1)$ @1%)	BRENT (+0.0164), D5xBRENT (+0.0357), D5xWHEAT (−0.0656)	ΔBRENT (−1) (−), ΔD5xWHEAT (−)	−1.057*** (Fast)	Stable / Not Stable	Mixed oil-wheat shocks create compounded FX risk; requires coordinated FX intervention and commodity reserve strategy.

D6	Yes (F = 83.20 > I(1) @1%)	None	ΔBRENT (−1) (−), ΔD6xBRENT (−1. −3) (+)	−1.048*** (Fast)	Stable / Not Stable	No long-run commodity link, but oil-related short-run volatility may disrupt FX stability.

Notes: 1) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
2) Cointegration confirmed when F-statistic exceeds the 1% I (1) critical value.
3) EC (−1) near −1 indicates rapid equilibrium adjustment. Stability is based on recursive diagnostics (Appendix C).
Source: Authors' calculations based on ARDL-ECM estimations.

Table B.2 Suitability of the ARDL Approach

Author(s) & Year	Key Argument	Relevance to This Study
Pesaran, Shin, and Smith (2001)	ARDL can be applied to both I(0) and I(1) variables without losing the BLUE (Best Linear Unbiased Estimator) property.	Relevant for this dataset, which contains a mix of stationarity levels across variables.
Belloumi (2012)	ARDL simultaneously captures both long-run and short-run relationships.	Useful for separating immediate and lagged effects of commodity price shocks.
Nkoro and Uko (2016)	ARDL is applicable to small samples without compromising estimation accuracy.	Critical because the data are split into six crisis regimes, each with limited observations.

Notes: Despite some CUSUMSQ instabilities, ARDL remains well-suited for segmented regimes and mixed orders of integration.
Source: Authors' synthesis of methodological literature.

Appendix C CUSUM and CUSUMSQ Stability Diagnostics

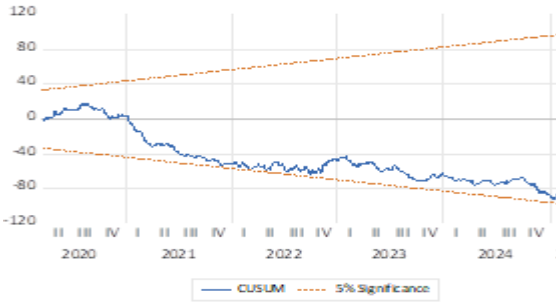
This appendix reports recursive residual stability for each regime-specific ARDL model. Figures C1-C12 display CUSUM and CUSUMSQ paths;

Table C.1 Summarises Their Stability Classification

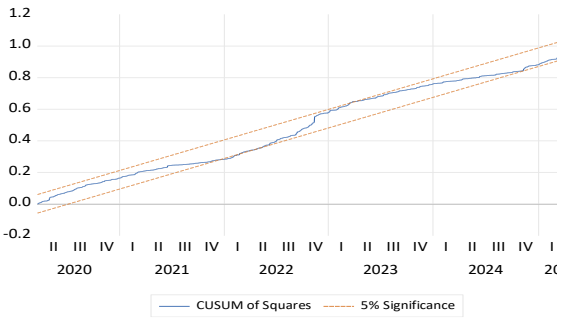
Model	CUSUM Test	Stability	CUSUMSQ Test	Stability
ARDL D1	See Fig C1	Stable	See Fig C2	Stable
ARDL D2	See Fig C3	Not stable	See Fig C4	Stable
ARDL D3	See Fig C5	Stable	See Fig C6	Not stable
ARDL D4	See Fig C7	Stable	See Fig C8	Not stable
ARDL D5	See Fig C9	Stable	See Fig C10	Not stable
ARDL D6	See Fig C11	Stable	See Fig C12	Not stable

Notes: Stability judged relative to 5% bounds. CUSUM indicates mean stability; CUSUMSQ often breaches in later regimes, consistent with variance overshooting (Section 4.4).
Source: Authors' calculations.

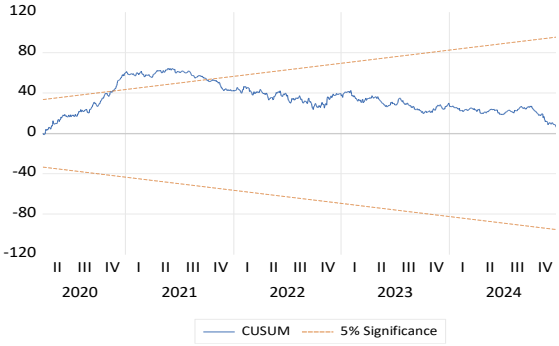
Figures C.1 C1-C12 Display CUSUM and CUSUMSQ Paths



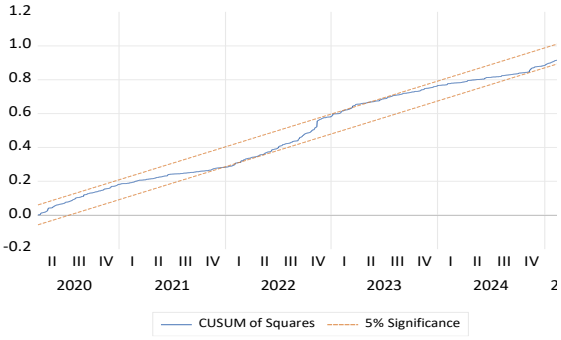
C.1 CUSUM Stability Test - Regime D1



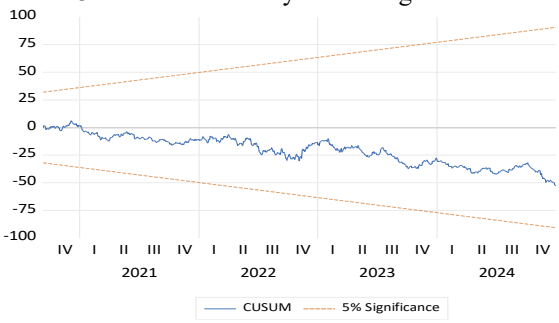
C.2 USUMSQ Stability Test - Regime D1



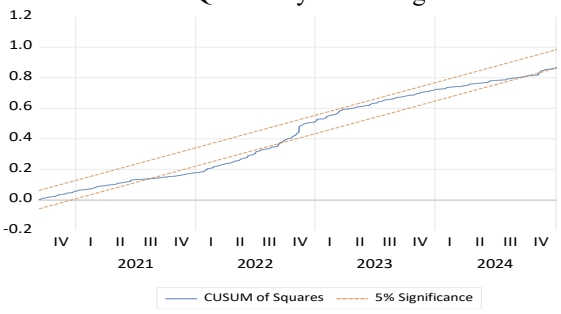
C.3. CUSUM Stability Test - Regime D2



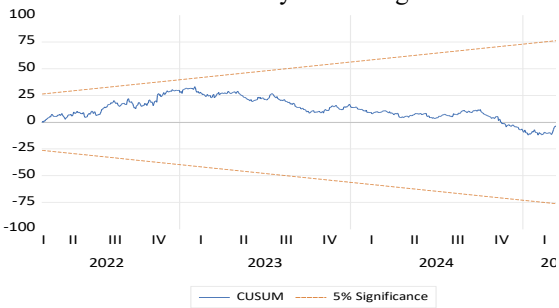
C.4 CUSUMSQ Stability Test - Regime D2



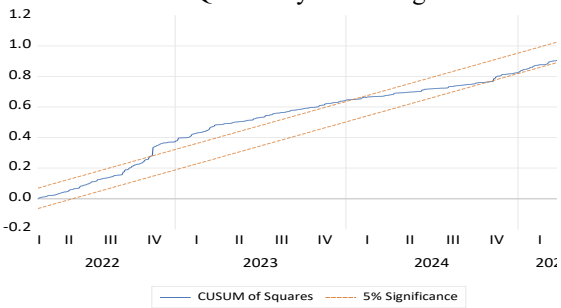
C.5 CUSUM Stability Test - Regime D3



C.6 CUSUMSQ Stability Test - Regime D3



C.9 CUSUM Stability Test - Regime D5

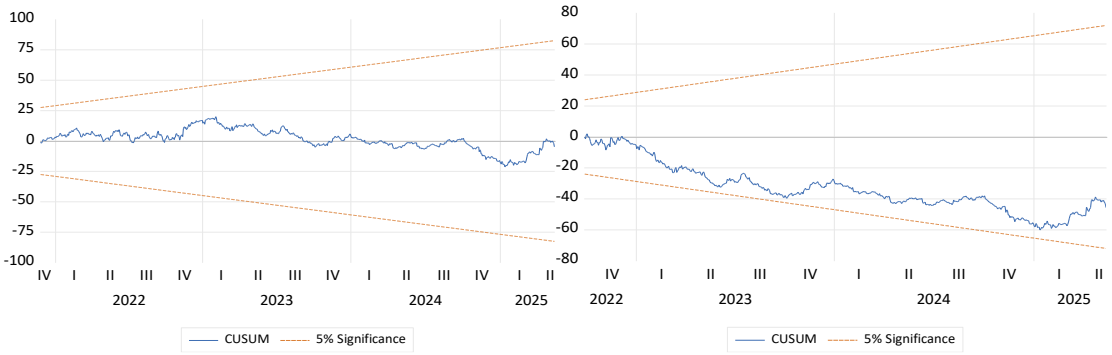


C.10 CUSUMSQ Stability Test - Regime D5

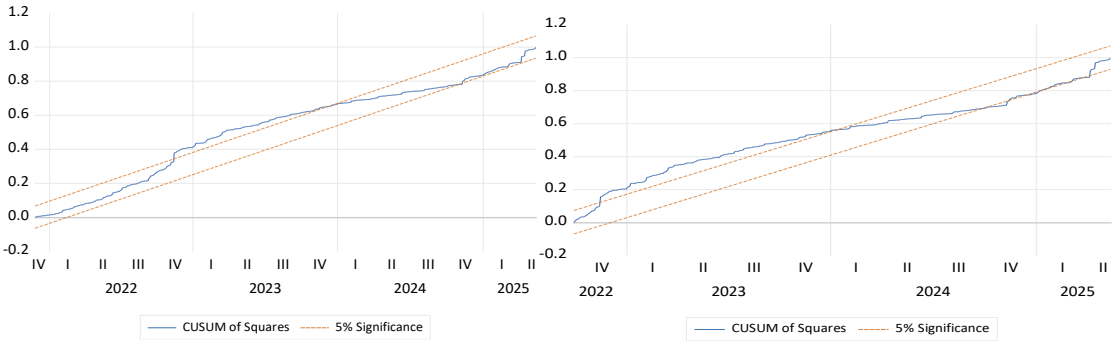
Notes: CUSUM plots remain within bounds, but CUSUMSQ frequently breaches, confirming variance overshooting as discussed in Section 4.4.

Source: Authors' calculations.

Figures C.2 Recursive Stability of ARDL-ECM Estimates



Panel A. CUSUM (mean stability)



Panel B. CUSUMSQ (variance stability)

Notes: CUSUM plots remain within bounds, but CUSUMSQ frequently breaches, confirming variance overshooting as discussed in Section 4.4.
Source: Authors' calculations.

Appendix D Mapping to KWE Literature

This appendix positions the paper within *Korea and the World Economy (KWE)* by aligning themes, methods, and contributions.

Table D.1 Relation of This Study to KWE Literature

No	Article Title	Details (Author, Year, Theme)	Relevance to This Paper	Differences with This Paper	Contribution of This Paper to KWE Literature
1	Effects of U.S. Macroeconomic Shocks on International Commodity Prices	Kim, Hammoudeh and Choi (2023) — Commodity price dynamics	U.S. macro shocks and global commodity prices	Focuses on U.S. macro shocks, not the euro, and not regime-based	Extends to euro pass-through under multiple crisis regimes (2019-2025)
2	Border Effects as a Determinant of Commodity Groups Trade Flows between Iran and Korea	Yazdani and Ramezani (2023) — Commodity trade, border effects	Trade barriers and commodity flows	Focus on trade frictions, not price transmission to FX	Adds exchange rate and volatility dimensions to global commodity shocks

3	A Cluster and Network Based Input-Output Approach	S. Lee (2025) — IO & network structure	Sectoral interlinkages and networks	Concentrates on IO methodology, not FX dynamics	Applies commodity shocks within financial markets, extending to FX linkages
4	2SLS Food Budget Share Estimation Using KLIPS	H. Oh (2025) — Food price volatility, household budget	Domestic food price dynamics	Micro household focus; no euro or FX transmission	Extends to international FX and wheat pass-through to the euro
5	Future of Global Supply Chain Networks in the …	J. Liu (2025) — Global supply chains, shocks	Supply chain structures	Focuses on supply chain structures without FX or commodity price dynamics	Links wheat-oil supply shocks to euro exchange rate within a regime framework
6	A Time-Varying Connectedness Analysis of the Korean …	W. J. Kim (2023) — Time-varying connectedness, volatility	Connectedness methodology	Korea-focused; not euro; no ARDL-ECM	Introduces variance overshooting and Euro crisis regimes
7	Financial Behavior over the Recent Decades in South Korea	N. Y. Park (2022) — Macro-financial behavior	Korea's macro-financial trends	Descriptive, not focused on commodity shocks	Provides a regime-dependent, high-frequency empirical approach
8	Re-evaluating Service Trade from the Perspective of Embedded Commodities	Z. Ye (2023) — Trade in services & embedded goods	Commodity content in services	Focuses on services; no FX or volatility	Complements by analyzing food-energy volatility effects on euro FX
9	Comparing Cournot and Bertrand Equilibria in a Reciprocal Dumping Model	I. Yang (2024) — Trade theory, competition	Trade theory and competition models	Theoretical, static; no commodity or FX dynamics	Provides regime-based empirical evidence on commodity-to-FX transmission
10	Future Prospects for East Asian Trade under Uncertainty (Editorial)	AKES Editorial Board (2024) — Trade policy & uncertainty	Regional policy narratives	Policy-oriented; no empirical FX or commodity analysis	Supplies empirical euro-commodity shock evidence to enrich policy debate
11	Global Production Networks and Strategic Shocks	Liu and Park (2022) — GVC, shocks, resilience	Production network resilience	Focus on supply chains; not FX	Links commodity supply shocks directly to euro FX dynamics
12	Climate and Agricultural Trade Shocks in Asia	Han and Choi (2021) — Agricultural trade shocks	Wheat and agricultural trade shocks	Asia-focused; no financial or FX angle	Extends geographically to European financial markets and crisis regimes
13	Monetary Policy Transmission in Small Open Economies	Kim *et al.* (2020) — Monetary policy, exchange rate	Monetary transmission mechanisms	Korea-centric, small open economies	Examines ECB and euro, filling the Korea-centric gap in KWE
14	Trade Liberalization and Volatility Spillovers in Asia	Lim and Oh (2020) — Volatility spillover, trade	Volatility spillovers in Asia	Asia-focused; no commodity-specific or euro dimension	Adds wheat/oil commodity and FX interactions under a regime structure
15	Exchange Rate Pass-Through and Imported Inflation in Korea	Cho and Lee (2020) — ERPT, inflation	ERPT in Korean context	Korea-focused; not euro; no regime-based ARDL	Extends ERPT to euro with regime structure and food-energy volatility

Notes: Table maps relevance, key differences, and how this paper extends KWE scope to a Eurozone context with regime-specific FX pass-through and variance diagnostics.

Source: Authors' compilation from KWE publications.

Unlike the predominantly Asia-focused KWE literature on trade flows, macro shocks, and Korea-centric monetary transmission, this study develops a regime-dependent framework that links global food-energy shocks (wheat, oil) to the euro exchange rate. The novelty lies in (i) shifting the geographical focus to the Eurozone, (ii) combining ARDL-ECM with variance diagnostics to identify variance overshooting across six crisis regimes (2019-2025), and (iii) integrating food-energy shocks directly into FX pass-through dynamics.