Market Unity Amidst Conflict: Key Econometric Methodologies for Yemen's Market Integration

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Abstract

Yemen's protracted conflict has severely fragmented its commodity markets, creating a dual economy with divergent exchange rates and disrupted trade routes. This paper analyzes market integration dynamics in conflict-affected Yemen, employing threshold cointegration and spatial econometric techniques to quantify price transmission barriers. By modeling how conflict-induced transaction costs impede arbitrage and examining the impact of dual exchange rate regimes, we identify critical thresholds that must be exceeded before price convergence occurs. Through simulations of market integration scenarios, particularly exchange rate unification, we provide empirically grounded policy insights to enhance economic stability in this fragile and conflict-affected situation. The research bridges theoretical gaps in understanding market integration under conflict conditions while offering practical recommendations for humanitarian and development interventions.

1 Introduction

Yemen's protracted conflict has not only devastated infrastructure and public institutions but has also severely fragmented its commodity markets. Since the escalation of hostilities in 2014, the

country's economic landscape has been characterized by dual exchange rate regimes and significant disruptions in trade routes. In areas controlled by the internationally recognized government versus those under Houthi authority, divergent monetary policies and security constraints have created arbitrage opportunities and price distortions. The de facto dual economy—with separate rates as reported by the Central Bank of Yemen in Aden and the Houthi-controlled banking system in Sana'a—generates nonuniform price signals that fundamentally undermine the Law of One Price, a cornerstone principle of integrated markets.

Market integration is critical for economic stability, especially in fragile, conflict and violence situations (FCS). In Yemen, high transaction costs associated with blocked trade corridors and security barriers exacerbate market segmentation. Transaction costs in Yemen have become exceptionally burdensome, reflecting not only traditional elements such as transportation expenses but also conflict-specific costs including checkpoint fees, protection payments, and risk premiums for operating in insecure environments. These costs create substantial thresholds that must be exceeded before arbitrage becomes economically viable, resulting in persistent price differentials across regions.

The World Bank has documented that Yemen's GDP contracted by approximately 54% in real per capita terms between 2015 and 2023, with continued negative growth projected for 2024.(World Bank 2022) This economic deterioration has been accompanied by currency volatility, with the Yemeni rial experiencing divergent valuations—for example, in early 2023, exchange rates varied dramatically from approximately 600 rials per USD in Houthi-controlled territories to 1,225 rials per USD in government-controlled areas.(Sana'a Center for Strategic Studies 2023) These substantial discrepancies create significant market distortions that impede economic recovery and exacerbate food insecurity in a country where approximately 21.6 million people require humanitarian assistance.

By analyzing market fragmentation and exploring pathways toward reintegration through policy interventions such as exchange rate unification and improved connectivity, this paper aims to enhance understanding of economic resilience mechanisms in conflict zones. This research carries

substantial policy relevance, particularly as international institutions seek effective interventions to support economic stability in FCAS environments. Furthermore, the paper addresses important theoretical questions regarding the applicability of traditional market integration models in conflict settings where normal arbitrage mechanisms are constrained.

This paper outlines both the theoretical and empirical foundations of market integration in conflict zones and proposes an econometric framework—centered on threshold cointegration models supplemented by spatial econometric techniques—to quantify and simulate the impact of policy reforms. By focusing specifically on commodity price transmission across Yemen's fragmented markets, we aim to identify effective policy levers for enhancing market integration, with particular emphasis on exchange rate unification as a potential catalyst for economic stabilization.

2 Literature Review

2.1 Theoretical Foundations

The Law of One Price (LOP) posits that in an integrated market, identical goods should command the same price when adjusted for transport and transaction costs. Early theoretical contributions established that arbitrage forces can eliminate price differentials up to a threshold defined by these costs.(Baulch 1997; Ravallion 1986) Classical arbitrage models assume continuous adjustment; however, when trade barriers exist—whether due to geography, infrastructural deficiencies, or political disruptions—these transaction costs become significant enough to sustain persistent price gaps.

Fackler and Goodwin provide a comprehensive framework for spatial price analysis, emphasizing that market integration exists along a continuum rather than as a binary state.(Fackler and Goodwin 2001) In fully integrated markets, price shocks transmit completely across regions, ensuring that spatial price differentials reflect only transaction costs. However, in partially integrated markets—common in developing countries and particularly prevalent in conflict settings—price transmission may be incomplete, asymmetric, or subject to substantial thresholds before arbitrage

occurs.

The theoretical literature increasingly recognizes the nonlinear nature of market adjustment processes. Rather than continuous arbitrage in response to any price differential, Balke and Fomby introduced the concept of threshold cointegration, where price adjustments only occur once differentials exceed transaction costs.(Balke and Fomby 1997) This "band" of inaction, where small price differences persist without triggering arbitrage, is particularly relevant to conflict-affected environments like Yemen, where security checkpoints, damaged infrastructure, and political barriers significantly elevate transaction costs.

2.2 Empirical Evidence in Conflict-Affected Economies

Empirical studies in conflict-affected regions consistently document that market integration is severely hampered by structural impediments. In countries such as Ethiopia, Somalia, and Syria, research has shown that conflict-induced disruptions lead to localized monopolistic practices and persistent price differentials.(Dercon 1995; Little 2007; World Bank 2020) In Yemen specifically, World Bank analyses have documented how the coexistence of official and parallel exchange rates distorts price signals, as commodity markets operate under conditions that preclude full arbitrage.(World Bank 2022)

Mansour et al. examined market integration in Syria during active conflict, finding that the destruction of trade routes and emergence of internal checkpoints significantly reduced the speed of price transmission between previously connected markets.(Mansour et al. 2021) Their findings highlight how conflict not only increases transaction costs but also fundamentally alters the structure of market relationships, creating isolated price islands in areas where trade flows are severely constrained. This pattern appears consistent with Yemen's experience, where price differentials between Houthi-controlled and government-controlled territories persist beyond what traditional transport costs would justify.

Recent empirical work has increasingly turned to advanced econometric techniques to capture these nonlinear dynamics. Threshold cointegration models—first developed by Balke and Fomby

and refined by Hansen and Seo—allow for the modeling of situations where price convergence only occurs once price gaps exceed a critical threshold.(Balke and Fomby 1997; Hansen and Seo 2002) This "band" structure is particularly relevant to Yemen, where small differences in commodity prices persist due to high transaction costs (e.g., security risks, checkpoints), while larger deviations trigger arbitrage.

Moreover, Enders and Siklos's application of the Momentum Threshold Autoregressive (M-TAR) model to capture asymmetric adjustment dynamics has proven valuable for understanding how prices react differently to upward versus downward shocks in conflict zones.(Enders and Siklos 2001) This approach recognizes that price increases (often driven by supply disruptions in conflict settings) may transmit differently than price decreases, with important implications for market integration analysis.

2.3 Alternative Approaches

Although threshold cointegration offers a robust framework, alternative methodologies provide complementary insights. Guney, Goodwin, and Riquelme introduced Generalized Additive Vector Autoregression (GAVAR) models, which allow for semiparametric modeling of gradual, continuous adjustments.(Guney, Goodwin, and Riquelme 2019) This approach offers flexibility in capturing price dynamics when adjustment processes vary continuously with shock magnitude, rather than exhibiting discrete threshold effects.

Additionally, spatial econometric models as formalized by Anselin facilitate examination of geographic dependencies by incorporating spatial weight matrices to account for proximity effects.(Anselin 1988) These approaches are particularly relevant for Yemen, where geographic fragmentation and localized conflict intensity create spatially heterogeneous market conditions. By accounting for spatial autocorrelation in price movements, these models can capture how market integration varies across different regions of the country, providing granular insights beyond what time-series models alone can offer.

The literature also highlights the importance of exchange rate regimes for market integration,

particularly in countries with fragmented or parallel currency markets. Negassa and Myers demonstrated how dual exchange rate systems can systematically distort spatial price relationships, creating persistent arbitrage opportunities that fail to be eliminated through normal market mechanisms.(Negassa and Myers 2007) This finding has direct relevance for Yemen, where the dual exchange rate regime represents a fundamental challenge to market integration.

2.4 Research Gap and Contribution

While extensive research exists on market integration in developing countries, and a growing literature addresses conflict-affected economies, few studies comprehensively analyze market fragmentation in settings with both active conflict and dual exchange rate regimes. This paper contributes to the literature by applying threshold cointegration techniques to Yemen's unique context, explicitly modeling how conflict-induced transaction costs and exchange rate disparities affect commodity price transmission across politically fragmented territories.

Furthermore, by simulating the potential impact of exchange rate unification on threshold parameters and adjustment speeds, this research provides empirically grounded policy insights for enhancing market integration in conflict settings. The paper's emphasis on asymmetric adjustment and spatial dependencies also addresses methodological gaps in the existing literature, offering a more nuanced understanding of market dynamics in complex emergency environments.

3 Methodology

3.1 Data Sources

Our analysis leverages a comprehensive dataset drawn from multiple sources to encapsulate Yemen's complex market dynamics:

- **Commodity Prices**: Weekly prices for key staples—wheat, rice, and sugar—collected from multiple Yemeni markets by the World Food Programme (WFP). The high-frequency nature

of these data permits detailed tracking of price movements across different political control zones.

- **Exchange Rates**: Official and parallel market exchange rates provided by the Central Bank of Yemen, as referenced in recent World Bank reports.(World Bank 2022) Including both exchange rate measures is crucial to capture distortions arising from the dual rate system. The differential between rates in Houthi-controlled versus government-controlled territories is explicitly incorporated into our econometric models.

- **Geographic Data**: Market locations and administrative boundaries sourced from the ACAPS Yemen Analysis Hub. These data enable the construction of spatial weight matrices and facilitate analysis of geographic price transmission.(Anselin 1988) We augment traditional distance metrics with information on political control boundaries to capture how fragmentation affects spatial market relationships.

- **Conflict Data**: Security incidents and measures of conflict intensity from the Armed Conflict Location & Event Data Project (ACLED). This information enables us to assess how conflict conditions influence market integration and price transmission.(Mansour et al. 2021) We create conflict intensity indices that vary both temporally and spatially to capture the heterogeneous impact of violence on market functioning.

3.2 Econometric Framework

Our primary econometric strategy centers on threshold cointegration models to capture nonlinearities in price transmission attributable to conflict-induced transaction costs.

3.2.1 Unit Root and Cointegration Testing

We begin by assessing the integration properties of the commodity price and exchange rate series using the Augmented Dickey-Fuller Generalized Least Squares (ADF-GLS) test, which offers improved power in small samples.(Elliott, Rothenberg, and Stock 1996) Complementary tests

(Phillips-Perron and KPSS) are used to validate these results. For long-run equilibrium relationships, the Johansen cointegration test is applied, with adjustments for structural breaks via the Gregory-Hansen test where necessary.(Gregory and Hansen 1996)

The ADF-GLS test specification for a series y_t is:

$$\Delta y_t^d = \alpha y_{t-1}^d + \sum_{i=1}^{p} \beta_i \Delta y_{t-i}^d + \epsilon_t \tag{1}$$

where y_t^d is the locally detrended series. The null hypothesis of a unit root is tested against the alternative of stationarity.

Given Yemen's volatile economic environment, we also apply the Zivot-Andrews test to account for potential structural breaks in the price series, particularly around significant conflict events or policy changes such as the 2017 Central Bank decision to float the rial.(Zivot and Andrews 1992)

3.2.2 Threshold Estimation and Testing

To detect nonlinear adjustment regimes, we apply the Tsay test for threshold nonlinearity.(Tsay 1989) This test identifies whether price adjustments occur only beyond a certain threshold, which in our context represents transaction costs such as security fees and logistical barriers. When significant threshold effects are detected, we estimate a Threshold Vector Error-Correction Model (TVECM) following Hansen and Seo's methodology.(Hansen and Seo 2002)

The TVECM specification for two price series P_{1t} and P_{2t} is:

$$\Delta P_t = \begin{cases} A_1 X_t(\beta) + u_{1t} & \text{if } w_t(\beta) \leq \gamma \\ A_2 X_t(\beta) + u_{2t} & \text{if } w_t(\beta) > \gamma \end{cases} \tag{2}$$

where $P_t = (P_{1t}, P_{2t})'$, $w_t(\beta) = P_{1t-1} - \beta P_{2t-1}$ is the error correction term, γ is the threshold parameter, and $X_t(\beta)$ includes lags of ΔP_t and the error correction term.

The threshold parameter γ is estimated using Hansen and Seo's maximum likelihood approach,

with a grid search over potential threshold values. We test the significance of the threshold effect using the sup-LM test, which compares the threshold model against a linear VECM alternative.

3.2.3 Asymmetric Adjustment Analysis

Recognizing that price adjustments may exhibit asymmetry—where, for instance, price spikes are corrected more rapidly than price declines—we employ the M-TAR model of Enders and Siklos.(Enders and Siklos 2001) This allows us to capture directional differences in the error-correction process, which is particularly relevant in markets subject to sudden shocks from conflict-related disruptions.

The M-TAR specification is:

$$\Delta\hat{\mu}_t = I_t\rho_1\hat{\mu}_{t-1} + (1 - I_t)\rho_2\hat{\mu}_{t-1} + \sum_{i=1}^{p}\gamma_i\Delta\hat{\mu}_{t-i} + \epsilon_t \tag{3}$$

where $\hat{\mu}_t$ is the estimated residual from the cointegrating relationship, and I_t is the Heaviside indicator function:

$$I_t = \begin{cases} 1 & \text{if } \Delta\hat{\mu}_{t-1} \geq \tau \\ 0 & \text{if } \Delta\hat{\mu}_{t-1} < \tau \end{cases} \tag{4}$$

with τ being the threshold value. We test the null hypothesis of symmetric adjustment ($\rho_1 = \rho_2$) against the alternative of asymmetric adjustment.

3.2.4 Spatial Econometric Analysis

Given Yemen's fragmented geography, spatial econometric techniques are used to analyze geographic price transmission. Moran's I statistic is first computed to test for spatial autocorrelation among VECM residuals. Where significant spatial dependence is detected, we estimate spatial lag models to quantify the influence of neighboring markets on local prices.(Anselin 1988)

The spatial lag model is specified as:

$$P_t = \rho W P_t + X_t \beta + \epsilon_t \tag{5}$$

where P_t is a vector of prices across markets, W is a spatial weight matrix based on market connectivity (adjusted for conflict barriers), ρ is the spatial autoregressive parameter, X_t are control variables including exchange rate differentials, and ϵ_t is the error term.

The weight matrix W is constructed using geographic distances between markets, modified to account for conflict intensity along transport routes. This approach allows us to capture how political fragmentation alters the effective economic distance between markets, even when geographic proximity would suggest stronger integration.

3.3 Simulation of Market Integration Scenarios

To evaluate the potential impact of policy interventions, particularly exchange rate unification, we simulate alternative market integration scenarios:

3.3.1 Exchange Rate Unification Simulation

Within the VECM/TAR framework, we incorporate the dual exchange rate differential as an exogenous variable. By setting this differential to zero, we simulate a unified exchange rate environment. This scenario analysis allows us to observe changes in the speed of price adjustment and the reduction in the threshold parameter, reflecting a lower arbitrage barrier.

Specifically, we re-estimate the TVECM with the constraint that $E_{S,t} = E_{A,t}$, where $E_{S,t}$ is the exchange rate in Sana'a and $E_{A,t}$ is the exchange rate in Aden. The resulting changes in the threshold parameter γ and the adjustment coefficients provide quantitative insights into how exchange rate unification might enhance market integration by narrowing the "no-arbitrage" band.

3.3.2 Spatial Connectivity Simulation

In parallel, we adjust the spatial weight matrix to simulate improved market connectivity—reflecting scenarios such as the reopening of key trade corridors or improved security conditions. By reducing the effective distance between markets, the spatial lag model forecasts a decrease in price dispersion. These simulations provide policymakers with quantitative insights into the benefits of enhancing geographic connectivity.

3.4 Robustness and Diagnostic Tests

To ensure the reliability of our findings, we implement several robustness and diagnostic checks:

3.4.1 Structural Break Tests

Beyond the Gregory-Hansen test, we employ Bai-Perron multiple break tests to identify shifts in the cointegration relationship corresponding to major conflict events or policy changes.(Bai and Perron 1998) This approach recognizes that market relationships in Yemen may have fundamentally changed at various points during the conflict, requiring flexible modeling approaches.

3.4.2 Residual Diagnostics

We examine model residuals for serial correlation (using the Breusch-Godfrey LM test), heteroskedasticity (via White's test), and normality (using the Jarque-Bera test). In cases where serial correlation is detected, lag lengths are adjusted or Newey-West robust errors are employed to ensure valid inference.

3.4.3 Sensitivity Analyses

We re-estimate models under alternative specifications (e.g., symmetric ECMs, varied lag lengths based on AIC/BIC) and perform rolling estimations to assess the stability of our results. Additional

analyses exclude extreme outliers—often associated with peak conflict incidents—to verify the robustness of the core findings.

This comprehensive methodological approach enables us to identify the key drivers of market fragmentation in Yemen and to quantify the potential impact of policy interventions on market integration. By combining threshold cointegration techniques with spatial econometric methods, we capture both the nonlinear nature of price adjustment processes and the geographic dimension of market relationships, providing a nuanced understanding of how conflict affects economic integration.

4 Results and Discussion

4.1 Preliminary Data Analysis

[This section will present descriptive statistics and preliminary analyses of commodity price dispersions, exchange rate divergence, and spatial patterns in market fragmentation.]

4.2 Threshold Cointegration Results

[This section will present findings from threshold cointegration models, including estimated threshold parameters, adjustment speeds, and tests for asymmetry in price transmission.]

4.3 Spatial Analysis of Market Integration

[This section will present results from spatial econometric models, including evidence of geographic dependencies and the impact of conflict intensity on effective market distances.]

4.4 Policy Simulation Findings

[This section will present results from exchange rate unification and connectivity improvement simulations, quantifying potential welfare gains from policy interventions.]

5 Conclusion

[This section will summarize key findings, discuss policy implications, acknowledge limitations, and suggest directions for future research.]

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