Market Unity Amidst Conflict

Price Integration Analysis in Yemen   —   An Econometric and Spatial Approach

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December 2024

Abstract

This paper investigates the nature and degree of market integration and price transmission across staple commodity markets in Yemen, a country affected by protracted conflict, institutional fragmentation, and a dual exchange rate regime. Employing a rigorous econometric and spatial framework, we combine cointegration analysis, vector error correction models (VECMs), spatial econometric specifications, and time-varying market integration indices to examine long-run equilibrium relationships, short-run dynamics, and spatial dependencies in commodity price movements. Our findings offer granular insights into the complex interplay of conflict, market fragmentation, transaction costs, and exchange rate distortions in shaping price formation and integration patterns. The results hold significant implications for policymakers, humanitarian organizations, and international development partners committed to enhancing food security, market efficiency, and economic resilience in Yemen's challenging environment.

Keywords: Market Integration, Price Transmission, Vector Error Correction Model, Spatial Econometrics, Exchange Rate Regime, Yemen, Aden, Sana'a, Commodity Prices, Economic Resilience, Food Security

1 Introduction

Market integration is a cornerstone of economic resilience, particularly in regions fraught with conflict and infrastructural fragility. Yemen, enduring prolonged periods of instability, presents a unique context for examining the intricacies of commodity price transmission and market cohesion between its principal economic centers, Aden and Sana'a. These cities function as critical nodes within Yemen's fragmented market landscape, influencing price dynamics and economic stability across diverse commodity sectors. Understanding the mechanisms underpinning price transmission between Aden and Sana'a is imperative for formulating policies that enhance market efficiency, mitigate price volatility, and ensure food security.

This study employs advanced econometric methodologies, including Vector Error Correction Models (VECM) and spatial econometric techniques, to dissect the bidirectional nature of price transmission between Aden and Sana'a. By analyzing a comprehensive set of commodities—ranging from staples like wheat and lentils to essential imported goods—the research delineates the speed and directionality of price adjustments, the impact of exchange rate regimes, and the spatial dependencies that characterize Yemen's market structure. The presence of significant error correction coefficients in both transmission directions signifies a dynamic interplay between these markets, wherein price signals are reciprocally integrated, albeit at varying speeds across different commodities.

Furthermore, the dual exchange rate regime in Yemen introduces a layer of complexity, particularly for imported commodities, by moderating price adjustment speeds and impeding seamless market integration. This study elucidates how exchange rate volatility acts as a barrier to efficient price transmission, thereby exacerbating regional price differentials and undermining market cohesion. Spatial econometric analyses, quantified through Moran's I statistics and spatial lag models, reveal a nuanced landscape of price dispersion juxtaposed with directional influences, underscoring the potential for strategic market linkages to enhance overall integration.

The findings of this research hold significant implications for policymakers and international development entities, such as the World Bank, aiming to foster economic stability and resilience in conflict-affected regions. By identifying key leverage points—such as exchange rate stabilization, infrastructure enhancement, and targeted interventions in high-impact commodities—this study provides a strategic roadmap for mitigating price disparities and advancing market integration. In doing so, it contributes to the broader discourse on economic recovery and development in post-conflict settings, offering empirical evidence and actionable insights to support sustainable economic growth and food security in Yemen.

2   Literature Review

2.1   Market Integration in Developing Countries

Market integration is a cornerstone of economic development as it influences resource allocation, price stability, and welfare distribution (Fackler and Goodwin, 2001; Ravallion, 1986). In integrated markets, arbitrage ensures that spatial price differentials remain within bounds defined by transport and transaction costs. Conversely, high transaction costs, infrastructural deficiencies, trade barriers, and information asymmetries can lead to persistent segmentation (Baulch, 1997; Dercon, 1995).

Studies in sub-Saharan Africa and South Asia illustrate that weak infrastructure, limited market connectivity, and policy-induced distortions impede price transmission and harm food security (McNew, 1996; Rashid et al., 2008). These findings resonate strongly with Yemen's context, where conflict-related disruptions, poor road infrastructure, and political fragmentation are expected to hamper the smooth functioning of commodity markets.

Fackler and Goodwin (2001) present a comprehensive review of spatial price analysis, underscoring the importance of cointegration and vector error correction models (VECMs) in evaluating long-term price relationships between markets. Ravallion (1986) emphasizes the necessity of testing for market integration, particularly in the context of policy reforms. His analysis highlights how transaction costs operate as a key barrier to market integration, a notion that holds particular relevance for conflict-affected regions like Yemen (Mansour et al., 2021).

2.2 Price Transmission in Conflict-Affected Regions

Conflict imposes severe structural impediments to trade and information flows. Empirical evidence from Ethiopia, Somalia, and Syria underscores that ongoing conflict raises transaction costs, creates localized monopolistic structures, and erodes market integration (Dercon, 1995; Little, 2007; Mansour et al., 2021). In Yemen, multiple factions control key trade routes and border crossings, restricting commerce and resulting in localized price spikes. The dual exchange rate regime—where a parallel market rate coexists with an official rate—further distorts price signals, particularly for imported staples (World Bank, 2022).

Recent studies of Syria's conflict-affected economy (Mansour et al., 2021) illustrate how control of trade routes and border crossings by local actors distorts price signals. In Yemen, a similar dynamic unfolds, as the presence of a dual exchange rate regime introduces further complexities. Exchange rate volatility influences the relative price of imports, contributing to significant price variability across regions with differing degrees of access to foreign currency (World Bank, 2022). Such variability poses considerable challenges for price transmission, particularly in regions dependent on imports for essential commodities.

2.3 Econometric Approaches to Market Integration

The assessment of market integration often begins with stationarity tests and cointegration analysis to identify long-run equilibrium relationships (Engle and Granger, 1987; Johansen, 1988). When cointegration is present, vector error correction models (VECMs) jointly characterize short-term and long-term price dynamics. More recently, spatial econometric models have been introduced to capture geographic patterns of price dependence and to measure how spatial connectivity, or the lack thereof, influences transmission (Anselin, 1988; Fackler and Goodwin, 2001).

The recognition that market integration can vary over time, responding to shocks, policy changes, or conflict intensity, has driven the use of time-varying integration indices and threshold cointegration techniques (Hansen and Seo, 2002). These advanced methodologies allow researchers to capture the dynamic nature of market relationships and identify critical thresholds where market behavior fundamentally changes.

This methodological evolution reflects growing awareness that market integration is not a static condition but rather a dynamic process influenced by various factors including infrastructure quality, institutional capacity, and security conditions. In conflict-affected settings like Yemen, these methodological advances are particularly relevant as they can help identify how specific shocks or policy changes affect market connectivity and price transmission mechanisms.

3 Data

3.1 Data Sources

Our analysis draws on a comprehensive dataset combining multiple sources to capture the complex dynamics of Yemen's commodity markets:

- **Commodity Prices:** Weekly prices of staple commodities (wheat, rice, sugar) collected from multiple markets

across Yemen, sourced from the World Food Programme (WFP). This high-frequency data allows us to track price movements and market dynamics with sufficient temporal granularity.

- **Exchange Rates:** Official and parallel market exchange rates from the Central Bank of Yemen (World Bank, 2022), enabling analysis of how the dual exchange rate system affects price transmission and market integration. The inclusion of both official and parallel rates is crucial for understanding price distortions in different market segments.
- **Geographic Data:** Market locations and administrative boundaries from ACAPS Yemen Analysis Hub, providing the spatial framework necessary for our analysis of geographic price transmission patterns and market connectivity (Anselin, 1988). This data helps identify natural barriers, trade corridors, and areas of political control.
- **Conflict Data:** Security incidents and conflict intensity measures from the Armed Conflict Location & Event Data Project (ACLED), allowing us to assess how security conditions affect market integration and price transmission (Mansour et al., 2021). This data captures both the temporal and spatial variation in conflict intensity.

3.2   Data Preparation

Our data preparation process involves several steps to ensure analytical robustness:

- **Time Period:** The analysis covers December 2019 to the latest available data, encompassing a period of significant variation in conflict intensity, exchange rate dynamics, and market conditions.
- **Data Cleaning:** Missing values are handled through careful interpolation where appropriate, or exclusion where interpolation would be inappropriate (Lütkepohl, 2005). We employ multiple imputation techniques for sporadic missing values while excluding periods with systematic data gaps.
- **Log Transformation:** Price series are converted to natural logarithms to:
  - Stabilize variance across the sample period
  - Allow interpretation of differences as percentage changes
  - Facilitate the detection of multiplicative price relationships
- **Market Segmentation:** Markets are segmented based on:
  - Political control (areas controlled by different factions)
  - Geographic regions (accounting for natural barriers and trade routes)
  - Exchange rate regime exposure (differential access to official vs. parallel market rates)
  - Infrastructure quality and accessibility

This comprehensive dataset, combining price, geographic, conflict, and institutional variables, enables us to analyze how various factors interact to influence market integration and price transmission in Yemen's complex economic environment (Fackler and Goodwin, 2001).

4   Methodology

Our methodological framework integrates multiple econometric tools to provide a holistic view of market integration in Yemen. We proceed in stages: stationarity testing, cointegration analysis, VECM estimation, spatial modeling, and

time-varying integration assessments.

4.1 Stationarity and Integration Tests

Before conducting cointegration analysis, we test whether individual time series are non-stationary and integrated of the same order. We employ both the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992) to assess stationarity.

The ADF test takes the form:

$$\Delta P_t = \alpha + \beta t + \gamma P_{t-1} + \sum_{i=1}^{k} \delta_i \Delta P_{t-i} + \varepsilon_t \tag{1}$$

where $\Delta P_t = P_t - P_{t-1}$ is the first-difference operator, α is a constant, βt is a trend term, and γ tests for the presence of a unit root. The optimal lag length k is selected based on information criteria.

4.2 Cointegration Analysis

Upon confirming that series are typically integrated of order one, we employ both Engle-Granger (Engle and Granger, 1987) and Johansen (Johansen, 1988) procedures to identify long-run equilibrium relationships among prices.

4.2.1 Engle-Granger Two-Step Procedure

First, estimate the long-run relationship:

$$P_{it} = \alpha_0 + \alpha_1 P_{jt} + u_t \tag{2}$$

Then test the residuals for stationarity:

$$\Delta u_t = \theta u_{t-1} + \sum_{i=1}^{k} \phi_i \Delta u_{t-i} + \eta_t \tag{3}$$

4.2.2 Johansen Test

For a system of prices $\mathbf{P}_t = (P_{1t}, P_{2t}, \ldots, P_{nt})'$, we consider a VAR model (Johansen, 1995):

$$\mathbf{P}_t = \mu + \Phi_1 \mathbf{P}_{t-1} + \Phi_2 \mathbf{P}_{t-2} + \cdots + \Phi_p \mathbf{P}_{t-p} + \varepsilon_t \tag{4}$$

This can be re-parameterized into VEC form:

$$\Delta \mathbf{P}_t = \Pi \mathbf{P}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{P}_{t-i} + \mu + \varepsilon_t \tag{5}$$

where $\Pi = \alpha\beta'$ contains information about long-run relationships.

4.3   Vector Error Correction Models

Given the presence of cointegration, VECMs capture both short-term price adjustments and the speed of reversion to the long-run equilibrium (Lütkepohl, 2005):

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \delta Z_t + \varepsilon_t \tag{6}$$

where β' defines the cointegrating vectors, and α measures the speed of adjustment.

4.4   Spatial Econometric Models

To incorporate geographic interdependencies, we estimate spatial lag and spatial error models (Anselin, 1988; LeSage and Pace, 2009). We construct spatial weights matrices using K-nearest neighbor criteria:

$$w_{ij} = \begin{cases} 1 & \text{if } j \text{ is among } k \text{ nearest neighbors of } i \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

4.4.1   Spatial Lag Model (SLM)

$$y = \rho W y + X\beta + \varepsilon \tag{8}$$

4.4.2   Spatial Error Model (SEM)

$$y = X\beta + u, \quad u = \lambda W u + \varepsilon \tag{9}$$

where W is the spatial weights matrix, and ρ and λ capture spatial dependencies.

4.5   Time-Varying Market Integration Index

Market integration may be dynamic, reflecting shifting frontlines of conflict, currency crises, or policy interventions. We implement a time-varying MII using a state-space model (Hansen and Seo, 2002):

$$\begin{aligned} y_t &= \alpha_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \\ \alpha_t &= \alpha_{t-1} + \eta_t, \quad \eta_t \sim N(0, \sigma_\eta^2) \end{aligned} \tag{10}$$

4.6   Price Differential Analysis

We analyze price differentials between markets:

$$\Delta P_{ijt} = \alpha + \beta_1 D_{ij} + \beta_2 C_{ijt} + \beta_3 E_t + \varepsilon_{ijt} \tag{11}$$

where D_{ij} measures distance, C_{ijt} captures conflict intensity, and E_t represents exchange rate effects.

4.7   Diagnostic Tests

We implement comprehensive diagnostic testing following Jarque and Bera (1987) and Breusch and Pagan (1979):

4.7.1   Statistical Tests

- Residual normality (Jarque-Bera test)
- Heteroskedasticity (Breusch-Pagan test)
- Serial correlation (Durbin-Watson test)
- Spatial autocorrelation (Moran's I)

4.7.2   Robustness Checks

- Alternative sample periods
- Different lag specifications
- Various spatial weight matrices
- Multiple threshold specifications

5   Results

This section delineates the empirical findings from our comprehensive analysis of market integration and price transmission across Yemen's commodity markets, with a particular emphasis on the pivotal comparison between Aden and Sana'a. By leveraging econometric models, price differential analyses, and spatial econometric techniques, we uncover both the challenges and the underlying resilience within Yemen's fragmented markets. The results highlight significant long-run equilibrium relationships, responsive short-term dynamics, and meaningful spatial interdependencies, especially between the major trading hubs of Aden and Sana'a. These insights not only underscore the complexities induced by prolonged conflict and institutional fragmentation but also illuminate pathways for enhancing market integration and economic resilience.

5.1   Overview of Key Findings

Our analyses reveal that Yemeni commodity markets exhibit a blend of fragmentation and resilience. Despite the pervasive conflict, significant long-run cointegration relationships persist among key staples, indicating underlying market linkages. Price differentials between Aden and Sana'a are both statistically significant and indicative of persistent yet manageable disparities, suggesting potential avenues for improved market synchronization. Spatial econometric results further affirm that while markets are generally dispersed, there exists a positive influence of neighboring markets on each other's prices, particularly between Aden and Sana'a. These findings collectively point to a fragmented yet interconnected market structure, with Aden and Sana'a serving as crucial anchors facilitating broader market integration.

5.2   Cointegration and Error Correction Models (ECMs)

The Error Correction Model (ECM) results provide robust evidence of long-run equilibrium relationships and short-term price adjustment dynamics between Aden and Sana'a across various commodities. Specifically, the ECM results for Aden-to-Sana'a and Sana'a-to-Aden directions highlight the following:

- Beans (Kidney Red and White): Both kidney red and white beans exhibit strong cointegration between Aden and Sana'a, with adjustment coefficients (α) of approximately 0.896 and 0.050 respectively in the South-to-North direction. The significant negative gamma coefficients indicate a robust short-term adjustment mechanism, facilitating price convergence following deviations from equilibrium. In the North-to-South direction, similar cointegration is observed, albeit with differing adjustment speeds, reinforcing the bidirectional nature of price transmission.

- Eggs: Eggs demonstrate a substantial adjustment coefficient of 1.224 in the South-to-North ECM, reflecting a rapid return to equilibrium after price shocks. The corresponding North-to-South model also shows significant adjustment ($\alpha = -2.873$), underscoring the responsiveness of egg prices between the two markets.

- Fuel (Diesel, Gas, Petrol-Gasoline): Fuel commodities exhibit varying degrees of price adjustment. Diesel and gas, in particular, show significant ECM coefficients, indicating effective price transmission between Aden and Sana'a. Petrol-gasoline also maintains a strong adjustment dynamic, though slightly less pronounced.

- Lentils: Lentils display a robust cointegration relationship with an adjustment coefficient (α) of 0.937 in the South-to-North direction and -2.708 in the North-to-South direction. This signifies a strong long-term linkage and effective short-term adjustment, facilitating price stability despite market fragmentation.

- Milling Cost (Wheat) and Oil (Vegetable): These commodities show significant ECM coefficients, suggesting stable long-run relationships and consistent price adjustments. The dual exchange rate regime's impact is evident, particularly in the milling cost of wheat, where the adjustment speed is moderated, reflecting the complexities introduced by parallel exchange rates.

- Onions, Potatoes, Rice (Imported), Salt, Sugar, Tomatoes, Wheat, Wheat Flour: All these commodities exhibit significant ECM coefficients in both directions, indicating persistent long-run relationships and effective price

transmission mechanisms. The unified ECM results further consolidate these findings, demonstrating a general tendency towards equilibrium reversion across all commodities.

Key Insights:

- Bidirectional Price Transmission: The presence of significant ECM coefficients in both South-to-North and North-to-South directions for most commodities underscores the bidirectional nature of price transmission between Aden and Sana'a.

- Speed of Adjustment: The variation in adjustment coefficients across commodities suggests differential responsiveness, with staples like wheat and lentils showing faster convergence compared to others, indicating their critical role in market stabilization.

- Impact of Exchange Rates: The dual exchange rate regime notably affects imported commodities, moderating their price adjustment speeds and highlighting the need for exchange rate stabilization to enhance market integration.

5.3   Price Differentials Between Aden and Sana'a

Price differential analyses provide granular insights into the spatial disparities between Aden and Sana'a, revealing both persistent gaps and instances of convergence. The following observations emerge from the price differential results:

- Statistical Significance: A majority of the p-values associated with price differentials between Aden and Sana'a are exceptionally low (e.g., 2.7057204006334E-06 for kidney red beans), indicating highly significant price gaps that are unlikely due to random fluctuations.

- Test Statistics: The negative test statistics consistently exceed the critical values at the 1%, 5%, and 10% significance levels, confirming the rejection of the null hypothesis of no price differential. For instance, the test statistic for kidney red beans (-5.896) surpasses the 1% critical value of -4.169, solidifying the presence of significant price disparities.

- R-squared Values: The R-squared values, ranging from 0.0027 to 0.9182, reflect varying levels of explanatory power across different commodity-market pairs. High R-squared values, such as 0.9182 for potatoes in Sana'a, indicate that the model effectively explains the price differential, suggesting robust underlying market mechanisms.

- Commodity-Specific Insights:

  - Kidney Red Beans and White Beans: Persistent and significant differentials between Aden and Sana'a highlight the challenges in harmonizing prices for essential staples. However, the presence of significant coefficients suggests that these disparities can be addressed through targeted interventions.

  - Eggs and Lentils: Significant price differentials for eggs and lentils between Aden and Sana'a reflect the influence of localized supply-demand imbalances and transportation constraints. Yet, the consistent

responsiveness to model variables indicates potential for narrowing these gaps with improved market conditions.

– Milling Cost (Wheat): The significant differentials in milling costs point to the operational challenges within the wheat supply chain. Nevertheless, the statistical robustness of these differentials underscores the effectiveness of potential policy measures aimed at cost reduction and infrastructure enhancement.

– Onions, Potatoes, Rice (Imported), Salt, Sugar, Tomatoes, Wheat, Wheat Flour: All these commodities exhibit significant price differentials between Aden and Sana'a, affirming the fragmented market structure. However, the model's explanatory power in many cases suggests that these gaps are not insurmountable and can be mitigated through strategic market integration efforts.

Key Insights:

• Persistent Yet Manageable Disparities: While significant price gaps exist between Aden and Sana'a, the statistical significance and explanatory power of the models indicate that these disparities are structured and responsive to economic variables, presenting opportunities for targeted policy interventions.

• Potential for Convergence: The ability of the models to explain a substantial portion of price differentials, especially for high R-squared commodities, suggests that enhancing market connectivity and reducing transaction costs could facilitate price convergence between Aden and Sana'a.

• Strategic Focus on High-Risk Commodities: Commodities with both high significance and high R-squared values, such as kidney red beans and potatoes, should be prioritized for integration efforts to maximize impact on food security and market stability.

5.4   Spatial Dependencies and Moran's I

Spatial econometric analyses provide a nuanced understanding of how commodity prices interact across different regions, with a special focus on the spatial linkages between Aden and Sana'a. The key findings from the spatial results are as follows:

• Moran's I Statistics:

– Negative Moran's I Values: Most commodities, including beans, eggs, fuel types, and staples like wheat and sugar, exhibit negative Moran's I values. This suggests a tendency towards price dispersion rather than clustering, indicating that high or low prices in one region are often surrounded by low or high prices, respectively.

– Significance: A significant proportion of Moran's I values have p-values below 0.05, confirming that these spatial patterns are statistically significant and not attributable to random chance. For instance, kidney red beans in Aden have a Moran's I of -0.0579 with a p-value of 0.001, signifying significant dispersion.

– Exceptions: Commodities such as fuel (diesel) and peas (yellow, split) in certain markets do not show significant spatial autocorrelation, indicating more random price distributions in these cases.

- Spatial Lag Price Coefficients:

  - Positive and Significant Coefficients: All spatial lag price coefficients are positive, indicating that an increase in price in neighboring regions is associated with an increase in the base market's price. This is particularly pronounced between Aden and Sana'a, where spatial lag coefficients for key commodities like beans and wheat are highly significant.

  - Implications for Market Integration: The positive spatial lag coefficients suggest that while overall spatial autocorrelation is negative, there exists a directional influence where neighboring markets influence each other's price levels. This highlights the potential for leveraging these spatial linkages to enhance market synchronization between Aden and Sana'a.

- R-squared Values: R-squared values from spatial models range from 0.0438 to 0.9182, indicating varying levels of model fit. High R-squared values, such as 0.9182 for potatoes in Sana'a, demonstrate strong explanatory power and effective capture of spatial dependencies.

- Variance Inflation Factor (VIF): All VIF values are 1.0, indicating no multicollinearity issues within the spatial models. This ensures the reliability of coefficient estimates and strengthens the validity of the spatial econometric findings.

Key Insights:

- Directional Influence Despite Dispersion: Even though Moran's I suggests dispersion, the positive spatial lag coefficients indicate meaningful directional influence between regions, particularly between Aden and Sana'a. This duality underscores the complexity of spatial interactions in fragmented markets.

- Role of Major Hubs in Price Transmission: Aden and Sana'a, as major market hubs, play a crucial role in transmitting price signals across regions. Enhancing the connectivity and operational efficiency between these hubs can amplify their positive influence on surrounding markets, fostering broader market integration.

- Potential for Targeted Spatial Interventions: The significant spatial dependencies observed for key commodities between Aden and Sana'a suggest that targeted interventions aimed at strengthening these linkages—such as improving transport infrastructure or stabilizing exchange rates—can have cascading positive effects on market integration and price stability.

5.5   Comparative Analysis: Aden vs. Sana'a

Aden and Sana'a, as principal trading and administrative centers, exhibit distinct yet interrelated market dynamics. The comparative analysis between these two markets integrates insights from ECMs, price differentials, and spatial econometrics to elucidate their roles in facilitating market integration.

- ECM Insights:

  - Bidirectional Adjustment: Both Aden-to-Sana'a and Sana'a-to-Aden ECMs reveal significant adjustment coefficients across multiple commodities, indicating robust bidirectional price transmission. For instance,

wheat and lentils show substantial adjustment speeds in both directions, reflecting the markets' responsiveness to each other's price changes.

– Asymmetric Dynamics: While bidirectional transmission is prevalent, some commodities exhibit asymmetries in adjustment speeds. For example, the adjustment coefficient for white beans is higher in the South-to-North direction ($\alpha = 0.050$) compared to North-to-South ($\alpha = -0.116$), suggesting a slightly faster convergence from Aden to Sana'a.

- Price Differential Insights:

  – Persistent Disparities with Convergence Potential: Significant price differentials between Aden and Sana'a for staples like white beans and wheat flour indicate persistent disparities. However, the high R-squared values (e.g., 0.5769 for white beans in Sana'a vs. Aden) suggest that these disparities are structurally driven and can be addressed through targeted market integration efforts.

  – Commodity-Specific Dynamics: Commodities such as eggs and milling costs display significant price gaps but also demonstrate high explanatory power, indicating that improving factors like transportation and exchange rate stability can effectively reduce these disparities.

- Spatial Econometric Insights:

  – Influence Across Regions: Spatial lag coefficients for commodities between Aden and Sana'a are consistently positive and highly significant, affirming that price changes in one market influence the other. This interconnectedness underscores the strategic importance of these two markets in the national price transmission network.

  – Resilience Through Connectivity: The positive spatial dependencies indicate that despite the overarching dispersion, the connectivity between Aden and Sana'a remains a critical conduit for price transmission. Enhancing this connectivity can amplify positive spillover effects, fostering greater market integration and price stability.

Key Insights:

- Aden and Sana'a as Integration Anchors: The bidirectional and significant price transmission between Aden and Sana'a positions them as key anchors for market integration. Strengthening their linkage can catalyze broader market harmonization across Yemen.

- Strategic Focus Areas: Enhancing infrastructure, stabilizing exchange rates, and improving market information systems between Aden and Sana'a can leverage their existing robust linkages, promoting more synchronized price movements and reducing regional disparities.

- Policy Leveraging: Policies aimed at reinforcing the Aden–Sana'a corridor—such as investment in transport infrastructure, currency stabilization measures, and conflict mitigation in key trade routes—can harness the inherent market linkages to drive national market integration and economic resilience.

5.6   Resilience and Opportunities for Market Integration

Despite the ongoing conflict and institutional fragmentation, the analysis uncovers several areas of resilience and latent integration within Yemen's commodity markets, particularly between Aden and Sana'a. These resilient patterns suggest that, with targeted interventions, significant strides can be made towards enhancing market integration and price stability.

- Stable Long-Run Relationships: The persistence of long-run cointegration across multiple staples indicates that fundamental supply-demand dynamics remain intact. This stability provides a foundation upon which market integration can be built, even amidst external disruptions.

- Responsive Short-Term Dynamics: The significant short-term adjustment coefficients in ECMs highlight the markets' capacity to respond swiftly to price shocks. This responsiveness is a positive indicator of market adaptability and the potential for rapid price convergence following targeted policy measures.

- Positive Spatial Linkages: The meaningful spatial lag coefficients between Aden and Sana'a underscore the potential for these markets to influence each other positively. By reinforcing these linkages, the overall market system can become more cohesive and less fragmented.

- High-Explanatory Power for Key Commodities: High R-squared values for commodities like potatoes and white beans in certain market comparisons demonstrate that a substantial portion of price differentials can be explained by the models, indicating that these differentials are manageable and predictable with the right interventions.

Key Insights:

- Leverage Existing Strengths: The stable long-run relationships and responsive dynamics between Aden and Sana'a should be leveraged to foster broader market integration. Policies aimed at strengthening these existing strengths can have multiplicative effects across the national market system.

- Targeted Interventions: Focused interventions on key commodities and strategic market corridors can enhance the overall efficiency and resilience of Yemen's commodity markets, contributing to improved food security and economic stability.

- Scalable Integration Models: The successful integration between Aden and Sana'a can serve as a scalable model for other regions, facilitating a more uniform and efficient market system nationwide.

5.7   Robustness and Consistency of Positive Signals

To ensure the reliability and robustness of our findings, a series of robustness checks and sensitivity analyses were conducted (see Appendix Tables A4–A6). These checks involved varying model specifications, altering spatial weight matrices, and testing different lag lengths. The core positive signals identified—such as stable cointegration relationships between Aden and Sana'a, significant spatial lag coefficients, and meaningful price differentials—remained

consistent across these alternative specifications. This consistency reinforces the credibility of our results and underscores the resilience of the observed market linkages.

Key Insights:

- Consistent Findings Across Models: The persistence of significant relationships across different model specifications indicates that the positive market integration signals between Aden and Sana'a are robust and not artifacts of specific modeling choices.

- Reliability of Cointegration and Spatial Dependencies: The stable presence of cointegration and spatial dependencies in key commodities across various robustness checks highlights the underlying strength and potential for market integration between Aden and Sana'a.

- Policy Confidence: The robustness of these positive findings provides policymakers and stakeholders with confidence in the identified pathways for enhancing market integration and price stability, supporting informed decision-making and strategic planning.

5.8 Comparative Resilience: Aden vs. Sana'a

A comparative analysis of Aden and Sana'a reveals nuanced insights into their roles as market anchors and their capacity to influence broader market integration. The following points synthesize the distinct yet complementary dynamics observed in each market:

- Aden:

  - Market Flexibility: Aden exhibits a higher speed of price adjustment in the South-to-North ECMs for several commodities, indicating a flexible and responsive market structure capable of rapid convergence.

  - Strategic Positioning: As a major port and trade hub, Aden's market dynamics are significantly influenced by international trade flows, which facilitates efficient price transmission to Sana'a.

  - Infrastructure Resilience: Despite conflict-induced disruptions, the relative stability of key commodities in Aden suggests resilience in its market infrastructure, enabling sustained price transmission even under adverse conditions.

- Sana'a:

  - Price Stability: Sana'a demonstrates substantial long-run equilibrium relationships with Aden, particularly for staples like wheat and lentils, reflecting its central role in national food security.

  - Spatial Influence: The spatial lag coefficients for commodities in Sana'a indicate a strong influence on surrounding markets, reinforcing its position as a critical market hub.

  - Information Dissemination: Sana'a's market is highly responsive to price changes emanating from Aden, underscoring the effectiveness of information flows and the potential for Sana'a to act as a stabilizing force in the broader market network.

Key Insights:

- Complementary Roles: Aden and Sana'a function as complementary anchors within Yemen's market system, each contributing unique strengths that enhance overall market integration and resilience.

- Interdependent Market Dynamics: The bidirectional and significant price transmission between Aden and Sana'a highlights the interdependence of these markets, suggesting that strengthening one can positively impact the other and, by extension, the entire market network.

- Focused Integration Efforts: Targeted efforts to reinforce the Aden–Sana'a linkage can amplify their positive influence, fostering a more synchronized and efficient national market system.

6 Discussion

The findings presented in this study highlight a complex yet navigable landscape of commodity market integration in Yemen, with Aden and Sana'a emerging as central nodes in the price transmission network. Despite persistent conflict, limited infrastructure, and a dual exchange rate regime, the core results indicate that underlying supply-demand relationships remain sufficiently robust to support meaningful cointegration. Essential staples, including wheat and lentils, demonstrate both stable long-run relationships and strong short-term adjustment capabilities. These patterns suggest a latent resilience in the national market system, and that, even in challenging environments, price signals can traverse economic and geographic boundaries.

One of the most striking outcomes is the combination of dispersion indicated by Moran's I tests with the consistently positive spatial lag coefficients. While negative Moran's I values underscore a tendency towards spatial price divergence, the strong and positive spatial lag terms confirm that neighboring markets—particularly Aden and Sana'a—do influence each other's price levels. This duality indicates that Yemen's commodity markets are not merely fragmented enclaves but rather interlinked nodes in a spatial network. Prices are not isolated; they reverberate across space, and Aden–Sana'a linkages, though tested by adversity, remain conduits of price information and stabilization.

The ECM analysis, showing significant bidirectional adjustment, reinforces the idea of anchored integration. In essence, Aden and Sana'a function as "integration anchors"—hubs through which external shocks and policy interventions may have ripple effects, promoting alignment across a broader range of commodities and regions. While persistent price gaps exist, they are not wholly intractable. The high explanatory power of certain models underscores the influence of identifiable factors—such as transportation infrastructure, input costs, and exchange rates—on price differentials. Targeted policies can address these variables, creating an environment conducive to narrower gaps and improved food security.

The dual exchange rate regime currently operating in Yemen introduces distortions that affect price formation, particularly for imported commodities. The results reveal that while robust long-term relationships and meaningful short-term adjustments exist between key markets like Aden and Sana'a, the uneven influence of parallel exchange rates can slow down price convergence and limit the potential benefits of market integration. Indeed, commodities such as milling wheat, rice, and other internationally sourced staples are disproportionately affected by currency volatility and segmented exchange markets.

This situation means that while underlying economic fundamentals support market connectivity, exchange rate fragmentation is a critical barrier to fully realizing the potential of these linkages. The persistent price differentials in

certain commodities, even when other sources of friction are accounted for, underscore that monetary policies—and especially exchange rate unification—are not peripheral concerns. Instead, they lie at the heart of achieving smoother and more efficient price transmission. In essence, current exchange rate conditions function like a filter, dampening or distorting price signals that would otherwise flow more freely between the two anchor markets.

A coherent, unified exchange rate regime emerges as a key lever for unlocking market efficiency. Current evidence suggests that aligning disparate rates could enhance responsiveness to price shocks, reduce unexplained price differentials, and streamline arbitrage opportunities. If Aden and Sana'a are to function effectively as integration anchors, they must operate within a stable, predictable monetary framework that allows prices to reflect fundamental supply-demand conditions rather than currency risk premiums.

Overall, the results challenge the narrative that ongoing conflict completely dismantles market coherence. On the contrary, the patterns revealed here provide an evidence-based foundation upon which policy practitioners, donors, and non-governmental organizations can build strategies to foster greater integration, stability, and resilience.

Reproducibility

To ensure full reproducibility of our analysis, we provide a comprehensive reproduction package containing all code, data processing pipelines, and documentation. The package is available at: `https://github.com/mohammadak95/Yemen_Market_Analysis_Reproduction`

The reproduction package includes:

- Complete Python codebase for all analyses

- Data processing and cleaning scripts

- Detailed methodology documentation

- Step-by-step reproduction instructions

- All presentation materials

Researchers can use this package to replicate our results, extend our analysis, or adapt our methodology to similar market integration studies in conflict-affected regions.

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