

Fuel-Food Price Transmission in a Conflict-Affected Food System: Evidence from Diesel, Wheat, and Sugar Markets in Syria

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Abstract

This study examines fuel-food price transmission in Syria during the prolonged civil conflict from 2011 to 2024, focusing on diesel, wheat, and sugar markets. Using wavelet coherence analysis and a frequency-domain time-varying parameter vector autoregression model, the study investigates how global oil price movements are transmitted to domestic diesel and food prices, and how these shocks affect food market dynamics across major Syrian cities. The selected commodities capture distinct economic channels: crude oil as an external energy benchmark, diesel as a key transport and logistics input, wheat as a strategic staple linked to domestic food security, and sugar as a more import- and distribution-dependent food commodity. The results show that fuel-food price transmission weakened during periods of intense conflict but strengthened after 2016, when partial stabilization of trade routes and market institutions improved domestic price adjustment. Wavelet coherence results indicate that the pass-through from global oil prices to domestic diesel, wheat, and sugar prices is time-varying and frequency-specific, suggesting that transmission depends not only on international price movements but also on local institutional and logistical conditions. Regional connectedness results further show that Damascus and Aleppo play relatively central roles in price transmission, while more peripheral markets remain less integrated. These findings highlight the importance of fuel availability, transport infrastructure, market governance, and political stability in shaping food price transmission under conflict. The study contributes new evidence on the fuel-food price nexus in fragile states and offers policy insights for food security monitoring, fuel logistics, and post-conflict market recovery.

Keywords: Syria; food prices; energy prices; civil conflict; wavelet coherence; dynamic connectedness

JEL classification: Q11; Q18; Q41; C32; D74

1. Introduction

Fuel and food prices are closely linked in fragile food systems because energy affects the cost of transport, storage, irrigation, processing, and distribution. In conflict-affected economies, this relationship becomes even more important. Violence, damaged infrastructure, fuel shortages, exchange-rate instability, sanctions, and fragmented governance can prevent international price movements from being transmitted smoothly to domestic markets, while also weakening the movement of food across regions. Understanding fuel-food price transmission is therefore central to food-security monitoring and post-conflict market recovery.

Syria provides an important case for examining these dynamics. Since 2011, the country has experienced prolonged civil conflict, large-scale displacement, severe damage to transport and productive infrastructure, and repeated disruptions to food and fuel supply chains. The fall of the Assad regime in December 2024, at the end of the sample period, further illustrates the depth of Syria's political and institutional transformation. A significant portion of the population continues to face food insecurity (World Food Programme 2024), while households have been exposed to sharp increases in the prices of staple foods and essential fuels. In this context, the key issue is not only whether prices rise, but also whether fuel and food prices continue to move across markets in ways that transmit scarcity signals, support arbitrage, and guide humanitarian and policy responses.

Market integration is relevant here not as an abstract statistical concept, but as an indicator of market functionality. When spatial markets are relatively integrated, price increases in one location can attract supplies from other areas, reduce excessive local price dispersion, and help identify where public intervention is most urgent. When markets are fragmented, local shortages may persist even when goods are available elsewhere; households face higher transport and search costs; and humanitarian assistance, public stockpiles, subsidies, or emergency distributions may fail to reach the areas where they are most needed. For this reason, price transmission and market connectedness are directly related to food access, household welfare, and the design of emergency food-security policy.

Theoretically, civil conflict can affect fuel-food price transmission through several channels. First, conflict raises transaction costs by increasing transport risk, checkpoint payments, delays, and uncertainty. Second, damage to roads, storage facilities, fuel distribution networks, and communication systems reduces the ability of traders to respond to price differentials. Third, territorial fragmentation can separate producing, importing, and consuming areas into partially disconnected market zones. Fourth, government intervention, including subsidies, procurement policies, price controls, exchange-rate rules, and emergency distributions, may dampen, delay, or redirect price transmission. Conflict is therefore not treated in this study as the sole determinant of market integration. Rather, it is understood as a shock that operates through infrastructure, governance, geography, and commodity-specific institutions.

This study focuses on three domestic commodities: diesel, wheat, and sugar. Diesel is a key fuel for transport, agricultural machinery, and distribution, and therefore represents the domestic energy channel through which global oil price movements may affect food markets. Wheat is Syria's most important staple food and has historically been shaped by domestic production, public procurement, and food-security policy. Sugar, by contrast, is more dependent on imports and distribution networks, making it useful for examining how external and logistical pressures affect a less domestically anchored food commodity. This commodity selection allows the analysis to distinguish among energy, staple-food, and import-dependent food-market channels rather than treating food prices as a single homogeneous category.

Fig. 1 shows a map of Syria, indicating the seven major cities analyzed in this study: Damascus, Aleppo, Deir ez-Zor, Homs, Latakia, Qamishli, and Hama. These cities differ in their economic functions and geographic positions. Damascus and Aleppo are the largest urban and commercial centers; Latakia is Syria's main seaport; Homs is located on a key transport corridor; Hama is linked to an important agricultural region; and Deir ez-Zor and Qamishli represent eastern markets with distinct logistical and cross-border conditions. These regional differences help interpret heterogeneity in price transmission, but the main focus of the paper remains the fuel-food price nexus rather than regional fragmentation as a separate phenomenon.

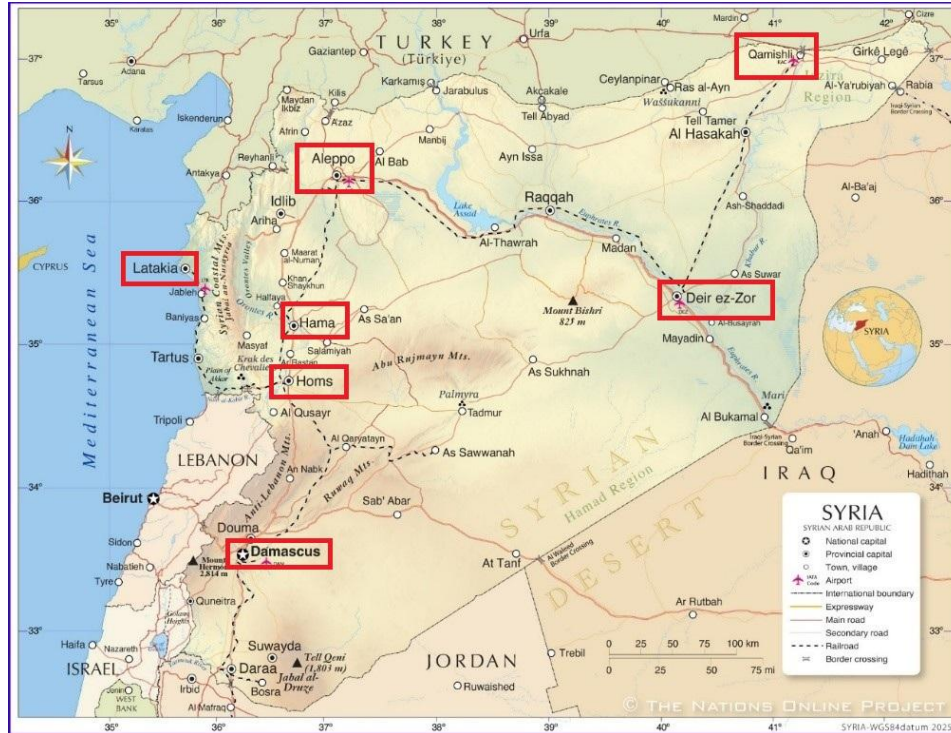


Fig. 1. Map of Syria showing the selected cities.

Notes: Map source: One World Nations Online (2025). The red rectangles indicate the seven major cities included in the analysis. These cities were selected based on their geographic distribution, economic importance, and exposure to conflict, and they serve as the primary spatial units for examining fuel-food price transmission and market integration in Syria.

Using monthly data from January 2011 to December 2024, this study combines wavelet coherence analysis with a frequency-domain time-varying parameter vector autoregression model. The sample period lies almost entirely within Syria's conflict period, so the analysis does not claim to estimate a clean pre-war/post-war treatment effect. Instead, it examines how fuel-food price relationships and domestic market connectedness evolve over time under changing conflict, institutional, and logistical conditions. Wavelet coherence analysis is used to identify time-frequency co-movement between global oil prices and domestic diesel, wheat, and sugar prices. The frequency-domain TVP-VAR connectedness model is then used to examine how shocks are transmitted across commodities and cities in the short and longer run.

This approach is appropriate for the Syrian case because conventional spatial price models often require information on bilateral trade flows, transfer costs, or stable long-run market equilibria that is difficult to observe during conflict. Gravity models are useful when trade volumes and transport-cost measures are available, but such data are limited and unstable in Syria. The methods used here therefore provide a flexible way to study dynamic price transmission when markets are disrupted, institutional conditions change, and the strength of price linkages varies over time.

This study makes four contributions. First, it places fuel-food price transmission within a food-security framework, showing why energy-price shocks matter for agricultural and food markets in fragile states. Second, it provides subnational evidence from Syria, a conflict-affected economy where domestic market data remain limited. Third, it treats diesel, wheat, and sugar as institutionally distinct commodities rather than assuming a single uniform food-market mechanism. Fourth, it shows how time-frequency and connectedness methods can be used together to identify changing patterns of price transmission when conventional trade and transport data are unavailable.

The remainder of this paper is structured as follows. Section 2 reviews the literature on energy-food price linkages, food security, and market integration under conflict. Section 3 describes the data, commodities, and city-level context. Section 4 presents the empirical methodology. Section 5 reports the results. Section 6 discusses policy implications for food-security monitoring, fuel logistics, and post-conflict market recovery. Section 7 concludes.

2. Literature Review

2.1 Energy and Food Linkages

Early studies on the relationship between energy and food prices focused mainly on the cost structure of agricultural production, especially the role of energy inputs such as fuel and fertilizers. The global food

price crisis of 2007-2008 then stimulated a broader literature on price linkages between energy and food markets. For example, Baffes (2007) and Mitchell (2008) highlighted the influence of oil prices and biofuel policies, while Headey and Fan (2008) emphasized the multifactorial nature of the crisis, including financial speculation and exchange-rate fluctuations.

Subsequent research has increasingly used dynamic econometric models, including vector autoregression, vector error correction, generalized autoregressive conditional heteroskedasticity, and TVP-VAR models, to examine price and volatility transmission between energy and agricultural commodity markets. Zhang et al. (2010) and Nazlioglu et al. (2013) analyzed risk transmission and asymmetric causality in price volatility, while Tiwari et al. (2021) used a copula-based approach to capture dependence structures and tail co-movement between oil and agricultural commodity markets under different regimes of geopolitical risk.

More recent studies have paid greater attention to geopolitical risk, climate shocks, and changing patterns of market interconnectedness. Spillover measures based on forecast error variance decompositions, such as those developed by Diebold and Yilmaz (2014), have been widely used to quantify connectedness and represent inter-market dynamics in network form. Structural VAR models, such as those developed by Ratti and Vespignani (2016), provide another important approach by distinguishing demand and supply shocks. Research on developing countries has also shown that energy-food price transmission is shaped by import dependence, infrastructure, and domestic market conditions. Gilbert (2010) examined the role of import dependency, while Varela et al. (2012) emphasized how transportation infrastructure and market distance influence price transmission and market integration.

Taken together, this literature shows that energy-food price linkages are not mechanical or uniform. They depend on production costs, transport costs, trade exposure, exchange-rate movements, market structure, and policy intervention. This insight is especially important for conflict-affected economies, where fuel shortages, damaged infrastructure, and fragmented governance may alter both the strength and timing of price transmission. The Syrian case therefore requires an approach that captures not only whether

energy and food prices are linked, but also how these linkages change across time, frequency, commodity, and location.

2.2 Energy and Food Markets in Syria

Since 2011, the relationship between energy prices, particularly fuel prices, and food prices has become increasingly important in Syria and the broader Middle East and North Africa region. In settings characterized by civil war, economic sanctions, infrastructure damage, and institutional fragility, disruptions to fuel supply can affect agricultural production, transport, storage, milling, and food distribution. Previous studies have shown that fuel supply disruptions and fuel price increases can contribute to higher food prices by raising production and distribution costs (Nguyen et al. 2023; Kemmerling et al. 2022). Macroeconomic analyses using computable general equilibrium models have also highlighted the inflationary effects of rising energy prices and their negative effects on real incomes and food consumption, which are consistent with patterns observed in Syria (Breisinger et al. 2011).

Statistical evidence also suggests a link between energy and food prices, although clear causal relationships are often difficult to establish in fragile and conflict-affected settings. Nonetheless, there is broad agreement that rising fuel prices exert upward pressure on food prices through production, transport, and distribution channels (e.g. Adeosun et al. 2023). This mechanism is particularly relevant for Syria, where fuel availability, exchange-rate instability, import constraints, sanctions, and damage to transport infrastructure have interacted with food-market disruptions.

However, the Syrian case also requires caution. Fuel-food price transmission cannot be interpreted as a simple pass-through from international oil prices to domestic food prices. Domestic prices are shaped by institutional arrangements, including subsidies, public procurement, price controls, exchange-rate rules, emergency distributions, and local control over transport routes. Moreover, different commodities are exposed to different mechanisms. Diesel functions as both an energy commodity and a logistical input; wheat is a strategic staple connected to domestic production and public food-security policy; and sugar is

more import- and distribution-dependent. This study therefore contributes to the Syria-related literature by examining fuel-food price transmission at a disaggregated commodity and city level, rather than treating food markets as a single homogeneous sector.

2.3 Spatial Market Integration, Conflict, and Market Governance

This study is also grounded in the spatial market integration literature, rather than in the literature on asset-market reactions to war. In classical spatial price analysis, market integration refers to the extent to which prices in different locations respond to common shocks once transport and transaction costs are taken into account (Ravallion 1986; McNew 1996; Fackler and Goodwin 2001). Baulch (1997) emphasized that simple price co-movement can be misleading if transfer costs are ignored, while Barrett and Li (2002) distinguished market integration from competitive equilibrium. This distinction is important for Syria: weak price co-movement may reflect blocked arbitrage caused by violence and high transaction costs, while strong co-movement may also arise from administrative pricing or policy interventions that suppress local scarcity signals.

Evidence from developing-country food markets shows that roads, remoteness, information costs, crime, and policy barriers shape the degree of price transmission. Moser et al. (2009) found that market integration in Madagascar varies by spatial scale and is constrained by high transfer costs and weak competition. Aker (2010) and Jensen (2007) showed that better market information can reduce price dispersion by improving arbitrage. In a cross-country study of consumer markets in developing countries, Baquedano and Liefert (2014) showed that world price transmission to domestic food prices is often slow and incomplete because exchange rates, market structure, transaction costs, and border policies mediate pass-through. Dillon and Barrett (2016) further demonstrated that global oil prices can affect local food prices through transport-cost channels, which is especially relevant for fuel-constrained conflict economies.

Conflict intensifies these frictions. Armed violence can close markets, destroy storage and transport assets, raise informal tolls, and prevent traders from responding to profitable price gaps. It can also create

feedback between food insecurity and insecurity: food price shocks and conflict jointly shape household welfare in Afghanistan (D'Souza and Jolliffe 2013), and the broader food security-conflict literature stresses the endogeneity between violence, food access, livelihoods, and public authority (Martin-Shields and Stojetz 2019; Kemmerling et al. 2022). Food prices also matter politically because large increases in food prices have been linked to social unrest (Bellemare 2015). For Syria, this means that market integration should be interpreted as one channel linking conflict to food security, rather than as a purely technical outcome detached from welfare.

The Syrian case also requires commodity-specific theorization. Wheat is a strategic staple shaped by domestic production, state procurement, public storage, milling, and bread subsidy institutions. Diesel is a fuel input whose availability affects transport, irrigation, milling, and household energy use, but its distribution is also shaped by administrative allocation, subsidies, smuggling, and local control of supply routes. Sugar is more import-exposed and therefore more directly affected by exchange rates, port access, foreign exchange availability, and the capacity of public or private importers. These differences imply that a single aggregate concept of market integration can conceal distinct transmission mechanisms.

This study therefore examines whether market connectedness weakens when violence, distance, and fragmented governance raise the cost of arbitrage, and whether these effects differ across commodities. It also examines whether periods of lower violence and improved route security are associated with partial recovery in transmission through institutionally mediated channels. The empirical analysis assesses whether connectedness declines during periods of severe conflict, whether central and port cities transmit more shocks than peripheral cities, and whether diesel, wheat, and sugar differ in their degree and frequency of transmission.

3. Data

This study uses monthly time-series data on food and energy markets from January 2011 to December

209 2024. The empirical analysis is organized in two stages. The first stage examines the relationship between
210 global crude oil prices and domestic Syrian prices for diesel, wheat, and sugar at the national-average level.
211 The second stage uses city-level prices for the same three domestic commodities to examine how fuel and
212 food price shocks are transmitted across major Syrian markets.

213 For the first stage, the dataset includes the global crude oil price (GOP) and average domestic prices
214 for wheat (SWP), sugar (SSP), and diesel (SDP) in Syria, as reported in Table 1. Domestic commodity
215 prices were obtained from the World Bank (2025) database and represent average nominal market prices.
216 Because the original domestic prices are reported in Syrian pounds, they were converted into U.S. dollars
217 using official exchange rates obtained from Investing.com (2025). This conversion provides a common unit
218 for comparing domestic Syrian prices with global oil prices. However, because official exchange rates may
219 not fully reflect parallel-market conditions during periods of conflict and macroeconomic instability, the
220 converted series should be interpreted as official-exchange-rate-adjusted price measures rather than as
221 direct measures of household purchasing power. The global crude oil price is represented by the West Texas
222 Intermediate benchmark and was retrieved from the International Monetary Fund Primary Commodity
223 Prices database (IMF 2025). The series is reported in U.S. dollars per barrel.

224 For the second stage, the analysis uses city-level monthly prices for diesel, wheat, and sugar in seven
225 major Syrian cities: Damascus, Aleppo, Deir ez-Zor, Homs, Latakia, Qamishli, and Hama. These data are
226 summarized in Table 2. The city-level prices were also obtained from the World Bank (2025) database and
227 represent average nominal consumer prices. As with the national-level series, prices were converted from
228 Syrian pounds to U.S. dollars using official exchange rates from Investing.com (2025). The use of a
229 common exchange-rate conversion allows the domestic price series to be compared across cities and with
230 the international oil benchmark, while the interpretation of results remains attentive to the role of exchange-
231 rate instability as part of Syria's broader conflict economy.

232 The three commodities were selected because they represent different market structures and
233 transmission channels. Wheat is both a staple food and a politically strategic crop. Before and during the

conflict, wheat and bread markets were strongly shaped by state procurement, milling, storage, and subsidy institutions; conflict disrupted production areas, collection centres, and transport routes, increasing reliance on imports in some periods (Yazigi 2015; Human Rights Watch 2021). Diesel is a cross-cutting energy input for transport, irrigation, milling, generators, and household consumption, so diesel price shocks can affect food prices through both production and distribution channels. Sugar, by contrast, is more import-exposed and less directly tied to domestic agricultural production, making it useful for distinguishing external price, exchange-rate, and distribution channels from domestic production and procurement channels. This commodity selection therefore avoids treating food prices as a single homogeneous category and allows the analysis to compare energy, staple-food, and import-dependent food-market dynamics.

The selected cities also reflect important geographic and institutional differences within Syria. Damascus and Aleppo are major consumption, administrative, and commercial hubs; Latakia is the principal seaport; Homs is a central transport node; Hama is linked to agricultural production areas; and Deir ez-Zor and Qamishli are peripheral eastern and northeastern cities affected by oil production, cross-border trade, and fragmented governance. These characteristics are not treated as fully observed controls, because price data alone cannot completely separate geography, infrastructure, conflict exposure, and governance. Instead, they provide the interpretive context for understanding heterogeneous patterns of price transmission across cities. This is a limitation of the research design, but it is also why a dynamic connectedness approach is informative: it allows the analysis to examine how the relative roles of cities and commodities change over time and across frequency bands.

Table 1. Variables for global energy and Syrian food and energy markets.

Variable	Abbreviation	Description	Source
Syrian diesel price	SDP	Average market price of diesel in Syria	World Bank (2025); Investing.com (2025)
Syrian wheat price	SWP	Average market price of wheat in Syria	World Bank (2025); Investing.com (2025)
Syrian sugar price	SSP	Average market price of sugar in Syria	World Bank (2025); Investing.com (2025)

Global crude oil price GOP WTI crude oil price, 40 API gravity,
Midland, Texas, US\$/barrel IMF (2025)

Notes: API, American Petroleum Institute; IMF, International Monetary Fund; WTI, West Texas Intermediate.
Domestic Syrian prices were originally reported in Syrian pounds and converted into U.S. dollars using official
exchange rates from Investing.com (2025).

Table 2. Variables for Syrian city-level energy-food markets.

Variable	Abbreviation	Description	Source
Damascus diesel price	DamascusD	Diesel consumer price in Damascus	World Bank (2025); Investing.com (2025)
Aleppo diesel price	AleppoD	Diesel consumer price in Aleppo	World Bank (2025); Investing.com (2025)
Deir ez-Zor diesel price	Deir.ez-ZorD	Diesel consumer price in Deir ez-Zor	World Bank (2025); Investing.com (2025)
Homs diesel price	HomsD	Diesel consumer price in Homs	World Bank (2025); Investing.com (2025)
Latakia diesel price	LatakiaD	Diesel consumer price in Latakia	World Bank (2025); Investing.com (2025)
Qamishli diesel price	QamishliD	Diesel consumer price in Qamishli	World Bank (2025); Investing.com (2025)
Hama diesel price	HamaD	Diesel consumer price in Hama	World Bank (2025); Investing.com (2025)
Damascus wheat price	DamascusW	Wheat consumer price in Damascus	World Bank (2025); Investing.com (2025)
Aleppo wheat price	AleppoW	Wheat consumer price in Aleppo	World Bank (2025); Investing.com (2025)
Deir ez-Zor wheat price	Deir.ez-ZorW	Wheat consumer price in Deir ez-Zor	World Bank (2025); Investing.com (2025)
Homs wheat price	HomsW	Wheat consumer price in Homs	World Bank (2025); Investing.com (2025)
Latakia wheat price	LatakiaW	Wheat consumer price in Latakia	World Bank (2025); Investing.com (2025)
Qamishli wheat price	QamishliW	Wheat consumer price in Qamishli	World Bank (2025); Investing.com (2025)
Hama wheat price	HamaW	Wheat consumer price in Hama	World Bank (2025); Investing.com (2025)

Damascus sugar price	DamascusS	Sugar consumer price in Damascus	World Bank (2025); Investing.com (2025)
Aleppo sugar price	AleppoS	Sugar consumer price in Aleppo	World Bank (2025); Investing.com (2025)
Deir ez-Zor sugar price	Deir.ez-ZorS	Sugar consumer price in Deir ez-Zor	World Bank (2025); Investing.com (2025)
Homs sugar price	HomsS	Sugar consumer price in Homs	World Bank (2025); Investing.com (2025)
Latakia sugar price	LatakiaS	Sugar consumer price in Latakia	World Bank (2025); Investing.com (2025)
Qamishli sugar price	QamishliS	Sugar consumer price in Qamishli	World Bank (2025); Investing.com (2025)
Hama sugar price	HamaS	Sugar consumer price in Hama	World Bank (2025); Investing.com (2025)

Notes: D, diesel; W, wheat; S, sugar. Domestic prices were originally reported in Syrian pounds and converted into U.S. dollars using official exchange rates from Investing.com (2025).

To address potential non-stationarity, all price series were transformed into monthly growth rates using logarithmic differencing. This transformation is appropriate because the analysis focuses on price movements and transmission dynamics rather than on price levels alone. Descriptive statistics and preliminary diagnostic tests were then conducted for both the national-level global energy-domestic market dataset and the city-level domestic energy-food market dataset. The results are reported in Table 3.

As shown in Table 3, the national-level variables display substantial heterogeneity in average growth and volatility. All variables exhibit negative mean growth rates except SWP, which has a positive mean growth rate. SSP shows the highest variance, indicating relatively high volatility in sugar price growth, while GOP shows the lowest variance. Skewness and kurtosis diagnostics (D'Agostino 1970; Anscombe and Glynn 1983) indicate asymmetric and fat-tailed distributions. All variables show negative skewness, and the high kurtosis values for SDP, SWP, and SSP indicate leptokurtic distributions, suggesting the presence of extreme price movements. The Jarque-Bera normality test (Jarque and Bera 1980) rejects normality for all variables. The Elliott, Rothenberg, and Stock unit root tests (Elliott et al. 1996) confirm that the log-differenced series are stationary.

Table 3 also reports the statistical characteristics of the city-level diesel, wheat, and sugar price series. Diesel prices exhibit negative mean growth rates across all cities. Wheat prices show positive mean growth rates in all cities except Deir ez-Zor, while sugar prices are positive in all cities except Damascus and Deir ez-Zor. Among the city-level series, diesel prices in Deir ez-Zor show the highest variance, indicating particularly high volatility in that local fuel market. Skewness is negative for all city-level variables, suggesting common distributional asymmetry. The high kurtosis values for diesel and wheat prices in Damascus and Homs indicate leptokurtic behavior and point to the presence of extreme local price fluctuations. Consistent with the national-level results, the Jarque-Bera tests reject normality for the city-level series. The unit root tests confirm that all log-differenced city-level variables are stationary.

These descriptive and diagnostic results support the empirical strategy used in the following sections. The non-normality and fat-tailed behavior of the series indicate that price changes in Syria were shaped by large shocks rather than smooth adjustment. The stationarity of the log-differenced variables allows the study to examine dynamic price relationships without relying on unstable price levels. The combination of national-level and city-level datasets makes it possible to analyse both the transmission of global oil price movements to Syrian fuel and food markets and the domestic connectedness of diesel, wheat, and sugar prices across Syrian cities.

Table 3. Summary statistics and preliminary diagnostic tests.

Analysis	Variable	Mean	Variance	Skewness	Kurtosis	JB	ERS
Global analysis	SDP	-0.016	0.027	-6.242*	46.732*	16183.156*	-6.004*
	SWP	0.001	0.030	-6.125*	47.686*	16766.208*	-6.822*
	SSP	-0.001	0.031	-5.378*	37.500*	10526.561*	-6.417*
	GOP	-0.001	0.012	-0.817*	9.016*	580.743*	-6.357*
Domestic analysis	DamascusD	-0.016	0.030	-6.368*	48.921*	17675.424*	-6.052*
	AleppoD	-0.017	0.042	-4.562*	31.215*	7315.213*	-6.672*
	Deir.ez-ZorD	-0.018	0.191	-0.214	9.629*	642.618*	-6.364*
	HomsD	-0.015	0.034	-5.477*	39.677*	11718.569*	-6.131*
	LatakiaD	-0.016	0.045	-2.809*	16.868*	2186.215*	-5.801*

QamishliD	-0.012	0.063	-0.244	5.172*	186.653*	-5.824*
HamaD	-0.016	0.042	-3.478*	22.851*	3946.225*	-6.354*
DamascusW	0.001	0.033	-5.520*	42.178*	13147.735*	-6.930*
AleppoW	0.000	0.034	-5.133*	34.927*	9166.568*	-7.107*
Deir.ez-ZorW	-0.008	0.040	-3.540*	23.313*	4106.003*	-6.385*
HomsW	0.002	0.033	-5.325*	40.243*	11986.208*	-6.857*
LatakiaW	0.001	0.034	-5.132*	38.381*	10917.778*	-6.735*
QamishliW	0.003	0.035	-4.365*	32.245*	7718.532*	-6.314*
HamaW	0.000	0.040	-4.499*	31.353*	7359.164*	-7.079*
DamascusS	-0.005	0.032	-4.926*	33.554*	8458.603*	-6.488*
AleppoS	0.002	0.036	-4.195*	25.707*	5057.609*	-7.192*
Deir.ez-ZorS	-0.009	0.062	-1.716*	11.074*	929.619*	-4.770*
HomsS	0.001	0.031	-4.692*	31.895*	7645.355*	-6.208*
LatakiaS	0.000	0.036	-4.344*	29.508*	6544.804*	-6.507*
QamishliS	0.001	0.039	-3.973*	24.175*	4479.048*	-5.985*
HamaS	0.000	0.040	-4.155*	25.509*	4978.572*	-6.532*

Notes: The variables are monthly log-differenced price series. JB denotes the Jarque-Bera normality test, and ERS denotes the Elliott, Rothenberg, and Stock unit-root test. Skewness was assessed using the D'Agostino (1970) test, kurtosis using the Anscombe and Glynn (1983) test, normality using the Jarque-Bera (JB) test, and stationarity using the Elliott, Rothenberg, and Stock (ERS) test (Elliott et al. 1996). * indicates significance at the 1% level.

4. Methodology

This study uses two complementary econometric approaches to examine fuel-food price transmission in Syria. The first approach focuses on the pass-through from global oil prices to domestic Syrian diesel, wheat, and sugar prices. The second approach examines how domestic energy and food price shocks are transmitted across Syrian city-level markets. This two-stage design reflects the structure of the research question: global energy shocks may affect domestic markets through fuel and logistics costs, while the degree to which these shocks spread across cities depends on domestic market integration, infrastructure, governance, and conflict-related frictions.

Standard spatial price models, gravity models, and parity-bounds approaches are useful when bilateral trade flows, transfer costs, road distances, and marketing margins are observed. In the Syrian case, however, consistent monthly information on intercity trade volumes, checkpoint costs, informal market margins, and route-level transport costs is not available for the full conflict period. Pairwise cointegration or error-correction models would also require relatively stable long-run relationships, whereas Syria's market structure changed repeatedly because of violence, territorial control, sanctions, exchange-rate instability, and policy interventions. The methods used here are therefore chosen to identify time-varying co-movement and dynamic price connectedness under severe data constraints. They are not intended to replace structural gravity estimation where the required trade and transport data are available.

In the first stage, wavelet coherence¹ analysis is used to examine whether global oil prices and domestic Syrian prices co-move at specific times and frequencies. This method is appropriate because price transmission under conflict may not be constant over the whole sample period. It may appear only during specific political, institutional, or logistical regimes, and it may operate differently across short and longer horizons. Short-run co-movement may reflect transport and distribution costs, while longer-run co-movement may reflect production, import dependence, policy adjustment, and broader macroeconomic conditions. Wavelet coherence is therefore used as a descriptive tool for identifying the timing, frequency, and direction of co-movement between global oil prices and Syrian diesel, wheat, and sugar prices.

In the second stage, the frequency-domain TVP-VAR connectedness model developed by Chatziantoniou and Gabauer (2021)² is used to examine domestic price transmission across Syrian city-

¹ Wavelet coherence originates from signal processing (Mallat 1989; Daubechies 1990) and has been widely applied in economics and energy-market analysis (Torrence and Compo 1998; Aguiar-Conraria and Soares 2014). Details are provided in Appendix A.

² The TVP-VAR model follows Cogley and Sargent (2005), Primiceri (2005), and Antonakakis et al.

level markets. This framework is suitable for the Syrian case because it allows the strength and direction of price transmission to vary over time. It also identifies whether particular cities or commodities act mainly as transmitters or receivers of shocks. By decomposing connectedness into frequency components, the model distinguishes short-run transmission, which is likely to reflect immediate logistical and market disruptions, from longer-run transmission, which may reflect more persistent structural and institutional linkages. The approach combines the connectedness framework of Diebold and Yilmaz (2012, 2014), frequency decomposition (Stiassny 1996; Barunik and Krehlik 2018), and the TVP-VAR estimation tradition.

Following the standard implementation of the TVP-VAR connectedness approach, the baseline model uses a Minnesota prior and forgetting factors of $\kappa_1 = \kappa_2 = 0.99^3$. Generalized forecast error variance decompositions are computed following Koop et al. (1996) and Pesaran and Shin (1998). The baseline specification uses a 12-month-ahead forecast horizon, which matches the monthly data to an annual adjustment horizon. To assess robustness, additional forecast horizons of $H = 10, 15, 20, 25$, and 30 months were also tested. The main qualitative results remained stable across these alternative horizons.

The preliminary stationarity tests reported in the data section should be interpreted in relation to this modelling strategy. Wavelet coherence can be applied to non-stationary series, so the stationarity tests are not used to justify the wavelet analysis. Rather, they are reported to describe the statistical properties of the transformed data and to support the connectedness analysis, which is estimated using monthly log-differenced price series. The use of log differences makes the variables comparable across commodities and

(2020), with details of the frequency connectedness framework provided in Appendix B.

³ The results were qualitatively similar across alternative forgetting factors ranging from 0.96 to 0.99. All results are available from the authors upon request.

cities and reduces the risk that common inflationary or exchange-rate trends dominate the estimated connectedness measures.

The empirical results should therefore be interpreted as evidence on time-varying price transmission and market functionality under conflict, rather than as a causal estimate of the effect of conflict relative to a non-conflict counterfactual. This distinction is important because the sample period falls almost entirely within Syria's conflict and immediate transition period. The analysis identifies when and where fuel-food price linkages strengthen or weaken, and how shocks are transmitted across commodities and cities, but it does not claim to isolate the full causal effect of conflict onset. This interpretation is consistent with the data constraints of the Syrian case and with the paper's objective of understanding fuel-food market transmission in a fragile and conflict-affected economy.

5. Empirical results

5.1 Global oil price transmission to Syrian domestic energy and food prices

We begin with the wavelet coherence results, which examine the relationship between global crude oil prices and domestic Syrian diesel, wheat, and sugar prices from January 2011 to December 2024. Fig. 2 reports the time-frequency co-movement between global oil prices and each domestic price series. The horizontal axis represents time, while the vertical axis represents the cycle length in months. The results are interpreted as evidence of time-varying co-movement and lead-lag patterns, rather than as causal estimates of the effect of global oil prices on domestic Syrian markets.

Fig. 2a shows that the coherence between global oil prices and Syrian diesel prices was limited before 2016. Significant coherence became more visible after 2016, particularly in the 1-4- and 4-8-month frequency bands. This pattern is consistent with a partial restoration of fuel logistics and market transmission after the most intense phase of urban conflict. Between 2016 and 2018, stronger co-movement

suggests that global oil price movements became more closely associated with domestic diesel price changes. However, the phase arrows in this period do not always indicate a straightforward pass-through from global to domestic prices. In some cases, the phase pattern suggests that domestic diesel prices moved ahead of global oil prices, which is more plausibly interpreted as reflecting policy intervention, local fuel shortages, exchange-rate pressures, or conflict-related disruptions rather than genuine domestic influence on global oil prices.

A second period of coherence appears in 2020-2021, coinciding with the Idlib ceasefire period and the COVID-19 pandemic. In this phase, global oil prices more clearly led domestic diesel prices, suggesting that Syria's fuel market became more responsive to external energy shocks when domestic market conditions were relatively more stable. This does not imply a complete or frictionless pass-through, but it indicates that international price signals were more visible in domestic diesel price movements than during the earlier years of the conflict.

A third coherence episode is observed in 2023, when global energy markets were affected by the war in Ukraine and related disruptions. Coherence remained visible in the 4-8-month frequency band, but the negative lead-lag pattern suggests that domestic diesel prices did not move in a simple one-to-one direction with global oil prices. This may reflect the role of subsidies, administrative price controls, rationing, exchange-rate management, or other regulatory mechanisms that buffered or delayed the transmission of global price changes to the domestic diesel market.

Overall, the diesel results suggest that Syria's domestic fuel market became more connected to global oil price movements after 2016, but this connectedness was episodic and institutionally mediated. During 2011-2015, when violence, infrastructure damage, and fragmented control were more severe, price transmission was weak or largely absent. After 2016, the stronger coherence indicates partial reactivation of fuel-market linkages, although the results also show that domestic prices remained shaped by policy interventions and local market disruptions.

Fig. 2b and 2c show the corresponding wavelet coherence results for wheat and sugar prices. For both food commodities, significant coherence with global oil prices appears between 2016 and 2018, especially around the 8-10-month frequency band. This pattern is consistent with the interpretation that global energy costs affected food markets through transport, storage, milling, distribution, and broader logistics channels once domestic market connections partially recovered.

A second coherence phase is visible in 2020-2021 in the 1-4-month frequency band. During this period, global oil prices appear to lead both wheat and sugar prices, suggesting that food markets became more sensitive to external energy shocks under conditions of relative stabilization and global volatility associated with the COVID-19 pandemic. The shorter frequency band indicates that the transmission operated more quickly during this period, which is consistent with a logistics-based channel linking fuel costs to food distribution.

A third episode appears in 2023 in the 4-8-month frequency band. In this period, the relationship between global oil prices and domestic wheat and sugar prices is not uniformly positive. The negative phase pattern suggests that food prices were not simply following global oil price increases. This may reflect intensified food-market interventions, including subsidies, price controls, public distribution, or exchange-rate management, aimed at limiting the pass-through of global shocks to staple food prices. Such interventions are particularly relevant for wheat, which is a strategic staple, but they may also affect sugar through import administration and distribution policy.

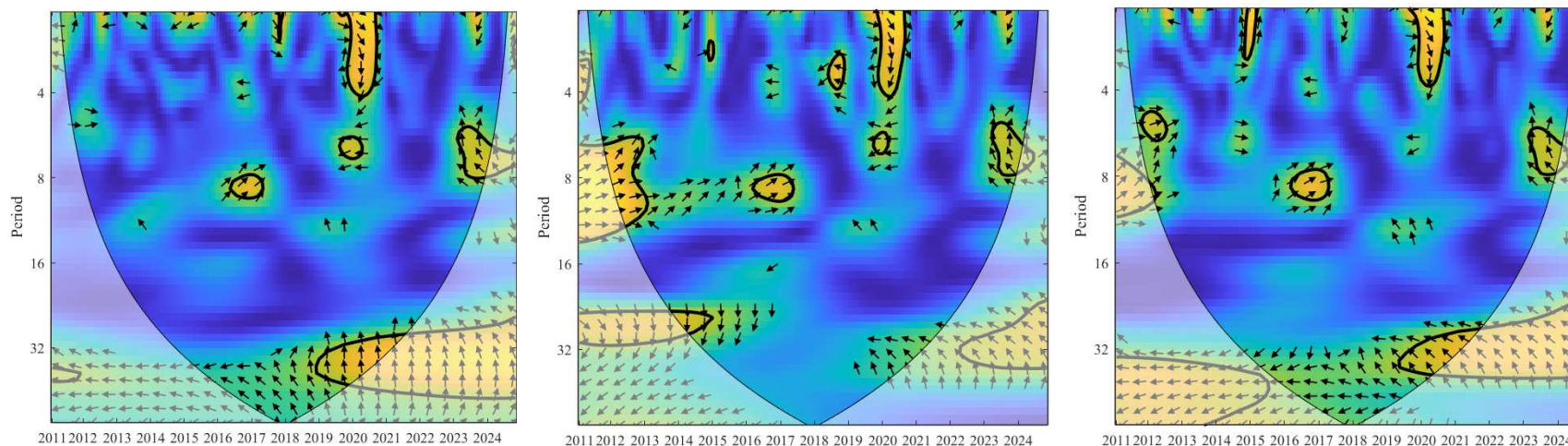
Unlike diesel prices, wheat and sugar prices show some isolated but significant coherence before 2016, particularly around 2012-2013. These early episodes may reflect the role of import dependence, exchange-rate pressures, and inelastic demand for essential food commodities. Even during intense conflict, basic consumption needs and partial market connectivity may have allowed some international energy-price signals to affect domestic food prices.

413 Taken together, the wavelet results show that the relationship between global oil prices and Syrian
414 domestic fuel and food prices was neither constant nor uniform across commodities. Food prices exhibit
415 episodic co-movement with global oil prices, while diesel prices show stronger post-2016 coherence. This
416 pattern is consistent with a conflict-affected market in which global price signals reach domestic consumers
417 only when logistics, exchange-rate conditions, and administrative pricing rules permit transmission.
418 Government interventions, including subsidies, administrative price controls, and exchange-rate
419 management, can dampen, delay, or redirect the transmission of global energy shocks (Demeke et al. 2009;
420 Timmer 2010). The main implication is that fuel-food price transmission in fragile states depends not only
421 on global energy prices, but also on the institutional and logistical capacity to move fuel, food, and market
422 information across space.

a. The wavelet coherence of SDP-GOP

b. The wavelet coherence of SWP-GOP

c. The wavelet coherence of SSP-GOP



423 Fig. 2. Wavelet coherence and phase-difference results.

424 Notes: Coherence is color-coded from blue (low coherence) to yellow (high coherence). Black contours indicate areas significant at the 5% level
 425 based on 1,000 Monte Carlo simulations. The cone of influence near the bottom indicates regions affected by edge effects. Phase arrows indicate the
 426 direction and sign of co-movement: rightward arrows indicate positive co-movement, while leftward arrows indicate negative co-movement.
 427 Upward-right and downward-left arrows indicate that x leads y, whereas downward-right and upward-left arrows indicate that y leads x.

5.2 Total dynamic connectedness between domestic fuel and food prices

Next, we examine domestic market dynamics by analysing the relationships between diesel, wheat, and sugar prices across seven major Syrian cities: Damascus, Aleppo, Deir ez-Zor, Homs, Latakia, Qamishli, and Hama. In the frequency-domain TVP-VAR framework, short-frequency connectedness refers to price transmission occurring within three months, while long-frequency connectedness refers to transmission over horizons longer than three months. In the Syrian context, short-frequency connectedness is interpreted as reflecting relatively rapid adjustment through transport costs, fuel availability, distribution constraints, and short-run arbitrage. Long-frequency connectedness may reflect more persistent channels, including production costs, import dependence, exchange-rate conditions, public procurement, subsidies, and broader institutional adjustment. This classification therefore captures the distinction between immediate logistics-based transmission and more persistent structural or policy-mediated price effects.

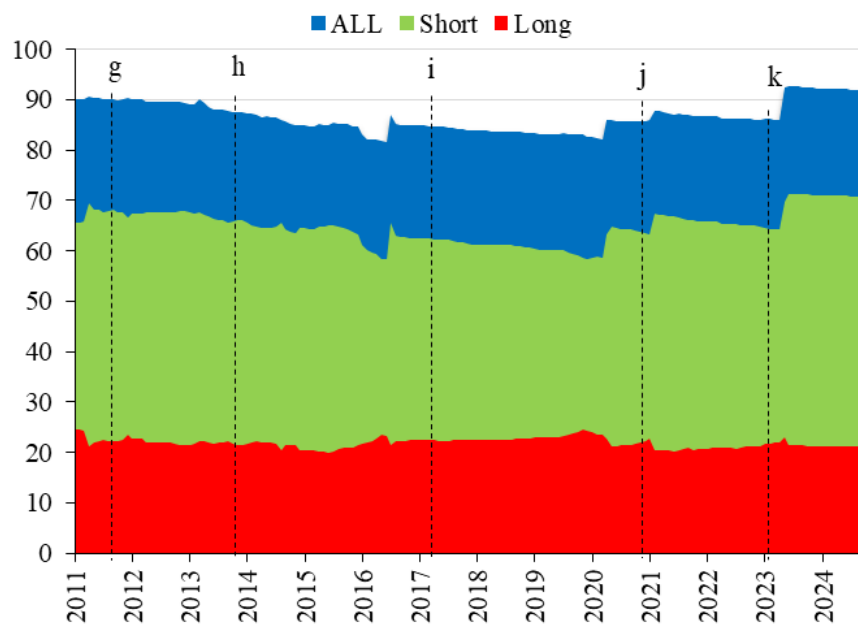
Fig. 3a and 3b show the evolution of the total connectedness index (TCI) for Syria's diesel-wheat and diesel-sugar markets across the short- and long-frequency domains. The TCI measures the overall degree of interdependence among the domestic energy and food price series. Both markets show relatively high connectedness, indicating that fuel and food prices were linked across major Syrian city-level markets. Short-frequency connectedness is generally higher than long-frequency connectedness, suggesting that diesel-related food-price transmission operated primarily through transport, distribution, and market-access channels rather than only through slower agricultural input channels.

Over time, short-frequency connectedness declined sharply during the early years of the civil war and reached its lowest level around mid-2016. This pattern is consistent with severe market fragmentation caused by widespread violence, infrastructure damage, disrupted transport routes, and weakened inter-regional trade. Beginning in 2017, connectedness gradually increased, suggesting a partial recovery of domestic price transmission as some transport corridors and market linkages were restored. The increase becomes more visible after 2020, a period associated with the Idlib ceasefire, partial route stabilization, and

the gradual resumption of agricultural and fuel distribution activities. The diesel-wheat and diesel-sugar markets show broadly similar recovery patterns. In both cases, short-run connectedness weakened during the most intense phase of the war and strengthened during periods of improved route security and institutional coordination. However, these patterns should not be interpreted as evidence that conflict alone explains market fragmentation. Geography, port access, state allocation, import dependence, exchange-rate conditions, and commodity-specific institutions remain important determinants of price transmission. The timing of the connectedness changes is nevertheless consistent with the argument that violence and territorial fragmentation raise transaction costs, restrict arbitrage, and weaken the price signals used by households, traders, and relief agencies.

Overall, the TCI results show that fuel-food price transmission in Syria was dynamic and uneven over time. Domestic fuel and food markets did not simply collapse into permanent fragmentation; rather, their connectedness weakened during periods of severe conflict and partially recovered when logistical and institutional conditions improved. This finding supports the paper's broader argument that market integration in conflict-affected economies should be understood as a functional indicator of food-market resilience, rather than as a purely technical measure of price co-movement.

a. Diesel-wheat market



b. Diesel-sugar market

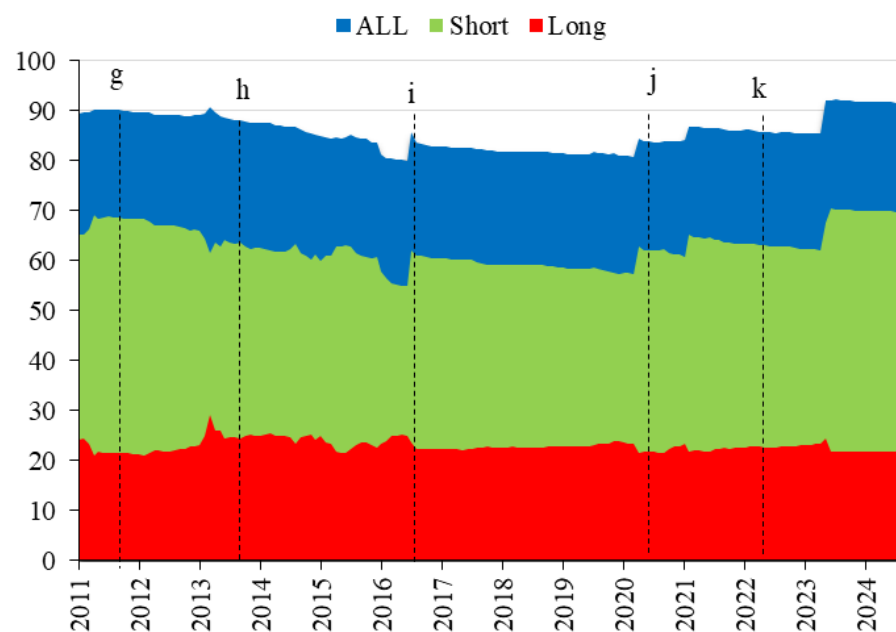


Fig. 3. Evolution of the total connectedness index for diesel-wheat and diesel-sugar markets.

Notes: Vertical dashed lines indicate key milestones in Syria's conflict and political process: (g) the formation of the Free Syrian Army and the shift toward armed conflict (July 2011); (h) the chemical weapons attack in the Damascus suburbs (August 2013); (i) the fall of Aleppo and the resumption of the Geneva peace talks (December 2016); (j) the Idlib ceasefire agreement (March 2020); and (k) the large-scale amnesty declared by the Assad regime (April 2022).

To identify the city-level sources of the aggregate connectedness patterns, the analysis next focuses on directional connectedness in the diesel-wheat market. Wheat is examined first because it is Syria's main strategic staple and is closely linked to food security, public procurement, milling, and bread distribution. Fig. 4a and 4b report the "to others" and "from others" connectedness of wheat prices in Damascus and Deir ez-Zor with wheat and diesel prices in the other Syrian cities. These two cities are selected for detailed discussion because they represent contrasting positions within Syria's domestic market network. Damascus is the capital and a central administrative, consumption, distribution, and policy hub, whereas Deir ez-Zor is an eastern peripheral market exposed to severe conflict, logistical disruption, and proximity to oil-producing areas. Comparing these two cities therefore illustrates how price transmission differs between a relatively central market and a conflict-affected peripheral market.

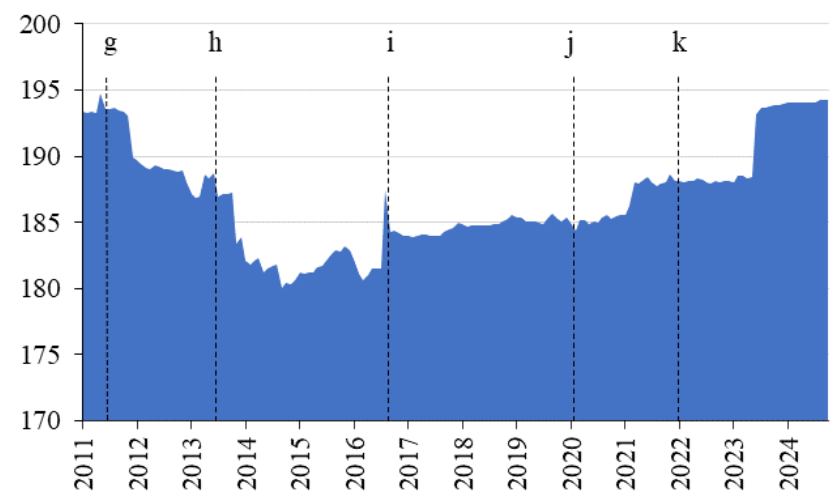
The first notable result is that the Damascus wheat market exhibits consistently higher connectedness than the Deir ez-Zor wheat market. This suggests that Damascus was more strongly embedded in the domestic fuel-food price network, both as a transmitter and receiver of price shocks. This pattern is consistent with its central role in administration, consumption, distribution, and policy implementation. By contrast, the lower connectedness of Deir ez-Zor indicates weaker integration into the national market system, reflecting its peripheral location and greater exposure to conflict-related disruption. Despite this difference in the level of connectedness, the two cities display broadly similar temporal dynamics. In both Damascus and Deir ez-Zor, wheat-market connectedness declined after the onset of the civil war and reached local minima around 2014 and 2016. From 2017 onward, connectedness gradually recovered, with further improvements around 2021 and 2023. This common trajectory suggests that both central and peripheral markets were affected by nationwide disruptions to transport, security, and market coordination, while also responding to the partial restoration of trade routes and market linkages in later years.

Fig. 4c reports conflict-related fatalities from 2011 to 2024 as a proxy for conflict intensity. Fatalities increased sharply after 2011, peaked in 2014, and declined after the collapse of major Islamic State (IS) strongholds in 2017 and the Idlib ceasefire in 2020. These indicators provide contextual information for

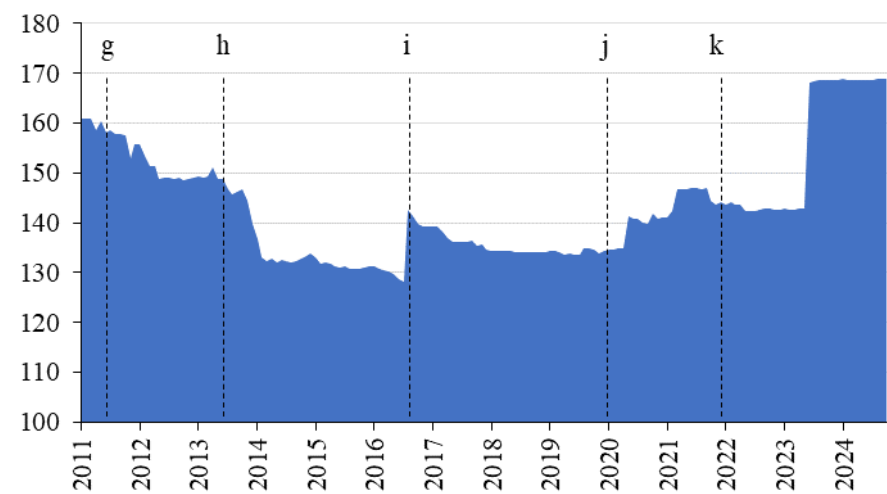
interpreting market connectedness, but they are not used to estimate a causal treatment effect. Comparing Fig. 4a-4c suggests that wheat-market connectedness and conflict intensity moved in opposite directions during several key phases of the Syrian war. Connectedness weakened when fatalities and territorial fragmentation were high, and recovered as conflict intensity declined and route security improved. These patterns are consistent with the interpretation that violence, damaged logistics, and fragmented governance reduced the ability of markets to transmit price signals across cities.

This evidence should therefore be interpreted as descriptive rather than causal. The sample lacks a pre-conflict baseline, and conflict coincided with other major shocks, including exchange-rate instability, sanctions, policy interventions, and fuel-supply disruptions. Nevertheless, the results are substantively important because they show that the weakening of diesel-wheat connectedness was systematically associated with periods of more severe conflict. For a strategic staple such as wheat, this finding has direct food-security implications. Lower connectedness means not only weaker price co-movement, but also a reduced capacity of the domestic market system to transmit scarcity signals, support spatial arbitrage, and reallocate supplies toward areas facing shortages. The results therefore suggest that restoring fuel logistics, transport corridors, and market coordination is central to rebuilding food-market resilience in post-conflict Syria.

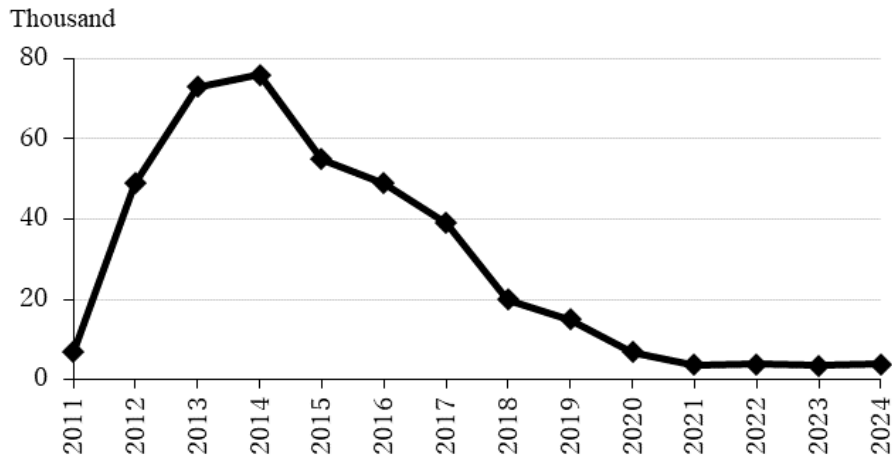
a. Damascus wheat market connectedness



b. Deir ez-Zor wheat market connectedness



c. Conflict-related fatalities in Syria



520 Fig. 4. Dynamic connectedness of wheat prices in Damascus and Deir ez-Zor and conflict intensity in Syria, 2011-2024

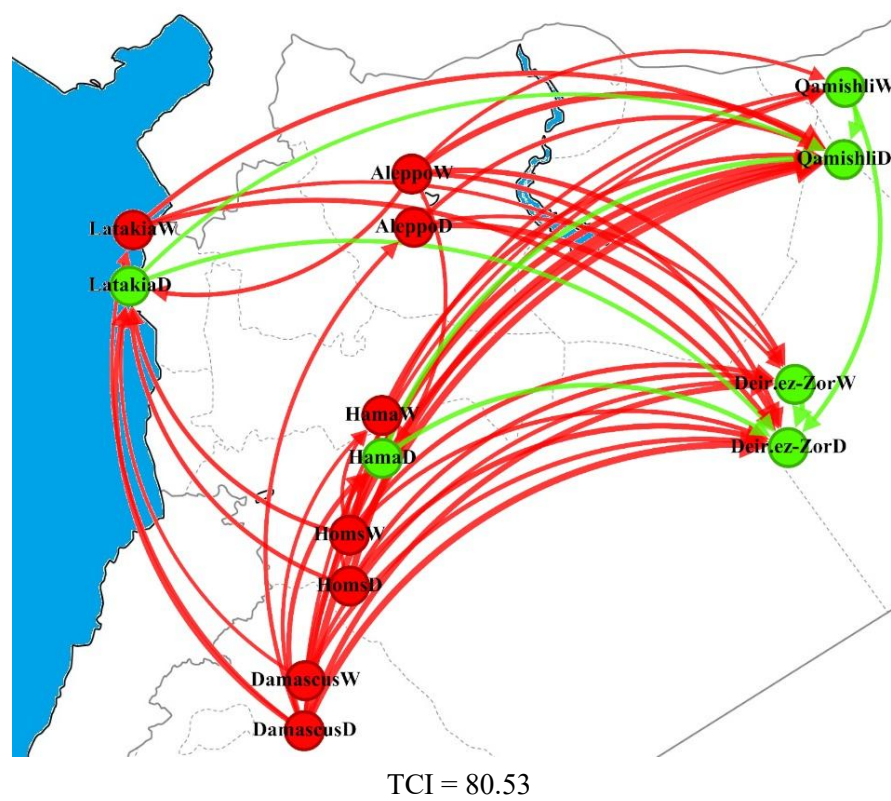
521 Notes: Panels a and b show the total directional connectedness (“to others” and “from others”) of wheat prices in Damascus and Deir ez-Zor, respectively, with
522 wheat and diesel prices in the other cities. Panel c shows conflict-related fatalities in Syria, based on data from the Syrian Observatory for Human Rights (2025).
523 Vertical dashed lines indicate key conflict and political milestones: (g) the formation of the Free Syrian Army and the shift toward armed conflict (July 2011);
524 (h) the chemical weapons attack in the Damascus suburbs (August 2013); (i) the fall of Aleppo and the resumption of the Geneva peace talks (December 2016);
525 (j) the Idlib ceasefire agreement (March 2020); and (k) the large-scale amnesty declared by the Assad regime (April 2022).

5.3 Average connectedness between domestic fuel and food prices in Syria

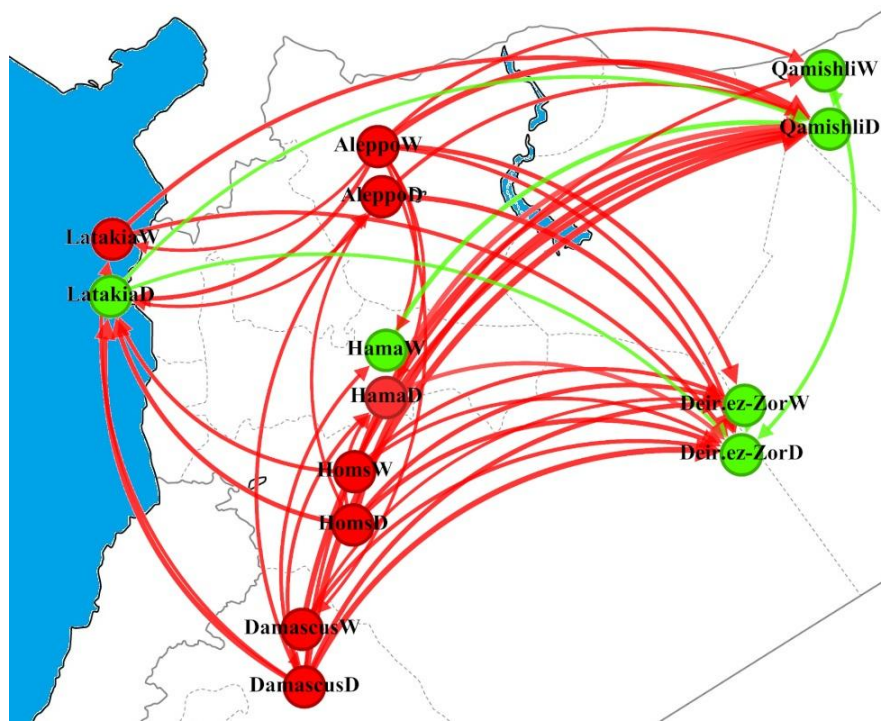
This section examines average connectedness between diesel and wheat markets across the seven Syrian cities. Fig. 5 reports the network structure across the overall, short-frequency, and long-frequency domains. Markets with positive net connectedness are interpreted as net transmitters of price shocks, whereas those with negative net connectedness are interpreted as net receivers. The results show clear heterogeneity across cities and commodities. Wheat prices in Deir ez-Zor and Qamishli, together with diesel prices in Deir ez-Zor, Latakia, Qamishli, and Hama, appear mainly as net receivers. By contrast, wheat prices in Damascus, Aleppo, Homs, Hama, and Latakia, as well as diesel prices in Damascus, Aleppo, and Homs, appear mainly as net transmitters. This pattern indicates that central and western markets played a more active role in domestic fuel-food price transmission, while eastern and northeastern markets were more weakly integrated into the national network.

The frequency-specific results also show that market roles were not fixed over time horizons. Hama wheat and Latakia diesel shift from net receiver positions in the short-frequency domain to net transmitter positions in the long-frequency domain. Conversely, Hama diesel and Homs diesel shift from net transmitter positions in the short-frequency domain to net receiver positions in the long-frequency domain. These differences suggest that short-run transmission was shaped mainly by fuel availability, transport costs, and market access, whereas longer-run transmission reflected more persistent institutional, production, and distribution channels.

a. Overall price transmission between wheat and diesel

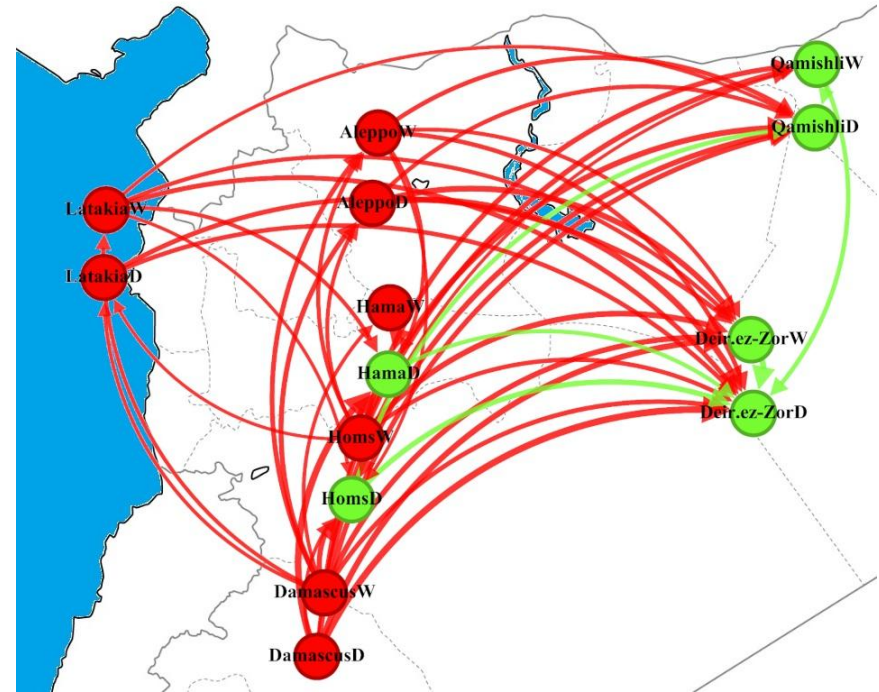


b. Short-term price transmission between wheat and diesel



TCI = 60.19

c. Long-term price transmission between wheat and diesel



TCI = 20.34

549 Fig. 5. Average frequency connectedness networks for the wheat-diesel market in Syria.

550 Notes: Red nodes indicate net transmitters of shocks, while green nodes indicate net receivers. Arrows show the direction of spillovers between variable pairs.
551 In each panel, net pairwise directional connectedness values are displayed from the mean to the maximum value. Variable abbreviations correspond to those
552 listed in Table 2.

Table 4 reports the overall average connectedness between diesel and wheat markets in detail. Deir ez-Zor and Qamishli occupy relatively weak positions in the national diesel-wheat price network. In Deir ez-Zor, the diesel market records a low "to others" value of 11.27 and a "from others" value of 42.75, while its own connectedness remains high at 57.25. A similar pattern is observed for Deir ez-Zor wheat. Qamishli also shows limited intercity connectedness and relatively strong local dependence. These results are consistent with weaker integration of eastern and northeastern markets, reflecting geographic remoteness, conflict exposure, damaged infrastructure, fragmented governance, and cross-border market orientation.

These findings indicate pronounced market fragmentation in eastern and northeastern Syria. Despite Deir ez-Zor's status as an oil-producing region, its weak integration with national markets suggests significant geographic and economic isolation, likely due to prolonged conflict, infrastructure destruction, and limited institutional capacity. Similarly, Qamishli's peripheral location and political separation contribute to a localised price formation process shaped more by regional dynamics and cross-border trade than by national market mechanisms. Western and central cities display stronger network positions. Damascus, Aleppo, and Homs show higher connectedness in both wheat and diesel markets, consistent with their roles as major consumption, administrative, and distribution hubs. Latakia is Syria's main port city, but its diesel connectedness remains more limited than that of Damascus and Aleppo. This suggests that port access alone did not guarantee strong national price transmission; administrative allocation, trade restrictions, and inland logistical bottlenecks also shaped the movement of diesel price signals.

Table 4 further shows that the number of net pairwise directional connectedness links is higher in wheat markets than in diesel markets, with 53 links for wheat compared with 38 for diesel. This indicates that wheat prices were more nationally connected than diesel prices. The stronger wheat connectedness is consistent with the institutional importance of wheat and bread distribution through procurement, reserves, milling, and public distribution systems. Diesel markets, by contrast, appear more fragmented because fuel availability depended more heavily on local route control, administrative allocation, informal trade, and physical supply bottlenecks.

Overall, these results show that fuel-food price transmission in Syria differed across commodities and cities. Wheat markets were relatively more nationally connected, while diesel markets remained more spatially fragmented. This distinction is policy-relevant because weak diesel connectedness can constrain food transport and distribution even when wheat markets themselves remain relatively integrated.

597 Table 4. Overall average connectedness between wheat and diesel markets.

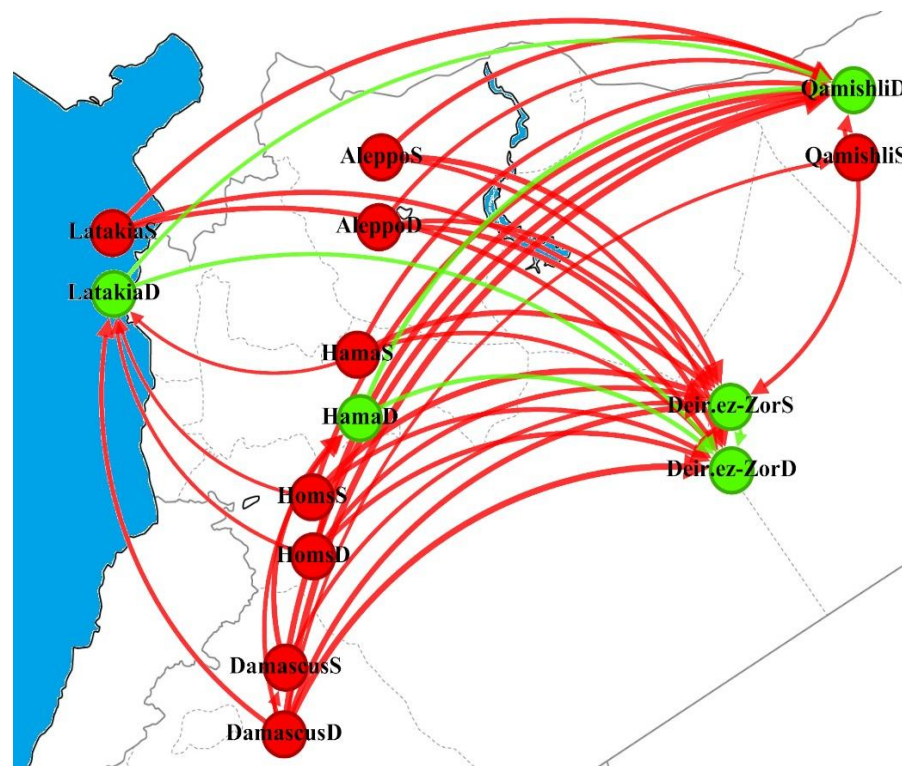
No.	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	FROM
1	DamascusW	13.22	9.91	4.78	10.75	7.91	8.20	7.91	8.83	6.78	0.63	7.74	4.71	3.30	5.34	86.78
2	AleppoW	9.37	12.8	5.24	9.83	8.07	7.32	8.11	9.36	6.65	0.59	7.93	4.98	3.05	6.70	87.2
3	Deir.ez-ZorW	6.82	8.03	19.87	7.49	6.15	6.79	5.14	8.60	8.12	1.75	8.35	6.22	1.17	5.50	80.13
4	HomsW	10.37	9.72	4.91	12.8	8.16	7.52	8.52	9.01	6.88	0.62	7.82	4.90	2.94	5.82	87.2
5	LatakiaW	8.57	9.23	4.59	9.29	14.85	7.30	7.81	9.62	7.30	0.88	7.38	4.89	2.85	5.43	85.15
6	QamishliW	9.75	9.00	5.67	9.42	7.97	15.98	7.43	8.66	5.88	0.95	6.98	4.98	2.43	4.89	84.02
7	HamaW	8.94	9.38	4.10	10.00	8.23	7.23	14.95	8.86	6.35	0.56	7.25	4.48	2.96	6.71	85.05
8	DamascusD	7.97	9.01	5.32	8.69	8.10	6.72	7.26	12.49	7.97	1.03	9.51	6.05	3.04	6.85	87.51
9	AleppoD	7.59	7.82	6.33	8.16	7.65	5.68	6.30	9.92	15.66	1.25	9.37	6.05	2.33	5.90	84.34
10	Deir.ez-ZorD	3.12	3.07	4.49	2.71	3.47	3.18	1.71	5.15	4.83	57.25	4.02	3.01	0.73	3.26	42.75
11	HomsD	7.67	8.56	5.82	8.07	6.85	5.90	6.42	10.30	8.27	0.85	13.66	6.51	3.09	8.04	86.34
12	LatakiaD	6.19	7.06	5.55	7.09	6.20	5.69	5.41	8.80	7.21	0.95	8.64	19.99	2.41	8.81	80.01
13	QamishliD	7.30	6.92	1.77	6.86	5.44	4.46	5.60	7.38	4.61	0.38	7.17	4.20	31.89	6.02	68.11
14	HamaD	6.36	8.45	4.79	7.52	6.16	5.02	7.46	9.54	6.40	0.83	9.38	7.65	3.28	17.17	82.83
	TO	100	106.16	63.37	105.88	90.35	81.01	85.08	114.03	87.26	11.27	101.52	68.63	33.59	79.27	
	Net	13.23	18.96	-16.76	18.68	5.21	-3.00	0.02	26.51	2.92	-31.48	15.18	-11.38	-34.52	-3.56	
	NPDC	9	11	2	12	8	5	6	13	7	0	10	3	1	4	

598 Notes: Larger values indicate stronger intercity connectedness. Net pairwise directional connectedness (NPDC) indicates how often each market acts as a net
599 transmitter of connectedness.

Fig. 6 presents the average connectedness between sugar and diesel prices across the overall, short-frequency, and long-frequency domains. In the overall network, sugar prices in Deir ez-Zor and diesel prices in Deir ez-Zor, Qamishli, Hama, and Latakia appear mainly as net receivers. By contrast, sugar prices in Damascus, Aleppo, Homs, Qamishli, Hama, and Latakia, together with diesel prices in Damascus, Aleppo, and Homs, appear mainly as net transmitters. These patterns indicate that central and western markets played stronger roles in transmitting sugar-diesel price shocks, while eastern and some peripheral fuel markets were more weakly integrated.

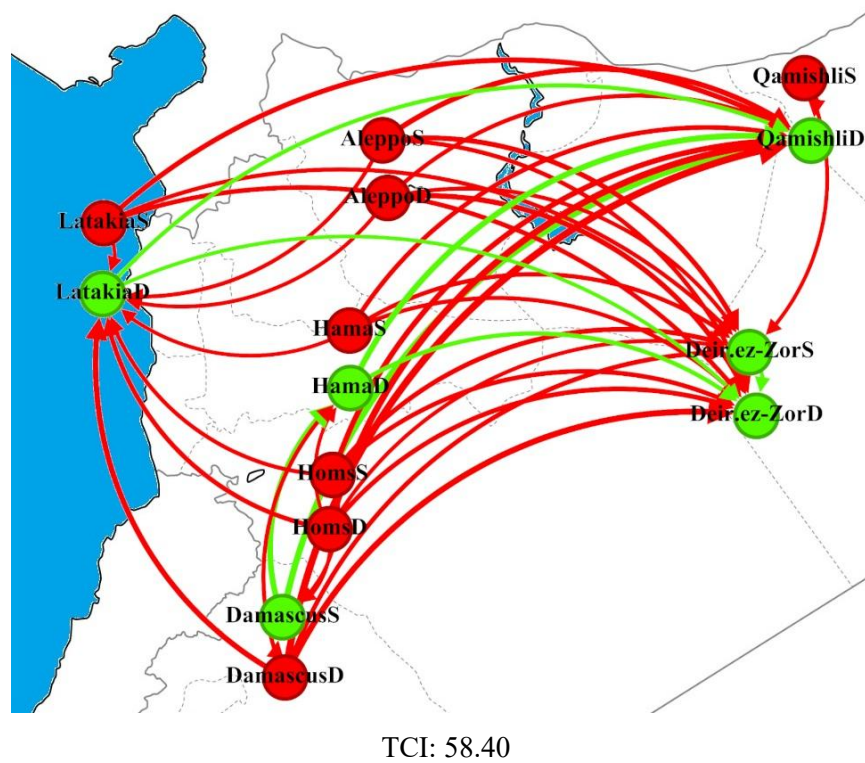
The frequency decomposition shows that market roles varied across horizons. Sugar and diesel prices in Aleppo and sugar prices in Qamishli shifted from net transmitter positions in the short-frequency domain to net receiver positions in the long-frequency domain. By contrast, diesel prices in Latakia and sugar prices in Damascus shifted in the opposite direction. These changes are consistent with the wheat-diesel results and indicate that domestic fuel-food price transmission was not fixed across either space or frequency.

a. Overall price transmission between sugar and diesel



TCI: 79.72

b. Short-term price transmission between sugar and diesel



c. Long-term price transmission between sugar and diesel

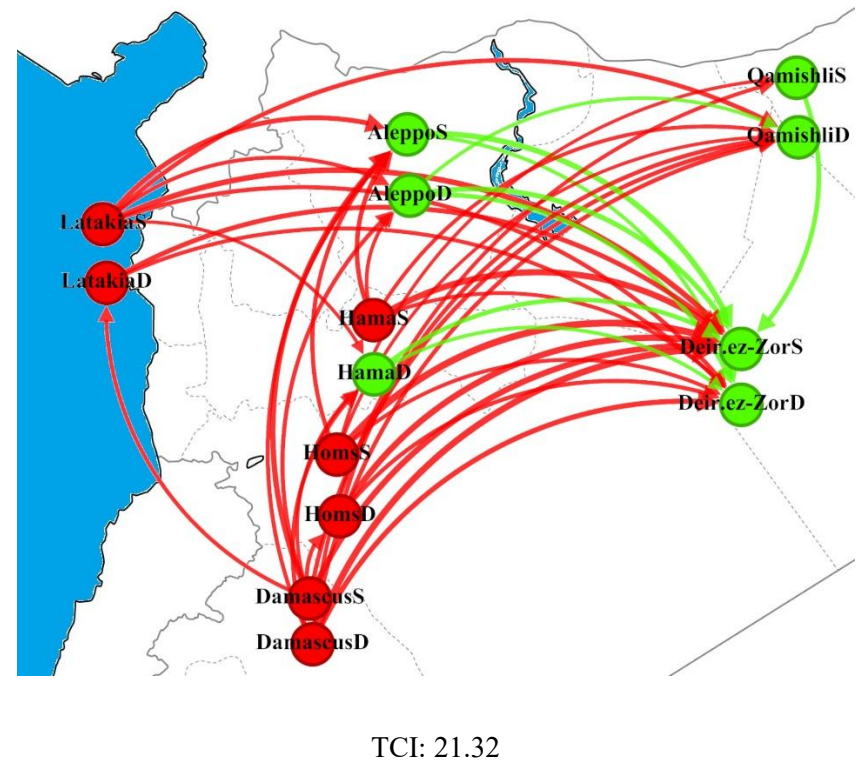


Fig. 6. Average frequency connectedness networks for the sugar-diesel market in Syria.

Notes: Red nodes indicate net transmitters of shocks, while green nodes indicate net receivers. Arrows show the direction of spillovers between variable pairs. In each panel, net pairwise directional connectedness values are displayed from the mean to the maximum value. Variable abbreviations correspond to those listed in Table 2.

Table 5 reports the overall average connectedness between sugar and diesel markets⁴. The Deir ez-Zor sugar market shows low outward connectedness (TO = 13.89) and inward connectedness (FROM = 44.47), but high own connectedness (55.53). This indicates that sugar price formation in Deir ez-Zor was relatively localised and weakly connected to the national market network. Qamishli shows a similar pattern, consistent with its peripheral location, cross-border orientation, and weaker integration into national distribution channels.

Compared with wheat, sugar markets show lower net transmission in major cities. For example, net connectedness values for sugar markets in Damascus (+4.04) and Aleppo (+8.26) are lower than those for wheat markets in the same cities (+13.23 and +18.96, respectively). This difference is consistent with sugar's greater dependence on imports, exchange-rate conditions, and administrative pricing rather than domestic production and procurement networks. The comparison reinforces the importance of interpreting connectedness through commodity-specific institutions rather than treating food markets as a homogeneous category.

Finally, the short- and long-frequency results reported in Appendix C, Tables A.1 and A.2, show that short-frequency connectedness generally exceeds long-frequency connectedness. This supports the total connectedness results and suggests that both wheat-diesel and sugar-diesel linkages were shaped more strongly by short-run logistics, fuel availability, and distribution constraints than by longer-run structural adjustment.

⁴ To conserve space, the short-term and long-term connectedness results for diesel and sugar prices are presented in Appendix C, Table A.2.

646 Table 5. Overall average connectedness between sugar and diesel markets.

No.	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	FROM
1	DamascusS	14.68	8.33	3.58	9.22	7.14	6.93	8.33	9.87	6.86	0.82	8.94	5.78	2.58	6.93	85.32
2	AleppoS	8.16	14.59	4.04	9.18	8.03	6.46	8.43	9.07	10.05	0.86	7.84	5.17	2.64	5.47	85.41
3	Deir.ez-ZorS	6.03	7.61	28.26	7.29	6.73	5.8	6.57	6.54	5.64	2.89	6.08	5.01	1.47	4.09	71.74
4	HomsS	8.04	8.29	3.43	13.27	8.43	8.28	10.73	9.61	7.45	1.14	7.64	5.17	2.79	5.73	86.73
5	LatakiaS	6.96	7.46	3.72	8.91	14.13	8.88	9.20	9.42	7.63	1.24	7.85	5.51	2.60	6.51	85.87
6	QamishliS	7.07	6.80	3.33	9.66	9.80	15.83	10.37	9.37	6.51	0.43	7.37	4.29	2.84	6.33	84.17
7	HamaS	7.53	7.71	3.22	10.88	8.93	9.23	13.65	9.34	7.48	1.20	7.35	5.12	2.39	5.98	86.35
8	DamascusD	8.20	7.72	2.90	9.17	8.19	7.64	8.50	12.80	8.08	1.06	9.65	6.19	3.13	6.78	87.20
9	AleppoD	6.85	10.29	2.94	8.35	8.17	6.58	8.25	9.62	15.30	1.10	9.01	6.11	2.11	5.32	84.70
10	Deir.ez-ZorD	2.31	3.42	4.50	3.94	4.2	1.62	3.66	5.25	4.48	55.53	3.88	3.16	0.77	3.29	44.47
11	HomsD	8.19	7.46	3.05	7.86	7.62	6.71	7.43	10.56	8.38	0.85	14.15	6.53	3.22	7.99	85.85
12	LatakiaD	6.98	6.64	3.51	6.91	7.03	5.09	6.77	9.01	7.39	0.97	8.53	19.93	2.29	8.94	80.07
13	QamishliD	5.10	5.66	1.65	6.05	5.94	5.19	5.25	7.79	4.53	0.53	7.49	4.36	34.13	6.33	65.87
14	HamaD	7.95	6.27	2.60	6.94	7.75	6.88	7.10	9.40	5.97	0.81	9.29	7.94	3.36	17.73	82.27
	TO	89.36	93.67	42.47	104.35	97.97	85.28	100.6	114.84	90.44	13.89	100.92	70.34	32.22	79.70	
	Net	4.04	8.26	-29.28	17.62	12.09	1.11	14.25	27.64	5.74	-30.58	15.06	-9.73	-33.65	-2.57	
	NPDC	6	8	2	12	9	6	11	13	6	0	10	3	1	4	

647 Notes: Larger values indicate stronger intercity connectedness. Net pairwise directional connectedness (NPDC) indicates how often each market acts as a net
648 transmitter of connectedness.

6. Policy implications

The findings do not imply that market integration should be pursued as an abstract policy objective. In conflict-affected economies, its value lies in improving food access, fuel availability, and the ability of public and humanitarian institutions to respond to local scarcity. The results suggest that policy should focus on reducing the transaction costs that prevent goods, fuel, and price information from moving across cities, particularly in weakly connected markets such as Deir ez-Zor and Qamishli.

In the short term, emergency reserves and humanitarian assistance should be guided not only by population size, but also by market connectedness. Cities that are weakly connected or highly self-dependent require larger buffer stocks because they cannot rely on rapid supply responses from other regions during shocks. Measures such as protected transport corridors, targeted fuel allocations for food distribution, temporary fee waivers, and negotiated reductions in checkpoint costs would directly address the short-frequency transmission failures identified in the analysis.

Policy responses should also be commodity-specific. For wheat, the priority is to maintain transparent procurement, reserve management, milling capacity, and bread distribution, rather than to withdraw the state abruptly from a strategic staple market. For diesel, the key concern is logistics: fuel availability for transport, irrigation, milling, generators, and food distribution should be protected because fragmented diesel markets can disrupt food movement even when food supplies exist. For sugar, which is more import- and exchange-rate exposed, policy should focus on port logistics, access to foreign exchange for essential imports, and monitoring of wholesale distribution.

In the long term, reconstruction of roads, bridges, storage facilities, rail links, and market information systems would reduce the transport and information costs that limit arbitrage. A national price and inventory monitoring system could help identify when specific cities become unusually disconnected from the wider market network. Competition policy may become important as markets recover, but abrupt liberalization or subsidy removal could worsen food insecurity if implemented before security, transport, and safety-net

institutions are restored. A sequenced approach is therefore preferable: preserve essential stabilization functions while increasing transparency, reducing rent extraction, and expanding competition where markets can function.

Finally, the results show that connectedness analysis can serve as a practical diagnostic tool for humanitarian and reconstruction planning. Instead of relying only on national average prices, policymakers can identify which cities transmit shocks, which cities are isolated receivers, and when diesel price disruptions are likely to affect food markets. Market integration should therefore be understood as a tool for prioritizing corridors, reserves, fuel logistics, and information systems, not as a substitute for broader political settlement and institutional rebuilding.

7. Conclusions

This study used monthly data from January 2011 to December 2024 to examine fuel-food price transmission in Syria under prolonged conflict. Wavelet coherence analysis was used to assess the relationship between global oil prices and domestic diesel, wheat, and sugar prices, while frequency-domain TVP-VAR connectedness analysis was used to examine domestic price transmission across seven Syrian cities. The results show that global oil price pass-through to domestic Syrian markets was episodic, time-varying, and institutionally mediated. Transmission strengthened during periods associated with partial recovery in logistics, market access, and administrative capacity, but weakened during periods of severe conflict and market disruption.

The main contribution of the study is to show that conflict affects not only price levels, but also the structure of price transmission. Damascus, Aleppo, and Homs generally played stronger transmitter roles, while Deir ez-Zor and Qamishli remained more weakly integrated into the national price network. The results also show clear commodity-specific differences. Wheat displayed stronger national connectedness than diesel, consistent with the continuing role of procurement, milling, reserves, and bread distribution

institutions. Diesel was more spatially fragmented, which is important because fuel availability shapes food transport and distribution. Sugar showed a more balanced and import-exposed structure, reflecting its greater dependence on trade, exchange-rate conditions, and distribution channels. These findings demonstrate the importance of interpreting fuel-food price transmission through commodity-specific institutions and conflict-related market frictions.

Several limitations remain. The sample covers Syria's conflict and immediate transition period but does not include a stable pre-conflict baseline. The results should therefore be interpreted as evidence of time-varying price transmission under conflict, rather than as a causal estimate of war relative to peace. Official price data may also understate informal and black-market dynamics, and the absence of consistent data on trade flows, inventories, routes, checkpoint costs, and quantities limits the use of structural gravity or parity-bounds models. Future research should combine price data with geocoded violence, road access, control-zone histories, market quantities, and policy intervention records. Such extensions would allow stronger tests of the mechanisms suggested here and would improve the use of market-integration analysis for food-security programming in fragile and conflict-affected economies.

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847

848 **Ethics declaration**

849 Not applicable. This study uses publicly available secondary market price and conflict data and does not
850 involve human participants, human data, or animals.

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