

Market resilience in times of crisis: The case of Darfur

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Abstract

This article focuses on market behavior during crises. It provides an analysis of market functioning in North Darfur, Sudan, over a decade when both natural and manmade disasters were experienced. Results obtained using two rigorous methodological approaches highlight how markets not only remained functional during crises, but even operated more efficiently after a shock than in normal conditions. While our analysis focuses on specific events, we argue that our findings have general validity and application.

KEYWORDS

crisis, Darfur, market integration, market-based interventions, price transmission

JEL CLASSIFICATION

O1; Q2; O5; O12; Q21; O55

1 | INTRODUCTION

It has been highlighted that famines occur with and without declines in food supply, under both socialist and capitalist economic systems, and with or without wars or natural disasters. This has led to the recognition of constraints to accessing food as a major cause of food deprivation (Dreze & Sen, 1989; Ravallion, 1997). Access is considered not only in terms of consumers' purchasing capacity, but also as one of the major economic factors that help to make supply meet demand (Seaman & Holt, 1980). In fact, the consideration that the majority of the world's population relies on markets to access food

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and organize its production highlights the key relevance of markets. The better the functioning of a market, the easier the matching of buyers and sellers.

Recognition of the importance of markets has led to the increasing adoption of market-based strategies to promote local economic growth and even recovery after disasters. It is argued that injecting cash into the local economy has a multiplier effect, improving access to finance, providing economic opportunities, protecting social capital, and promoting local networks. In its extreme version, market-support interventions target market actors, service, or infrastructure providers, with the final aim of benefiting the local community that relies on the local market system.

But what really happens to market functioning during a crisis? Do markets continue to function unaffected or is their activity disrupted, even ceasing completely? Or, if somewhere in between, what is the size of the disruption, if this can be measured at all? This study contributes to the discussion of market resilience during crisis periods through a specific case study: market functioning in Darfur during one of the major humanitarian crises in recent years. The discussion below is organized as follows: Section 2 presents current knowledge; Section 3 outlines the methodology and data used in this analysis; Section 4 presents and discusses the empirical results; and Section 5 summarizes the findings and concludes.

2 | LITERATURE REVIEW

2.1 | Market resilience during crisis

The link between market functioning and famine has been the subject of ample discussion. Along the lines of Adam Smith's (1776) classic case for free trade in foodstuffs, supporters of free trade argue that markets help to minimize the damage done by harvest shortfall. By pursuing their comparative advantage and promoting the exchange of their produce, producers in different regions increase the aggregate output and income, thereby reducing the damage caused by any given shortfall. On the contrary, a different view argues that markets can exacerbate subsistence crises by helping to move food from needy areas with low purchasing power to richer less-affected areas (Dreze & Sen, 1989).

Despite the conflicting perspectives, the verdicts of empirical analyses on market behavior during famines are mixed. Various studies have found evidence of market failure with reference to major famines, including the Great Bengali Famine of 1942–1943, the Bangladesh Famine of 1974, and the famines in Sudan, Kenya and Ethiopia during the 1980s, to mention just a few (von Braun et al., 1999; Quddus & Becker, 2000; Ravallion, 1987, 1997; Sen, 1981). On the contrary, a few studies have found that the severity of the crisis can overwhelm market forces even when dealing with functioning markets. This was the case with the famines of 1693–1694 and 1708–1710 in France, during the 1840s in Ireland, during the 1860s in Finland, and in India in the nineteenth century. O'Gráda (1997, 2001, 2005) shows that during these crises, markets worked smoothly and even more reactively than under normal conditions.

Most economists would agree that efficient market structures are a prerequisite for further economic growth (Studer, 2008), and therefore the results of O'Gráda's (1997, 2001, 2005) analysis are encouraging and supportive of market-based strategies for promoting recovery after a crisis and even market resilience during crises. In fact, during the past few years the international community has become progressively aware of the relevance of market-based interventions, which led to a proliferation of market-based interventions and research about their feasibility, efficiency and effectiveness (e.g., Albu, 2010; Barrett et al., 2007; De Matteis et al., 2017; Lentz et al., 2013; Margolies & Hoddinott, 2015, among others).

The following factors affect market resilience: stakeholders' capacity, social and physical infrastructure, governance and local institutions. All such elements play a key role in affecting market functionality in one way or another and, arguably, the same factors are expected to affect local development in the long term.

Analysis of household data in vulnerable settings suggests that vulnerable groups typically rely heavily on markets as a source of food (Ravallion, 1997).¹ Survey evidence shows that the share of poor households' food consumption procured through the market is usually high in both stable and unstable conditions. This reflects a common pattern across countries and different levels of development.² Furthermore, research has shown that urbanization and rapidly spreading supermarket networks, particularly in middle- and low-income countries, are contributing to raising the proportion of household food which is procured through markets (Bettencourt et al., 2007; Dolislager, 2017; Gómez et al., 2013; Huang & Bouis, 2001; Kennedy & Reardon, 1994; Senauer et al., 1986).

While the demand for food—and particularly staple or basic food—is inelastic to price changes, particularly among the lower strata of population, the situation is rather diverse in terms of elasticity of supply. Under an assumption of free trade and perfect competition, supply for a small importing country is perfectly elastic. In almost all cases in middle- and low-income countries, producers and traders face increasing marginal costs so that the elasticity of supply is greater than zero. De Matteis (2014) makes the case that supply elasticity in marginal and resource-poor areas is on the average lower than in productive areas, particularly when they are a long way from major commercial centers and transport networks. Supply elasticity can be constrained by the reduced availability of—and/or access to—critical inputs such as commodities or credit. In middle- and low-income countries the supply chain and access to credit are less than perfect at the best of times, and it is very likely that their performance worsens during a crisis (Ravallion, 1997). In this regard, there is abundant evidence that market and non-market credit institutions perform less well during crises, undermining the supply chain. In general terms, quite often unbalanced market behavior reflects a low level of competition due to, for instance, collusion between traders (Sanogo & Amadou, 2010). Nevertheless, Levine (2017) highlights how price rises determined by an imbalance of supply and demand, due to either a shortage of the former or an increase in the latter, sometimes perceived as a sign of market failure, are often powerful and effective signals that stimulate new trade into a market.

In vulnerable and crisis-prone economies, markets are not simply arenas of economic exchange. Research has abundantly shown how political and military powers restrict business opportunities and the flow of goods and services to favor some groups over others, with the final aim of gaining, maintaining, and/or strengthening their position of power (e.g., Acemoglu et al., 2002; Easterly, 2001; Easterly & Levine, 2003; Flachaire et al., 2014; Levine, 2017). This reaches its worst expression in war economies. Having said that, case studies have shown how the governance and moral economy of markets are far from straightforward and require a more in-depth sociological and anthropological understanding (Levine, 2017). For instance, various accounts report that despite deliberate and continued attacks on traders that raised the costs of moving food, looting was rather limited and trade never stopped completely (e.g., Barbelet & Diallo Goita, 2015; Mosel & Henderson, 2015).

2.2 | The case of Darfur

Darfur provides an excellent opportunity to study market resilience during crises. It is a vast region that is generally resource-poor, remote, and rather disconnected from the main economic and political centers, both in Sudan and abroad, with fragile social and physical infrastructure. Institutional capacity and overall governance at all levels are weak, and are both the source and the outcome of

protracted periods of instability. Nonetheless, Eldredge and Rydjeski (1988) concluded that markets are the major and most effective response mechanisms to food crises in Darfur, and in general in the semi-arid areas of Sudan, where people are permanently at risk of food shortages and crises.³

Darfur occupies a vast, sparsely populated territory in western Sudan where seasonal weather impacts on livelihoods. Except for land near the *wadis* that permits intensive cultivation, the environment is best suited for extensive farming and herding. Sedentary agro-pastoralists grow rainfed millet, sorghum, groundnuts and sesame. Yields are relatively low, reflecting unreliable rainfall, poor soils, and low-input agriculture. Semi-nomadic and nomadic pastoralists are involved at different degrees with seasonal migrations, following the northward advance of the rains and returning when the rains retreat southward 2–3 months later. For agro-pastoralists, the hungry season occurs during the rainy season when labor requirements are highest but consumption is the lowest. For pastoralist groups, the hungry season comes in the last months of the dry season between March and June when few animals provide milk and food consumption is limited to market purchases and wild foods (Hamid et al., 2005).

Households attempt to diversify their incomes to cope with expected seasonal stresses. In addition to farming and herding, nearly all Darfur households engage in some sort of trading.⁴

De Waal (1989, 1991) and El Dukheri et al. (2004) identify three tiers of grain markets in Darfur: village markets, large rural markets, and urban markets. The village market is the first level of the marketing process, in the form of few village shops, where consumers can purchase basic food commodities, and also where farmers can sell agricultural products in small quantities. Rural markets are the next level of the marketing system, where people from many villages get together weekly or bi-weekly. Rural markets work as an aggregating point of merchandise. They vary markedly in size, where some are exceptionally big attracting traders from across state boundaries or even from neighboring countries. Finally, urban centers have specialized grain markets in the main urban centers, where wholesalers often engage in retailing too.

Grawert (1998) provides a good insight of Kutum market, one of the largest markets in Darfur. During the main season, twice a week the market center is packed with petty vegetable traders. During the rainy season, the market shrinks to about a quarter of its summer size, because the bulk of the harvest from the *wadi* gardens is sold by then, and customers as well as petty traders are busy cultivating their fields. The prices for vegetables on offer at Kutum market fluctuate according to supply and demand throughout the year. During December, supply is scarce and prices at their highest level. Those few traders who can afford to store their produce for such a long time make high profits, particularly if they sell them in El Fasher. July is the month with the least profit, because most of the producers need the cash immediately after harvest and do not have suitable storage facilities. Some petty traders have special contracts with middlemen or wholesalers, who resell those crops at the markets of El Fasher, Um Keddada, and other centers, making much higher profits than the Kutum market vendors (Umbadda & Abdul-Jalil, 1984). Only a few gardeners take advantage of the high profits from vegetable sales at urban markets, sharing the sale of their vegetables between husband and wife: whereas the man takes the better quality crops to El Fasher by camel or lorry, the woman sells the crops of poorer quality to Kutum customers (Grawert, 1998).

Historically, the greater Darfur region was self-sufficient in cereal production, and in years of widespread drought the food gap was filled through commercial grain flows from Central Sudan into the region (De Waal, 1989; Teklu et al., 1991). Despite these sporadic grain flows, the economic forces driving food prices and market flows in the two areas are different, even because both are landlocked and isolated from international food markets.

The sub-Saharan drought of 1983–1985 precipitated a widespread famine in Sudan, which reached its peaks in Darfur where it killed more than 100,000 people and left many more destitute (De Waal, 1991). Afterwards, a few years of drought accompanied the turn of the century and the breakout

of the internal conflict of the early 2000s exacerbated the situation. The conflict greatly hindered commercial flows between Darfur and Central Sudan, while also causing a plunge in cereal production in the former due to displacement and reduced access to farmland. The displacement turned many cereal producers into net consumers and rapid displacement-induced urbanization also triggered an increase in the demand for cereals (Buchanan-Smith et al., 2014; Young et al., 2005). Despite Darfur's long tradition of cross-border trade with Chad and the Central African Republic, the huge gap between increased demand and reduced supply was hard to fill due to conflict and insecurity that disrupted trade routes and raised transportation and trading costs. Anecdotal reports remark how trade routes opened and closed according to the changing dynamics of the conflict. While some trade flows changed direction as local sources became available, a few were remarkably resilient, constantly adapting to the dynamics of localized conflicts (Buchanan-Smith & Fadul, 2008; Buchanan-Smith et al., 2014).

Food aid was unprecedented in scale and coverage, especially in the early years of the conflict.⁵ It helped to offset the reduction of Darfur's cereal production and the limited commercial inflow of grain caused by the conflict. Contrary to the usual criticism of the disruptive impact of food aid by forcing cereal farmers and traders out of business and delaying market recovery after a crisis (e.g., Barrett et al., 1999; Gelan, 2006; Levine, 2017; Tadesse & Shively, 2009), in Darfur in-kind food aid was likely an important source of supply that facilitated the functioning of cereal markets and stabilized prices (Buchanan-Smith et al., 2014; Dorosh & Subran, 2011).

Overall, markets in Darfur have regularly been under stress due to either manmade or natural disasters. Nevertheless, available evidence seems to show that they are resilient overcoming protracted and repeated conditions of hardship.

2.3 | Market integration

Spatial price transmission has been widely analyzed in the context of the “law of one price” which assumes that if two markets are linked by trade in a perfectly efficient market, the movement of prices in one market will be reflected in price movements of the same magnitude in the other market in the long run, although there may be deviations in the short run. In this context, spatial price transmission can be defined as the process and degree to which markets for homogeneous commodities at spatially separated locations share long-run market information (Amikuzuno, 2009; McNew, 1996). Therefore, although price analysis tells us little or nothing about actual trading behavior (Barrett & Li, 2002; Baulch, 1997), it is common practice to analyze price transmission to assess market integration, with the implicit or explicit assumption that lack of market integration implies market inefficiency (Rashid & Minot, 2010). This is done with the understanding that there may be market integration without price transmission if transaction costs are nonstationary, and there may be price transmission between two markets without market integration if there is a third market explaining the price-making in the other two.

A simple measure of the degree of price transmission between two markets is the correlation of time series of prices which are prevalent in the two markets over time. Generally, a high correlation implies more integration (FEWSNET, 2009). A more in-depth and reliable analysis can be conducted through the methodological framework related to cointegration. The concept of cointegration (Granger, 1981) and the methods for estimating a cointegrated system (Engle & Granger, 1987; Johansen, 1988, 1991, 1995) provide a framework for estimating and testing equilibrium relationships between nonstationary⁶ integrated variables. Cointegration methods are not immune to limitations (Barrett & Li, 2002; Rapsomanikis et al., 2003); however, they are currently considered the most appropriate approach for analyzing spatial market relationship (Rapsomanikis et al., 2003). A

comprehensive analytical framework for this econometrics approach can be found in Balcombe and Morrison (2002) and Rapsomanikis et al. (2003).

Cointegration between the price series implies that prices may behave in a different way in the short run, but that they will converge toward a common behavior in the long run. Therefore, if this property of the dynamic relationship between prices is verified, the analysis can lead to measure both the degree of price transmission from one market to the other and the speed of price transmission (Prakash, 1999). These results are much more informative—beyond being more precise—than those provided by a simple correlation. Nevertheless, they are also more demanding in terms of time and skill resource requirements. Therefore, while cointegration analysis is widely adopted in studies of development policy, its use is rare when dealing with crisis situations.⁷

The studies conducted by O'Gráda (1997, 2001, 2005) are particularly relevant to the purposes of the present research. The results of his analysis of spatial and temporal patterns of food-price movements during famines in pre-industrial Europe and in India indicate that markets functioned “normally” in times of crisis.

With particular reference to Sudan, Dorosh and Subran (2011) conducted cointegration analysis of staple food price time series in the main markets throughout the country. Their analysis highlighted the absence of a stable commercial interconnection confirming the existence of separate markets in Darfur and in the rest of the country, as mentioned above.

Along the same analytical approach adopted by Dorosh and Subran (2011) and particularly by O'Gráda (1997, 2001, 2005), the present analysis will focus deeper at local level in Darfur, in order to assess the degree of market resilience during crises.

3 | DATA AND METHODOLOGY

3.1 | Data

Studies of market integration can consider the prices and the quantities exchanged, or focus only on one of these two variables due to data limitation, as in the present case. The present analysis makes use of price time series data. In particular, we make use of monthly millet prices as millet is Darfur's preferred staple food and most important agricultural crop.

Data were sourced from the Darfur Food Information System (DFIS) which was run by Save the Children in North Darfur from the early 1990s until 2004. The initiative had its roots in the famine in North Darfur in the mid-1980s and ended as a consequence of the drastic worsening of security conditions induced by the conflict. Throughout its lifespan the DFIS was able to document local livelihood patterns and changes under both stable conditions and various conditions of stress. The Consumer Price Index for North Darfur from the Central Bureau of Statistics is used to deflate millet prices, which are expressed in Sudanese Dinar (SDD).

This study focuses on four markets, with three urban markets—Kutum, Um Keddada and Al Malha—which relate to the major market in El Fasher, the capital of North Darfur, as shown in Figure A1.

The period covered by this study runs from January 1996 to December 2004, when the DFIS project stopped. By the end of the project, the regional conflict had already been going on for more than a year, and the impact of insecurity on agricultural production and cereal trade is captured through a dummy (D_{Conflict}) from July 2003 onward. Along the same lines, the high variability in cereal production, typical of Darfur, is captured through another dummy (D_{Harvest}), which, on the basis of agricultural production data from the Ministry of Agriculture and DFIS, highlights how the year 1998–1999

recorded a good harvest compared to the medium and poor harvests recorded in all the other years in the period considered. In particular, because of the absence of data about the amounts of local production and trade flows, the dummy D_{Harvest} was defined to be equal to 1 in months of poor harvests (i.e., through the months corresponding to the higher level of prices compared to the average trend observed in El Fasher, Kutum, Al Malha, and Um Keddada markets). Our assumption that higher prices characterize periods of lower harvests has led us to identify the two periods—respectively between January 1996 and November 1998 and between January 2000 and June 2003—when market prices were influenced by lower harvest.

Table 1 provides the summary statistics about millet price data in the four markets considered in this study. The lowest minimum price is found in Kutum and the mean price tends to regularly increase when moving from Kutum to El Fasher and Um Keddada. This provides support to what was mentioned by Grawert (1998) about the trading patterns between Kutum and the other two markets. Nonetheless, maximum prices are regularly lower in El Fasher than in the other markets.

In addition to the above, the widest price variability is observed for the relatively smaller market in Al Malha. It is worth considering that Al Malha is the farthest urban center—among the ones considered here—from El Fasher, and the two centers are connected by a secondary road.

The correlation matrix in Table 2 tells us more about how the series of millet prices in the four markets are related. All correlations are statistically significant. The highest correlation is observed between Um Keddada and El Fasher, which are closely tied to each other by the main road. El Malha—which is a distant center from El Fasher and the two centers are connected to each other by a secondary road—has comparably the smallest correlation (although still high) with El Fasher.

The points raised above lead us to a couple of considerations. First of all, millet prices in Um Keddada, Kutum and Al Malha are closely correlated with millet prices in El Fasher. In fact, each of the three markets has its highest price correlation with El Fasher. Although this consideration does not imply any direction of causality, it highlights the relevance of El Fasher as a price maker. This supports the geographical distribution of the four centers and the availability of road transport interconnecting them: logistically, Um Keddada, Kutum and Al Malha are directly connected only with El Fasher. In addition to the above, the correlation coefficients revealed that, the farther the market center from El Fasher, the smaller the price interaction due to more limited trade flow. In this case, we are referring not only to physical distance, but also to economic distance, since the transport unit costs are expected to be higher when making use of secondary roads than primary roads. All the points above lead us to assume that El Fasher is the central market within each of the three market pairs.

The considerations just raised are supported by the analysis of pairwise causality. Results of the Granger causality tests⁸ reported in Table 3 indicate the existence of bilateral causality between El Fasher and Um Keddada and unilateral causality running from these two centers toward remaining two—Kutum and Al Malha. In other words, the two larger markets that are connected to each other by main road have the power to influence prices in Kutum and Al Malha. Having said that, test results indicate also that the price-making power exercised by El Fasher on the other markets is greater than the one exercised by Um Keddada. This is a plausible finding, given that El Fasher has direct road

TABLE 1 Summary statistics of millet real price data (SDD/kg, logged)

Market	No. of obs.	Mean	Std. dev.	Min	Max
El Fasher	108	2.14	0.36	1.43	3.08
Al Malha	84	2.09	0.48	1.53	3.21
Kutum	108	2.06	0.43	1.32	3.32
Um Keddada	108	2.26	0.45	1.43	3.39

TABLE 2 Correlation matrix

	El Fasher	Al Malha	Kutum	Um Keddada
El Fasher	1			
Al Malha	0.77 ^{***}	1		
Kutum	0.84 ^{***}	0.76 ^{***}	1	
Um Keddada	0.94 ^{***}	0.75 ^{***}	0.82 ^{***}	1

Significance: ***= 0.01; **= 0.05; *= 0.1.

TABLE 3 Granger causality between market pairs

	El Fasher	Al Malha	Kutum	Um Keddada
El Fasher	.	0.74	0.95	2.41 [*]
Al Malha	3.84 ^{***}	.	1.73	2.14 [*]
Kutum	7.83 ^{***}	1.84	.	5.12 ^{***}
Um Keddada	3.24 ^{**}	0.88	0.82 ^{***}	.

Note: Direction of causality is from column to row.

Significance: ***= 0.01; **= 0.05; *= 0.1.

access to these secondary markets, whereas the influence exercised by Um Keddada appears to be an indirect effect due to lack of direct road access.

Secondly, the remarkable degree of correlation—higher than 70%—among all the market pairs is also a consequence of the four markets being part of the same geographical region and economic context.

3.2 | Autoregressive approach

This study makes use of time series analysis of market price data to assess the degree of market integration, which is commonly used to examine the effectiveness of market functioning. The basic principle is the assumption that the closer the changes in prices experienced in two markets, the more integrated the two markets can be seen to be. In order to study the interdependence of price time series of a commodity between any pair of markets x and y , we can refer to a linear relationship of the type:

$$y_t = \theta_1 + \theta_2 x_t + u_t, \quad (1)$$

where y_t represents the retail price prevalent on market y at time t , x_t represents the retail price prevalent on market x at time t , and u_t represents the error term.

To conduct a simultaneous analysis of the short- and long-run dynamics of market prices, we make use of the autoregressive distributed lag (ARDL) model, a technique of cointegration developed by Pesaran et al. (2001). The geographical distribution of the market centers considered in this study, as well as the limited availability of transport connections among such centers, suggest that the three markets Kutum, Um Keddada and Al Malha only indirectly relate to each other. Therefore, we feel

that a separate estimation of price change transmission between El Fasher and each of the three markets can help to capture the impact of crisis conditions induced by either conflict or food shortage better. This translates methodologically into preferring ARDL and Seemingly Unrelated Regression (SUR) to a Vector Error Correction (VEC) model approach.⁹ The ARDL model is represented by the following equation:

$$\varphi(L, p)y_t = \sum_{i=1}^k \beta_i(L, q_i)x_{it} + \delta'w_t + u_t, \quad (2)$$

where:

$$\varphi(L, p) = 1 - \varphi_1L - \varphi_2L^2 - \dots - \varphi_pL^p,$$

and

$$\beta_i(L, q_i) = 1 - \beta_{i1}L - \beta_{i2}L^2 - \dots - \beta_{iq_i}L^{q_i}, \quad i = 1, 2, \dots, k.$$

In Equation 2, y_t is the dependent variable, x_{it} denotes the i dependent variables, L is a lag operator, and w_t is a vector of deterministic variables, including intercept terms, dummy variables, time trends, and other exogenous variables. The selection of the optimum lags is conducted through the available selection criteria.

After the estimation of long-run coefficients and of their asymptotic standard error through ordinary least squares, the short-term analysis requires the development of the Error Correction Model (ECM) version of the selected ARDL model. The ECM can be obtained by rewriting Equation 2 in terms of the lagged levels and first difference of $y_t, x_{1t}, x_{2t}, \dots, x_{kt}$ and w_t as follows:

$$\Delta y_t = -\varphi(1, \hat{p})EC_{t-1} + \sum_{i=1}^k \beta_{i0}\Delta x_{it} + \delta'\Delta w_t - \sum_{j=1}^{\hat{p}-1} \phi^* y_{t-j} - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_{i-1}} \beta_{ij}^* \Delta x_{i,t-j} + u_t, \quad (3)$$

and finally, in the above equation, the error correction term, EC_t , is defined by

$$EC_t = y_t - \sum_{i=1}^k \hat{\theta}_i x_{it} - \psi'w_t. \quad (4)$$

In the above equations, ϕ^* , δ' , and β_{ij}^* are the coefficients related to the short-run dynamics of the model convergence to equilibrium, and $\varphi(1, \hat{p})$ is the speed of adjustment.

3.3 | Seemingly unrelated regressions

The autoregressive approach proposed above raises a methodological issue. Each ARDL model is in itself a classical regression, where parameters are estimated consistently, if not efficiently, one equation at a time using ordinary least squares. This assumption of independence of the error terms in each equation implies there are no common factors that influence all the markets. In our case it would be naïve to assume this, because the markets are located in one region and all are embedded in the same macroeconomic structure, and therefore may be intrinsically affected by common economic factors that are not addressed in the model. Therefore, a SUR model is appropriate (Zellner, 1962). SUR is a

type of generalized linear regression model which assumes that error terms of the equations are correlated, implying that there are common observable factors for all equations. SUR provides consistent and efficient parameter estimates, unlike single-equation linear regression models, such as ARDL, that provide only consistent estimates. We use the Breusch–Pagan test to ascertain this.

3.4 | Model specification

Pretesting the order of integration of the variables in question is a preliminary step in the analysis of time series data to avoid spurious regressions. We use the augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Zivot–Andrews unit root tests for stochastic nonstationarity of the price series. The Zivot–Andrews test takes into account endogenous breaks in the series unlike the other two. The sharp price changes between 1998 and 2000 suggest an endogenous break and therefore the Zivot–Andrews unit root test is used.

Of the four series considered, only Kutum is found to be nearly nonstationary.¹⁰ Using under-differenced series can harm regression results more than over-differencing can do (Plosser & Schwert, 1977). The visual inspection of the original and first differenced series, presented in Figures 1 and A2 respectively, as well as the results of the Zivot–Andrews test support the presence of unit roots. Therefore, first-differenced series are used for model estimation.

The presence of unit roots in the price series implies that the markets do not regain equilibrium in the short-run following a shock such as an unusually good or bad harvest or unusual conditions imposed by conflict. Since the short- and long-run dynamics differ, the regression model should include an adjustment parameter. Thus, both the SUR and the ARDL models should be expressed in error-correction form. While we have presented the ECM for the ARDL model in Section 2, we also need an ECM for our SUR model. Following the same reasoning, several studies dealing with various subjects employed a SUR model in the error-correction form (e.g., Karagiannis et al., 2000; Nzaku et al., 2012; Nzuma & Sarker, 2010; Singh et al., 2011; Su & Cook, 2015 have applied this approach for the analysis of consumption demand). This paper adopts the same model estimation approach as in O’Gráda (2001), where the model is built through cointegration techniques. The SUR model in error-correction form is presented below:

$$\begin{bmatrix} \Delta P_{1,t} \\ \Delta P_{2,t} \\ \Delta P_{3,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \beta \begin{bmatrix} \Delta P_{A,t} \\ \Delta P_{A,t} \\ \Delta P_{A,t} \end{bmatrix} + \delta_1 \begin{bmatrix} S_{1,1} \\ S_{1,2} \\ S_{1,3} \end{bmatrix} + \delta_2 \begin{bmatrix} S_{2,1} \\ S_{2,2} \\ S_{2,3} \end{bmatrix} + \delta_3 \begin{bmatrix} T_{1,1} \\ T_{1,2} \\ T_{1,3} \end{bmatrix} + \delta_4 \begin{bmatrix} T_{2,1} \\ T_{2,2} \\ T_{2,3} \end{bmatrix} + \varepsilon \begin{bmatrix} u_{1,t-1} \\ u_{2,t-1} \\ u_{3,t-1} \end{bmatrix} + \begin{bmatrix} r_1 \\ r_2 \\ r_3 \end{bmatrix}, \quad (5)$$

where P_i is the price of millet at time t , A identifies the market in El Fasher, $i = 1, 2, 3$ identifies each of the other three markets, and S_1 , S_2 , T_1 , and T_2 are the interaction dummies aimed at capturing the impact of conflict and medium-poor harvest on the process of price transmission:

$$S_{1,i} = D_{Conflict} \times \Delta P_{A,t},$$

$$S_{2,i} = D_{Harvest} \times \Delta P_{A,t},$$

$$T_{1,i} = D_{Conflict} \times (P_A - P_i)_{t-1},$$

$$T_{2,i} = D_{Harvest} \times (P_A - P_i)_{t-1}.$$

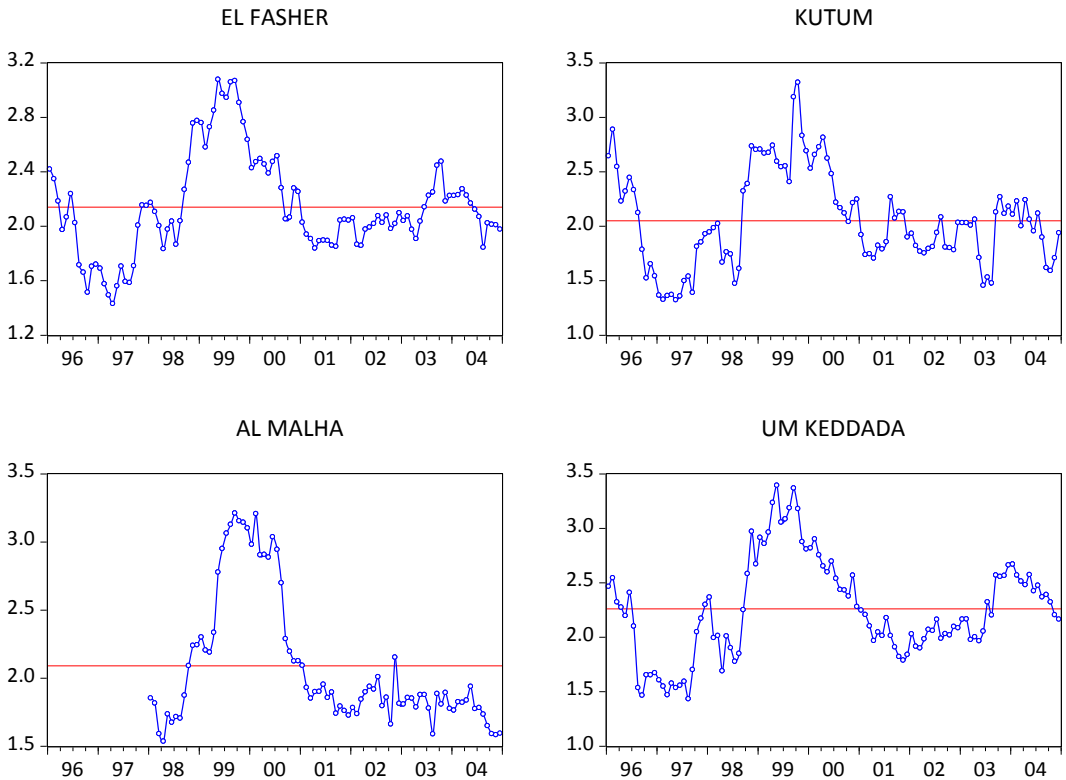


FIGURE 1 Evolution of millet price in four markets. Darfur, Sudan (SDD/kg, logged)

Note: Horizontal line shows the mean over the period considered. [Colour figure can be viewed at wileyonlinelibrary.com]

The interaction dummies $S_{1,i}$ and $S_{2,i}$ measure how much of the price changes registered in El Fasher is explained by the conditions of conflict and medium-low harvest, respectively. The two interaction dummies $T_{1,i}$ and $T_{2,i}$ capture simultaneous price adjustments during conflict and medium-low harvest periods.

Equation 5 is in the standard form of an error-correction model. Right-hand variables include a lagged error-term u_{t-1} obtained from the estimation of static (long-run) SUR and incorporated into the model to capture the speed of adjustment parameter ε (Phillips, 1995; Phillips & Hansen, 1990). The lagged difference between dependent and independent variables, both at level, is used to construct $T_{1,i}$ and $T_{2,i}$ dummy variables. As it stands, the SUR in ECM is the equivalent of the ECM of ARDL (1,1); however, in this case the model is estimated with a systemic approach.

As to the interpretation of parameters, the conflict and limited harvest dummies are equal to unity for conflict and medium-poor harvest periods, and are equal to zero otherwise. As mentioned above, the error term u_{t-1} is incorporated into the model to capture the speed of adjustment. Its coefficient ε is expected to be smaller than zero, as it shows the decay time of the impact of a shock. α explains autonomous variation in contemporaneous prices – i.e., it is meant to capture the effect of other factors that are not included in the model but which can affect the contemporaneous price change. β captures the impact of price changes in El Fasher on contemporaneous price change in each of the three other markets. In other words, β explains the synchronization of price transmission between El Fasher and each of the three other markets. δ_1 and δ_2 measure how much price transmission between each market

pair is affected by conflict and poor-medium harvest: a positive value of these parameters implies that in such conditions El Fasher and other markets, considered on a one-to-one basis, are more integrated than in normal conditions, in the sense that a higher than normal share of price changes in El Fasher is transmitted to each of the other markets. On the other hand, if parameters δ_3 and δ_4 are found to be greater than zero, this means that restoring price equilibrium between El Fasher and each of the other three markets is slower during/after a conflict or a poor-medium harvest.

4 | FINDINGS

The SUR model can be estimated using a generalized least-squares (GLS) estimator, or a maximum likelihood estimator (MLE) if the normality assumption does not hold for residuals (Myung, 2003). To check the normality assumption, skewness, kurtosis, and normality tests have been conducted on the model error terms. As presented in Table 4, the normality assumption of error terms is rejected for all equations. For this reason, the model is estimated with an iterated SUR which is equivalent of MLE (Poi, 2008). We check for autocorrelation using the Cumby–Huizinga test and error terms are found to be free from autocorrelation at lag one.

Table 5 reports the results of the Breusch–Pagan test of independence conducted on the residuals of the SUR estimation. As stated in Section 3.3, this test is meant to check whether the few markets considered in this study may be intrinsically affected by common economic unobservable factors that are not addressed in the model. The test results are significant as expected, implying that the SUR model provides a better estimation compared to single-equation models.

As shown in Table 6, the null hypothesis of no cointegration is rejected by the bound test (F -statistic is above the upper critical value) confirming the presence of a long-run equilibrium association. However, as shown in Table A2, neither the normality assumption or the condition of autocorrelation at lag one hold for ARDL (1,1). As stated by Schmidt and Finan (2018), while violation of the normality assumption, particularly if the number of observations is greater than 10 ($N = 83$, for this paper), does not bias coefficient estimates, autocorrelation does. In this regard, in a dynamic model setting with one term lagged dependent and independent variables, the SUR estimation delivers more robust results when estimating market integration between El Fasher on one side and Kutum, Al Malha and Um Keddada, on the other. The superiority of the SUR estimation is not limited to regression assumptions, but also includes parameter estimates, as previously mentioned. In fact, the SUR approach provides parameter estimates which: (1) have smaller variance than the estimates provided by ARDL (i.e., SUR is more efficient than ARDL), and (2) are consistent (i.e., as the sample size grows, the parameter estimate converges toward its true value). In contrast, parameter estimates provided by ARDL are only consistent.

TABLE 4 Tests of autocorrelation and normality of SUR residuals

Model	Cumby-Huizinga			Normality	
	lag	χ^2	p-val	Pr(Skewness)	Pr(Kurtosis)
El Fasher Kutum	1	0.460	0.498	0.000	0.000
El Fasher Al Malha	1	3.356	0.067	0.000	0.000
El Fasher Um Keddada	1	1.012	0.314	0.000	0.000

TABLE 5 Tests of independence of SUR residuals

	χ^2	Pr
SUR Model - ECM (short-run) component	28.218	0.000
SUR Model - Static (long-run) component	21.011	0.000

TABLE 6 Bound test for cointegration

$F(\text{El Fasher} \mid \text{Kutum})$	19.270 ^{***}	
$F(\text{El Fasher} \mid \text{Al Malha})$	12.335 ^{***}	
$F(\text{El Fasher} \mid \text{Um Keddada})$	5.506 ^{**}	
Critical values ($k = 1$)	I(0)	I(1)
1.0%	4.94	5.58
2.5%	4.18	4.79
5.0%	3.62	4.16
10.0%	3.02	3.51

Significance: ***= 0.01; **= 0.025.

TABLE 7 Long-run estimates for SUR and ARDL models

	El Fasher Kutum		El Fasher Al Malha		El Fasher Um Keddada	
	SUR	ARDL	SUR	ARDL	SUR	ARDL
Price in El Fasher	0.985 ^{***}	0.905 ^{***}	1.120 ^{***}	1.441 ^{***}	1.122 ^{***}	1.134 ^{***}
Constant	-0.076	0.188 ^{**}	-0.408 [*]	-0.938 [*]	-0.134	-0.249 ^{***}
Adj R ²	0.678		0.599		0.832	

Significance: ***= 0.01; **= 0.05; *= 0.1.

Table 7 presents the parameter estimates for the long-term component of the SUR and ARDL models. With the exception of the high ARDL estimate for the El Fasher–Al Malha pair, the rate of price transmission in the long run ranges between 90% and slightly more than 110%. In all cases, the high value of coefficients and their high significance highlight a strong process of price transmission between the three market pairs, showing a good degree of market integration and functioning. This result is especially noteworthy when considering the degree of isolation and fragility which characterizes the area on which this analysis focuses. The SUR and ARDL estimates are very similar to each other. Interestingly, ARDL seems to overestimate the parameters compared to SUR when price transmission is beyond 100%, as in the cases of El Fasher–Al Malha and El Fasher–Um Keddada. The opposite seems to be true when price transmission falls below 100%, as in El Fasher–Kutum.

Table 8 reports the parameter estimates for the dynamic component of the SUR and ARDL models. As expected, even in this case there are some minor differences between SUR and ARDL estimates; however, the signs and significance of parameters do not change between the short- and long-run estimates. Both models confirm the presence of a long-run equilibrium between El Fasher and the

TABLE 8 Short-run (ECM) estimates for SUR and ARDL models

	El Fasher Kutum		El Fasher Al Malha		El Fasher Um Keddada	
	SUR	ARDL	SUR	ARDL	SUR	ARDL
β	-0.008	-0.041	0.108**	0.132***	0.306***	0.270***
ε	-0.635***	-0.580***	-0.105***	-0.136***	-0.605***	-0.477***
δ_1	0.983***	0.995***	0.993***	0.979***	0.864***	0.844***
δ_2	0.981***	1.018***	0.979***	0.946***	0.860***	0.846***
δ_3	-0.598***	-0.551***	-0.111***	-0.142***	-0.552***	-0.424***
δ_4	-0.616***	-0.599***	-0.100***	-0.110***	-0.504***	-0.365***
Adj R ²	0.832	0.870	0.879	0.893	0.800	0.854

Note: Estimates of the constant are not reported.

β is the coefficient related to price change in El Fasher.

ε is the coefficient of the error correction term.

δ_1 is the coefficient of dummy $S_{1,i}$, which measures the transmission of price change between market pairs during conflict.

δ_2 is the coefficient of dummy $S_{2,i}$, which measures the transmission of price change between market pairs during medium-low harvest.

δ_3 is the coefficient of dummy $T_{1,i}$, which captures the dynamics of price adjustment between market pairs during conflict.

δ_4 is the coefficient of dummy $T_{2,i}$, which captures the dynamics of price adjustment between market pairs during medium-low harvest.

Significance: ***= 0.01; **= 0.05; *= 0.1.

other markets: with the exception of Kutum, β is significant and has the expected sign, and in all cases the error-correction term ε is found to be significant and smaller than zero, as expected. Having said that, it is necessary to consider that price transmission is much weaker in the short run than the impressively high long-run rates. Furthermore, in terms of speed of adjustment, among the three market pairs the integration between Kutum and El Fasher is shown to be the quickest restoring equilibrium, whereas that between Al Malha and El Fasher is the slowest. In the latter case, the impact of a shock vanishes approximately after a period, estimated as $1/|\varepsilon|$, ranging between 7 and 10 months, while for the other two market pairs it takes less than 2 months. The longer adjustment period required for the El Fasher–Al Malha market pair can be explained by the higher degree of isolation and smaller economic relevance of Al Malha compared to Kutum and Um Keddada. In other words, the economic and physical fragility of secondary or peripheral markets is reflected in the strength of their connectivity with the main market center.

As mentioned above, the dummies S and T allow us to see whether markets behaved differently during a crisis than in normal conditions. An outcome of $S > 0$ would indicate that price movements in each pair of markets were more synchronized during a crisis than normally the case, while an outcome of $T > 0$ would suggest that markets adjusted more slowly during a crisis than in normal times. Results in Table 8 consistently confirm such considerations. In particular, the coefficients of S_1 and S_2 —that is, δ_1 and δ_2 , respectively—provide evidence that price transmission between El Fasher and all the other markets considered here became more synchronized during the periods of conflict or following medium-poor harvests. The remarkable size of δ , particularly in comparison to the value of the long-run parameter β , is of particular interest: the results show that prices became two to eight times more synchronized during a crisis compared to normal. These results are consistent across the SUR and ARDL approaches, as well as among markets and, perhaps most remarkably, for the two types of crisis considered in this study. In other words, periods of both limited harvest and conflict were

characterized by a substantial increase in price synchronization. This consideration is particularly relevant since it refers to a typical feature of market integration and ultimately of market functioning.¹¹

Along the same lines, O'Gráda (2001) reaches the counterintuitive conclusion that under such critical conditions a quicker-than-normal price adjustment process was a usual occurrence. This is well reflected in our analysis: the negative sign of the last two dummies in Table 8—that is, δ_3 and δ_4 —indicates that achieving equilibrium for all three market pairs took a shorter time during a crisis, whether related to insecurity or to limited harvest size. In particular, the values of $1/|\epsilon + \delta_3|$ and $1/|\epsilon + \delta_4|$, which estimate the period required to re-establish the long-term balance between market prices during a period of limited harvest or conflict, range between 0.8 and 1.2 months for El Fasher–Kutum and El Fasher–Um Keddada, respectively, while they range between approximately 3.5 and 5.0 months in the case of El Fasher–Al Malha. Again, the estimates appear to be independent of the nature of the crisis. In other words, our results reveal that during a crisis the speed of price adjustment is double its usual level.

The insignificant value of β in Table 8 raises doubts about the process of price transmission between El Fasher and Kutum, leading to consider the possibility of an inverse direction of causality. As reported in the Appendix, in the long run Kutum, Al Malha and Um Keddada had a degree of influence on El Fasher, revealing some long-run bilateral causality. However, while the results of the SUR analysis of the short-run dynamics do not provide any evidence of different price-transmission behavior during stress periods, the ARDL results partly confirm our findings that the speed of price adjustment increased during such periods, with the exception of the price signal flow from Um Keddada to El Fasher.¹²¹³

Overall, our results seem to contradict the considerations expressed by some other studies, particularly with regard to market behavior during the conflict in Darfur. In fact, it was documented how widespread conflict and insecurity disrupted trade routes and increased transportation and overall costs, pushing cereal traders out of business. Along the same lines, the massive in-kind food assistance, which on one hand was an important source of supply for Darfur's cereal markets, ended up subverting traditional market price behavior on the other hand (Buchanan-Smith & Fadul, 2008; Buchanan-Smith et al., 2014; El Dukheri, 2007; El Dukheri et al., 2004; Hamid et al., 2005; Jaspars, 2018). Having said that, it is important to remark how the present analysis covers only the initial months of the conflict, which continued long beyond the timespan covered by this study. Although the delimitation of the study timespan is primarily justified by the availability of data, it enables an analysis of local supply and more generally of market behavior in a period without the confounding effects of the widespread escalation of violence and the unprecedented in-kind response that followed.

Therefore, while our findings about market behavior during conflict are limited to the initial phase of increasing insecurity, it is possible to consider that, although counterintuitive, our findings appear plausible. Their possible interpretation lies in some of the many interlinked events and changes that typically characterize crisis conditions, with a particular focus on markets as well as on relevant economic stakeholders and institutions. In particular, the most immediate economic consequence of such unfavorable events as a limited harvest and conflict is reduced supply, which is inevitably expected to lead to a price rise. In addition, in contexts strongly linked to food trade, for either economic purposes or simply social reasons, the increase in the price of staple food is also expected to have implications for other sectors, in this way generating a much larger process of rising prices. In consequence, a large proportion of small and medium traders—and other economic actors in general—may be crowded out of the economic scene because they are simply no longer able to cope with the increasing costs and decreasing returns, as amply documented even with reference to Darfur (e.g., Buchanan-Smith & Fadul, 2008; Buchanan-Smith et al., 2014; Grawert, 1998). This self-selection process leads to a drastic reduction in the number of traders and other economic actors who remain active as the crisis

develops. They are normally the biggest entrepreneurs, who can operate competitively in the presence of increasing costs and to mobilize the resources required to deliver in difficult economic and operational environments. This race to the top in terms of operating standards helps to explain the increased efficiency of price transmission that we have found to occur during crises. In other words, more capable and better-equipped operators are expected to act more efficiently and effectively than less capable and less-equipped competitors, who are pushed out of the market, leading to the improvement and speeding-up of price transmission. Of course, this process is not reflected in the quantities traded, which, on the contrary, are expected to decrease during a crisis.

Although the possible explanation above sounds very appealing, we do not have enough data to countercheck it using the rigorous approach followed so far in this study. Nevertheless, as a follow-up we strongly recommend further analysis of this topic, particularly in view of its critical relevance for planning and policy purposes.

5 | CONCLUSIONS

Markets are a main determinant of most people's livelihoods, and this consideration has led to the increasing adoption of market-based strategies to promote local economic growth and even to promote recovery after disasters. Nevertheless, markets' behavior during crises is still an under-researched subject, and a good understanding of whether and how they function during a crisis is still lacking. This article contributes to filling this gap. It has provided an analysis of market functioning in North Darfur over a decade which saw both natural and manmade disasters. In particular, it has focused on the rigorous analysis of price transmission as a proxy for market functionality. Results obtained using two methodological approaches confirm the robustness of our findings. In all cases, the short-run effect as captured by the movement of prices is more synchronized during periods of limited harvest and in the early stages of conflict compared to other times. Along the same lines, the speed of price adjustment required to re-establish the pre-crisis market price balance increases during crises. These results indicate that markets not only remained functional during crises, but even operated more efficiently in the aftermath of a shock than in normal conditions.

Unfortunately this analysis provides only a limited picture of market reaction to crisis, since it is based only on price behavior, as unfortunately no information is available on the volume of trade. During critical periods the volume of trade is expected to decrease—even drastically—compared to normal times due to shortage of food and/or worsening security and/or increasing costs. It can be argued that all these factors are expected to induce a process of selection of traders and other market operators, crowding out the less competitive thereby contributing to increased overall market efficiency.

While our analysis focuses on the specific case of Darfur, our findings may have general validity and application. Overall, the implications of the main findings of this study can be appreciated considering the increasing relevance of the use of market-based strategies in response to crises. This requires a good understanding of market behavior during crises, which cannot be taken for granted, particularly considering the paucity of current knowledge on this topic.

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DATA AVAILABILITY STATEMENT

The data used for this study are available upon request.

DECLARATION OF INTEREST

The authors declare no conflict of interest.

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ENDNOTES

- ¹ The extent to which income affects food consumption patterns is conditional on the theory of supenumerary income, which suggests that households alter their consumption patterns only after required expenses have been met, as households use discretionary income to acquire other utility-generating goods (Satter, 2007; Stone, 1954).
- ² Data on household food consumption are widely available. The Food and Agriculture Organization has developed an interesting application (ADePT-FSM) to improve the quality and consistency of data derived from household surveys, such as Living Standards Measurement Surveys (LSMS), Household Income and Expenditure (HIES), and Household Budget Surveys (HBS). See: www.fao.org/economic/ess/ess-fs/fs-methods/adept-fsn/en/.
- ³ De Waal (1989) provides an interesting review of how famines—due to both natural and manmade disasters—have historically forged the livelihood of Darfurians.
- ⁴ Long-distance labor migration is also common, and gathering and consumption of wild foods are usual habits during the hardest times.
- ⁵ See Jaspars (2018) for a critical overview of events and policy related to food assistance in Sudan.
- ⁶ A time series is stationary when it has constant mean and variance over a period of time; otherwise it is said to be non-stationary.
- ⁷ A general overview on the topic can be found in Fackler and Goodwin (2001).
- ⁸ If the price series are cointegrated, the Granger causality test should report at least the existence of unilateral causality. Therefore, we applied the Granger causality test to check whether market pairs are integrated as well as to determine the direction of causality within each market pair.
- ⁹ It is also important to consider how a VEC approach can produce more than a single cointegrating relationship. As a multiple cointegrating relationship is expected in view of the intermediary role of El Fasher with the other three markets, a VEC seems inappropriate, or at least, less preferable.
- ¹⁰ See Table A1 in the Appendix.
- ¹¹ This finding, which may sound counterintuitive, is not new to the literature. In fact, as considered in Section 2.1, the analysis conducted by O'Gráda (2001) highlights that market prices in the nineteenth-century Finland were more synchronized during the famine period than in other years.
- ¹² As a robustness check for endogeneity, the hypothesis of inverse direction of causality has been tested through a vector error correction model, where all markets are treated endogenously. The results obtained, not reported here, were similar to those reported above.
- ¹³ Any divergence about the direction of causality of price transmission between markets observed in Tables 3 and A3 is the result of adopting different approaches to test long-run causality. In Table A3, SUR and ARDL tested long-run causality while taking into account transmission dummies; instead in Table 3 the Granger causality test solely focuses on the predictive power of one series on the other in a pairwise price setting. Nonetheless, both of these approaches confirm the validity of our statement that El Fasher plays a role of price maker in the long run.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.

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