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Sorghum Prices and Markets Integration in Sudan

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Abstract

The main objective of this paper is to examine the relationship between sorghum prices and markets integration in Sudan. Other objective is to check the presence or absence of causality between the cointegrated markets if any present. In this study, monthly sorghum prices for a period of years from 2002 to 2010 for eight markets in different parts of Sudan were tested spatially; A group of five markets in peaceful regions linked with a net of paved roads and shared good trade information flow were tested in addition to three markets in western Sudan, where poor infrastructures and political strife prevails as a result of civil conflicts.

Keywords: Arbitrage; Cointegration; Causality; Food security

Introduction

The stable food grains in Sudan include sorghum, millet and wheat. These three food grains spread geographically in the country regions where some are more dominant and less so others. In the urban areas of the country and the northern states (River Nile and Northern States), wheat is traditionally the main food grain followed by sorghum, whereas in eastern and central Sudan sorghum is more dominant, while in western Sudan millet is the dominant food grain followed by sorghum. This dominance and diversification of food grains is dictated by the variation of the agro-climate zones and the farming systems in Sudan; whether irrigated, semi-mechanized rain fed, or traditional rain fed agricultural sub sector.

According to Faki et al. [1] in Sudan more than 80% of sorghum and millet are grown in the rain fed sub-sector, while the irrigated sub-sector monopolizes wheat production in addition to a sizeable amount of sorghum. The semi-mechanized farming is the main producer of sorghum; producing about 65% of the total production and thus it plays a major role in determining whether the country enjoys a food surplus or suffer a food deficit in any single season.

Prices are standard and important component of market and food security analysis, because they serve as an indicator for both food availability and food access [2]. Prices of food grains tend to rise during the lean seasons and reach a peak prior the next harvest as demand exceeds supply, and they tend to fall as supply increases during years of bumper harvest.

Prices observed through time are, as a result of a complex mixture of changes, associated with seasonal, cyclical, trend and irregularity factors. The most common regularity observed in agricultural prices is the seasonal pattern of change. Understanding price seasonal variation and trend is of crucial importance for all stakeholders; the producers, the consumers and the policy and decision makers. Producers confer their products at lower prices at harvest, and consumers need the same amount of food all seasons given their limited income. For instance, prices affect directly the household purchasing power; as prices rise and household's income remain constant the same amount of money buy less amount of food grains.

Cereals and food grains witnessed globally long-run hikes and soars due to; the substantial increases of food demand, the recent trend to produce bio-fuel from grains, the slow pace of supply compared to demand due to the unfavourable weather conditions, pests and plant diseases, civil conflicts and the negative response of farmers to price trough in some seasons, etc. In the short-run on the other hand, surges in food grain prices occur due to seasonality.

Spatial price analysis examines how prices in different markets over space are related. Arbitrage triggers the flow of food across space in an attempt to balance supply and demand taking into account cost of transportation. Through efficient spatial arbitrage the risk of crop failure in some regions is shared over a large market area and prices are more stable and food shortages may be prevented.

According to Mukeere [3], the degree of market integration can be derived econometrically in order to measure the relationship among spatially separated markets (or market locations). Some of the advantages of an integrated market include: enhanced security of supply, reduced price risks, reduced market entry barriers leading to increased numbers of suppliers etc. Well-integrated markets support the effectiveness of macro-level economic policies. In food security terms, the lack of integrated markets may lead to serious incidences of localised food insecurity in parts of a country when other areas are experiencing food surpluses. If agricultural markets are not integrated, then any local food scarcity will tend to persist, as distant markets (with no scarcity) will not be able to respond to the price signals of isolated markets with food surpluses.

The producers' marketing decisions are based on market price information, and poorly integrated markets may convey inaccurate price information, leading to inefficient product movements [4].

Two trading markets are assumed integrated if price changes in one lead to price response in the other, and markets share a long-run relationship. In contrast, segmented markets exhibit no long-run relationship.

Methodology

The data

The data of this paper are of a secondary source, time series of monthly sorghum prices for the years (2002- 2010) for eight markets were obtained from the Corporation of Strategic Reserve. The eight sorghum markets studied are Gadaref and Damazine (south east Sudan), Sennar and Rabak (in the central Sudan) these four sorghum markets are located in the biggest sorghum producer areas in Sudan,

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where located the mechanized rain fed farming system. El Fasher and Nyala (in the western Sudan) where millet as a food stuff is more dominated than sorghum, but sorghum is produced in a small scales by rain fed, El Obeid and Om Durman (are a consumption centers). Figure 1 map shows the locations of the studied sorghum markets.

Analytical procedure

Time series statistical stationarity test (unit root test): The unit root test is a prerequisite for cointegration analysis as the presence of a unit root (non-stationarity) is important to proceed to cointegration analysis. A series is said to be stationary if its mean and variance remain constant over time and is referred to as *I(0)* "integrated of order zero". Non-stationary stochastic series have varying means or time varying variance.

Rapsomanikis et al. [5] stated that "a non-stationary series has time-dependent statistical properties. Non-stationary series may contain stochastic or deterministic trends. Variables that contain stochastic trends are called 'integrated' and exhibit systematic, but unpredictable variation, as compared to series that contain deterministic trends and display completely predictable variation".

The non-stationarity or presence of a unit root in any series means that the series embodies integrated data. Thus, an econometric model cannot be specified unless we know the order of integration of the variables. The order of integration (existence or absence of non-stationarity) in the time series in this study was checked by the augmented Dickey-Fuller (ADF) test, which is the most widely used method for unit root tests. For more information see [6].

To determine the order of integration, the individual t-values of the estimated coefficients are compared to the critical values of the ADF test based on the following null and alternative hypotheses:

$Ho : P_t \sim I(1)$ vs $H1 : P_t \sim I(0)$ if the null hypothesis cannot be rejected, then P_t are non-stationary and could be integrated of order one, *I(1)*, or integrated of order two, *I(2)*, or even of a higher order. In the event that different series have different orders of integration, we conclude that they are not integrated collectively.

Cointegration test: Prices in spatially separated markets (or

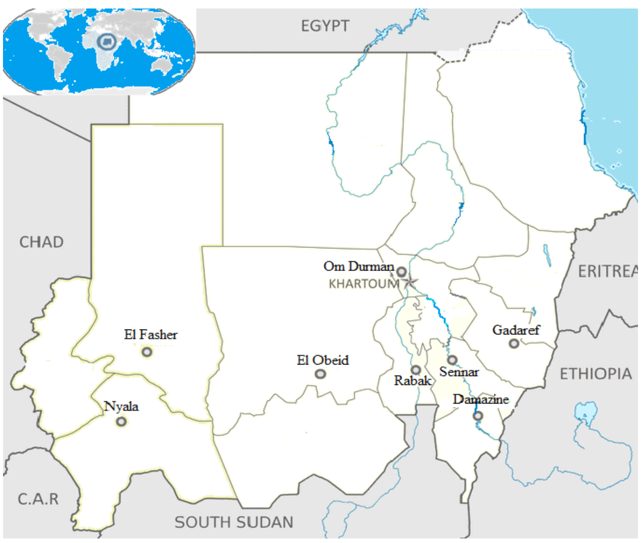

Figure 1: The republic of the Sudan, locations of the studied markets.

at different levels of the supply chain), $P1_t$ and $P2_t$, which contain stochastic trends and are integrated of the same order, say *I(d)*, are said to be co-integrated if;

$$p1_t - bp2_t \qquad (1)$$

u_t is *I(0)*, *b* is referred to as the cointegrating vector, u_t is the estimated residual and the equation is known as cointegrating regression. More specifically, $p1_t$ and $p2_t$ are co-integrated if there is a linear combination between them that does not have a stochastic trend even though the individual series contains stochastic trends, i.e. if u_t is non-stationary, then, $p1_t - bp2_t$ is not a cointegrating relationship. Two or more series are said to be co-integrated if each is individually containing a unit root, but there exists a linear combination between the series that is stationary of the same order.

The data of the markets selected are subjected to cointegration analysis utilizing Johansen [7] and Johansen and Juselius procedures [8]. However, the simple cointegration tests developed by Granger [9] and Engle and Granger [10] fail to address linkages between more than two series.

Under Johansen's procedure, cointegration among the price series is tested using Johansen's maximum likelihood test based on the error correction representation (ECR) or a reduced rank model because the coefficients to be tested should have no full rank. The model is also known as the vector error correction (VEC) model [11].

The form of the multivariate system is as follows:

$$\Delta p_t = \mu + \sum_{i=1}^{i=k-1} \varphi_i \Delta p_{t-1} + \pi p_{t-k} + \varepsilon_t \qquad (2)$$

where p_t is *(n x 1)* vector of *I(1)* variable, $\Delta p_t = p_t - p_{t-1}$, ϕ_1 and π are *(n x n)* coefficient matrices, *(t)* is time, $t = 1, 2,\dots, T$, $k = 1,2,\dots, t-1$, μ is constant, and is ε_t an error term.

The maximum likelihood procedure relies on the relationship between rank of matrix and its characteristic root. The Johansen's maximal eigenvalue and trace tests detect the number of cointegrating vectors that exist between two or more time series that are economically integrated.

According to Bierens, Johansen's approach is to estimate the VECM by maximum likelihood, under various assumptions about the trend or intercept parameters and the number (*r*) of cointegrating vectors, and then conduct likelihood ratio tests. Assuming that the VECM errors ε_t are independent $N_n[0,\Sigma]$ distributed, and given the cointegrating restrictions on the trend or intercept parameters, the maximum likelihood $L_{max}(r)$ is a function of the cointegration rank *(r)*. Johansen proposes two tests for *(r)*, the lambda-max test and the trace test.

The lambda-max test is calculated in this equation:

$$\lambda_{max}(r) = -TLn(1 - \lambda_{r+1})$$

This test is based on the log-likelihood ratio $Ln[L_{max}(r)/L_{max}(r+1)]$, and is conducted sequentially for $r = 0, 1,.., k-1$. The name comes from the fact that the test statistic involved is a maximum generalized eigenvalue. This test tests the null hypothesis that the cointegration rank is equal to *r* against the alternative that the cointegration rank is equal to *(r+1)*.

The trace test is calculated in the following equation:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} Ln(1-\lambda_i)$$

Ln is the natural logarithm ($\log_e$), where T is the number of observations and λ_i is the *i-th* largest squared canonical correlation between the two residuals generated by regressing Δy_t and Δy_{t-1} on $\Delta y_{t-1}, \Delta y_{t-2}, \ldots, \Delta y_{t-(k-1)}$, respectively. This test is based on the log-likelihood ratio $\mathrm{Ln}[L_{max}(r)/L_{max}(k)]$, and is conducted sequentially for $r = k-1, \ldots, 1, 0$. The name comes from the fact that the test statistic involved is the trace of a diagonal matrix of generalized eigenvalues. This test tests the null hypothesis that the cointegration rank is equal to *(r)* against the alternative that the cointegration rank is (*k*). The latter implies that is trend stationary. In addition if the cointegration rank is zero the series are not cointegrated and if the rank is *(k – 1)* the series are cointegrated. For example, a bivariate time series model, that is, for k = 2, there are three cases for the value of r; r = 0 implies no cointegration relationship, while r = 1 implies one long-run relationship between the processes, i.e., they maintain the equilibrium over time, if r = 2 then the series are stationary.

Test for causality: Cointegration between two variables implies existence of long-run causality for at least one direction. Testing cointegration and causality should be considered jointly.

Alexander and Wyeth [12] "stated that, after the detection of series cointegration we can proceed to investigate causality. This is because at least one Granger-causal relationship exists in a group of co-integrated series". Granger causality is a statistical concept of causality that is based on prediction. According to Granger causality, if a signal X_1 "Granger-causes" (or "G-causes") a signal X_2, then present and past values of X_1 should contain information that helps predict future X_2, in other words, X Granger-cause Y if X helps in the prediction of Y, or equivalently if the coefficients on the lagged X's are statistically significant. Two-way causation is frequently the case; X Granger-causes Y and Y Granger-causes X. It is important to note that the statement "X Granger-causes Y" does not imply that Y is the effect or the result of X. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term. The causality test is represented by the error correction equation below:

$$\Delta p_{it} = \beta_0 + \beta_1 p_{i(t-1)} + \beta_{2(t-1)} + \sum_{k=1}^{m} \delta_k \Delta p_{i(t-k)} \sum_{h=1}^{n} \alpha_h \Delta p_{j(t-h)} + \ell_{it} \quad (3)$$

Where *m* and *n* are number of lags determined by Akaike Information Criterion.

Rejection of the null hypothesis that $\alpha_h = 0$ for $h = 1, 2, 3, \ldots, n$ indicates that prices in market " *j* " Granger-cause prices in market "*i* ". If prices in market "*i* " also Granger-cause prices in market "*j* ", then prices are determined by a simultaneous feed-back mechanism (SFM). This is the phenomenon of bi-directional causality. If the Granger-causality runs one way, it is called unidirectional Granger-causality and the market which Granger-causes the other is tagged the exogenous market.

Results and Discussions

Figure 2 shows nominal monthly sorghum prices trends of the selected markets (2002-2010). It shows a steady rise and concurrently surges along the time; these price surges are the result of continuous and growing gap between the deteriorated sorghum production and increasing food and feed demand in Sudan. According to FAO-SIFSIA study, total cereal production in the Sudan accounts for about 65% of the total annual grain requirement, the balance being mainly imported. The nominal prices were deflated by the CPI to negate the effects of inflation and prepare the prices to be checked for any real price trends.

Unit Root test results

The price series of the eight sorghum markets in the study were subjected to unit root test using ADF test. Table 1 shows that the values of the ADF t-statistics are smaller in absolute terms than the critical value(s), indicating that the null hypothesis of non-stationarity could not be rejected and all the series are containing a unit root at their levels. When the series were first differenced, however, the null hypothesis of a unit root is rejected in favour of the alternative, as the values of the ADF t-statistics are greater in absolute term than the critical value, which means that all the series of the variables are integrated of the same order.

Cointegration analysis results

Gadaref, Damazine, Sennar and Rabak sorghum markets are centers of mechanized rain fed sorghum schemes, Om Durman is the national capital and the biggest sorghum consumption center in Sudan. The series of markets were deflated by the CPI, and then tested to determine the existence or absence of a long-run relationship utilizing the Johansen's cointegration procedure. Table 2 shows that the likelihood ratio (L.R) indicates that, Gadaref, Damazine, Sennar, Rabak and Om Durman sorghum markets series enjoys one cointegrating equation at 5% significance level i.e. the series are co-integrated and the markets are integrated; price changes in any market cause immediate change in other markets which is a good indication of market efficiency. The mentioned markets are linked with a net of good paved roads and telecommunications facilitating immediate market information flow.

Another group of series of occasional sorghum deficit markets of the traditional rain fed farming sub-system in Sudan includes El Obeid, El Fasher and Nyala at the western Sudan; the series were also tested for

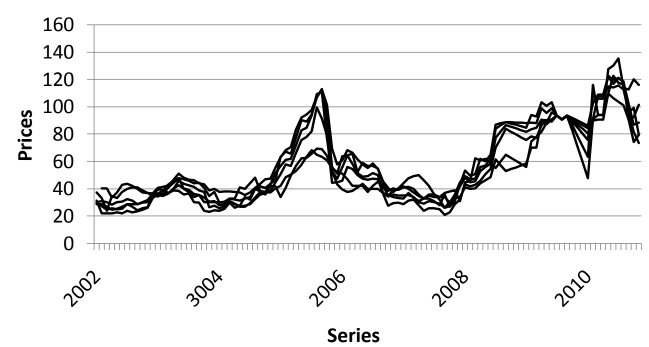

Figure 2: Trend of nominal monthly sorghum prices for the selected markets (2002-2010).

Series	Levels test statistics	First difference test statistics
	ADF*	ADF
Om Durman	-2.0873	-5.6288
El Obeid	-2.2608	-5.3116
Gadaref	-2.2087	-5.418
Damazine	-2.366	-5.0849
Sennar	-2.3319	-3.9019
Rabak	-2.4031	-3.6901
El Fasher	-2.1818	-4.6613
Nyala	-2.0743	-5.0358

*(ADF) levels critical values are -3.5007 and -3.5023 for price levels and first differenced price series respectively at 1% critical region.

Table 1: Unit Root Test Results for the Selected Markets (2002-2010).

co-integration. Table 3 shows that the L.R rejects any cointegration at 5% significance level, i.e. the markets are segmented referring to years (2002- 2010).

Table 4 shows cointegration pair-test for El Fasher and Nyala sorghum markets, also the L.R rejects any cointegration at (5%) significance level for El Fasher and Nyala, which are the biggest markets in insecure Darfur region, where civil strife and conflict started in 2003. Market inefficiency and segmentation is due to restrictions imposed on flow of trade and hence food, as a result of civil conflict in the region, lack of good roads, frequent and temporary short cuts of information flow and the occasional blockage of trade flow along supply roads by the rebels. This situation matching the statements by Brinkman and Hendrix [13], "conflict often affects the ability to produce trade and access food. It crowds out normal economic activity such as food production, destroys infrastructures and cuts off access to food supplies. The effects of conflict induced food insecurity are both immediate and long-term".

Om Durman and El Obeid markets are sorghum consumption centers were also tested for any long-run relationship, Table 5 shows that the likelihood ratio (L.R) indicates that, there is a one cointegrating equation at 5% significance level i.e. the two markets are cointegrated.

Eigen value	Likelihood ratio	5% critical value	1% critical value	Hypothesized No. of CE (s)
0.332003	93.86134	76.07	84.45	None **
0.205642	52.70716	53.12	60.16	At most 1
0.114735	29.22464	34.91	41.07	At most 2
0.098526	16.79411	19.96	24.6	At most 3
0.059105	6.214218	9.24	12.97	At most 4
*(**) denotes rejection of the hypothesis at 5% (1%) significance level. L.R. test indicates 1 cointegrating equation at 5% significance level.				

Table 2: Johansen Cointegration Test for Series: Sennar, Rabak, Om Durman, Gadaref and Damazine sorghum markets (2002-2010).

Eigen value	Likelihood ratio	5% critical value	1% critical value	Hypothesized No. of CE(s)
0.17309	34.06436	42.44	48.45	None **
0.087764	14.86837	25.32	30.45	At most 1
0.053851	5.590885	12.25	16.26	At most 2
*(**) denotes rejection of the hypothesis at 5% (1%) significance level. L.R. rejects any cointegration at 5% significance level.				

Table 3: Johansen Cointegration Test for Series: El Obeid, El Fasher and Nyala sorghum markets (2002-2010).

Eigen value	Likelihood ratio	5% critical value	1% critical value	Hypothesized No. of CE(s)
0.13027	22.754	25.32	30.45	None **
0.08214	8.65719	12.25	16.26	At most 1
*(**) denotes rejection of the hypothesis at 5% (1%) significance level. L.R. rejects any cointegration at 5% significance level.				

Table 4: Johansen Cointegration Test for Series pair: El Fasher and Nyala sorghum Markets (2002-2010).

Eigen value	Likelihood ratio	5% critical value	1% critical value	Hypothesized No. of CE(s)
0.41668	59.188	25.32	30.45	None **
0.04592	4.74738	12.25	16.26	At most 1
*(**) denotes rejection of the hypothesis at 5% (1%) significance level. L.R. indicates 1 cointegrating equation(s) at 5% significance level.				

Table 5: Johansen Cointegration Test for Series pair: Om Durman and El Obeid sorghum Markets (2002-2010).

Causality test results

Table 6 shows the results of causality test for Gadaref, Damazine, Sennar, Rabak and Om Durman sorghum markets. The hypothesis that "Rabak does not Granger-cause Sennar", and "Sennar does not granger-cause Rabak" can be rejected; they share a bidirectional Granger-causality, each market can help in predicting sorghum prices of the other market. This may be due to the short distance between the two markets.

The hypothesis that Gadaref does not Granger-cause "any of the other four markets" can be rejected, due to the minor probabilities [14]. This is because Gadaref state enjoys the biggest semi-mechanize farming system and constitutes the main supplier of sorghum in Sudan. It seems to be a Granger-cause of all other selected sorghum markets in the group, but the reverse is not true, it is a unidirectional Granger-causality, in the a sense that past and present Gadaref sorghum prices can help in predicting future sorghum prices in the four other markets

The hypothesis that Damazine does not granger-cause "any of the other four markets" cannot be rejected, i.e. present or past Damazine sorghum prices can not help in predicting sorghum prices of any of the four markets.

Conclusions

In this study market cointegration test for eight sorghum markets was carried. Price series analysis of a group of markets shared peaceful region and connected with a net of paved roads in Sudan showed positive market cointegration results, which means, price changes in any market in the group cause positive changes in all prices of the other markets in the group, this is an indication of market efficiency, which facilitates policy implementation, as policy intervention in a single market is enough to cause a positive results in the other markets in the group, besides the cointegrated markets help decision makers to be more assure in a long-term about food security in the region. Other group of markets include civil conflict region, lacking good infrastructures "like paved roads" showed market segmentation, which means policy makers should dictate to any market its own policy, and they should

Null Hypothesis	F-Statistic	Probability
Rabak does not Granger Cause Sennar	5.03671	0.00824
Sennar does not Granger Cause Rabak	4.70054	0.01119
Om Durman does not Granger Cause Sennar	1.71513	0.18519
Sennar does not Granger Cause Om Durman	7.43266	0.00098
Gadaref does not Granger Cause Sennar	6.04711	0.00332
Sennar does not Granger Cause Gadaref	2.66139	0.0748
Damazine does not Granger Cause Sennar	0.0137	0.9864
Sennar does not Granger Cause Damazine	10.3087	8.50E-05
Om Durman does not Granger Cause Rabak	1.45655	0.23794
Rabak does not Granger Cause Om Durman	6.92126	0.00153
Gadaref does not Granger Cause Rabak	5.23657	0.00687
Rabak does not Granger Cause Gadaref	0.99814	0.37221
Damazine does not Granger Cause Rabak	0.91949	0.40207
Rabak does not Granger Cause Damazine	14.7604	2.40E-06
Gadaref Does not Granger Cause Om Durman	13.3791	6.90E-06
Om Durman does not Granger Cause Gadaref	0.26091	0.77086
Damazine does not Granger Cause Om Durman	1.18521	0.30986
Om Durman does not Granger Cause Damazine	6.04026	0.00332
Damazine does not Granger Cause Gadaref	1.2247	0.29813
Gadaref does not Granger Cause Damazine	19.1868	8.50E-08

Table 6: Pair wise Granger-causality Tests for Sennar, Rabak, Om Durman, Gadaref and Damazine Sorghum Markets.

deal with markets as individuals concerning the strategic food reserves or other food security actions and not as a group of markets in a region. A region of segmented (non-cointegrated) markets may be vulnerable to food insecurity incidence and may not respond to food surplus in other regions, this may be the cause of historically reported localized famine and food insecurity in the western Sudan. Concerning causality tests, it is found that Gadaref is a Granger-cause all other markets in the cointegrated markets in the group, which means that; Gadaref past and present sorghum prices can help in predicting future sorghum prices in Om Durman, Damazine, Sennar and Rabak sorghum prices.

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