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Abstract
The main objective of this study is to investigate price movements among important sheep markets in the Sudan to explore their pricing efficiency. The short period of long-run equilibrium adjustment indicated that there are strong price linkages between Omdurman and other four markets (Elobied, Medani, Sennar and Nyala markets). The prices causality indicated unidirectional relation causality of Nyala market through Medani and Elobied markets. Nyala markets as terminal market located in production area Granger cause Medani and Omdurman as major consumption markets; this was taken as evidence that price movements were primarily driven by supply shocks. That mean the system was centred on Nyala i.e. Nyala could be considered as a supply market in sheep market which means the prices were supply driven.

Keywords: Market efficiency; Sheep; Multivariate cointegration; Sudan

Introduction

Background
The global economy witnessed a number of economic and financial crises since the late of 19th and early of 20th century, which caused a decline in consumption and private sector investment, rise in unemployment rate and slowdown in economic growth rates.

The global financial crisis of 2008, discerned with banking crisis, instability of foreign exchange and imbalances in stock markets. As the result of linkage between the international financial markets, their adverse effects outweighed the performance of the international financial markets and the real sector through the slackening demand for goods and services. This engendered a decline in their prices, including oil prices during the last quarter of 2008.

The government plan toward agricultural development is to invest a part of oil revenues for the activation of agricultural sectors and to boost production to achieve the aspirations and economic goals, especially the creation of the economic boom in exports of non-petroleum resources like agriculture and livestock [1]. Unfortunately, slight progress in performance of the agricultural sector, relatively attributed to the implementing some of the development programs and the downturn in the animal resources section. In the additional; (1) reasons of this section drop is obvious the agriculture sector shares are still little and humble revenues with unstable shift, and (2) the overall state for all items of exports of non-petroleum products didn’t attain the desired share of the export revenue or promote the state of the trade balance of the year 2007 as shown in Table 1.

Table 1 above indicates high surplus with value of 2.456 Billion US$ in 2010 compared with surplus in 2008, 2007 with value 2.319, 1.1 million US$ respectively. In the last decade the government has sought to increase exports of livestock and livestock products. Sudan’s livestock exports fell dramatically in 2000-2001, however, when Saudi Arabia and other Gulf countries temporarily banned imports of live animals from Sudan [2]. Since 2002 Sudan’s livestock exports have rebounded, but they constitute a smaller part of non-oil exports than during the 1990s. In 2005, oil accounted for 82% of Sudan’s total exports by value; livestock and livestock products were just 3-2%of exports by value (or nearly 18% by value of non-oil exports).

In 2003 President Al-Bashir issued a set of directives to spur livestock exports, putting the Ministry of Foreign Trade in charge of re-organizing and improving Sudan’s livestock markets. In November 2003 the Ministry directed the creation of a pilot Cattle Auction Project at El Muwelih market in Omdurman [3]. This project would require payment in cash at the time of transaction and sales by weight and open auction, theoretically improving the overall efficiency and transparency of the marketing system [4]. If the project succeeds at El Muwelih it would be replicated at other livestock markets, but for now, the auction project is stalled owing to problems in organizing financial services to facilitate cash payments.

Sudan is among the richest African countries in term of size of its national herds. The livestock population keeps increasing through the years, in the year 2010 the livestock population comprised about 42 million cattle, 4.623 million camels, 52 million sheep and 43 million goats as presented in Table 2 below.

Table 1: The trade balance (U.S.A Million Dollar) during the period 2005-2010.

<table>
<thead>
<tr>
<th>Period</th>
<th>Petroleum export</th>
<th>Non-petroleum export</th>
<th>Total export</th>
<th>Total import</th>
<th>Trade balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>4187.360</td>
<td>636.918</td>
<td>4824.278</td>
<td>6756.820</td>
<td>(1932.542)</td>
</tr>
<tr>
<td>2006</td>
<td>5087.211</td>
<td>569.357</td>
<td>5656.568</td>
<td>8073.498</td>
<td>(2416.930)</td>
</tr>
<tr>
<td>2007</td>
<td>8418.258</td>
<td>460.722</td>
<td>8879.250</td>
<td>8775.457</td>
<td>1027.93</td>
</tr>
<tr>
<td>2008</td>
<td>11094.111</td>
<td>576.393</td>
<td>11670.502</td>
<td>9351.540</td>
<td>2318.964</td>
</tr>
<tr>
<td>2009</td>
<td>7131.255</td>
<td>702.441</td>
<td>7833.696</td>
<td>9690.918</td>
<td>(1857.222)</td>
</tr>
<tr>
<td>2010</td>
<td>9905.248</td>
<td>1377.351</td>
<td>11282.779</td>
<td>8389.400</td>
<td>2456.000</td>
</tr>
</tbody>
</table>

Source: (Sudan, 2012).

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One of the main problems of livestock marketing is that, the livestock markets approach is the sellers dominated market. According to ref. [7], the main constraints to animals marketing include poor marketing infrastructure, lack of marketing organization, lack of market intelligence, absence of marketing extension services and absence of grades and standards. The main problems indicated by the herders include shortage of drinking water, spread of animals' diseases, and lack of veterinary services and encroachment of agricultural activities on grazing land.

The problem statement

Despite the significant importance of sheep to Sudanese economy but its markets still not well developed. The main constraints to animals marketing include poor market infrastructure, lack of market organization, lack of market intelligence, inadequacy of market finance, shortage of drinking water, spread of animals diseases, and lack of veterinary services and transport services, these constrains are affecting marketing efficiency.

The questions of the study

To achieve the objectives of this study, the following questions need to be answered:

1. Are sheep prices data in the Sudan have stationary properties over time?
2. Is sheep price shock that happens in one market affecting the other markets?
3. Are the sheep markets integrated?
4. Is there any cointegration between these markets in the short and long run?

The objectives of study

The main objective of this paper is to investigate sheep markets in the Sudan to explore their price efficiency.

From the mentioned research problem the following sub-objectives are distinguished:

1. To investigate sheep market integration through analyzing price variation in selected markets.
2. To outline some policy recommendations, that might help policy makers to draw plans to improve the livestock marketing system.

Data and Methodology

The study focused on scrutinizing the sheep markets in Sudan by considering the prices of five livestock markets which were Eloibied, Omdurman, Medani, Sennar and Nyala. The study covered the periods from January 1995 to December 2011. The data used in these prices were monthly prices which have been collected from the Animal Resources Company; these prices were wholesale price i.e. the selling price of a head of animal measure in Sudanese Pound (SDG). To attain the cointegration analysis the data should be in real terms to avoid spurious regression, so all price series were deflated by GDP deflator rather than consumer price index. The deflated prices data were transformed in term of natural logarithm so as to attain a constant variance in the series, and then this logged deflated prices data used in the empirical analysis [8]. See Figures 1-3 for visual appreciation.
Figure 1: Monthly nominal wholesale price (Sudanese pound per head) of camels in the selected markets, January 1995 – December 2011.

Figure 2: Monthly deflated wholesale price (Sudanese pound per head) of sheep in the selected markets, January 1995 – December 2011.

Figure 3: First difference of monthly deflated wholesale price (Sudanese pound per head) of sheep in the selected markets, January 1995 – December 2011.
Johansen Maximum likelihood ratio approach:

Johansen’s methodology takes its starting point in the vector autoregression (VAR) of order \( p \) given by:

\[
Y_t = u + A_1 y_{t-1} + ... + A_p y_{t-p} + \varepsilon_t
\]  
(1)

Where \( y_t \) is a \( k \)-dimension vector of variables which are assumed to be I(1) series (but could also be I(0)), \( A_1, A_2, ..., A_p \) is the coefficient matrix, and \( \varepsilon_t \) is a \( k \)-dimension vector of residuals. Subtracting \( y_{t-1} \) from both sides of equation (1) yields:

\[
\Delta y_t = u + \prod_{i=1}^{p} A_i y_{t-i} + \varepsilon_t
\]  
(2)

This VAR can be re-written as:

\[
\Delta y_t = u + \prod_{i=1}^{k-1} A_i y_{t-i} + \varepsilon_t
\]  
(3)

Where \( \Pi = \sum_{i=1}^{r} A_i \).

and \( \Gamma_i = \sum_{j=i+1}^{r} A_j \).

From equation (3) the only one term in the equation, \( \Pi y_{t-1} \), is in levels, cointegration relations depend crucially on the property of matrix \( \Pi \). It is clear that \( \Pi y_{t-1} \) must be either I(0) or zero except that\( y_t \) is already stationary. There are three situations:

(a) \( \Pi = \alpha \beta' \) has a reduced rank 0 < \( r < k \),

(b) \( \Pi = \alpha \beta' \) has a rank of zero, and

(c) \( \Pi = \alpha \beta' \) has a full rank.

Under situation (a), \( \alpha \) and \( \beta \) are both \( k \times r \) matrices and have a rank of \( r \). There are \( r \) cointegrating vectors \( \beta \varepsilon_t \) which are stationary I(0) series. It is equivalent to having \( r \) common trends among \( y_t \). The stationarity of \( \beta \varepsilon_t \) implies a long-run relationship among \( y_t \) or a sub-set of \( y_t \) the variables in the cointegration vectors will not depart from each other over time. \( \beta \varepsilon_t \) are also error correction terms in that departure of \( \Pi y_t \) from its levels implies a long-run relationship among \( y_t \) or a sub-set of \( y_t \). The second cointegration test is maximum eigenvalue statistic which tests the null hypothesis of \( r \) cointegrating relations against the alternative of \( k + r \) cointegrating relations. This test statistic is computed as:

\[
\pi_{\text{max}}(r / r+1) = -T \max\left\{ \lambda_i \right\}
\]  
(7)

Neither of these test statistics follows a chi square distribution in general; asymptotic critical values could be found in Johansen and Juselius [9] and are also given by most econometric software packages. Since the critical values used for the maximum eigenvalue and trace test statistics are based on a pure unit-root assumption, they would no longer be correct when the variables in the system are near – unit-root processes. By default, E-views program reports the value based on MacKinnon et al., [10] p-values for Johansen’s cointegration trace test and maximum eigenvalue test.

Results and Discussion of the Multivariate Cointegration Approach for Sheep

This section presents the results of the second cointegration analysis approach which is the system based tests using the vector autoregression (VAR) of Johansen [11,12] in which the joint effects of prices in all markets in concern were accounted for.

The order of vector autoregressive models

A major requirement in conducting [13,14] cointegration tests and estimation of a VAR system, either in its unrestricted or restricted Vector Error Correction (VEC) forms, is the choice of an optimal lag length. Noting that, the lag length ought to be set long enough to ensure that the residuals are white noise and considering that the study was based on monthly data. The lag structure of the estimated VAR was then examined using a combination of VAR lag order selection information criteria [15] (AIC), Bayesian (SBC), likelihood ratio (LR) and [16] (HQ) information criterion and checking that the inverse roots of the characteristic polynomial lie within a unit circle, which is a condition for having a stable VAR system. This process led to the choice of two lags as shown in Table 3, which was used in the cointegration test and subsequent analysis.

According to Table 3 below while the SC and HQ criteria suggested the use of one lag, the AIC and LR criterion suggests the use of two lags which was used in the cointegration test and subsequent analyses.

<table>
<thead>
<tr>
<th>Lag</th>
<th>LogL</th>
<th>LR</th>
<th>FPE</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-103.5315</td>
<td>2.08e-06</td>
<td>1.107464</td>
<td>1.191090</td>
<td>1.141320</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>308.6366</td>
<td>799.1014</td>
<td>4.01e-08</td>
<td>2.843230</td>
<td>2.341478</td>
<td>2.640997</td>
</tr>
<tr>
<td>2</td>
<td>337.0304</td>
<td>53.60052</td>
<td>3.87e-08</td>
<td>2.877861</td>
<td>1.957982</td>
<td>2.505450</td>
</tr>
<tr>
<td>3</td>
<td>351.9707</td>
<td>27.44142</td>
<td>3.90e-08</td>
<td>2.775211</td>
<td>1.437205</td>
<td>2.23522</td>
</tr>
<tr>
<td>4</td>
<td>367.3639</td>
<td>57.4779</td>
<td>4.75e-08</td>
<td>2.677182</td>
<td>0.921049</td>
<td>1.966216</td>
</tr>
<tr>
<td>5</td>
<td>384.4530</td>
<td>29.6444</td>
<td>5.17e-08</td>
<td>2.596459</td>
<td>0.422200</td>
<td>1.716215</td>
</tr>
<tr>
<td>6</td>
<td>402.7361</td>
<td>30.77512</td>
<td>5.57e-08</td>
<td>2.527873</td>
<td>0.664513</td>
<td>1.478351</td>
</tr>
<tr>
<td>7</td>
<td>416.1288</td>
<td>21.87289</td>
<td>6.31e-08</td>
<td>2.409477</td>
<td>0.601306</td>
<td>1.190677</td>
</tr>
<tr>
<td>8</td>
<td>437.4491</td>
<td>33.72091</td>
<td>6.62e-08</td>
<td>2.371930</td>
<td>1.056711</td>
<td>-0.938352</td>
</tr>
</tbody>
</table>

*Indicates lag order selected by the criterion.

LR: LR test statistic (each test at 5% level).
FPE: Final Prediction Error.
AIC: Akaike Criterion.
SC: Schwarz Criterion.
HQ: Hannan-Quinn information criterion.

Table 3: Vector autoregressive (VAR) lag order selection criteria.
Examination of the inverse roots of the AR characteristic within the unit circle for the VAR specification indicates that a VAR satisfies the stability condition under using two lag. i.e. if the estimated VAR process is stationary, then all AR roots should lie inside the unit circle as showing in Table 4a and Figure 2 below. No root lies outside the unit circle. VAR satisfies the stability condition.

The stationary condition for general AR (p) processes is that the inverted roots of the lag polynomial lie inside the unit circle. There is no particular problem if the roots are imaginary, but a stationary AR model should have all roots with modulus less than one. From Table 4a above the roots computed for six lag corresponding to that AR model should have all roots with modulus less than one. It is no particular problem if the roots are imaginary, but a stationary AR model satisfies the stability condition under using two lag. i.e. if the estimated VAR process is stationary, then all AR roots should lie inside the unit circle. The stationary condition for general AR (p) processes is that the inverted roots of the lag polynomial lie inside the unit circle.

Table 4b: Johansen tests results for number of cointegrating vector, sheep prices 1995 M1 – 2011 M 12.

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace statistic</th>
<th>0.05 critical value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.155684</td>
<td>80.60235</td>
<td>69.81889</td>
<td>0.0054</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.081920</td>
<td>46.58737</td>
<td>47.85613</td>
<td>0.0655</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.071724</td>
<td>29.40775</td>
<td>29.79707</td>
<td>0.0554</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.056180</td>
<td>14.44816</td>
<td>15.49471</td>
<td>0.0714</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.019363</td>
<td>2.826300</td>
<td>3.841466</td>
<td>0.0927</td>
</tr>
</tbody>
</table>

Trace test indicates 1 cointegration equation(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.

Table 5: Maximum eigenvalue test.

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Max-Eigen statistic</th>
<th>0.05 critical value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.155684</td>
<td>34.01498</td>
<td>33.87687</td>
<td>0.0482</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.081920</td>
<td>17.17961</td>
<td>27.58434</td>
<td>0.5646</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.071724</td>
<td>14.95960</td>
<td>21.13162</td>
<td>0.2917</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.056180</td>
<td>11.62186</td>
<td>14.26460</td>
<td>0.1257</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.019363</td>
<td>2.826300</td>
<td>3.841466</td>
<td>0.0927</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.

Table 6: Table of root moduli.

<table>
<thead>
<tr>
<th>Root</th>
<th>Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.931192</td>
<td>0.931192</td>
</tr>
<tr>
<td>0.793502</td>
<td>0.793502</td>
</tr>
<tr>
<td>0.540547</td>
<td>0.540547</td>
</tr>
<tr>
<td>-0.315481</td>
<td>0.315481</td>
</tr>
<tr>
<td>-0.073369</td>
<td>0.073369</td>
</tr>
<tr>
<td>-0.010658</td>
<td>0.010658</td>
</tr>
</tbody>
</table>

Table 4a: Roots of characteristic polynomial.
Estimation of vector autoregressive (VAR) model for sheep

The lag structure of the estimated VAR was examined using a combination of VAR lag order selection information criteria with two lag length as indicated in Table 6 below. The results of the VAR model are presented in the following Table 6.

Each column in the table corresponds to an equation in the VAR. For each right-hand side variable it was reported the estimated coefficient and the t-statistic. For example, the coefficient for El Elobied on Medani (-1) equation is (0.00790). The numbers at the very bottom of the table are the summary statistics for the VAR system as R-squared and F-statistic.

To examine the results presented in Table 6 above, collectively, the results significant according to the standard F test for each model which were (46.99166), (85.16735), (47.85076), (52.89212) and (29.16726) for El Elobied, Medani, Nyala, Omdurman and Sennar models respectively. By considering the first equation of each variable, only El Elobied at lag one and Nyala at lag one month was statistically significant. The sings of the significant vector autoregression in the El Elobied model suggest that, an increase in the level of El Elobied lag one month leads to an increase in the level of prices of Nyala lag one month.

Turning to Medani equation, only Medani at lag two is statistically significant according to t-statistic. According to the Omdurman equation, only Nyala at lag one and Omdurman itself at lag two were statistically significant according to t-statistic. That means the prices of sheep in Nyala and Omdurman itself in the two previous months affected the prices of Omdurman in the current month. The positive coefficient sings explained the positive relationship between Omdurman and Nyala prices.

Sennar market affected just by its own prices in the previous month and no other market affected it. Nyala equation shows that the prices of sheep affected by its own prices in the previous two months and affected by the prices of El Elobied market in the previous month.

Estimating vector error correction (VECM) model for sheep

After obtaining the order of vector autoregressive models, the number of cointegration vectors and estimation of vector autoregressive (VAR) model results, the next stage in the model building process requires the construction of a multivariate VECM for sheep prices in El Elobied, Omdurman, Medani, Sennar and Nyala where the time series were found to be cointegrated. Using information constructed from above results, one cointegration vector and one lag lengths were imposed in estimation of Vector Error Correction (VECM) Model and the long and short run matrices were extracted and presented in Table 7 below. These matrices describe the system dynamics.

Cointegration short run dynamics matrices (Γ) for sheep

The short run test results reported in Table 7 which presents the short run matrix for sheep prices in selected markets. Again as the Vector Autoregression (VAR) estimates result in Table 6, each column in the table corresponds to an equation in the VECM (short run dynamics). For each right-hand side variable, E-views report the estimated coefficient and the t-statistic.

El Elobied sheep prices were not affected by any other market price as shown in the first column. The second column in the table shows that Omdurman market was affected just by its own prices and affected by Nyala prices in the previous month, but according to F-statistic Omdurman market not affected by all other markets in the short run. Medani sheep prices affected by own prices and by Nyala market prices in the short run.

The fourth equation shows that Sennar is affected by its own prices in the previous month and by Nyala prices lag one month also. Nyala market equation shows two significant coefficients that are Nyala itself in the previous two month and Sennar lagged one month. The linkages between markets are presented in Figure 5 below.

Omdurman, Medani and Sennar were affected by their own prices and affected just by Nyala market, while Elobied market seems to be separated from the other markets, this due to feature of this market and affected just by Nyala market prices also. Nyala market equation shows two significant coefficients that are Nyala itself in the previous two month and Sennar lagged one month. The linkages between markets are presented in Figure 5 below.

Cointegration long run equilibrium matrices (II) for sheep prices

The long run equilibrium matrices (II) describe the long run effect. These matrices are extracted from the error correction models presented in Table 8 below.

---

Table 7: Vector error correction estimates (short run dynamics matrix (Γ)) for sheep.

<table>
<thead>
<tr>
<th>Error correction</th>
<th>D(ElElobied (-1))</th>
<th>D(ElElobied (-2))</th>
<th>D(Omdurman (-1))</th>
<th>D(Omdurman (-2))</th>
<th>D(Medani (-1))</th>
<th>D(Medani (-2))</th>
<th>D(Sennar (-1))</th>
<th>D(Sennar (-2))</th>
<th>D(Nyala (-1))</th>
<th>D(Nyala (-2))</th>
<th>R-squared</th>
<th>F-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(ElElobied (-1))</td>
<td>-0.127281</td>
<td>-0.109718</td>
<td>0.003343</td>
<td>0.024603</td>
<td>0.063939</td>
<td>-0.705011</td>
<td>-0.058338</td>
<td>-0.064432</td>
<td>0.077171</td>
<td>-0.064141</td>
<td>0.162374</td>
<td>3.447366</td>
</tr>
<tr>
<td></td>
<td>(-1.26265)</td>
<td>(-1.32665)</td>
<td>(0.04679)</td>
<td>(0.34907)</td>
<td>(0.58112)</td>
<td>(-0.57988)</td>
<td>(-0.62177)</td>
<td>(-0.70397)</td>
<td>(1.47767)</td>
<td>(-1.22032)</td>
<td></td>
<td>3.330701</td>
</tr>
<tr>
<td></td>
<td>(0.001576)</td>
<td>(0.007629)</td>
<td>(-0.353459)</td>
<td>(-0.132673)</td>
<td>(0.063939)</td>
<td>(0.079296)</td>
<td>(0.080315)</td>
<td>(-0.06432)</td>
<td>(1.04987)</td>
<td>(-0.017767)</td>
<td></td>
<td>3.447366</td>
</tr>
<tr>
<td></td>
<td>(1.55952)</td>
<td>(0.141907)</td>
<td>(0.08632)</td>
<td>(-1.22900)</td>
<td>(-3.89883)</td>
<td>(0.79878)</td>
<td>(0.83040)</td>
<td>(-1.32673)</td>
<td>(3.14905)</td>
<td>(1.22032)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.121860)</td>
<td>(-0.023880)</td>
<td>(2.003732)</td>
<td>(0.069326)</td>
<td>(1.05906)</td>
<td>(1.20594)</td>
<td>(1.23804)</td>
<td>(-0.035194)</td>
<td>(1.63277)</td>
<td>(-0.059202)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.62604)</td>
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Source: drawing using vector error correction estimates, Table 7.

Figure 5: Lines connected multivariate sheep markets whose prices were cointegrated in the short run, 1995 ml – 2011 ml2.

As evident in Table 8 the error correction terms have been found to be statically significant in Elobied and Sennar markets indicating that, the level of sheep prices in Elobied and Sennar exert significant long run effect on the current development of prices of Medani, Elobied, Omdurman, Sennar and Nyala markets, suggesting the validity of the long run equilibrium relationship in Elobied and Sennar markets. But the levels of sheep prices in the other five markets have no significant long run effect on Omdurman, Medani and Nyala prices.

- Note: the coefficients in bold font are significant at 0.05 significant levels.
- The figures in parentheses are the t-ratio for the estimates.
- D stand for the changes in the variables in concern.
- Source: Calculated from appendix (B) using E-views software computer program.

The sings of the significant error correction terms suggest that the increase in the level of Omdurman, Sennar and Nyala prices in the long run leads to an increase in the level in Elobied sheep market and decrease in the level of Sennar sheep prices, while an increase in the level of Elobied itself and Medani prices in the long run leads to decrease in the level of Elobied sheep prices market and increase in the level of Sennar prices market. Figure 6 below presents these linkages between markets.

The figure shows that Omdurman, Medani and Nyala markets were not cointegrated. The lack of cointegration among these markets because of the long distances separating the major sheep production areas from the consumption areas, the slow means of transport and communication and the high marketing costs are the main reasons for this phenomenon. The trekking route from Nyala to Elobied, for instance, is about 600 kilometers, and that between Elobied and Omdurman is about 560 kilometers [20], giving a total trekking route from Nyala to Omdurman of about 1.160 kilometers. The journey along this route takes 75 to 80 days, making the total marketing costs about 24% of the total costs. The error correction model takes into account the adjustment of long-run disequilibrium in markets and time to remove disequilibria in each period.

Table 8 shows that 5-22% of disequilibrium is removed in each period. For example, for the prices of Elobied market about 7% of the disequilibrium is removed in Medani in one month, while for the prices of Sennar market about 6% of the disequilibrium is removed in Medani in one month.

**Diagnostic tests**

In order to select an ECM, it needs to satisfy a range of diagnostic tests. These diagnostics provide information about the data properties and evaluate restrictions on the estimated coefficients, including the special case of tests for omitted and redundant variables. The diagnostic tests usually include Lagrange multiplier test for autocorrelation, Ramsey’s “RESET” test for functional form, normality and. The results of diagnostic tests of sheep prices data in Table 9 are robust as they satisfy almost all relevant diagnostic tests. But with respect of Elobied, the models suffer from normality problem as indicated in Jarque-Bera test p-value (0.34676) [21] which failed to reject the null hypotheses of non-normal distribution. One possible explanation for this problem is
The short period (5 months) of long-run equilibrium adjustment indicates that there are strong price linkages between the two markets (Omdurman with Elobied and Nyala markets individually) and also justifies the physical arbitrage adjusting for any disequilibrium between the two markets.

Figure 9 below depicts a standard error shock in Medani and its response in Sennar, Elobied, and Nyala markets. In response to a standard error shock in Medani market, the above mentioned Omdurman, Medani, and Nyala markets adjusted within four months which means there was a strong relationship among Sennar market and these sheep markets. Elobied market adjusted within five months, this may due to the same nature of these two markets as supply markets.

When the series were drawn against time it was noticed that the time paths during 1990's were slightly different from previous years [22]. This is quite understandable because of the instability which has characterized the Sudanese economy during this period. Owing to this problem, the models for predicting the future path of its variables should be used cautiously.

Impulse response approach results

An impulse-response analysis was carried out to better understand dynamic price interrelationships, how price shocks were transmitted, and how long take for shocks to be eliminated in alternate markets. The Figures 7-10 below give response function to a price shock equal in size to one standard error in each market equation over a 36 months horizon.

Figure 7 below depicts the impulse response in Elobied, Omdurman, Sennar and Nyala markets due to one standard error price shock in Medani market. It’s obvious that Omdurman and Nyala take eight months for Medani market to eliminate the price shock and converge onto long-run equilibrium, the long distance between Medani and Nyala justified this result while Omdurman associated with Medani as demand markets. Elobied and Sennar take six months to remove any disequilibrium and move back to long-run equilibrium. This result indicates that Omdurman market is main source of sheep for Medani market in which took the same period of Sennar market to eliminate prices disequilibrium.

Figure 8 below depicts a standard error shock in Elobied and its response in Medani, Omdurman, Sennar and Nyala, which shows that the adjustment take a five months to eliminate the price shock and converge onto long-run equilibrium for all markets. This result is reasonable because of short distance in case of Nyala and because Omdurman and Medani markets were considered as demand markets depend on Elobied market to supply them with sheep. Therefore, the information of sheep prices between these markets was continuous.

The Elobied, Medani, Sennar and Nyala markets, which in response to a shock in Omdurman markets. Elobied, Nyala and Sennar adjust within five months. While Medani market takes more than four months to converge onto long-run equilibrium, this justified by the short distance between these two markets.

The short period (5 months) of long-run equilibrium adjustment indicates that there are strong price linkages between the two markets (Omdurman with Elobied and Nyala markets individually) and also justifies the physical arbitrage adjusting for any disequilibrium between the two markets.

Figure 9 below depicts a standard error shock in Sennar and its response in Elobied, Omdurman, Medani, and Nyala markets. In response to a standard error shock in Sennar market, the above mentioned Omdurman, Medani, and Nyala markets adjusted within four months which means there was a strong relationship among Sennar market and these sheep markets. Elobied market adjusted within five months, this may due to the same nature of these two markets as supply markets.

Figure 10 below depicts a standard error shock in Nyala and its response in Elobied, Omdurman, Medani and Sennar markets, which shows that the adjustment take four months to eliminate the price shock and converge onto long-run equilibrium for Elobied, and Medani markets. The close production areas of Nyala and Elobied justified this result for the easy information movement. Omdurman and Sennar
Market takes more than six months to eliminate the price shock and converge onto long-run equilibrium, the interpretation behind this may due to the long distance between Nyala and these two markets.

**Pairwise granger causality analysis for sheep prices**

Granger causality is also estimated between pairs of livestock markets in Sudan during the period of study. Granger causality means the direction of price formation between two markets and related spatial arbitrage, i.e., physical movement of the commodity to adjust for these prices differences. If markets located in sheep production areas, tended to Granger-cause prices in major consumption markets, this is taken as evidence that price movements were primarily driven by supply shocks. If, however, terminal markets tended to Granger-cause other markets, this is taken as evidence that price movements are caused by demand shocks. Table 10 gives the results of the Granger causality test.

Table 10 above show that, Medani, Elobia, Omdurman, Sennar and Nyala markets exert a causality relations, which was Nyala market created unidirectional relation causality through Medani and Elobia market. That mean the sheep price of Nyala granger cause Medani and Elobia an on the other hand, the sheep price of Medani and Elobia granger cause Nyala. There were bidirectional relations which were Elobia market granger cause Sennar while Nyala granger causes Omdurman and Sennar, also Omdurman granger cause Elobia. Mention these results, Nyala market granger cause all other markets. The short run dynamics analysis of sheep prices holds significance results that Nyala sheep prices affecting Sennar, Medani and Omdurman markets. Nyala market as terminal market located in production area granger cause Medani and Omdurman as major consumption markets; this was taken as evidence that price movements were primarily driven by supply shocks. That mean the system was centered on Nyala i.e. Nyala could be considered as a supply of sheep market which means the prices were supply driven.

**Concluding Remarks**

This paper discusses the multivariate cointegration regression results for sheep prices using (Engle and Granger) test [23] and the vector autoregression (VAR) of Johansen. The first step toward cointegration tests is the stationarity tests using three approaches; these were Dickey-Fuller test, Phillips Perron test and panel unit root test. The results show that all price series are non-stationary in level, while they are stationary in first differences for all variables and then all prices were integrated of order 1(I1). Hence these series could be tested for the existence of a long run (cointegration) relationship between them through multivariate cointegration approaches.

As the long run analysis of sheep prices in selected markets indicated, a strong evidence of cointegration of pairs of markets exists. The last month disequilibrium in prices of Medani on Sennar corrected in the next month by 5%, where it seems to adjust slowly towards the long-run equilibrium. On the other hand, with respect to Omdurman on Elobia prices relationship, the last month disequilibrium in prices was corrected in the next month by 15%.

In the long run the level of sheep prices in Medani, Elobia, Omdurman, Sennar and Nyala exert significant long run effect on the current development of prices of Elobia and Sennar markets, thus suggesting the validity of the long run equilibrium relationship in Elobia and Sennar markets. But the levels of sheep prices in the five markets have no significant long run effect on Omdurman, Medani and Nyala prices. This result indicate that Elobia sheep markets consider as leader market. The long run analysis showed that Omdurman and Nyala markets were not cointegrated. The lack of cointegration among these markets may be due to the long distances separating the major sheep production areas from the consumption areas, the slow means of transport and the high marketing costs. The trekking route from Nyala to Elobia, for instance, is about 600 kilometers, and that between Elobia and Omdurman is about 560 kilometers, giving a total trekking route from Nyala to Omdurman of about 1,160 kilometers. The journey along this route takes 75 to 80 days, making the total marketing costs about 24% of the total costs.

In the short run the sheep prices of Nyala market does not have any impact on the rest of the prices of other markets except Medani market. Babiker [24] found that the sheep prices of Nyala market are affected by their own prices only in the short run. The prices of sheep in Elobia market affect the sheep prices in Omdurman livestock market by 33% in the short run, Elobia affect Medani by 44% Omdurman affect Elobia by 34%, Medani affect Sennar by 36% and Sennar affect Medani by 46%. This coherent affecting of sheep prices may due to the active commercial movement between these markets because of the ease of transportation, as well as to the relatively near distances between these markets [25].

The periods that sheep markets need to eliminate the price shock and converge onto long-run equilibrium was fluctuated between four and five months. Elobia, Nyala and Sennar adjust the shock in Omdurman market within five months and converge onto long-run equilibrium, while Medani market takes four months to converge onto long-run equilibrium, this justified by the short distance between these two markets. The short period of long-run equilibrium adjustment indicated that there are strong price linkages between Omdurman and other four markets (Elobia, Medani, Sennar and Nyala markets). The prices causality indicated unidirectional relation causality of Nyala market through Medani and Elobia markets. Nyala market as terminal market located in production area granger cause Medani and Omdurman as major consumption markets; this was taken as evidence
that price movements were primarily driven by supply shocks. That mean the system was centred on Nyala i.e. Nyala could be considered as a supply market in sheep market which means the prices were supply driven.

References