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Market Integration Analysis of Tomato Markets in Sudan

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Abstract:
Tomato is a leading crop in the world and in Sudan that is characterized by seasonality and perishability, which causes instability in market supplies and prices in the world, including Khartoum State and other markets of Sudan. This study aimed to estimate market integration in Khartoum State, Sudan. The study depended mainly on secondary data obtained from relevant sources. The study used descriptive analysis, Box-Jenkins Autoregressive Moving Average (ARMA), and Autoregressive Integrated Moving Average (ARIMA) time series analysis. The results of the time series analysis indicated that the prices of tomatoes were stable and variable throughout the year, reflecting a seasonal pattern. The results of the co-integration analysis indicated the strong integration among the different tomato markets in Sudan, with Khartoum and Port Sudan having 85% and Khartoum and Zalingei markets having a 67% level of co-integration. The study concluded that despite the poorly organized marketing system, the tomato market channel is well-integrated as prices tend to move up and down together in all markets of Sudan. The study recommended the encouragement of production and marketing cooperatives for farmers and traders under the close supervision and management of concerned institutions, ministries, and national and commercial banks and the introduction of adequate and appropriate transportation vehicles and packaging material for tomatoes.

Keywords: *Market integration, tomato, time series, Sudan*

1. Introduction

Markets are essential determinates of food availability and food access (WFP, 2007). It is also argued that market integration is a prerequisite for successful economic integration (Artingi, Ego, 2006).

Tomato is a leading vegetable crop in the world and was introduced into Sudan as early as 1821 by the Egyptians (Mustafa, 1999). Today the crop has become popular in almost every meal in Sudan, but the data about the total area under production of tomatoes is not known. However, there are assumptions that the crop may be grown in an area exceeding 125000 feddans. The crop is grown in many states, including Khartoum, River Nile, Northern, Kassala, Gadarif, Gazira, Blue Nile, Sinnar, Kordofan, and Darfur states under rivers, seasonal streams, and borehole systems.

El Haj (1987) indicated that about 74% of the Gezira tomatoes were channeled to markets of Khartoum (46.7%) and Wad Medani (27.3%). Almost all produced tomato is consumed fresh in large towns and cities, namely in Khartoum State. Per capita consumption of tomatoes in Khartoum State is estimated at 30 – 35 kg per annum (Ministry of Agriculture, Animal Wealth and Irrigation, 2020). The state has the largest consumer market for vegetables and fruits. The population of the State is estimated at around 8 million. Based on this data, the annual consumption of tomatoes is estimated at 240,000-280,000 tons which reveals a big gap to be filled by more production.

Available studies on tomato marketing in Sudan and elsewhere revealed high prices obtained by early-grown tomatoes harvested in late September in Khartoum markets (Abdalla, 1965). In the same pattern, tomato prices tended to move up from May to peak in July-August, and drop down slowly by September in Omdurman Central Market of Khartoum State. The supply of tomatoes started to increase in November and peaked in December-January. July-August scores the highest prices. Omdurman market receives most of the inflow of tomato supplies during autumn.

Despite production efforts, a high shortage occurs during the summer months of each year, from April to September, resulting in high prices for consumers. However, the selling price during the off-season remained very high, which warranted the need to look for an alternative solution.

For any country, markets are essential for economic growth and sustainable development. However, the emphasis on development policies has usually been placed on increasing agricultural production to serve as a base for rural development. In the absence of well-functioning markets, agricultural production can experience several drawbacks.

Sudan has a good potential in horticultural crop production for which smallholder farmers have diversified from staple food subsistence production to more market-oriented and higher value commodities. Despite this production potential and the importance of horticultural crops for the country, there have been limited studies with regard to the performance of vegetable markets and challenges faced in marketing vegetable products.

Market integration is considered an essential determinant of food flow, availability, accessibility, and price stability. In other words, integrated markets are markets in which the price of comparable goods does not move independently. According to the Law of One Price (LOP), if two markets are integrated, a change in price in one market due to excess demand or supply shocks will have an equal impact on the related market price. If this equilibrium condition holds, the two spatially separated markets are said to be integrated. Otherwise, markets may have some constraints on efficient arbitrage, such as barriers to entry, information asymmetry, or imperfect competition in one or more markets. Hence, the study of spatial market relationships provides the extent to which markets are related and efficient in pricing (Erik, 2011).

Among the key factors, weak infrastructure and large market margins that arise due to high transfer costs have been asserted as the main factors that partly insulate domestic market integration. Especially in developing countries, poor infrastructure, transport, and communication services give rise to large marketing margins due to the high costs of delivering locally produced commodities to the reference market for consumption.

The concept of market integration has retained and increased its importance over recent years, particularly in developing countries where it has potential application to policy questions regarding government intervention in markets. From the economic point of view, market integration concerns the free flow of goods and information and thus prices over space.

An alternative definition of market integration is that when a price shock takes in one location, it will be perfectly transmitted to the other if and only if the two markets are integrated. As a result, the price differentials between markets should be identical to the storage costs or processing costs if there is market integration across time or form. Several methodologies have been proposed to examine spatial price relationships. Over the last three decades, advances in time series econometrics have led to the development of models that address some of the perceived weaknesses. In what follows, four different methods are identified:

- Simple bivariate correlation coefficients,
- Multivariate regression methods,
- Ravallion method,
- Co-integration and Error Correction model.

Each of these methods has been widely applied to test for market integration across various goods and industries. Here we use simple bivariate correlation coefficients.

Early research on market integration focused on measuring the co-movement of two price series in distinct markets. The correlation coefficient is a relative measure of the linear association between two series. Though there are some limitations in using a correlation coefficient to express the relationship between time series variables, it is still one of the most popular, frequently used, and easy-to-calculate tools (Gerald, 1997; Danial et al., 1999).

The coefficient can indicate the strength of the relationship between two series. A low correlation coefficient is an indicator of a weak or non-integration of the two markets. A correlation coefficient of:

- Above 60 percent indicates a strong connection,
- Between 30 and 60 percent indicates a weak connection, and
- Below 20 percent, there is no connection between the variables

Despite the wide application of the bivariate correlation as an index of market integration, the approach has severe weaknesses as a tool for market integration testing. The most frequently referred drawback is the existence of common trends within price series over time. The approach produces high correlation results for markets with even no physical contact, road, or any other means of the transport connection. The high correlation could be the result of common price trends such as inflation, common seasonal variation due to similar climatic conditions, legal factors simultaneously affecting prices, or other shocks among the markets.

1.1. The Problem Statement

Tomato is a nutritious winter vegetable crop that has secured a high demand in the Sudanese food menu. In Sudan, seasonality and perishability are two main problems affecting tomato marketing in terms of quantity supplies and price fluctuations.

Tomato production and marketing in Sudan are concentrated in urban centers, especially in Khartoum State. The production and marketing of the crop are closely associated with food security for a large share of the population in Sudan. Tomato production and marketing face several problems. One of the problems is the increased diversity of tomato production in autumn and summer in the different parts of Sudan, which could not solve the marketing seasonality problem. Another problem relates to inadequate supplies due to a shortage of cool storage and proper transportation facilities and the high cost of transportation.

The study intended to investigate the current situations of tomato production and marketing and search for alternatives that could mitigate the negative impacts of the current structure.

1.2. Study Objectives

The objectives of this study were to:

- Estimate market integration in Khartoum State, Sudan, and

- Estimate the profitability of each actor and the feasibility of the current chain in reducing supply deficits and price variability.

2. Methodology

2.1. Data Sources and Types

This analysis utilized monthly prices time series data on tomatoes obtained from Planning and Agricultural Economics (PAE) spanning from 2017 to 2020 in Khartoum State and other relevant States markets in Sudan.

2.2. Methods of Data Analysis

The time series analysis method is aimed to analyze the price integration and co-integration of tomatoes through time and among different markets in Sudan. Correlation coefficients directly measure how closely prices of a commodity move together in various marketplaces. They are often invoked to test the hypothesis that local markets in developing countries are not integrated and, therefore, not efficient. Examinations of price relations that could be supplemented with the observation of trading activity have proved to be useful tests of the hypothesis.

As products move successively through the various stages, transactions occur between multiple chain actors, money and information are exchanged, and value is progressively added.

The time series analysis is described below:

2.3. Time Series Analysis

In time series analysis, the Box-Jenkins methodology applies Autoregressive Moving Average (ARMA) or Autoregressive Integrated Moving Average (ARIMA) models to find the best fit of a time series to past values of this time series to make forecasts. Box-Jenkins represents a powerful methodology that addresses trend and seasonality well. ARIMA models have a strong theoretical foundation and provide an effective technique for approximating any stationary process.

2.4. Seasonal ARIMA Model

A stationary time series x_t is said to follow an autoregressive moving average model of order p and q, denoted by ARMA (p, q), if satisfies the following equation:

$$x_t - \alpha_1 x_{t-1} + \alpha 2 x_{t-2} + \ldots\ldots + \alpha p x_t\text{-}p = \omega_t + \beta 1\ \omega_{t-1} + \beta 2\ \omega_{t-2} + \ldots\ldots + \beta q\ \omega_{t-q}$$

Where:

- The α's and the β's are the constants,
- The model is both stationary and invertible,
- ω_t is a white noise

In case the time series is seasonal, the Box-Jenkins methodology proposes multiplicative seasonal models coupled with long-term differencing, if necessary, to achieve stationarity in the mean.

At each stage of the differencing process, the series is tested for stationarity until it is attained. Here, the Augmented Dickey-Fuller (ADF) test shall be used after each stage of differencing (Ronal et al., 1970).

3. Results and Discussion

3.1. Time Series Analysis

In order to develop a viable strategy for dealing with volatile farm prices, one must understand how and why agricultural prices change. Therefore, the importance of accurate price forecasting for producers has become even more acute. The main purpose of agricultural commodity price forecasting is to allow producers to make better-informed decisions and manage price risk. Price forecasting is more acute with vegetable crops, particularly tomatoes, due to their highly perishable nature and seasonality. The tomato is grown in practically every country of the world and is one of the most important agricultural products among fresh vegetables in most countries in the world. Sudan is among the countries producing various kinds of vegetables at high production levels due to suitable ecological conditions. The objectives of this study were to analyze the seasonal price variation of tomato crops and to develop a Seasonal ARIMA (SARIMA) model to forecast the monthly tomato prices at the wholesale level in Khartoum state.

Tomato kilogram monthly price data in Khartoum state were collected from January 2017 to December 2020 from the Planning and Agricultural Economics Directorate (PAE). The Planning and Agricultural Economics Directorate (PAE) in the Ministry of Agriculture provided the data. In addition, monthly tomato prices per Kilogram were provided for other eleven markets besides Khartoum for the same period to be used in the analysis of the correlation between different markets.

These monthly data were used in the time series analysis applying the Box-Jenkins methodology. The monthly data were also used for correlation between different markets. The prices of tomatoes varied during the year (figure 1). The prices show a declining tendency during the first half of the year. They picked up in July, and prices started to decline in November and kept declining till March because of open field growing and the excessive supply of tomatoes.

This analysis aimed to fit a time series seasonal ARIMA model to the monthly prices of tomatoes in Khartoum. The best-fit model will also be used for forecasting future prices of tomatoes in Khartoum.

The following analysis mainly focuses on the application of Box-Jenkins SARIMA modeling techniques to estimate the appropriate model that can be used for forecasting future monthly prices of tomatoes in Khartoum.

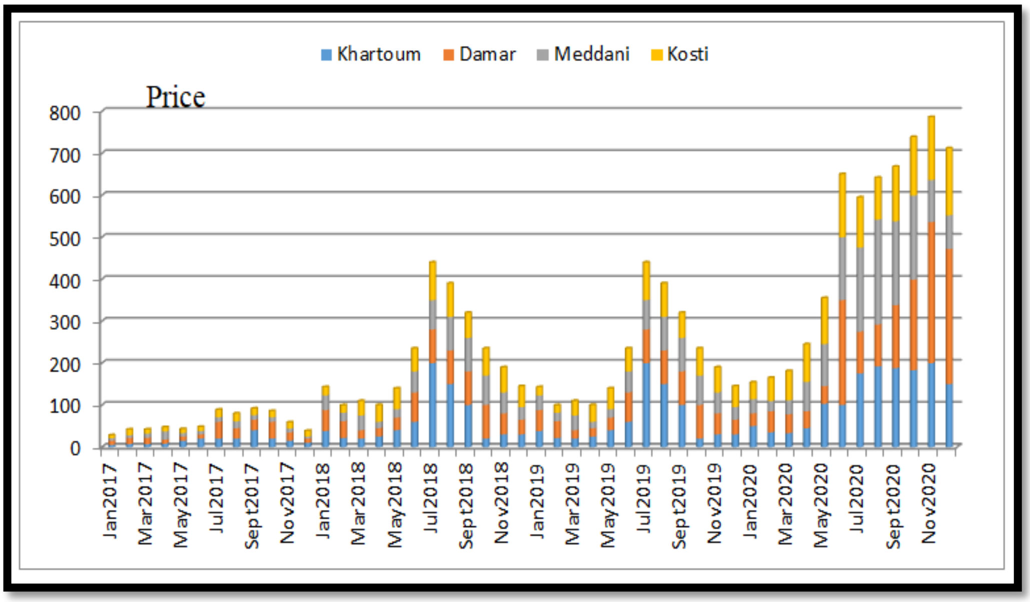

Figure 1: Tomato Monthly Prices per Kilogram in Different Markets

3.2. Analysis

The process consists of several stages in an analysis of this type.

First, as with any data analysis, a time plot of the data is constructed, and then the graph is inspected for any anomalies. If, for example, the variability in the data grows with time, it will be necessary to transform the data to stabilize the variance. In such a case, the Box-Jenkins class of power transformation could be employed. The same time plot gives first answers to questions of stationary or whether the time series shows a seasonal pattern.

This was then followed by an identification of the initial model. This is achieved by establishing seasonality in the dependent series and using function plots in the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the dependent time series to decide which (if any) autoregressive or moving average component should be used in the model. Secondly, the parameters for a tentative model that has been selected. In estimates, thirdly, the estimated model is tested or checked for adequacy to determine if it is the best-fit model for the data. If the estimation is inadequate, step one is repeated. Lastly, the final best-fit model is then chosen and used to predict future values of time series (Spyros et al., 1978).

3.3. Modeling Seasonal Time Series

The data set was plotted to give an initial guess about the data generation process. Figure 2 illustrates a time series plot of the original tomato monthly prices data in Khartoum from January 2017 to December 2020.

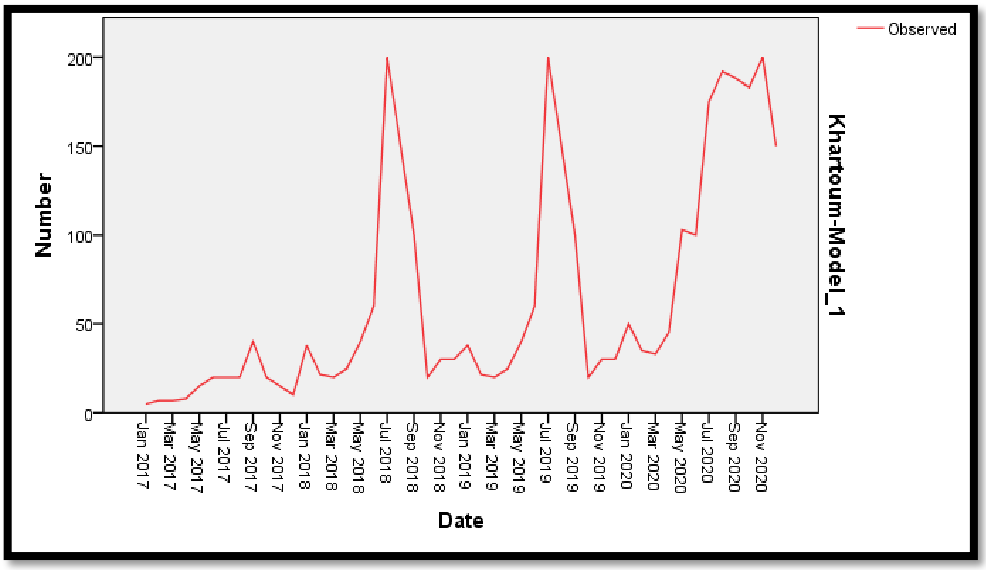

Figure 2: Time Series Plot of the Original Monthly Prices Data

From the time plot, the price data of tomatoes rose and then dropped suddenly within the same year throughout the series from January 2017 to December 2020. One could really see that there is a seasonal pattern. Throughout, it seems to have some sort of trend for part of the time in the level and then increase. In addition, the ACF and PACF plots shown in figure 3 of the original series confirm that the data set is stationary. Therefore, differencing will not be necessary to attain stationery.

3.4. Empirical Results

Model identification and Estimation: The first step in developing a SARIMA model is to determine if the monthly tomato price series are stationary. For this, graph and ACF, and PACF were used. The analysis produces several results, including two tables and one plot. Table 1 identifies the variable used in this analysis and that the model estimated was ARIMA (0, 1, 1) model.

			Model Type
Model ID	Khartoum	Model_1	ARIMA(0,1,1)

Table 1: Model Description
Source: Secondary Data Analysis

Table 2 reports the Stationary R-squared of 0.002 and the R-squared of 0.590. It also reports the value of the Ljung–Box Q statistic (46.398), its associated degrees of freedom (17), and its associated level of statistical significance (0.000).

Model	**No. of Predictors**	**Model Fit Statistics**		**Ljung-Box Q(18)**			**No. of Outliers**
		Stationary R-squared	R-squared	Statistics	DF	Sig.	
Khartoum-Model_1	1	.002	.590	46.398	17	.000	0

Table 2: Model Statistic
Source: Secondary Data Analysis

Figure 3 reports the ACF and the PACF, respectively, for the residuals resulting from the estimated ARIMA (0,1,1) model. As observed from figure 3, tomato prices do not indicate a significant trend. This indicates that the series is in a stationary structure. It is indicated that all ACF and PACF values should extend within the confidence limits in stationary series. ACF and PACF values were found to be high at specific lags for this series. These values were determined as making sudden peaks and not disappearing, especially at periodic lags of 12 months (19, 31, and so on).

Reading from the bottom, both figures show no pattern in the correlations reported among the residuals, nor do any of the correlations extend beyond the vertical 95% confidence intervals included in the plots. This, combined with the Ljung-Box Q statistic, suggests that the ARIMA (0,1,1) model appropriately modeled the dynamics for this time series.

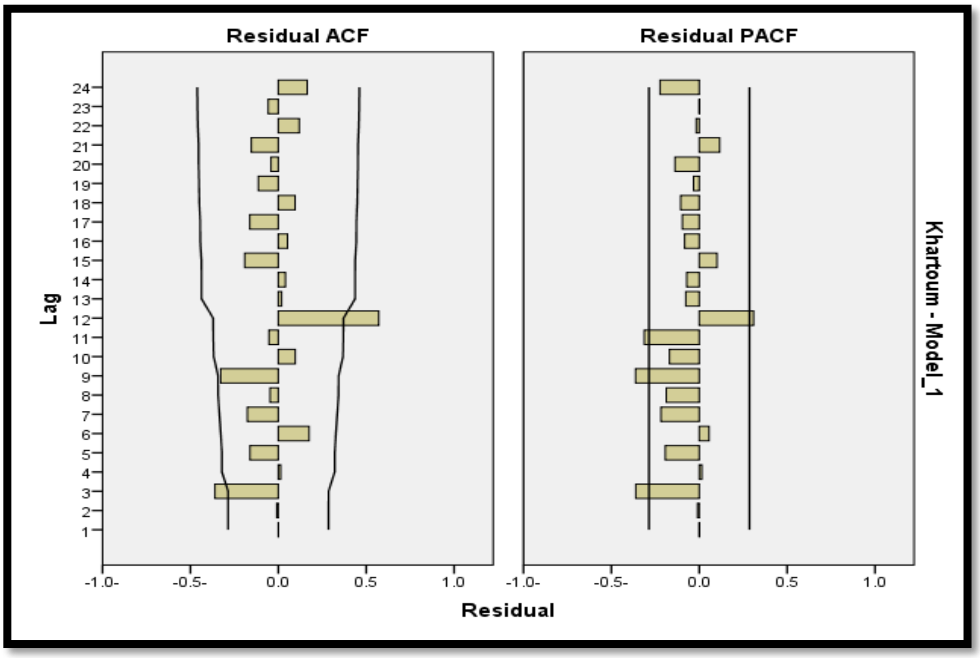

Figure 3: ACF and PACF Plots of the Monthly Prices Data

3.5. Model Selection

The model was analyzed based on the seasonal part of the model to select the SARIMA model, which will be used to forecast the prices of tomatoes (0,1,1). The selected SARIMA (0, 1, 1)12 model was used to forecast the mean monthly real tomato prices from January 2017 to December 2020 by using the observed data from January 2017 to December 2020. Forecasting performance of the selected SARIMA model is measured by using mean absolute percentage error (MAPE) criteria. The MAPE is based on the one-a-head forecast errors, which are the difference between the data value at time *t* and the forecast of that value at time t - 1 and time t + 1 (Spyros et al., 1978)

The predicted prices were compared with the observed prices (Table 3). The predicted real tomato prices were close to the observed prices. This result indicates that the model provides an acceptable fit to predict tomato prices.

The results obtained from this study showed that the prices of tomatoes in Sudan have not shown any trend toward an increase or a decrease. In other words, the prices exhibit a stationary structure. The forecasts predicted from the SARIMA (0,1,1)12 model, which has been chosen to determine the course of the prices of the next 3 years, show that any significant changes will not occur in Real Tomato Prices by the end of 2023.

Date	Observed (SDG/kg)				Predicted (SDG/kg)			
	17	18	19	20	17	18	19	20
Jan	5	38	38	50	19	26	47	47
Feb	7	22	22	35	19	52	52	64
Mar	7	20	20	33	16	33	33	46
Apr	8	25	25	45	15	29	29	42
May	15	40	40	103	20	32	32	52
Jun	20	60	60	100	22	45	45	108
Jul	20	200	200	175	20	62	62	102
Aug	20	150	150	192	17	201	201	176
Sep	40	100	100	188	35	147	147	190
Oct	20	20	20	183	13	95	95	183
Nov	15	30	30	200	5	12	12	176
Dec	10	30	30	150	19	20	20	191

Table 3: Real Tomato Prices Observed and Predicted

The stationary structure of real prices can be considered as negative regarding the sustainability of tomato production, while the increase in real prices of input is taken into account. In fact, the decrease in income of tomato growers may make the farmers unwilling to continue to produce tomatoes.

The table below represents the correlation coefficients between Khartoum and other states' markets and the coefficients between markets themselves. It shows a highly significant correlation ranging between 0.85 as a higher correlation between Khartoum and Port Sudan and a lower correlation (0.67) between Khartoum and Zalingei, which indicates a strong connection between Khartoum markets and states markets. The correlation between Gedarif and other states shows a significant correlation, but with less degree than that of Khartoum and other states (0.55 – 0.77), while the correlation between Sennar and other states shows the same strong significance as that of Khartoum. The highly significant correlation is between Port Sudan and other states, followed by Medani and Fasher. The lowest correlation was observed between Nyala and Gedarif and Nyala and Damar (0.55) for both, while the highest correlation was observed between Medani and Fasher, as illustrated in table 4 below.

Market	Gedarif	Sennar	Damar	Port Sudan	Meddani	Nyala	Fasher	Kosti	Kadogli	Zalingei	Damazine
Khartoum	.690**	.834**	.688**	.852**	.799**	.678**	.796**	.819**	.678**	.670**	.757**
Gedarif	1	.699**	.729**	.674**	.591**	.547**	.618**	.771**	.698**	.598**	.603**
Sennar	.699**	1	.866**	.833**	.796**	.675**	.841**	.861**	.830**	.714**	.843**
Damar	.729**	.866**	1	.675**	.614**	.547**	.712**	.847**	.721**	.707**	.701**
Port Sudan	.674**	.833**	.675**	1	.895**	.858**	.908**	.753**	.750**	.639**	.826**
Meddani	.591**	.796**	.614**	.895**	1	.908**	.923**	.805**	.834**	.659**	.805**
Nyala	.547**	.675**	.547**	.858**	.908**	1	.875**	.746**	.688**	.667**	.700**
Fasher	.618**	.841**	.712**	.908**	.923**	.875**	1	.809**	.805**	.743**	.818**
Kosti	.771**	.861**	.847**	.753**	.805**	.746**	.809**	1	.846**	.866**	.825**
Kadogli	.698**	.830**	.721**	.750**	.834**	.688**	.805**	.846**	1	.683**	.818**
Zalingei	.598**	.714**	.707**	.639**	.659**	.667**	.743**	.866**	.683**	1	.723**
Damazine	.603**	.843**	.701**	.826**	.805**	.700**	.818**	.825**	.818**	.723**	1

Table 4: Correlation Coefficient between Khartoum and Other States Markets and Coefficients between Other Markets Themselves

4. Conclusions

The above results show that the market system is efficient since the prices tend to move together. While it is true that the prices tend to move together, they may do so for other reasons. Common price trends like general inflation, common seasonality, especially in agriculture, or any other synchronous common factor may produce sympathetic but unrelated price changes. Correlation coefficients are not unequivocal indicators of market conditions, and as applications became more indiscriminate.

The study concludes that reliable statistics on tomatoes area and production in Sudan are lacking. However, the study concludes that tomato is becoming an important crop grown in many parts of Sudan. Seasonality and perishability are very important factors limiting the regular supply of the crop all year round. The poor transportation and packing of the crops result in high waste and spoilage of the commodity, especially when transported from remote areas. The absence of appropriate harvest and post-harvest practices also leads to more crop loss and damage.

Despite the poorly organized marketing system, yet tomato market channel proved to be integrated as prices tend to move up and down together in all markets of Sudan. However, the common price trends may be motivated by the general inflation striking the economy at large and may also be caused by seasonality.

Supplies of tomatoes come in most cases from proximate areas (Khartoum, Gazira, and White Nile), while tomatoes produced in other areas (Red Sea, Kassala, Gdarif, Kordofan, and Darfur) find difficulty in arriving at central markets in fresh and good conditions. This could be related to the type of vehicles used in transportation and the type of containers used in packing the crop (tins).

The study recommended the encouragement of production and marketing cooperatives for farmers and traders under the close supervision and management of concerned institutions, ministries, and national and commercial banks and the introduction of adequate and appropriate transportation vehicles and packaging material for tomatoes.

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