ANALYSIS OF INTEGRATION OF SORGHUM MARKETS IN KENYA

LUMUMBA BRIAN OMONDI

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DECLARATION

This thesis is my original work and has not been submitted for the award of a degree in any other university.

Signature ………………………………………. Date ……………………….

Lumumba Brian Omondi (A56/81431/2015)

This proposal has been submitted with our approval as university supervisors:

Signature …………………………………….. Date ……………………….

Dr. Jonathan Nzuma, Ph.D.

Department of Agricultural Economics

University of Nairobi

Signature ………………………………………. Date ……………………….

Dr. John R. Busienei, Ph.D.

Department of Agricultural Economics

University of Nairobi

DEDICATION

I dedicate this thesis to God Almighty who gave me the guidance, to my loving parents and family as well as other colleagues and friends who created an enabling environment for me to complete this thesis.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACF: Autocorrelation Factor
ADF: Augmented Dickey Fuller
AIC: Akaike Information Criterion
ASALS: Arid and Semi-Arid Lands
ASDS: Agricultural Sector Development Strategy
DF: Dickey Fuller
EABL: East African Breweries Limited
ECM: Error Correction Model
GDP: Gross Domestic Product
HQC: Hannan-Quinn Criterion
ICRISAT: International Crops Research Institute for the Semi-Arid Tropics
KEBS: Kenya Bureau of Standards
KEPHIS: Kenya Plant Health Inspectorate Service
KPSS: Kwiatkowski-Phillips-Schmidt-Shin
KG: Kilogramme
LOP: Law of One Price
MOALF: Ministry of Agriculture, Livestock and Fisheries
MT: Metric Tons
MTAR: Momentum Threshold Autoregressive Models
MTECM: Momentum Threshold Error Correction Models.
NCPB: National Cereals and Produce Board
OLS: Ordinary Least Squares
PBM: Parity Bounds Model
PP: Phillips-Peron
SC: Schwarz Criterion
SMU: Sorghum for Multiple Uses
SRM: Switching Regression Models
TAR: Threshold Autoregressive Models
TVECM: Threshold Vector Error Correction Models
VAR: Vector Autoregressive Models
VECM: Vector Error Correction Model

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ABSTRACT

This study evaluated the integration of sorghum markets in Kenya using a cointegration approach. Bimonthly wholesale prices for sorghum for five major markets; Kalundu Market (Kitui County), Soko Posta Market (Busia County), Homabay Town market (Homabay County), Kibuye Market (Kisumu County) and Gikomba Market (Nairobi County) for the period 2011 to 2017 were used.

The findings of this study indicate that Kalundu and Sokoposta markets have the lowest mean prices. Sokoposta, Kibuye and Homabay markets have the highest variability scores implying that wholesale sorghum prices are unstable over time. The markets are integrated with the presence of four cointegrating vectors . This implies that the markets share a long run equilibrium relationship.

Granger causality test results reveal that Gikomba and Kalundu have a bidirectional relationship, Homabay, Sokoposta and Kibuye unidirectionally granger cause Gikomba market while Sokoposta unidirectionally granger causes other markets. The presence of independent and unidirectional relationships in most majority of the market pairs imply that there exists price shock transmission inefficiencies thus lowering the level of integration.

The study makes certain key recommendations that will help improve sorghum market integration. Firstly, an improvement of transport infrastructure will help improve integration and reduce price volatility. This will in turn help increase access to sorghum markets. Additionally, the development and strengthening of market information systems within the analysed markets will improve price transmission thereby increasing market efficiency and enhancing market integration.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Agricultural markets act as key avenues through which food produce moves from the production to consumption zones. Price mechanisms play a critical role in the proper functioning of markets as they drive resource allocation and guide various decisions by economic actors. According to Golettie (1995), market integration can be defined to as the long run relationship of prices or the co-movement of information and price signals or shocks across spatially separated markets.

Without market integration there will be localized food scarcities as surplus areas fail to react to price signals from deficit areas (Dreze and Sen, 1995). Efficiency emerges where markets are integrated as it allows productions according to comparative advantage. This in turn leads to increased incomes for farmers while also helping to bridge the gap in consumption caused by structural deficiencies. Sorghum is one of the key grains grown in Kenya although it falls behind other cereals like maize, wheat and rice (ASARECA Project Report, 2011).

Sorghum is produced mainly as a food source in Kenya especially in low potential areas. It is an important crop for smallholder farmers in these areas as surplus is sold in the markets. The economic contribution of sorghum to the GDP has improved in terms of commercial use in the beer the industry. Over the past five years the total value of sorghum has improved from Kenya Shillings 4.7 billion in 2010 to Kenya Shillings 7.54 billion in 2016 (MoALF, 2016). Furthermore, sorghum is used in the production of edible oils, syrup and bakery industry thus generating employment opportunities along the value chain (FAOSTAT, 2012).

The total acreage of sorghum in Kenya is at 214,000 hectares with an average yield of 0.81MT per hectare (MoALF, 2016). Kitui, Tharaka Nithi, Homabay and Busia counties had the largest acreage under sorghum production in 2016 thus contributing to the large share of sorghum volume produced. Kitui had the largest area under cultivation at 59,530 hectares with an average yield of 0.63 MT per hectare, Tharaka Nithi at 21, 227 hectares with an average yield of 0.42 MT per hectare, Homabay at 20,401 hectares with an average yield of 1.62 MT per hectare and Busia at 13,109 hectares with an average yield of 1.3 MT per hectare (MoALF, 2016).

In the last five years, the total sorghum production increased from 94,955 MT in 2010 to 144,000 MT in 2017 (KNBS, 2017). Data for 2010 and 2016 shows that there changes in the total production volumes, imports and exports. Sorghum exports in 2010 were 76,000 MT and this dropped to 49,000 MT in 2016 (KNBS, 2017). Sorghum imports dropped to 71,000 MT in 2016 compared to 108,000 MT in 2010 (KNBS, 2017). The main varieties grown in Kenya include Dobbs, Serena, E6518, E1291, Ikinyakura, BJ28, Seredo and Gadam (ICRISAT, 2016).

Over the past seven years, sorghum consumption levels increased from 81,000 MT in 2010 to 188,000 MT in 2016 (KNBS, 2017). According to the KNBS (2017) report, out of the total 188,000 MT of sorghum used in Kenya, 65,000 MT was for human consumption, 28,000 MT in industrial processes, 19,000 MT and 3000 MT were used for feed and seed respectively (KNBS, 2017). Other uses of sorghum include the production of edible oils, syrups, baked and brewed products (FAOSTAT, 2012). In terms of per capita consumption, maize ranks first at 59.7 kg per year, wheat at 34.9 kg per year, rice at 11.9 kg per year while sorghum comes fourth at 2.3 kg per year (KNBS, 2017). This implies that there is a greater preference for other cereal grains compared to sorghum.

Despites efforts to increased sorghum acreage, yields remain low. It is not clear if the current market demand for sorghum stimulates increased production. According to Golettie and Taigas (1995), variations in production in different regions is one of the key factors of market integration. Various stakeholders have attempted to improve consumption of sorghum by using interventions targeting increased sorghum production. Moreover, the Government of Kenya through the Traditional High Value Crops Program and other private organizations have made substantive investments in the development of the sorghum sector.

Market integration refers to presence of long run relationship between prices and other information across spatially separated markets (Goletti and Tsigas, 1995). More specifically, tradability is a key element of market integration as it describes the ability of a good to be traded across markets, and in the current context it describes the movement of surplus demand from one to another market. Evaluating whether markets are integrated can inform on the ability of markets in these regions to effectively transfer surplus sorghum to deficit urban markets. One key question is the extent to which sorghum markets are integrated. The answer has significant effects on the design of agricultural price policies to ensure that all sorghum stakeholders that include farmers, traders and processors benefit from the whole value chain.

In Kenya’s sorghum sector, evaluation of market integration is necessary as production zones are spatially separated from deficit regions. Understanding the degree to which sorghum producing areas are integrated with deficit regions is essential as the information can be used to design effective sorghum based agricultural policies. Kenya Agricultural Productivity Programme (2011) recommended an in-depth analysis of how the sorghum price mechanism functions to provide insights into the efficiency of markets. The current study aimed at bridging this gap in knowledge by analysing wholesale prices using time series data in order to establish whether sorghum markets in Kenya are integrated.

1.2 Statement of the Research Problem

There has been increased interest in the sorghum sector from researchers over the past few years owing to its potential as a climate adaptive crop. However, challenges like low production volumes, lack of market access and poor prices continue to dominate this sector. Markets are a critical avenue through which food produce moves from production to consumption zones. In order to improve the sorghum sub-sector, there is need to have a clear understanding of how the market functions.

Research along the sorghum value chain has mainly focused on production and biological aspects (Mutisya et al. 2016; Muui et al. 2016 and Oyier et al. 2017) while Orr et al. (2016) assessed the sorghum value chain. While these studies offer critical information, there is lack of empirical evidence on the integration of sorghum markets in Kenya. Moreover, many of the studies on the integration of agricultural markets in Kenya have focused on maize (Gitau and Meyer, 2018; Ngare, 2014; Nzuma and Sarker, 2008). This study aimed at bridging this gap in knowledge by analysing price dynamics between sorghum markets thereby contributing to the literature of market integration studies in Kenya.

An understanding of the integration of sorghum markets is of particular interest to farmers, traders, policy makers and other stakeholders in the sorghum sector. This is because the information generated from such a study can be used to design effective sorghum market oriented policies thus improving the overall value chain. Furthermore, such a study is essential, as it will improve the understanding of the dynamics of sorghum markets in Kenya while also providing some preliminary guidance for addressing the marketing constraints such as poor price information faced in the sorghum sector.

1.3 Purpose and Objectives of the Study

The purpose of this study was to analyse the integration of sorghum markets in Kenya.

The specific objectives of this study were:

i. To characterize the trends in wholesale sorghum market prices in Kenya.

ii. To assess market integration between spatially separated sorghum markets in Kenya.

iii. To identify the direction of causality among wholesale sorghum markets in Kenya.

1.4 Study Hypotheses

The following hypotheses were tested:

i. That sorghum markets in Kenya are not integrated.

ii. That sorghum market prices do not granger cause each other.

1.5 Justification of the Study

The choice of sorghum in this study can be justified based on its economic importance and its contribution to the food security status in Kenya. Its contribution to the GDP over the past seven years has increased from Ksh. 4.7 billion to Ksh. 7.54 billion (MoALF, 2016) thus a key source of revenue and employment due to its related industries. Additionally, sorghum production and utilization has gained prominence through the Traditional High Value Crops Project by the Ministry of Agriculture (MoALF, 2016), an indication of its importance to overall food security.

An understanding of the price relationships in various markets is critical for sorghum farmers, as it will guide towards production plans as well as where to sell to maximize earnings. Sorghum traders also require price information in order to decide on where to purchase and sell; furthermore, traders use price information in order to decide the volume of storage to maintain steady flows of income. County governments focused on enhancing the livelihoods of citizens can apply the findings of this study to design policies that will intensify the production of sorghum as an alternative crop to maize and thus enhance food security while also improving incomes by selling to deficit markets.

Understanding whether sorghum markets in Kenya is critical, as it would provide insights on the ability of the market system to stimulate transfer of sorghum between deficit and surplus markets. Additionally, a market integration study is critical as it provides information on how markets interact thereby informing on the existing price differences. Overall, the applied value of this study is that it helps stakeholders acquire information on the relationship between different sorghum markets. This would then guide in the design of appropriate market oriented policies for the sorghum sector. Furthermore, it contributes to the empirical analysis of food markets in Kenya focusing on one of the traditional food crops in Kenya.

1.6 Organization of the study

The thesis study consists of a total of five sections. Chapter one is the introduction of the thesis. The section provides background information on the sorghum sector in Kenya and discusses various aspects under market integration. Additionally, the statement of the problem and the objectives that guide the study are discussed. The justification of the study in relation to the problem is discussed at the end.

Chapter two describes the methodologies used to evaluate market integration. It states the merits and limitations of different approaches, providing direction on which model to use in the study. This is followed by a review of previous studies describing the similarities and differences in relation to the current study. Chapter three presents the empirical procedures and models applied in the study.

Chapter four presents the results from the application of selected empirical models. The results are discussed and inferences drawn, these are later used to outline various recommendations which are then discussed subsequently under chapter five. Chapter five discusses the policy implications and viable recommendations and concludes by suggesting topic areas which require more research.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews the concept of market integration and the various approaches used in analysing market integration. This is followed by a review of past related studies on the integration of agricultural markets with an emphasis on the sorghum subsector.

2.1 Market Integration

The extent to which agricultural markets are integrated is a critical aspect of a country's market efficiencies. According to Golettie (1995), market integration can be defined to as the long run relationship of prices or the co-movement of information and price signals or shocks across spatially separated markets. Barrett and Li (2002) define market integration as the contestability or tradability between markets which includes the market clearance process where transaction, demand and supply costs determine prices and trade, as well as transmission of price shocks from one market to another.

Baulch (1997) describes three categories of market integration: inter-temporal market integration, which refers to co-movement of prices across periods, spatial integration, which refers to movement of prices across spatially separated markets, and vertical market integration as the relationship of prices across different market levels.

Dreze and Sen (1995) note that lack of integration in agricultural markets can result into localized food scarcities as distant surplus markets fail to react to price signals from deficit locations. Therefore, evaluating market integration is key in determining the effectiveness of agricultural price policies. Baulch (1997) argues that the absence of integration in agricultural markets would result in increased price volatility while agricultural producers would fail to specialize in food production hence limited gains from trade.

Tradability is a key component of market integration and it describes the notion that a good is traded between two markets or more where of excess demand is transferred from one market to another through potential or actual physical flows (Barrett, 2005). Furthermore, market integration is an indicator of market inter-relationships processes. In essence, it can be measured from the existence of one price or price co-movement (Barrett and Li, 2002).

An empirical analysis of how market integration from the basis of price movement enables economists to know how the changes in one market affect the prices of a similar commodity in another market, social welfare consumption and output. Furthermore, it helps forecast information on how consumers and producers in the markets will react to price changes. Under the neoclassical model, the spatial arbitrage condition ensures that the prices of a commodity in two spatially separated markets only differs by an amount that is equal or at most equal to transfer costs.

Such costs come in the form of transportation costs, quality inspection, search costs, supervision and in the absence of product homogeneity and standards. Poor market integration results from poor infrastructure and inefficient market links which in turn reduces incomes for producers, while encouraging monopoly or oligopoly type of market structures.

Market integration can be viewed under three premises: market conduct, market performance and market efficiency. Market conduct refers to the behaviour and actions undertaken by market agents in relation to sales promotion actions, price determination and government regulatory activities. This directly affects market integration. For instance, where market agents set up prices through illegal cooperation or where the government puts restriction on dissemination of market information in the form of laws, this leads to inefficient and non-integrated markets.

Market performance is as a result of market conduct. Narver and Savitt (1971) define market performance as the net effect of market conduct that is measurable in terms of net profits, rate of return and efficiency in resource use. Market integration is directly linked to market performance in that it describes economic results in terms of pricing efficiency. Thus, the level of prices can help determine the degree of market integration.

A competitive system allows market agents to work freely and this could result in marketing efficiency, which is a requirement for quick delivery of goods. An efficient market system is characterised by fairly less price spreads (Seth and Sharma, 2015). A lower price spread implies that producers are gaining a logical profit while consumers are paying reasonable prices. The theory of marketing efficiency can be viewed as; lower price spread, maximization of input-output ration and existence of competition.

Under market integration, price of goods between spatially separated markets may get differed only by transaction costs and where low price spreads exist then this indicates market integration. Highly integrated markets are characterized by price efficiency, as there is improved operations in terms of buying, selling and pricing. Market integration supports these functions as it consists of improved access to information, market news and competition thereby leading to increased returns along the value chain.

2.2 Approaches used in Market Integration Analysis

A number of approaches have been applied in the analysis of agricultural market integration; these are classified into linear and non-linear approaches. The linear approaches applied include correlation analysis, Ravallion model analysis and cointegration analysis. The non-linear models, which recognize the non-linear nature of prices, are the threshold and parity bound models.

2.2.1 Correlation Analysis

The evaluation of market integration started with the application of correlation and regression analysis. According to Hossain and Verbeke (2010), the approach involves estimation of bivariate correlation for two price series and regression coefficients to examine how prices move, keeping transaction costs constant. The existence of correlation between prices implies that these prices move together and thus explains the idea of integrated markets.

For example, if P_t^1 and P_t^2 represent prices in markets one and two linked by trade of a homogenous commodity, then market integration is determined by the value of r, that lies between -1 and +1. Correlation analysis is applied in order to understand the share of variation of one variable in relation to other variables as explained by the goodness of fit R^2 (Hossain and Verbeke, 2010). It is based on the premise that the correlation of prices in different markets is linked to the notion that integrated markets show prices that co-move together. A positive correlation analysis *r*-value indicates that the markets are highly integrated while a negative *r*-value implies market segmentation (Hossain and Verbeke, 2010).

According to Golettie *et al.*, (1995), the main advantage of correlation analysis is that it is simple and easy to estimate using only price data. However, their assumption of fixed transaction costs and stationary price behaviour tends to underestimate the degree of market integration (Baulch, 1997). Another demerit is that the coefficient value can be high or equal yet there is no trade between the two markets under study. The methodology stipulates that prices follow parallel movements and that is not plausible. Such movements can be due to inflation, seasonality or the presence of autocorrelation residuals in the price series (Goodwin & Piggott, 1999). Finally, this approach fails to capture the dynamic nature of prices in terms of seasonality as it assumes instantaneous price adjustment that can lead to spurious results (Ravallion, 1986).

2.2.2 Ravallion Model

The Ravallion model is an improvement on correlation analysis because it distinguishes between long run and short-run market integration after controlling for common trends, seasonality and autocorrelation (Negassa, Meyers and Maldhin, 2003). The main motivation for this model is that agricultural markets can be slow in adjusting to prices, there is need to incorporate time lags. The model incorporates dynamic considerations correcting for the limitations of the correlation models (Ravallion, 1986).

The Ravallion model assumes a radial spatial market structure, which consists of a number of local markets linked to one main market. It is applied to determine whether the price in a producer market is influenced by price in a central market (Negassa, Meyers and Maldhin, 2003). Furthermore, it allows for the test for different hypothesis in relation to short and long run market integration, central market hypothesis and market segmentation. The prices in a producer market are influenced by its own lags and lagged prices in the central market. Through this process, a binary relationship between the central market and each local market is analysed.

The main merit of this method is that it comprehensively assesses market inter relationships (Ravallion, 1986). Secondly, it allows for the index of market concentration that easily measures short run market integration between two markets. On the other hand, it tends to assume a radial market structure where the price in the central market is exogenous. However, the assumption fails to hold due to the existence of direct trade links and inter-seasonal flows between regional markets (Barrett C. , 1996). Furthermore, the model fails to take into account issues related to non-stationarity and transaction costs (Okoh and Akintola, 2005).While the Ravallion model improved the analysis of market integration, it did not address the issue of non-stationary nature of time series.

This led to the development of cointegration analysis. According to Conforti (2004), cointegration between a set of price series is achieved when, they converge in the long run leading into a long run equilibrium relationship. The price series does not have to be stationary and there are no restrictions unlike Ravallion's model. Engle and Granger (1987) and Johansen (1988) developed and advanced cointegration analysis procedures.

2.2.3 Cointegration Model

The Engle and Granger (1987) cointegration test is a two-step model procedure adopted from Ravallion's radial market structure model. The first step involves testing the price series for the order of integration. If the series are integrated of the same order, OLS regression is applied to test for a long run relationship between the central market and other markets. Cointegration is confirmed if the residuals are found to be stationary through unit root tests. Delgado (1986) argues that the Engle and Granger model cannot incorporate more than one cointegrating relationship. Another weakness as noted by Stock and Watson (2003) is that the prices can influence each other leading to endogeneity problems.

Johansen (1998) extended the Engle and Granger procedure by introduction of multivariate analysis thus eliminating the problem of the inability to account for more than one cointegrating relationship. The first step involves Johansen maximum likelihood test procedure, which is based on a reduced rank model that tests for cointegration between price series. This relies on the maximal eigenvalue and trace tests that enable one to detect the number of cointegrating vectors between two or more price series (Johansen and Juselius, 1990). These are likelihood ratio test statistics that test the null of r cointegrating vectors against the alternative r+1. A rejection of the null hypothesis implies that there are r-cointegrating vectors thus the series are said to be cointegrated (Johansen, 1988).

The main advantage of the cointegration analysis, more especially, the Johansen procedure is that it allows one to estimate multiple long run equilibrium relationships. Secondly, it enables one to test for different economic hypotheses through linear restrictions (Johansen and Juselius, 1990). Conversely, Johansen and Juselius (1994) point out that problems may be encountered in relating economic relationships with various cointegration vectors. Another demerit according to Barret and Li (2002) is that cointegration analysis does not incorporate transaction costs.

2.2.4 Variance Component Model

The variance component approach was developed by Delgado (1986) to examine price transmission and integration of markets by testing time series for seasonal differences. The method disaggregates the analysis on seasonal basis and controls for heteroscedasticity in the price series before testing for market integration (Delgado, 1986). The main assumptions made include: that transaction and transport costs for the marketing of a crop are constant based on random disturbance in a season and that the price variance for a certain crop remain constant over the season.

Its advantage is that it allows statistical inference for a sample of market prices subject to regional and seasonal differences in the variance of prices. The weakness of this model lies in its assumptions of constant price variances over the season and constant transaction costs.

2.2.5 TAR Models

Non-linear approaches are able to take into account transaction costs as well as price adjustments (Rapsomanikis, *et al.,* 2004). Enders and Siklos introduced the threshold autoregressive (TAR) model in 1999 and unlike the cointegration model; it recognizes the impacts of transaction costs on traders.

According to Goodwin and Piggot (1999), TAR models take into account the presence of transaction costs in determining thresholds, which should be exceeded hence equating price modifications. These thresholds are assumed as a function of adjustment and transaction costs that act as a barrier to market agents in terms of adjusting to changes in markets (Rapsomanikis and Karfakis, 2007).

TAR models involve the process of splitting thresholds into one or multiple regimes. For example, Meyer (2004) notes that the model can be split into three regimes. Regime one occurs when there is no trade between markets 1 and 2. Regime two implies that if trade flows from market 1 to market 2 then the price in market 2 should be equal to price in market one plus transfer costs. Regime 3 occurs when trade flows from market 2 to market one, thus the price in market 1 is equal to price in market 2 plus transfer costs (Meyer and Von Cramon-Taubadel, 2004).

The main advantages of TAR models are that they are able to account for transaction costs, which do affect efficiency of markets (Abdulai, 2000). Secondly, transaction models provide a measure of the degree to which a specific market violates the spatial arbitrage condition by assessing asymmetries in price adjustments (Fackler and Goodwin, 2001). However, threshold models tend to assume the existence of constant transfer costs that implies a fixed unbiased band over a certain period (Abdulai, 2007). Barrett (2005) argues that TAR models ignore the time properties of data, limiting the analysis of short run and long run integration.

2.2.6 Parity Bound Model

The Parity Bound Model takes into account all obtainable market data (transaction cost, trade movements and capacities, prices) to give a comprehensive description of market integration (Abunyuwah, 2007). The motivation for this model is that transaction costs determine the price efficiency band (parity bounds) within which prices between two markets engaged in trade varies independently (Baulch, 1997).This model examines the extent of market integration by differentiating three trade regimes. In the first regime, a parity bound occurs where inter market price differences equals to transfer costs.

The existence of effective arbitrage conditions that are binding facilitates trade, resulting in prices between markets to move in a similar manner (Sanogo, 2008). Regime two lies within the parity bound where inter market price differences is less than transfer costs. Hence, trade fails to occur as well failure to achieve spatial arbitrage conditions. Regime three falls outside the parity bound thus transaction or transfer costs are exceeded by inter-market price changes, although resulting in violation of arbitrage conditions (Baulch, 1997).

According to Barrett (1996), the PBM model has the advantage of accounting for a variety of inter-market arbitrage conditions and therefore accomodates time varying transaction costs and trade discontinuities. In addition to that, it can clearly distinguish between perfect market integration and market segmentation unlike other models that readily reject a null hypothesis at a given level of significance (Kilima, 2006).

Conversely, Barrett (1996) argues that various transaction costs are difficult to measure as some components are unobservable to trading margins. This can lead to underestimation of transaction costs resulting in biased results from the PBM model. Furthermore, Baulch (1997) notes that the PBM only considers contemporaneous spreads in estimation thus it does not consider lagged price adjustment as suggested in the Ravallion models.

2.2.7 Regime Switching Model

Regime switching models also form part of the non-linear approaches to testing for market integration. The Markov switching model is the most common and was developed by Hamilton (1989).

It allows for switching between multiple structures in different regimes thus able to capture intricate dynamic trends. The model allows price dynamics for correlated data that exhibits dynamic patterns during different periods. Its unique feature is that the switching mechanism is controlled by state variables, which are unobservable and follow Markov chain's first order. Unlike the linear VAR model, the Markov switching VAR is much more flexible being nonlinear and that it provides a multivariate framework that allows parameters to change based on different regimes.

The main limitation of this model is that it is difficult to interpret as state variables are not observable (Zhao, Goodwin, & Pelletier, 2012).

From the approaches reviewed, the conclusion is that each method builds upon the limitations of the preceding models. Kilima (2006) argues that cointegration analysis accounts for data stationarity based on price data available. While the non-linear approaches account for transaction costs, such data is usually unavailable. Given the time series nature of market data and richness of sorghum price data and based on the co-movement assumption, the current study employed cointegration analysis.

2.3 Granger Causality

Causality refers to the cause and effect relationship between two variables. The concept of causal ordering facilitates understanding of causality, in that a variable x is said to Granger cause another variable y, if the past values of x can predict the current value of y. Granger (1969) is credited with developing the concept of Granger causality in that x is a cause of y if it is able to increase the accuracy of predicting y while only considering past values of y. Granger causality test can be applied in three different situations. First, a simple Granger causality test only consists of two variables and their lags. Secondly, a multivariate Granger causality test consists of analysing more than two variables in that both can affect the results.

The other form involves application of a VAR framework to test for Granger causality whereby the multivariate model is extended to test for simultaneity of all variables (Foresti, 2006). Several variants of Granger (1969) causality test have developed such as Sims (1972) causality test and the Toda and Yamamoto (1995) procedure. Sims (1980) and Sargent (1979) introduced the vector auto regression model which generalizes the simple granger causality test into a multivariate setting. This model is able to add more variables that could predict y and thus help to avoid spurious correlations that are associated with Granger tests (Qin, 2011). While the multivariate VAR causality test is robust, it can be affected by sensitivity due to lack of frequent observations or mis-specified lag length.

Engle and Granger (1987) addressed this problem through the introduction of cointegration in running the VAR model. Cointegration entails the removal of a stochastic trend by a linear function and where two variables share a common trend then the presence of granger causality is high in either one or between the variables.

The Johansen procedure allows one to further test for direction of causality where various tests are applied to the cointegrating VARs. The current study applies this test procedure in that it does not suffer spurious causality which occurs where variables are omitted (Stern, 2011). In certain instances, time series can either be integrated of different orders or not cointegrated. The Toda and Yamamoto model accounts for such situations whereby the Granger non-causality relationship is improved with more lags. Their modification allows for variables in level form to be robust to occurrence of unit roots (Stern, 2011).

2.4 Review of Past Empirical Studies

A number of studies have analysed the integration of agricultural markets in Sub Sahara Africa. These studies have utilized different approaches to explain and offer recommendations improvement of market infrastructure within a country.

Abdalla (2016) examined the integration of sorghum markets in Sudan using a variety of approaches. The study analysed monthly sorghum prices for the period 2002 to 2010. The study employed cointegration analysis to test for spatial integration in eight sorghum markets. Four key markets in the higher production zones, two in the low production and two in the consumption zones.

Cointegration analysis results confirmed that markets linked with well-paved roads were integrated while Gadaref market was found to granger cause other markets. The current study is similar to the study under review as it employs cointegration analysis from the study under review to inform sorghum stakeholders about the integration of sorghum market in Kenya. However, it is different as it analyses five wholesale markets in spatially separated areas.

Amassaib *et al.* (2015) evaluated the integration of international and domestic sorghum markets in Sudan. The study applied a dynamic linear regression model which is a variant of the correlation model to analyse data covering the period 1970-2007. Results revealed that the domestic markets were positively integrated with world markets. Additionally, the domestic sorghum prices were inelastic both in the short run and long run. The author concluded that devaluation policies would lead to increased domestic prices.

While the Amassaib (2016) examined the international and domestic market integration, the current study evaluates the integration of domestic markets in Kenya. Furthermore, it applies a cointegration model unlike the linear regression model.

Blay *et al.* (2015) evaluated the level of integration between sorghum and millet in the Ghanaian markets. The markets sampled included Accra, Techiman (reference market), Tamale, Bolgatanga, Kumasi and Wa. The study employed the Threshold Vector Error Correction Model (TVECM) and Momentum Threshold Autoregressive Model (MTAR) to a set of price series for the periods 2006 to 2013.

The findings of the study revealed that both sorghum and millet markets exhibited asymmetric adjustment in relation to the reference market. While the methodology used in the study under review took into account transaction costs, it assumed constancy. The current study employs cointegration analysis to evaluate integration of sorghum markets unlike the study reviewed which evaluated both sorghum and millet.

Zungo (2017) examined the degree of price transmission and price linkages in both maize and rice markets in Tanzania. Through purposive sampling the researcher was able to sample ten surplus and deficit markets and a dataset covering the period from July 1992 to December 2012. The study employed a cointegration and causality model to identify which markets share a price relationship.

Results revealed that nine of the markets were integrated with each other. Through application of the error correction model, it was established that most of the market pairs denied price transmission between the two markets. Based on these findings, it was recommended that there should be improved infrastructural development to ensure movement of both maize and rice in all-weather seasons. The study applied the error correction model to examine short run price transmission but current study is different in that it focuses only on one crop that is sorghum. While it employs cointegration and causality model, it does not explore the short run price relationships between the five markets sampled.

Blay et al. (2015) analysed the integration of maize, sorghum and millet markets in Dawanau Nigeria using the Momentum Threshold Error Correction Model in the analysis of three commodities within one market. The findings revealed that only the sorghum markets were not integrated in the long run while all commodities exhibited an asymmetric adjustment nature. This implies that price changes across the market are not transmitted instantaneously and that this results in inefficient markets.

Although the study analysed the integration of sorghum market using a threshold model the current study applies the cointegration model. The model is applied to a single commodity unlike the study reviewed which evaluated cross commodity market integration.

Zalkuwi *et al.* (2015) examined spatial integration between two sorghum markets, Karnataka and Maharashtra in India. The study employed Johansen cointegration procedure to analyse sorghum price data from 2003 to 2015. The findings revealed that both markets were integrated with causality tests showing that Karnataka granger causes Sholapur. The current study adopts the same methodology to analyse price relationships between surplus and deficit areas unlike the approach of examining markets in production zones only.

Tamru (2013) analysed spatial integration among seven markets in Ethiopia applied a threshold autoregressive model (TAR). The study focused on teff, wheat, sorghum and maize. Using weekly time series data for a period of ten years, the results revealed that market integration had greatly improved for teff, wheat and maize markets. The integration of sorghum markets had not improved over the years of study. The present study employs the cointegration model, unlike the study reviewed above which used a TAR model that assumes constant transaction costs. Furthermore, the current study evaluates the integration of sorghum markets rather than multiple food crop market integration.

Mayaka (2013) assessed the integration of dry bean markets in Kenya. Key regional markets analysed were Kitale, Nakuru, Eldoret and Nairobi. A TAR model and subsequent causality tests were applied to a dataset covering the period 1994 to 2011. The results indicated presence of integration between the four markets while causality tests revealed presence of only one market link. The TAR model revealed that it took three weeks for a shock in Nairobi to be transmitted to Kitale.

The current study applies cointegration analysis to evaluate the integration of sorghum markets unlike the study under review that applied the TAR model, which assumes constant transaction costs.

Asche *et al.* (2012) evaluated the integration of seven sorghum markets in Tanzania. The dataset used comprised of sorghum prices from 1993 to 2002. All the seven markets were highly integrated. Singida and Iringa were found to be the central markets thus the locations at which market surveillance and intervention measures can be carried out (Asche, Gjolberg and Gultormsen, 2012). The current study is similar as it applies cointegration analysis to evaluate the integration of sorghum markets in Kenya. Furthermore, it examines how markets interact in terms of price shocks through causality tests.

Ngare et al. (2016) tested the central market hypothesis in central Kenya applied a pairwise granger causality model. The study focused on nine maize and bean markets and the data analysed was from January 1994 to December 2009 using Augmented Dickey Fuller and Phillips Peron Tests and on first differencing the series became stationary. Findings established that maize market pairs had more causality compared to bean markets. Central markets for beans and maize where both within the consumption zones.

The current study will adopt the pairwise causality model as it is related to the cointegration model. While the study reviewed examined both maize and beans in one area, the current study examines causality across markets in different zones while focusing solely on sorghum.

In Malawi, Mtumbuka et al. (2014) assessed the extent of market integration among different markets in order to ascertain whether there is efficiency in flow of information. Bean price data from 1995 to 2011 was analysed for nine markets representing all regions in Malawi. A threshold autoregressive model (TAR) was used to show the effect of transaction costs on market integration.

The presence of high threshold values was attributed to high transaction costs as seen in some market pairs thus an indication of market inefficiencies. However, the bean prices moved in the same direction a clear indication of integration. A key policy recommendation is that the government should improve transport and information services to reduce transaction costs. While the study took into account the importance of transaction costs, it assumed that they were constant. The current study employs a cointegration model which with particular interest on sorghum and does not account for transaction costs due to inadequate data.

Maina (2013) analysed the level of integration of livestock markets in Kenya through application of both cointegration and causality models. The researcher applied trace statistic test to determine the number of cointegrating vectors among 10 spatially markets based on weekly beef cattle prices from 2006 to 2010. Through the cointegration model, it was established that beef markets in Kenya share more than one stochastic process in that one was in the northern rangelands and the other in the southern rangelands.

Granger causality tests established that some markets do not share a price relationship and that Nairobi was the central market. The key reasons stated for the lack of strong price relationships include barriers to entry and exit, high transportation costs and insufficient market information. The author concludes that there is need to improve information flow in the livestock-marketing sector as well as establishment of a price early warning tool.

The current study is similar to the study under review in that it also applies the cointegration model and causality tests. Nonetheless, it differs as it analyses bi monthly sorghum prices unlike the study reviewed that used beef price weekly data.

Wheat is a major food crop in Pakistan, in an effort to fill the gap left by previous studies that only focused on Punjab province, Sahito (2015) assessed integration of wheat markets by examining five markets representing different provinces.

The study used a dynamic model to analyse 280 observations from January 1998 to April 2011. The dynamic model consisted of running a cointegration, vector error correction model (VECM) and threshold vector error correction (TVECM) model. Pairwise cointegration results indicate that there indeed exists a long run equilibrium relationship between all five market pairs implying integration. TVECM tests revealed that market pairs showed higher adjustments in two regimes compared to those of VECM. It was concluded that the TVECM results provide significant policy recommendations in that there is need for increased private sector roles in wheat trading as well as investment in storage facilities.

The study indeed applies the robust TVECM model to examine the effects of transaction costs on integration of wheat markets, however, this method assumes constant transaction costs. The current study applies the cointegration model to assess price dynamics of sorghum which is not a major food crop like wheat. Additionally, the current study is anchored on the vector autoregressive model (VAR) unlike the study reviewed which applied a VECM model, which is a re-parameterization of the VAR model.

Yeboah (2012) employed the consistent threshold autoregressive (CTAR) model to examine whether market participants have the ability to respond to maize price shocks faster or slower in Ghana. This involved the analysis of wholesale maize price data from 2002 to 2010 for five markets to determine the nature of price response. Cointegration tests revealed that the regional markets were integrated while bidirectional causality was present between market pairs in both the short and long run. Findings from the CTAR model showed that traders responded to price changes faster when margins are squeezed compared to when they are stretched thereby existence of asymmetries in maize markets. Improvement in communication infrastructure is proposed as being the main solution to enhance trade between the studied regions.

The current study differs from Yeboah's in that it only examines integration and causality. It employs the Johansen cointegration and VAR model to analyse bi-monthly price data while the study reviewed applied the CTAR model to examine monthly data. The study reviewed extends to test for the presence of asymmetry in maize markets while this current study only examines the existence of causal relationships in Kenyan sorghum markets.

Brorsen & Hu (2014) studied the efficiency of spatial urea market prices in the New Orleans region of the United States of America. The author applied both the VECM and the Parity Bound Model (PBM) to analyse monthly urea price data from 1960 to 2013. Unit root tests were first carried out and on differencing all three markets were found to be stationary. Johansen cointegration tests revealed that all price pairs were integrated while granger causality tests established that markets share a bidirectional relationship. VECM estimated parameters showed that spatial price equilibrium violations slowly adjusted in the New Orleans-Middle East urea market compared to that of Arkansas River-New Orleans pair. Additionally, the PBM tests showed that price spreads were greater than transportation costs.

The study under review applied robust methods to examine the thin urea market due to its nature as a not openly traded commodity. While the author applied the PBM model, it has a number of limitations such as sensitivity to distributional assumptions and depends much on transportation costs. The current study differs in that it employs a cointegration model which is not sensitive to distributional assumptions and does not require transportation data which is not readily available.

Zhao et al. (2012) apply a totally different approach to examine market integration in four corn and three soybean markets in United States of America. The approach entails application of a Markov-Switching autoregressive model that allows for time-varying probabilities and describes two unobservable states, arbitrage and non-arbitrage.

The estimation procedure is facilitated by the use of an Expectation-Maximization algorithm on daily market prices between 2005 and 2010. Findings demonstrate that both corn and soybean markets are characterized by switching regime relationships implying existence of market integration in both arbitrage and non-arbitrage regimes. It was concluded that this model is more robust and that transaction costs are a major component of efficient arbitrage.

While this study reviewed brings in a different perspective in terms of the model accounting and allowing for different transition probabilities, it is difficult to interpret due to unobservable variables. Due to these methodological issues, the current study employs a cointegration model, which is able to account for stationarity in data, and does not assume the existence of any state. Furthermore, the current study utilizes bi-monthly data to evaluate the integration of one single crop while the study analysed focused on two crops.

The foregoing literature review seems to suggest that the cointegration approach is the most widely used model in market integration studies. While threshold models take into account transaction costs, they assume constancy of transaction cost, which is a limitation of the method.

The cointegration model is able to account for data stationarity and evaluate multiple price relationships (Johansen and Juselius, 1990). Therefore, the current study applies cointegration analysis to evaluate the integration of sorghum markets in Kenya.

CHAPTER THREE

METHODOLOGY

This chapter presents the procedure through which the study was operationalized. It begins with a description of the study area, data type and sources as well as data analysis procedures. This is followed by a discussion of the theoretical and empirical methods used in the study.

3.1 Study Area

The study covered five markets in Kenya in five different counties. They included Soko Posta market in Busia County, Homabay town market in Homabay County, Kalundu market in Kitui County, Kibuye market in Kisumu County and Gikomba market in Nairobi County. Soko Posta, Homabay and Kalundu markets were chosen as they lie within sorghum production zones. Kibuye and Gikomba represent deficit markets as they are distant from sorghum producing regions.

3.2 Data Type and Sources

The study employed bi-monthly wholesale prices of sorghum covering the period 2011 to 2017. The price data was obtained from the Ministry of Agriculture, Livestock and Fisheries (Agribusiness and Market Department) and respective sub counties' food price reports for the five markets. The price units collected where for a 90 kilogram bag for surplus markets that include Kalundu, Soko Posta and Homabay while the deficit markets are Gikomba and Kibuye.

3.3 Data Analysis

Descriptive analysis was used to characterize sorghum price patterns in Kenya. Eviews 7 software was used for econometric analysis of unit root tests, cointegration analysis and granger causality tests.

The price series were converted to represent the price of a kilogram of sorghum. Empirical analysis was based on the logarithmic transformation of prices to aid in interpretation.

3.4 Theoretical Framework

The ability of a market system to effectively and efficiently perform its functions is based on the ease with which prices respond when transmitted spatially. Therefore, the movement of prices over time in different markets is a vital indicator of market efficiency. The ideal market structure for market integration is a perfectly competitive market in that it ensures that prices adjust quickly to new information.

In essence the evaluation of market integration is important as it allows one to understand whether exploiting price movements in surplus markets can be used for the prediction of prices in a deficit market (Okoh & Egbon, ,2005).

The Law of One Price (LOP) provides the main framework for spatial market integration analysis. The law states that the price of a homogenous good in spatially separated markets is equal safe for the transfer costs (Fackler and Goodwin, 2002). According to Garcia-Enriquez *et al.* (2012), under perfect competition, the LOP assumes that the price differences between spatially separated markets cannot exceed the arbitrage cost. Following Rapsomanikis *et al* (2004), the relationship between two prices can be specified as:

$P_{1t} = P_{2t} + c$……………………………………………………………………………... (3.1)

Where P_{1t} is the price in market one, P_{2t} is the price in market two and c is the transfer cost.

If the relationship in equation 3.1 holds, market one and two are integrated.

The spatial arbitrage condition postulates that the difference in prices of a product will be less than or equal to the costs of transactions involved.

Trade in one market will be affected by changes in demand and supply thus affecting prices in other markets and through the spatial arbitrage condition, equilibrium will be restored. According to Fackler and Goodwin (2001), trade will occur in spatially integrated markets and this can be expressed as:

$$P_{2t} - P_{1t} \geq c \qquad (3.2)$$

Where P_{2t} is the price in market two, P_{1t} is the price in market one, and c is the transfer cost. The spatial arbitrage condition is attained if the spatial price difference is greater than the transfer costs. Subsequently, traders will move sorghum from surplus markets to deficit markets, only if the price in the deficit market is greater than or equal to the transfer costs involved. However, if the spatial arbitrage condition is violated, that is the spatial price differences is less than transfer costs, then there is an indication of barriers to trade between markets P_{2t} and P_{1t} (Baulch, 1997). Such barriers to trade include government controls and infrastructural challenges (Baulch, 1997).

Violation of the spatial arbitrage condition represents an autarky market condition where lack of profitable arbitrage conditions exists between markets P_{2t} and P_{1t}. According to Baulch (1997), the autarky condition is expressed as:

$$P_{2t} - P_{1t} \leq c \qquad (3.3)$$

Where P_{2t} is the price in market two, P_{1t} is the price in market one, and c is the transfer cost.

Under autarky conditions, the prices between the two markets are independent and shocks are not transmitted between markets due to high transaction costs. Baulch (1997) notes that the main implication of autarky conditions is that there is loss of economic welfare as there is reduction of price information available to market chain actors. Therefore, decisions made result in poorly or lack of integrated markets.

3.5 Empirical Methods

This study applied a cointegration technique to evaluate the integration of sorghum markets in Kenya. The model was chosen as it takes into account the nonstationary nature of time series price data. Goodwin and Schroeder (1991) note that the interdependence of prices between a set of markets can be expressed by the following linear relationship:

$$P_{1t}=\alpha_o+\alpha_i P_{2t}+\mu_t \quad \text{……} \quad (3.4)$$

Where P_{1t} is the commodity price in market one at time t, P_{2t} is the commodity price in market two at time t, α_o and α_i are parameters to be estimated and μ_t is the error term. The price series of a homogenous commodity can be stationary or non-stationary at level thus, the need to carry out unit root tests. According to Asteriou and Hall (2007), the economic implication of analysing non stationary data is that it will generate spurious results.

If a price series, say A_t is non-stationary, differencing the series leads to stationarity (Asteriou D. and Hall S., 2007). Where the series becomes stationary on first difference, it is integrated of order one which can be expressed as $A_t \sim I(1)$. On the other hand, if price series A_t is stationary at level, it is integrated of order zero (Asteriou and Hall , 2007) and denoted as $A_t \sim A_t(0)$. Furthermore, Asteriou and Hall (2007) note that if two price series A_t and B_t are I(1), then their linear combination expressed as $B_t - \alpha - \gamma A_t = \varepsilon_t$ also I(1). If the trends in A_t and B_t cancel out when $B_t - \alpha - \gamma A_t = \varepsilon_t$ is formed then error term ε_t is I(0), stationary. In this special case, A_t and B_t are cointegrated with β as the cointegrating parameter (Asteriou and Hall, 2007).

According to Engle and Granger (1991), a pair of price series, in this case A_t and B_t are said to be cointegrated if they are individually I(d) in that d is the order of integration, but there exists a linear combination of them $B_t - \alpha - \gamma A_t = \varepsilon_t$ which is I(0). Fundamentally, cointegration analysis is a twofold procedure.

The first step is to establish if each pair of the time series is stationary or if both or either is non-stationary. If non-stationary, differencing the series is done until stationarity is achieved (Johansen, 1988). Consequently, if the series have the same order of integration, the second step is to regress one price series on the other price series and establish if they are cointegrated (Johansen, 1988).

3.5.1 Stationarity

A stochastic process, which is a collection of random variables ordered in time is stationary if its mean and variance are constant over time (Gujarati, 2004). In essence, it is time invariant. A stationary data set, specifically a time series, returns to its mean and fluctuates around the mean. In other words, a stationary process does not drift far away from its mean value because of the finite variance (Gujarati, 2011). On the other hand, a non-stationary time series exhibits a time varying mean or time varying variance or both (Gujarati, 2003). The implication of running a non-stationary time series is that it will result in spurious results (Dickey and Fuller, 1979). The condition of stationarity can be expressed as follows:

$$Z_t = \emptyset Z_{t-1} + \mu_t \quad \text{……} \quad (3.5)$$

If $\emptyset<1$, then series Z_t is stationary and if Ø=1, the series is non-stationary and is known as a random walk implying that the variance and mean of series Z_t change with time. μ_t is a random walk with constant variance and mean zero. Differencing enables one to make Z_t stationary. When this series is differenced d times it is said to be integrated of order d expressed as *I(d).* Where equation (3.5) has a constant and a time trend this can be expressed as:

$$Z_t = \propto + \beta_t + \varphi Z_{t-1} + \mu_t \quad \text{……} \quad (3.6)$$

Where Z_t is the price of sorghum at time t, α, β and φ are parameters to be estimated. Equation (3.6) has two types of trends. If β=0 and φ=0, then:

$Z_t = \propto\ + \mu_t$ ………………………………………………………………………… (3.7)

Then Z_t follows a stochastic trend which can be upward or downward depending on the sign of α. Where β≠0 and φ≠0, then:

$Z_t = \propto\ + \beta_t + \mu_t$ …………………………………………………………………… (3.8)

Then Z_t follows a deterministic trend which can be upward or downward depending on the sign of β which is trend stationary. If β≠1 and φ≠0 then both stochastic and deterministic trends are present. If β≠0 and φ≠1 but φ<1, the series has a deterministic trend and is stochastically stationary. The stochastic trend in (3.7) can be removed by differencing making Z_t difference stationary.

3.5.2 Unit Root Tests

The test for stationarity is based on analysing data to establish the existence of unit roots. The presence or absence of unit roots in a price series is established using Augmented Dickey Fuller (ADF) and Phillips Peron (PP) test procedures (Gujarati, 2004).

The ADF test is an extension of the Dickey Fuller (DF) test and it is a parametric test (Gujarati, 2004). According to Gujarati and Sangetha, (2007), the ADF test starts with an estimation of a price series Z_t which is a random variable with drift and a stochastic trend. This can be expressed as (Gujarati, D and Sangetha, 2007):

$\Delta Z_t = \beta_1 + \beta_2 + \delta Z_{t-1} + \sum_{i=1} m\, \alpha_1\, \Delta Z_{t-1} + \varepsilon_t$ ……………………………………………(3.9)

Where Z_t is the price of sorghum in market Z, Δ is the difference operator, t is the trend variable, *m* is the number of lag differences, ε_t is the error term, β's and α's are parameters to be estimated.

The null hypothesis to be tested is that δ=0 (presence of a unit root) against the alternative δ<0 (no unit root). The null hypothesis δ=0 is rejected if the calculated absolute value of tau (τ) statistic exceeds the DF/Mackinnon critical tau (τ) critical value (Dickey and Fuller, 1979). If the null hypothesis is rejected, the conclusion is that the price series is stationary. If the results fail to reject the null hypothesis, that is, the calculated absolute value of tau (τ) is less than the DF/Mackinnon critical tau (τ) critical value, then the series is differenced (Dickey and Fuller, 1979). On differencing, if the series becomes stationary (no unit root) at d times, then the series is integrated of order d, I(d).

While the ADF is a parametric test with a low power, the Phillips Peron test is robust to serial correlation (Ng and Perron, 1995). It requires the application of Ordinary Least Squares method to the following equation as proposed by Dickey and Fuller (1979):

$$\Delta Z_t = \beta_1 + \beta_2 + \Theta Z_{t-1} + \sum_{i=1} m\, \alpha_1\, \Delta Z_{t-1} + \varepsilon_t \qquad (3.10)$$

Where Z_t is the price of sorghum in market Z, Δ is the difference operator, t is the trend variable, m is the number of lag differences, ε_t is the error term, β's and α's are parameters to be estimated. The null hypothesis to be tested is that Θ=0 (presence of a unit root) against the alternative Θ<0 (no unit root).

The null hypothesis Θ=0 is rejected if the calculated absolute value of tau (τ) statistic exceeds the DF/Mackinnon critical tau (τ) critical value (Dickey and Fuller, 1979). In this case, if the null hypothesis is not rejected at level, but is rejected after the first differencing, the series has one-unit root and is integrated of order one (Dickey and Fuller, 1979).

3.5.3 Determination of Optimal Lag Length

If the unit root tests reveal that the series are integrated, the next step involves the analysis of cointegration. The process first involves running an unrestricted VAR in Eviews and then followed by a determination of the number of lags. Time series models tend to be sensitive to the number of lags employed in the respective autoregressive model. Based on Gujarati (2011), the ideal lag length was determined by linking existing information criteria with a model fit of regression residuals.

According to Vahid and Engle (1993) the selection criteria is based on these steps. First estimate p using the standard informational criteria, that is Schwarz Criteria (SC), Akaike Criteria (AC) and Hanna-Quinn (HQ) criteria. A lag that minimizes the information criteria within VAR in levels is chosen. The lag length chosen is then used to find the number of cointegrating vectors using the Johansen cointegration model. The information criteria can be written as the following equations:

$$SC(p,s) = \sum_{i=n-s+1}^{T} \ln\left(1-\lambda_i^2(p)\right) + \frac{\ln T}{T} \times N \quad (3.11)$$

$$AIC(p,s) = \sum_{i=n-s+1}^{T} \ln\left(1-\lambda_i^2(p)\right) + \frac{2}{T} \times N \quad (3.12)$$

$$HQ(p,s) = \sum_{i=n-s+1}^{T} \ln\left(1-\lambda_i^2(p)\right) + \frac{2\ln(lnT)}{T} \times N \quad (3.13)$$

Where N is the number of parameters while n is the number of variables, T is the number of observations and λ are Eigen values calculated for each p. To calculate each pair of (p,s), no restrictions are assumed and p is fixed into the following vector autoregression of order p, VAR (p):

$$y_{t=\sum_{i=1}^{p} A_i y_{t-i}} + \varepsilon_i \quad (3.14)$$

Then λ is derived, the procedure continues for every p whereby p and s chosen minimize the information criteria (p, s). Following this selection the next process is to determine the cointegrating relation using Johansen procedure.

Selecting the number of lags m is quite critical to ensure that the errors remain uncorrelated. According to Gujarati (2004), the lag length can be chosen through sequential likelihood ratio tests or information criteria which include Schwarz Information Criteria (SIC), Hannan and Quinn Information Criteria (HQIC) and Akaike Information Criteria (AIC). Ivanov and Kilian (2005) argue that likelihood ratio tests fail the information criteria. The authors concur that as the sample size increases the AIC dominates both SIC and HQIC, therefore the AIC will be used for the study. Furthermore, the AIC was selected, as it is able to minimize underestimation while offering an opportunity to recover the true lag length (Ivanov and Kilian, 2005).

3.5.4 Cointegration Tests

There are two main cointegration approaches applied to analysis of time series data. The first is the Engle and Granger (1987) two-step procedure which estimates cointegration. The procedure begins with a simple regression equation as shown by Utkulu (2012), the expression is:

$$A_t = \beta Y_t + \mu_t \qquad (3.15)$$

Where both A_t and Y_t have unit roots and are integrated of order one, in this case, At ~ I (1) and Y_t ~1. For A_t and Y_t to be cointegrated, then the residuals from equation (3.15) should be stationary (Engle and Granger, 1987), in this case $\mu_t \sim I(0)$. Analysis will involve testing the residuals for presence of unit roots using ADF and PP tests as discussed in the previous section (Engle and Granger, 1987).

The second step proceeds if the residuals are found to be stationary, an indication of cointegration. The following step involves estimating an Error Correction Model (ECM) as outlined by Engle and Granger (1987).

According to Asteriou and Hall (2007), the Engle and Granger procedure has two major drawbacks. The procedure only uses residuals from a single relationship thus, it cannot be applied in a situation where there are more than two variables. Secondly, it is a sequential procedure thus errors generated in the first step can lead to invalid results once used in the second step.

The Johansen maximum likelihood procedure as postulated by Johansen and Juselius (1990) is multivariate, capable of testing for more than one cointegrating relationship. According to Johansen and Juselius (1990), the test for cointegration begins with the application of a Vector Autoregressive (VAR) model, which is expressed as:

$$P_t = A_t P_{t-1} + \ldots\ldots\ldots + A_k P_{t-k} + \mu_t \ldots\ldots\ldots \quad (3.16)$$

Where P_t denotes an (nx1) vector of I (1) variables which consist of exogenous and endogenous variables, A_t denotes (nxn) matrix of parameters and μ_t denotes (nx1) vector of white noise errors.

In this case, we assume P_t as non-stationary thus on first differencing or error correction form, as shown Johansen and Juselius (1990) we obtain:

$$\Delta P_t = \pi P_{t-1} + \Gamma_1 \Delta P_{t-1} + \ldots + \Gamma_{k-1} \Delta P_{t-k+1} + \mu \ldots\ldots\ldots \quad (3.17)$$

Where Γ_1 = - ($1-A_1- A_2 \ldots A_i$) and (i= 1, k-l). Γ_1 represents short run elasticities in the short term while long run elasticities are presented by π.

The number of cointegrating interactions between variables P_t is known by π rank of a matrix. In which the matrix π is 0<r>m, P_t variables consists of r stationary linear combinations.

Therefore, π can be further be disintegrated into α, which is an error correction presentation that measures speed of adjustment in ΔP_t while β represents the cointegration association among non-stationary variables consisting of r cointegrating paths.

This procedure generates two statistics, the trace test statistic and maximum eigenvalue statistic. Utkulu (2012) notes that the Johansen maximum likelihood procedure begins with the calculation of trace and maximum Eigen value statistics which are then compared with Osterwald-Lenum critical values. Based on Johansen and Juselius (1990) the two tests can be expressed as:

Λ_{trace} (r) = $-T\Sigma_{tr+1}^{p} \ln (1-\lambda_i)$……………………………………………………….(3.18)

Λ_{max} (r, r+1) = $-T \ln (1-\lambda_{r+1})$...……………………………………………………… (3.19)

Where λ_I is the maximum Eigen value, T is the number of observations and T represents sample size and $(1-\lambda_{r+1})$ represents max-eigenvalue estimate. The trace statistic 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 maximum Eigen value statistic tests the null hypothesis of r cointegrating vectors against the alternative of r+1 cointegrating vectors. Concurrently, the trace test statistic and maximum Eigen value test the null hypothesis that there at most r cointegration vectors, hence following a similar procedure in determining the number of co-integrating vectors (Johansen and Juselius, 1990).

The null hypothesis $r_0 = 0$ against the alternative hypothesis $r_0 > 0$. The calculated absolute values are then compared to the tabulated Osterwald-Lenum (1992) critical values.

The null hypothesis is rejected if the trace test statistic and maximum Eigen value statistic values are greater than the Osterwald-Lenum critical values (Johansen and Juselius, 1990). This implies that there is at least one cointegrating vector. The next procedure is to test the null hypothesis of $r_0 = 1$ against the alternative $r_0 > 1$.

The null hypothesis is rejected if the trace test statistic and maximum Eigen statistic values are greater than Osterwald-Lenum critical values, this implies that there is more than one cointegrating vector (Johansen, 1988).

On the other hand, if the trace and maximum statistic values are lesser than Osterwald-Lenum critical values, we fail to reject the null hypothesis and conclude that there is only one cointegrating vector.

3.5.5 Granger Causality Test

Granger and Lee (1989) note that the existence of cointegration implies that the price series have a linear relationship that is causal in nature. A time series of price P_{1t} (sorghum price in market 1 at time t) is said to granger cause price P_{2t} (sorghum price in market 2 at time t) if its current and lagged values are able to improve prediction of prices in market 2 (Gujarati, 2004). Comprehensively, causality is a measure of the predictability of prices in that, market price adjustments can be used to predict price changes in another market.

The test according to Granger (1969) is specified as:

$$P_{1t} = \sum_{i=1}^{n} \alpha i \, P_{1t-1} + \sum_{j=1}^{n} \beta j \; P_{2t-1} + \mu_{1t} \qquad (3.20)$$

$$P_{2t} = \sum_{i=1}^{m} \lambda j \, P_{1t-1} + \sum_{j=1}^{m} \beta j \; P_{2t-1} + \mu_{2t} \qquad (3.21)$$

Where the disturbances μ_{1t} and μ_{2t} are uncorrelated. Equation (3.20) denotes that P_{1t} is predicted by lagged variables of P_{1t} and P_{2t}.

While equation (3.21) represents the predictability of P_{2t} determined by its lagged values and those of P_{1t}. Granger causality tests are then determined by estimating the lagged coefficients $\sum\alpha_i$ and $\sum\lambda_j$ to test if they are different from zero using F-statistic (Granger, 1969). The null hypothesis tested is that $\sum\alpha_i = 0$ and $\sum\lambda_j = 0$ are not different from zero in that market 1 prices do not granger cause market 2 and that market 2 prices do not granger cause market 1 (Engle and Granger, 1987). The null hypothesis is rejected if the calculated values are statistically significant based on F-tests.

According to Rashid (2004), granger causality can be expressed in three ways. A unidirectional causality means that shocks in market 1 cause prices in market 2 but there is no reverse effect. In this case the null hypothesis is that $\sum\alpha_i$ is statistically different from zero against $\sum\lambda_j$ is not statistically different from zero. A bidirectional relationship means that shocks in market 1 causes prices in market 2 and there is a reverse effect. Here, the coefficients $\sum\alpha_i$ and $\sum\lambda_j$ are all different from zero. While an independent relationship exists if none of the markets causes price changes in the other. In this case, $\sum\alpha_i$ and $\sum\lambda_j$ are not statistically different from zero (Rashid, 2004).

CHAPTER FOUR

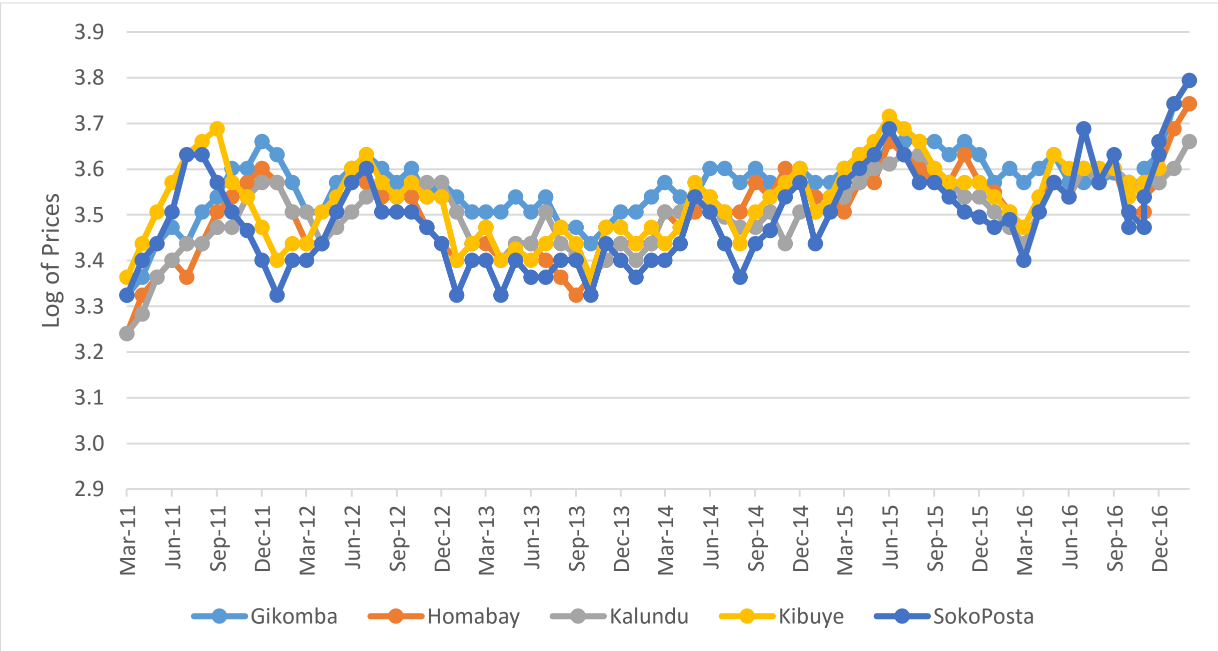
RESULTS AND DISCUSSION

This chapter presents the results of the study. First, the descriptive results are presented. The second part discusses the results of the unit root tests, cointegration tests and Granger-Causality tests.

4.1 Description of Sorghum Wholesale Prices

Figure 4.1 presents results for logarithmic values of sorghum price trends in selected markets in Kenya. Wholesale sorghum prices across all the markets fell in 2013 then begun to rise again in 2014 and further rose in 2015. The upward price spike in June 2015 coincides with the drought experienced during the period in Kenya implying that supply was depressed (MoALF, 2016).

Figure 4.1: Price trends in sorghum markets



Source: Author's Computations

Wholesale sorghum prices generally over the period studied appear to be upward trended (Figure 4.1). The trends imply that the mean value of sorghum prices change over time suggesting nonstationary behaviour and thus need to run unit root tests. The results concur with Nzuma and Sarker (2008) who found out that cereal prices in Kenya exhibit time invariant trends.

Table 4.1 presents the descriptive statistics of the sorghum price trends in Kenya

Table 4.1: Descriptive Statistics for Sorghum Prices (Ksh/kg)

Variables	**N**	**Mean**	**Maximum**	**Minimum**	**Std. Dev.**	**Coefficient of Variation (%)**
Gikomba	144	35.53	45.56	27.78	2.57	7.22
Homabay	144	33.55	42.22	25.56	3.04	9.05
Kalundu	144	33.46	41.11	25.56	2.61	7.81
Kibuye	144	34.54	46.67	28.89	3.28	9.31
Sokoposta	144	33.01	44.44	27.78	3.45	10.43

Source: Author's calculation

The mean sorghum price is highest in Gikomba and Kibuye at Ksh. 36/kilogram and Ksh. 35/kilogram respectively while it was lowest at Kalundu and Sokoposta markets at Ksh. 33/kilogram. Gikomba and Kibuye are deficit markets and this may explain the slightly high price in relation to the other markets. Kalundu and Sokoposta markets lie within the main sorghum producing zones and thus the reason for lower prices because of abundant supply. The finding is in line with Ngare (2014) who established that maize and bean markets in the low production zones of Eastern Kenya exhibit high prices.

With respect to coefficient of variation, Soko Posta has the highest price variability in relation to other sorghum market prices at 10.43 percent. The coefficient of variation score is indicative of the volatility of sorghum market prices. Homabay market also has a high score of 9.05 percent (Table 4.1).

The high price variations in these surplus markets are presumed to be as a result of sorghum outflows to other regions thereby creating supply fluctuations. Kalundu market has a coefficient of variation score 7.81 percent, this implies that supply is much more consumed in the region and that outflows are lesser compared to Soko Posta and Homabay markets. These findings agree with those of Mayaka (2013) who found out that bean production zones in Kenya experience high price volatility.

The deficit markets of Gikomba and Kibuye have a score of 7.22 percent and 9.31 percent. Gikomba market is much more centrally located compared to Kibuye and thus able to receive inflows from different regions and thus prices are less volatile. On the other hand, while Kibuye is a deficit market, it is also an outflow to other locations while another reason could be due to high demand for sorghum thus affecting prices.

4.2 Econometric Analysis of Market Integration

The second objective was addressed by obtaining unit root tests before cointegration analysis was done.

4.2.1 Unit Root Tests (Augmented Dickey Fuller and Phillips-Peron Tests)

Table 4.2 presents results of both ADF and PP unit root tests in levels and first differences.

Table 4.2: Unit Root Test for Sorghum Price Series

	Augmented Dickey Fuller Test		Phillips Peron Test	
Series	Level	1st Diff.	Level	1st Diff.
Gikomba	-2.41	-5.75	-2.69	-12.4
Homabay	-2.6	-6.05	-2.93	-11.51
Kalundu	-2.75	-4.04	-3.24	-12.35
Kibuye	-1.67	-5.45	-2.37	-11.6
Sokoposta	-2.58	-7.86	-2.83	-12.65
5% Critical	-3.44	-3.44	-3.44	-3.44

Source: Author's Computation.

This involved testing the null hypothesis that δ=0 (presence of a unit root) against the alternative δ<0 (no unit root). The null hypothesis δ=0 is rejected if the calculated absolute value of tau (τ) statistic exceeds the DF/Mackinnon critical tau (τ) critical value (Dickey and Fuller, 1979) The ADF tau (τ) statistic results are -2.41 for Gikomba, -2.6 for Homabay market, -2.75 for Kalundu, -1.67 for Kibuye and -2.58 for Soko Posta. The PP tau (τ) statistic results at level are -2.69 for Gikomba, -2.93 for Homabay market, -3.24 for Kalundu, -2.37 for Kibuye and -2.83 for Soko Posta (Table 4.2).

The calculated ADF and PP tau (τ) statistic test results for the level series are less than the critical values for all price series. Thus, the null hypothesis of the presence of a unit root cannot be rejected for all five price series. It can therefore be concluded that the level price series in the five markets are non-stationary.

When the prices are differenced once, then null hypothesis of unit roots, δ=0 (presence of a unit root) is rejected at 5 percent for all markets (Table 4.2). This is because the calculated ADF and PP tau (τ) statistic test results are greater than the critical values for all price series. This implies that the price series have a constant mean and variance which are independent over time, therefore analysis yields accurate results.

The price series are therefore I(1), integrated of order one These results are similar to Tuyushime (2014) who found out that Rwanda rice prices are integrated of order one. The next step in the analysis involved undertaking cointegration tests.

4.2.2 Co-integration Analysis

Johansen cointegration test was carried out to determine if there is a long run relationship among selected sorghum markets in Kenya. The process first begun with determining the number of necessary lags. According to Kilima (2006), the lag lengths should be optimum to ensure sufficient degrees of freedom while also ensuring randomness of the error term. Through determining the best lag length, a researcher is able to remove autocorrelation in the series thus ensuring that the error becomes a white noise process. A model becomes correctly specified once there is proper lag estimation. Table 4.3 shows the results of the optimal lag length that were used to run the Johansen cointegration test.

Table 4.3: Selection of optimal lag length

Lag	Likelihood Ratio	Final Predictor Error	Akaike Information Criteria	Schwarz Criterion	Hannan Quinn Criterion
0	NA	72.21	18.47	18.57	18.51
1	664.33	0.70*	13.83*	14.47*	14.09*
2	20.41	0.86	14.03	15.19	14.50
3	38.29*	0.90	14.08	15.77	14.77
4	26.09	1.04	14.22	16.44	15.12
5	28.46	1.18	14.32	17.07	15.44

*indicates lag order selected by criterion

The selection of the ideal lag should be based on the information criterion which exhibits the smallest criterion value (Gujarati,2003). The Akaike Information Criteria (AIC) with lag one has the smallest value that is 13.83 compared to the Schwarz Criterion and Hannan-Quinn Criterion with values 14.47 and 14.09 respcetively (Table 4.3). Following the identification of one optimal lag, an unrestricted VAR model was run in Eviews with the inclusion of a linear deterministic trend. Table 4.4 presents the Johansen cointegration test results.

Table 4.4: Johansen cointegration test results

Hypothesized No. of Cointegrating Equations(s)	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	145.065	68.52	76.07	67.6173	33.46	38.77
At most 1 **	77.448	47.21	54.46	36.0234	27.07	32.24
At most 2 **	41.424	29.68	35.65	23.544	20.97	25.52
At most 3 *	17.879	15.41	20.04	14.941	14.07	18.63
At most 4	2.939	3.76	6.65	2.939	3.76	6.65

Note: The critical values are from tabulated Osterwald-Lenum (1992). *(**) denotes rejection of null hypothesis at the 5 percent and 1 percent level.
Source: Author's computation.

The cointegration analysis involved regressing Gikomba as the dependent variable while the independent variables included Kalundu, Homabay, Kibuye and Soko Posta. Wholesale sorghum price cointegration results for the null $r_0 = 0$ (no cointegrating vector) are Trace statistic 145.07 and maximum Eigen statistic 67.62. These are greater that the Osterwald-Lenum critical values 68.52 and 33.46 for both Trace and Maximum Eigen respectively (Table 4.4). Thus, the null of no cointegrating vector against the alternative of at least one cointegrating vector is rejected.

The next step involves testing the null that $r_0 = 1$. Since the trace statistic 77.45 and maximum Eigen statistic 36.02 are greater than the critical values 47.21 and 27.07 thus the null hypothesis is rejected (Table 4.4). The null $r_0 = 2$ is then run and we again fail to reject the null hypothesis as the trace and maximum Eigen values are greater than the critical values.

The process proceeds until we fail to reject the null $r_0 = 4$. This is because the trace statistic 2.94 and maximum Eigen statistic 2.94 are lesser than the Osterwald-Lenum critical values 3.76. Based on this finding, it can therefore be concluded that Gikomba, Kibuye, Kalundu, Homabay and Sokoposta markets are integrated with the presence of four cointegrating vectors. The presence of four cointegrating vectors implies that there are four long run relationships among the five price series. Table 4.5 presents bivariate cointegration results indicating the number of cointegrating vectors.

Table 4.5: Bivariate cointegration results

1. Homabay Town and Gikomba Sorghum Markets				
H_o	**Trace Statistic**	**Trace (95%)**	**Max Eigen Statistic**	**Max Eigen (95%)**
r=0	20.06**	15.41	16.86*	14.07
r≤1	3.21	3.76	3.21	3.76
2. Kalundu and Gikomba Sorghum Markets				
H_o	**Trace Statistic**	**Trace (95%)**	**Max Eigen Statistic**	**Max Eigen (95%)**
r=0	24.77**	15.41	21.6**	14.07
r≤1	3.17	3.76	3.17	3.76
3. Kibuye and Gikomba Sorghum Markets				
H_o	**Trace Statistic**	**Trace (95%)**	**Max Eigen Statistic**	**Max Eigen (95%)**
r=0	23.86**	15.41	20.49**	14.07
r≤1	3.36	3.76	3.36	3.76
4. Soko Posta and Gikomba Markets				
H_o	**Trace Statistic**	**Trace (95%)**	**Max Eigen Statistic**	**Max Eigen (95%)**
r=0	27.77**	15.41	25.19**	14.07
r≤1	2.57	3.76	2.57	3.76

Note: The critical values are from tabulated Osterwald-Lenum (1992). *(**) denotes rejection of null hypothesis at the 5 percent and 1 percent level.

Gikomba was chosen as the reference market as it is a vital market for sorghum produce and a central consumption point (Kilambya & Witwer, 2013). Homabay Town and Gikomba sorghum prices for the null of no cointegrating vectors are Trace statistic 20.06 and 16.86 for Maximum Eigen value. As both the Trace and Maximum statistics are greater than the critical values of 15.41 and 14.07 (Table 4.5), the null of no cointegrating vector against the alternative of existence of at least one-cointegrating vector is rejected.

The next step involves testing the null of one cointegrating vector against the alternative of more than one, since the statistic for both tests is 3.21 and is less than the critical value of 3.76, we fail to reject the null hypothesis. It can therefore be concluded that Homabay and Gikomba sorghum prices are cointegrated. This implies that Homabay and Gikomba markets share a long run price equilibrium relationship.

Kalundu and Gikomba sorghum price cointegration results are 24.77 for Trace statistic test and 21.6 for Maximum Eigen statistic. The null of no cointegrating vector is therefore rejected since the statistic values are greater than the critical values of 15.41 and 14.07. Next, the null of one cointegrating vector is tested against the alternative of at least two cointegrating vectors. As shown in table 5, the statistics tests are both 3.17 which is less than the critical value of 3.76, thus we fail to reject the null hypothesis of one cointegrating vector.

Since the rank is equal to one, which is greater than zero, the conclusion is that Kalundu and Gikomba prices are cointegrated of rank 1, thus have one cointegrating vector. The finding implies that the two market price series converge towards equilibrium in the long run. Kibuye and Gikomba sorghum price cointegration results are 23.86 and 20.49 for the Trace and Maximum Eigen statistics respectively. Following that these values are greater than the critical values of 15.41 and 14.07 the null of no cointegrating vector is rejected (Table 4.5). The null of one cointegrating vector against the alternative of at least two cointegrating vectors is tested.

The statistic results in table 4 is 3.36 both for the Trace and Maximum statistic test. The value of 3.36 is less that the critical value of 3.76. Consequently, the null hypothesis of one cointegrating vector is not rejected. As the rank is equal to one, which is more than zero, the indication is that Kibuye and Gikomba prices are cointegrated of rank 1, thus one cointegrating vector. This implies that Kibuye and Gikomba sorghum markets share a long run price relationship.

Lastly, cointegrating results for Soko Posta and Gikomba sorghum prices are 27.77 for the Trace statistic and 25.19 for the Maximum Eigen statistic. The null of no cointegrating vector is rejected because both Trace and Maximum Eigen statistics are greater than the critical values of 15.41 and 14.07 (Table 4.5). The null of one cointegrating vector against the alternative of at least two cointegrating vectors is tested.

The statistics results as shown in table is 2.57 for both the Trace and Maximum Eigen statistics. This is less that the critical value of 3.76 for both statistics. Subsequently, the null of one cointegrating vector is not rejected. As the rank is equal to one, this implies that Soko Posta and Gikomba markets are cointegrated of rank one. The presence of one cointegrating vector indicates that Gikomba and Soko-Posta sorghum market price converge towards equilibrium in the long run.

Based on the above cointegration tests, it can be concluded that local sorghum markets in Kenya are integrated. Further bivariate analysis has revealed that Gikomba wholesale sorghum prices co-move with prices of other markets implying that price information is readily passed between these markets and that there are significant trade flows. These results concur with those of Maina (2013) who noted that improved information flow contributes to the integration of beef cattle markets in Kenya.

4.3 Granger Causality Tests

Granger causality tests were used to address the third objective. Causality tests are important in determining the direction in which price shocks are transmitted between two market series. The null hypothesis that market 1 does not granger cause market 2 is rejected if the p-value is less than the alpha level of significance (Granger, 1969), in this case five percent level of significance. Unidirectional causality means that a price shock in market 1 cause prices in market 2 but there is no reverse effect. Bi-directional causality occurs when a price shock in market 1 can be used to forecast prices in market 2 and vice versa. Independent causality indicates that there is no price shock transmission between the two markets.

Table 4.6 presents results of the Granger causality tests for wholesale sorghum markets in Kenya. Gikomba and Kalundu market pairs rejected the null hypothesis of no granger causality. This implies that a shock in Gikomba is simultaneously transmitted to Kalundu and vice versa. The bi-directional causality relationship between Gikomba and Kalundu indicates any price changes in one can help predict price changes in the other or there is price shock transmission. In conclusion, there is efficiency in market information transmission between Gikomba and Kalundu markets.

This finding confirms the bivariate cointegration results where Gikomba and Kalundu were found to be integrated implying that the two markets share a long run equilibrium relationship and that there is considerable sorghum supply volume movement from Kalundu to Gikomba. This finding is in line Mayaka (2013) who established that Nairobi-Kitale markets are cointegrated and share a bi-directional Granger causality relationship. The result can be attributed to a good communication and infrastructural network between the two markets that enhance market efficiency.

Table 4.6: Granger causality test results

Null Hypothesis(H_0)	N	F-Statistic	P-value	Decision	Type of Causality
Kalundu → Gikomba	142	3.712	0.027*	Reject	Bi-directional
Gikomba→ Kalundu	142	4.826	0.009*	Reject	Bi-directional
Kibuye → Gikomba	142	8.680	0.000*	Reject	Uni-directional
Gikomba → Kibuye	142	0.981	0.378	Fail to Reject	Independent
Homabay → Gikomba	142	10.045	0.000*	Reject	Uni-directional
Gikomba → Homabay	142	1.709	0.185	Fail to Reject	Independent
Sokoposta → Gikomba	142	10.462	0.000*	Reject	Uni-directional
Gikomba → Sokoposta	142	0.087	0.917	Fail to Reject	Independent
Kibuye → Kalundu	142	9.574	0.000*	Reject	Uni-directional
Kalundu → Kibuye	142	1.364	0.259	Fail to Reject	Independent
Homabay → Kalundu	142	10.718	0.000*	Reject	Uni-directional
Kalundu → Homabay	142	1.105	0.334	Fail to Reject	Independent
Sokoposta → Kalundu	142	9.338	0.000*	Reject	Uni-directional
Kalundu → Sokoposta	142	0.207	0.813	Fail to Reject	Independent
Homabay → Kibuye	142	0.209	0.812	Fail to Reject	Uni-directional
Kibuye → Homabay	142	5.103	0.007*	Reject	Independent
Sokoposta → Kibuye	142	8.220	0.000*	Reject	Uni-directional
Kibuye →Sokoposta	142	0.271	0.763	Fail to Reject	Independent
Sokoposta → Homabay	142	6.810	0.002*	Reject	Uni-directional
Homabay → Sokoposta	142	0.089	0.915	Fail to Reject	Independent

→ denotes "does not granger cause"

* denotes rejection of null hypothesis at five percent level

Source: Author's computation

The granger causality test between pairs of Gikomba-Kibuye, Gikomba-Homabay and Gikomba- Sokoposta is not rejected indicating independent relationships. This implies that a price change in Gikomba does not affect price movements in Kibuye, Homabay and Sokoposta. This contradicts the earlier bivariate cointegration finding whereby Gikomba was found to share a long run equilibrium relationship with Kibuye, Homabay and Sokoposta. The implication of this finding is that when prices increase in Gikomba the same increases cannot be predicted in Kibuye, Homabay and Sokoposta suggesting market inefficiencies and thus weak market integration. Other factors that could explain this finding include the distance between these markets and the existence of inefficient sorghum supply networks.

While on the other hand, Kibuye, Homabay and Sokoposta markets unidirectionally granger cause Gikomba. This means that when sorghum prices increase in Kibuye, Homabay and Sokoposta there is bound to be an increase in prices in Gikomba. The main implication of this finding is that the market information infrastructure in Gikomba is well established and efficient in that price changes are readily adjusted to reflect changes in the other market pairs. Sorghum price changes in Gikomba is a result of changes in prices in Kibuye, Sokoposta and Homabay markets.

Kibuye and Homabay unidirectionally granger cause Kalundu while Kalundu does not granger cause any. This suggests that price changes in Kalundu do not affect Kibuye and Homabay but the reverse holds as seen in the rejection of the null hypothesis. Homabay was found to granger cause Kibuye implying that price shocks move one way. This can be attributed to the fact that Homabay lies within a major producing zone and thus price changes there are bound to affect prices at the deficit Kibuye market. The presence of unidirectional relationships concurs with Abdalla (2016) who estalibshed that Gadaref being a sorghum producing zone in Sudan Granger causes other deficit markets that include Rabak, Sennar and Damzine.

Conversely, the lack of causality between Kibuye and Homabay and Sokoposta imply that the wholesale price of sorghum in Kibuye cannot as a predictor for the other two markets. This possibly is an indication of inefficient market information transmission.

Sokoposta is the only market that granger causes all other markets. This is evident as the null hypothesis of no granger causality is rejected in the Sokoposta-Gikomba, Sokoposta-Kalundu, Sokoposta-Homabay and Sokoposta-Kibuye pairs. This indicates that wholesale sorghum price changes in Sokoposta influence prices in other sorghum markets. Therefore, price movements in Sokoposta can predict price changes in other sampled markets. This implies that Sokoposta is a central market, in that past prices in Sokoposta can be used to predict prices in other sorghum markets (Ravallion, 1986). Ngare (2014) established that Ishiara and Siakago undirectionally Granger cause all other maize markets in Eastern Kenya while Asche et al (2012) found out that Singida and Iringa maize markets undirectionally Granger caused sorghum markets in Tanzania. Therefore, the results are in agreement that there exists central markets in the cereal sector in East Africa region.

The finding that Sokoposta is a central market is unique. This is because it comes third in terms of sorghum production when compared to where Kalundu and Homabay markets lie. The economic inference that can be deduced is that Sokoposta plays a role in wholesale sorghum price formation. Furthermore, Sokoposta market lies close to the Ugandan border thus cross-border trade can be attributed to influence sorghum prices.

A total of nine market pairs indicate the existence of independent causality relationships and it is evident in surplus-deficit markets as well as surplus-surplus market pairs. This implies that one series does not Granger cause the other, that is price in market A cannot predict prices in market B.

Another interpretation is that, from the results, Homabay market does not incorporate price information from Gikomba. Therefore, the price relationships in markets exhibiting independence are not that strong.

The economic implication arising from this finding is that while there has been improved market integration over the years analysed there still exists sorghum market information inefficiencies in markets exhibiting independent relationships. Additionally, the independent causal relationships imply that the market pairs have high price spreads thus producers receive low prices while consumers pay higher prices for sorghum.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The purpose of this study was to analyse the integration of sorghum markets in Kenya. The study therefore sought to understand the price dynamics within the Kenyan sorghum subsector which is not well understood. The study had three specific objectives. The first was to evaluate and characterize the trends in sorghum prices in Kenya. The second was to assess the degree of market integration between spatially separated sorghum markets. The third objective was to identify the direction of causality among wholesale sorghum markets in Kenya.

Bi-monthly sorghum time series data covering 2011 to 2017 was used to analyse market integration and causality for five selected markets. Graphical trend analysis revealed that sorghum prices across all the markets are upward trending indicative of non-stationary behaviour. Coefficient of variation scores established that producing markets exhibit higher price volatility in comparison to deficit markets. Augmented Dickey Fuller tests confirmed the presence of non-stationary behaviour as seen in the graphical trend analysis and on differencing the price data became integrated of order one.

Cointegration tests revealed that the markets share four long run cointegrating relationships implying that prices converge in the long run. Granger causality tests established that Gikomba and Kalundu markets share a bidirectional relationship and this confirmed that the two markets are integrated. A total of nine market pairs indicated the existence of independent causal relationships implying that there still exists inefficiencies in market price information transmission.

5.2 Conclusions and Recommendations

The study found out that sorghum markets in Kenya are integrated with the presence of four cointegrating vectors among the five markets and concluded that the sampled sorghum markets share a long run equilibrium relationship. Based on this finding there is need to facilitate market access through improvement of rural infrastructure as this will help increase sorghum market integration and lead to gains for farmers, traders and all those along the sorghum value chain.

Furthermore, Granger causality tests revealed the existence of independent causal relationships between nine sorghum market pairs implying inefficiencies in price shock transmission processes. Therefore, it is recommended that a viable option would be to develop and strengthen the existing market information systems, as this would enhance the transmission of sorghum price changes between integrated markets. This will in turn enable producers, traders and consumers to rationalize their decisions to purchase or sale sorghum based on efficient market information.

5.3 Contribution of this Study

This study utilizes a cointegration model and granger causality tests to evaluate the integration of sorghum markets in Kenya. The empirical contribution of this study is that it provides information on the degree of market integration and direction of causality across five sorghum markets. The current study contributes to knowledge on the integration of agricultural markets in Kenya being the first to focus on sorghum crop.

The empirical results from the cointegration analysis reveal that sorghum markets are indeed integrated and thus various agricultural market reforms have indeed improved the sorghum subsector. Conversely, the granger causality tests find that most markets exhibit either unidirectional or independent price relationships.

This implies that there are inefficiencies in market information transmission. In conclusion, this study confirms that the problem of poor price information is still persistent and thus it is important to implement the suggested policy recommendations.

5.4 Suggestion for Future Research

The body of knowledge in the sorghum sector can be improved by understanding the integration of retail markets. Moreover, there is need for a study on the performance and structure of the sorghum sector. Through examining the activities and behaviours of sorghum traders, the market competitiveness and constraints will be identified. While an understanding of the integration of sorghum retail markets will help in understanding the impacts of stimulative prices to producers and affordable prices for consumers.

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