AN EVALUATION OF TRANSMISSION OF WORLD MAIZE PRICES INTO KENYA'S DOMESTIC MARKET

KURGAT KIBIWOT SAMSON

A56/60410/2011

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS

DEPARTMENT OF AGRICULTURAL ECONOMICS

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2022

DECLARATION

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

Signed … Date…… 03/08/2022

Kurgat Kibiwot Samson

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

Signature Date: August 03, 2022

Dr Jonathan M. Nzuma

Department of Agricultural Economics

University of Nairobi

Signature........... .... Date…03 AUGUST 2022…………

Dr Patrick Irungu

Department of Agricultural Economics

University of Nairobi

DEDICATION

This thesis is dedicated to my beloved family for their endurance, love and affection.

ACKNOWLEDGEMENTS

I wish to sincerely thank all the people who helped me throughout my study. I am profoundly grateful to the Collaborative Masters in Agricultural and Applied Economics (CMAAE) Programme for their financial support that enabled me to undertake this master's degree course. My special gratitude goes to my supervisors Dr. Jonathan Nzuma and Dr. Patrick Irungu for their invaluable support and guidance throughout this research.

I wish to acknowledge the assistance of staff from Kenya's Ministry of Agriculture, Livestock, Fisheries and Cooperatives for their cooperation and support during data collection. I extend my sincere thanks to my uncles, Cosmas Cherop and Albert Cherop, and my colleagues for providing me with a favorable environment that enabled me to complete my study.

Table of Contents

List of Tables

List of Acronyms and Abbreviations

AECM:	Asymmetric Error Correction Model
ADF:	Augmented Dicker Fuller
ADL:	Auto-Regressive Distributed Lag
AIC:	Akaike Information Criterion
COMESA:	Common Market for Eastern and Southern Africa
CPI:	Consumer Price Index
CSRP:	Cereal Sector Reforms Program
DF:	Dickey-Fuller
CV:	Coefficient of Variation
DRC:	Democratic Republic of Congo
EAC:	East African Community
ECM:	Error Correction Model
ERA:	Economic Review of Agriculture
FAO:	Food and Agriculture Organization of the United Nations
FAOSTAT:	Food and Agriculture Organization Corporate Statistical Database
FPE:	Final Prediction Error
FPI:	Food Price Index
HQ:	Hannan-Quinn Information Criterion
KES:	Kenya Shillings
KIHBS:	Kenya Integrated Household Budget Surveys
KMDP:	Kenya Maize Development Program
LOP:	Law of One Price
LR:	Likelihood Ratio
MLE:	Maximum Likelihood Estimator
MOA:	Ministry of Agriculture
NCPB:	National Cereals and Produce Board
OLS:	Ordinary Least Squares
PP:	Phillips-Perron
ReSAKSS:	Regional Strategic Analysis and Knowledge Support System
SAP:	Structural Adjustment Programs
SBC:	Schwarz's Bayesian Information Criterion
SGR:	Strategic Grain Reserve
SSA:	Sub-Saharan Africa
USA:	United States of America
USD:	United States Dollar
USDA:	United States Department of Agriculture
USAID:	United States Agency for International Development
VAR:	Vector Autoregressive
VECM:	Vector Error Correction Model

Abstract

In Eastern and Southern African region maize grain prices is recorded highest in Kenya. There has been a reduction of prices of agricultural commodity from their recorded peak in 2008, but, this has not been the case in Kenyan maize prices. This then necessitates a study on transmission of world prices into Kenyan maize prices. By broadly examining the level of price transmission between the global and domestic maize markets in Kenya. Thus, this study assessed the integration of maize markets in Kenya, and evaluated the international maize prices transmission into domestic markets in Kenya. The deflated wholesale monthly price data spanning January 2002 to December 2020 was used. The data for maize prices data for Nairobi, Nakuru, Eldoret, Kisumu and Mombasa was sourced from Ministry of Agriculture, Livestock, Fisheries and Cooperatives Kenya, while the international wholesale maize prices was obtained from the FAO, GIEWS database. Co-integration, Granger Causality and Error Correction models were employed to test for market integration and price transmission. A strong integration was found between world and domestic maize markets as indicated by a high long-run elasticity of 0.60. The speed of price adjustment is relatively fast implying that 60 percent of the maize prices variations of the world are transmitted to Kenyan markets in long-run, on average it takes a month to correct 13 percent of the deviations from equilibrium. Hence, the improvement of rural areas infrastructure to accelerate movement of goods and services should be done by government of Kenya. The government should not engage in Maize trade as this distorts competitive functioning of maize markets. These results provide evidence on the need for policy makers to formulate policies which avoids market exploitations and reduce distortions. This will help in enhancing efficiency of the maize marketing system.

CHAPTER ONE: INTRODUCTION

1.1 Background

Sub-Saharan Africa (SSA) nations have embarked on economic reforms over the past two decades, which comprised elimination of price controls and liberation and privatization of state-controlled sectors (Abdulai., 2000). The measures for liberalization of such markets are consistent with economic theory, which hypothesizes that the appropriate functioning of markets is essential for allocating resources optimally (Abdulai., 2000). This has also been the case in Kenya and especially in grain markets where halfway liberalization of the maize market started in the early 1980s (Karugia *et al*., 2003). Minimization of market share of National Cereals and Produce Board (NCPB) had let to liberalization of the maize market, elimination of program like price controls found on trading of maize, decontrolled maize and maize meal prices, and eradication of direct subsidies on maize offered to enlisted mill operators (Ariga and Jayne., 2009).

One of the measures of market efficiency is the extent of market integration in a region (Samuelson, 1952). Market integration refers to as the extent to which prices changes in one part of the market lead to changes in prices in another part of the market (Alexander and Wyeth, 1994). An Ineffective markets integration might deliver erroneous information on prices resulting to inefficient movement of product (Goodwin and Schroeder, 1991).

According to Fackler and Goodwin (2001), the magnitude of market integration likewise has ramifications for formulating agricultural price stabilization strategies. In developing countries, the reduction in rural household’s poverty levels has a positive association with the linkages to marketing centres (Krisha *et al*., 2004).

In addition, high degree of transmission of price is the characteristic of an efficient marketing system. Therefore, Minot (2010) described the concept of price transmission as the prices in a single market influence on the prices in another market. Various analysts have adopted the behavior of spatial price in markets of cereals as an indicator of market performance in several nations (see for example, Alderman, 1993; Abdulai, 2000; Rapsomanikis, 2004, Ankamah, 2013).

The ultimate issue while analyzing trade policy in global farming business sectors is the magnitude to which domestic farm product markets in developing countries answer changes in international prices (Rapsomanikis *et al*., 2004). To importance of understanding the magnitude international price shocks are transmitted to native markets, which is mostly estimated in terms of the transmission elasticity provide a need to examine diffusion of prices from the world to local markets. The magnitude of transmission of global price shocks to domestic market is best understood through adequate analysis of price transmission.

According to Rapsomanikis *et al* (2004), inadequate price transmission arising due to either trade and different strategies or transaction costs, for example unfortunate transport and communication infrastructure, brings about a decrease in the information of prices accessible to economic agents and subsequently may prompt choices which yield inefficient outcomes. This has important implications on economic agents' welfare. Price transmission can be measured for related commodities or goods at various points within the supply chain (Minot, 2011). In such cases the attention is for the most part on business sectors for similar commodities in two locations, which is called "spatial price transmission" (Minot, 2011).

Knowledge of the magnitude to which the fluctuations of prices in the worldwide markets are transferred to the native market is important because Kenya is a net importer of maize and thus price fluctuations in the international markets will have an impact on welfare of rural households if such price changes transmit into local markets. This is particularly the case in maize price movement because food security in Kenya is synonymous to "maize security" (Jayne *et al*., 2001). Given that the primary food in Kenya is maize, it represents 65 percent of absolute caloric of staple food intake and more than 30 percent of the total caloric intake (Ariga *et al*., 2010). Wheat, beans and rice then follow in that order with each accounting for 17, 9, and 5 percent of staple food consumption (Ariga *et al*., 2010).

Production is mainly dominated by small-scale farmers who produce 75 percent of all maize with the other 25 percent being grown by large-scale farmers (Kang'ethe, 2011). According to USDA (2020), the national maize production was 4 million metric tons per annum against national annual consumption of 4.5 million metric tons. To meet the maize supply deficit, Kenya imports maize from South Africa, USA, Tanzania and Zambia.

In the Eastern and Southern African region maize prices are highest in Kenya. According to Chapoto and Jayne (2009), it was only in Malawi that mean maize prices exceeded those in Kenya in 2009. Despite market reforms in 1990s to allow private trade, the NCPB continues to exert an indirect influence on maize prices in Kenya (Jayne *et al*., 2008). For example, as per Jayne *et al*. (2008), the NCPB purchases domestically marketed output in Kenya ranging from 10-20 percent mainly from large-scale producers. The procurement and sale operations of NCPB raised wholesale maize prices by 17-20 percent in 1995 and 2005 (Jayne *et al.*, 2008).

The increased poverty level in Kenya and stagnation of economic has been attributed to inefficient maize marketing system (Kang'ethe, 2011). For example, factors like rational government policies, more efficient market, increase in productivity increased productivity could emphatically hinder the economic contribution of the maize subsector turning into a crtitical elemetni speeding up development and minimization of poverty.

Grain prices in Kenya vary greatly from one market to another (Odhiambo, 2012). For instance, maize prices have been noted to be high in North Eastern and Eastern sections of the country and low in the Western regions where most of production occurs (Odhiambo, 2012). Karugia *et al.* (2002) notes that persistent maize shortages in the country compromises the welfare of Kenya's citizens, especially the poor. The Eastern parts of the country continue to experience maize shortages while at the same time farmers in the Central Rift and Western Kenya have maize surpluses they cannot dispose of because of low prices (Karugia *et al,* 2002).

Considering that ecological conditions frequently affects differences in patterns of crop production, governments are keen in understanding the relationship of price movements of staple foods in various nations to maximize the benefits accruable from comparative advantage. This study evaluated the price transmission in Kenya's maize markets from price movements in international markets.

1.2 Statement of the Problem

The highest maize prices in Eastern and Southern African region maize is found in Kenya (Ariga, et al., 2010). There has been a reduction of prices of agricultural commodity from their recorded peak in 2008, but, this has not been the case in Kenyan maize prices. According to Chapoto (2010), prices in Nakuru, Eldoret and Nairobi have remained significantly higher compared to levels of world market during 2000 to 2009 period. It is only in Kenya and Malawi where the price level of maize is higher compared to other major markers in Zambia, Tanzania, Mozambique, and South Africa (Chapoto and Jayne, 2010).

Kenya imports maize from international market to meet its domestic requirements. Therefore, fluctuations in the global prices will have an influence on local prices. The knowledge on the association among Kenya’s maize prices and world maize prices will give an insight on the tendencies of transmission of prices. It will also provide the likely image of the influence of changes in world maize prices on Kenya’s economy. This study will also offers an essential information on how maize markets are integrated in the domestically. It is against the background of the current study that is emphasizing to fill this gap on why Kenyan domestic maize prices has not kept pace with international maize prices in terms of price decreases. This will be achieved through the price transmission dynamics analysis between international maize prices and Kenyan domestic maize prices.

1.3 Purpose and Objectives of the study

The purpose of this study was to examine the transmission dynamics of world maize prices to Kenya's domestic maize markets. The specific objectives of the study were:

1. To assess the integration of domestic maize markets in Kenya.
2. To evaluate the transmission of world maize prices into domestic markets in Kenya.

1.4 Hypothesis tested

The hypothesis to tested in this study were:

1. That maize markets in Kenya are not integrated.
2. That the international maize price changes are not transmitted into the domestic maize prices in Kenya.

1.5 Justification of the study

Maize is Kenya's main staple food crop (USAID, 2010). About 98 percent of the 3.5 million small-scale farmers grow it, representing around 56 percent of farmed land in Kenya, and gives in excess a third of the total caloric intake (Kirimi, 2012). Large scale production accounts for 25 percent of the total production. It is estimated that a low income earner in Kenya spends about 28 percent of their income on maize (USAID, 2010).

Kenya has an average annual maize production of 4 million metric tons (USDA, 2020). Annual maize consumption is estimated at 4.5 million metric tons, which by far outweighs production and the deficit is imported (USDA, 2020). The country imports maize mainly from South Africa, USA, Tanzania, and Zambia.

An effective integrated world maize market shows competitive valuing and price efficiency and suggets that the world maize market is a dependable source to fulfill domestic demands (Cheng, *et al*., 2016). In addition, the world maize market integration suggests that significant exporters lack market power to charge higher prices than those dominant in the market. Thus, Kenyan strategies like the annually announced maize purchase prices by government through NCPB is in itself inefficient and costly. This study formally tests for the integration of Kenya's maize markets and the price transmission dynamics from the world maize market into the domestic maize markets.

The knowledge of the causes of instability of domestic food price among developing nations and degree to which it is transferred from international to domestic markets is essential to assist in formulating better global, regional, and domestic guidelines to adapt to extreme food cost unpredictability and to safeguard most helpless groups (Ceballos *et al*., 2015). Therefore, the findings of this study will aid policy makers in Kenya design sound policies that will deal with the usual dilemma of what prices farmers get for their produce and what prices consumers pay for the vital food commodity, without hurting each one of these groups. It will also help design policies to strengthen the maize sector's response to changes in international market price of maize.

The price transmission dynamics can provide insights on the stability of world prices. On the off chance that a diminishing in global price is incompletely transmitted to domestic price, then decreases in world supply and expansions in world demand that would have in any case happened won't occur (Atanu Ghoshray, 2011). Thus minimizing price more acute and prolonged (Atanu Ghoshray, 2011). Besides, dialogues in agriculture since the 1986 Uruguay Round of the General Agreement on Tariffs and Trade have followed the objective of tariffication, that is, to convert all prevailing trade intervention instruments into trade taxes or subsidies (Atanu Ghoshray, 2011). It is contended that this goal can prompt total end of quantitative trade restrictions. With a steady import tariff (tax or subsidy in the case of exports) international price signals would be transmitted to domestic prices. (Atanu Ghoshray, 2011).

1.6 Organization of the Thesis

The structure of this thesis is as follows: Chapter One gives the background of the research topic, then followed by the problem statement, objectives and hypothesis of the research, this section ends with the study justification. Chapter Two provides the literature review, which entails an in-depth discussion of the various approaches being adopted to assess integration of market and price transmission between markets in different locations. Chapter Three presents the theoretical framework that underpins the study methodology. This section also contains the sources of data and methods adopted for data analysis. Chapter Four presents the results of data analysis which include the integration of maize markets in Kenya and the components of the price transmission analysis. Finally, the key findings of the study, conclusions and policy recommendations were presented in Chapter Five.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Price Transmission

The Law of one price (LOP) is the key underlying theory base on spatial transmission of prices (Listorti and Esposti., 2012). LOP has primary anchor the transmission of spatial price. It proposes that at the equilibrium the prices of homogenous goods in two spatially separated markets will be equivalent to one another, apart from the cost of conveying the products from one place to another (Fackler and Goodwin, 2002).

To guarantee that commodity prices will vary based on the quantity which is mostly equivalent to the transfer costs with the association between the prices being recognized as the following inequality will be attained through spatial arbitrage (Fackler and Goodwin, 2001). In case the dissimilarities in prices is more than the price transmission, creation of arbitrage and profit maximizing traders will buy products at a small price surplus markets and sell them in a large price deficit markets (Ankamah-Yeboah, Isaac., 2012).

2.1.2 Market Integration

The equilibrium of spatial market suggest implies that markets are interconnected or integrated along a long-run association described by transaction cost and the nature of trade restrictions (Abunyuwah, 2007). Because market information transmission or goods between markets are crucial for maintaining spatial market equilibrium over time, it follows that (perfect) integrated markets must exhibit price co-movements over time, if tradability holds.

Meanwhile the cost of transactions cost plays a critical role, then prices might not co-move if rent to trade falls below the cost of trade (Abunyuwah, 2007). Furthermore, the LOP has anchored integration of market, which proposes, all points of time, allowing for transfer costs, for transporting the commodity from one market to another, the association between the prices can be represented by equation (1) above (Rapsomanikis, 2003). Thus, there is integration of market in case it holds that the relationship is similar to (1) above (Rapsomanikis, 2003).

However, according to Rapsomanikis (2003), particularly in the short-run, such extreme case may not arise. On other hand, assuming the appropriations of two prices being viewed as totally independent, then one might feel comfortable saying that there is no market integration and no price transmission. (Rapsomanikis, 2003).

2.2 Approaches for Estimating Market Integration and Transmission of Price

Analyzing linear price transmission has been possible through various methods. These include the Ravallion model, Granger causality approach, and the co-integration techniques. In any case, there are different methodologies that perceive the nature of non-linear relationship transmission of price, which comprise the parity bound method and the threshold approach. This study focused on linear price transmission analysis and will reviewed earlier developments on linear price transmission analysis.

2.2.1 The Correlation Coefficient and Regression Methods

Testing in agricultural markets for spatial market integration based on simple correlation analysis has been adopted on prior research work on price transmission (Abdulai, 2007). He observes that there was a correlation between two variables based on the results of correlation coefficient, which fall in the range zero and one where zero implies no relationship, and one means perfect correlation (Abdulai, 2007).

The estimation of this method is easy and can be understand is the benefit of this approach understand because the coefficient of determination R^{2} (Abdulai (2007), shows the variation share in one variable explained by another variable. But, the drawback of this method is that it only take into account the association between prices at same time, however, it fails to consider other confounders as well as the lags of prices (Abdulai, 2007). A major limitation is where the coefficient of correlation being statistically significant because of common trends in the price pairs from factors like inflation and seasonality (Getneta *et al*., 2005).

The omission of dynamic adjustment processes is the criticism of the model due to shocks. Such processes are normally sluggish and comprise considerable time lags (Getneta *et al*., 2005). Also, the coefficient of correlation could be high and, surprisingly, equivalent to one while no trade exists between the two business sectors (Nkendah, 2006). This could be a scenario where the market price between two business sectors are impacted by the similar features like volatility and seasonal movements (Nkendah, 2006). The method also fails to address the problem of non-stationarity of time series price data.

2.2.2 The Ravallion Method

Various rural markets structure linked to a principal market and afterward conducting tests on market integration to decide if the product price is influenced by its price in the focal market in a given market is being definite under the model of Ravallion (1986). The principal price in market is set by the model being impacted by contemporary and lagged price in any remaining business sectors and their individual lags whereas the price in markets of different country is affected by lagged values and the contemporary of price in the principal market and their individual lagged value merely (Fackler and Goodwin, 2002).

Ravallion method can be utilized to test several hypothesis consisting of segmentation of markets, and short-run, long-run market integration, and central market (Fackler and Goodwin, 2001). An index of market connection (IMC) employed by Timmer in 1987 to expand the value of the method of Ravallion offered an effectively understandable of short-run market integration estimation between two markets (Timmer, 1987).

Conversely, there exist ambiguity in the interpretation of the IMC since a higher value of IMC, for instance, might shows absence of market integration otherwise that markets are integrated, however, costs of transport possess a higher degree of persistence is being display by transport costs (Kilima, 2006). Similarly, small IMC proposes that markets are not confined yet it is hazy the way in which associated the business sectors are. (Kilima, 2006). Ravallion model stems main disadvantage entails its core radiated markets system assumption of exogenous market prices are thought to be theoretical (Abunyuwah, 2007).

Also, ignorance of the effect of exchange amongst local markets appears to be an exceptionally severe assumption (Abunyuwah, 2007). Another shortfall of the Ravallion method is that it assumes a linear relationship between prices and given that it excludes directly eliminates inter-market price of transmission from the model, making it prone to improper rejection and conclusion of the market integration hypothesis (Abunyuwa, 2007).

Palaskas *et al.* (1993) argue that while testing alternative hypotheses of market integration and segmentation this approach includes difficult issues that the outcome in inefficiency estimator. The shortcomings of Ravallion technique and the nature of non-stationary for majority series price, yields research works that used co-integration approaches to test for long-run market integration (Fackler and Goodwin, 2002).

2.2.3 The Test of Granger Causality

As per Vasciaveo, *et al*. (2013), the amount by which the recent *y* can be clarified by a past value of *x* and afterward to see whether adding lagged value can improve the explanatory power of the model was possible through the introduction of the test of Granger causality (1969). The Granger causality test of Granger (1969) is like the technique of Ravallion whereby an error correction mechanism is used to evaluate the degree to which current and past price variations in one market explain price changes in another (Baulch, 1997).

This approach has been employed in conjunction with other market integration techniques such as the co-integration approach to test for causality of price series, that is, to test for the direction of causality of prices in two markets (Alexander and Wyeth, 1994). Alexander and Wyeth (1994) emphasize that granger causality tests are necessarily implicitly nested within dynamic regression models and thus patterns of Granger causality should be considered to enrich the inferences offered in empirical studies.

Granger-caused is equal to *Y* by *x* if *x* helps in the prediction of *y*, or equivalently if the coefficients on the lagged *x*'s are statistically significant (Vasciaveo, *et al*., 2013). To determine whether a variable is exogenous can be achieve by utilizing test of Granger causality. A variable can be viewed as exogenous in case it is affected by a particular variable within the model (Mengistu, 2010). Although the Granger causality test may provide some inferences regarding the existence of statistically significant lead-lag linkages among regional prices, a number of shortcomings limit its usefulness (Fackler and Goodwin, 2001).

For example, according to Maleko (2013), the Granger causality test, taken by itself, only provides inferences concerning the principal and relationship of lag between markets for the analysis period and not the actual nature of the relationship that is, about the values of the parameters being evaluated. The relationship being substantial significant, which entails being totally inconsistent with conventional concepts of integration of market could exist and be taken as support for spatial integration by the Granger causality test (Maleko, 2013).

Therefore, it is imperative that results of Granger causality tests be supplemented by other inferential procedures to ensure that mistaken inferences are not drawn. (Fackler and Goodwin, 2001). Also, different limits related with correlation coefficients and regression approaches to testing for market integration also apply to the Granger causality test (Fackler and Goodwin, 2001).

2.2.4 The Engle-Granger Co-integration Approach

As per Engle and Granger (1987), time series data co-integration technique and the error correction model (ECM) was established by Engel and Granger where by co-integration among the price series indicates that while two prices might act in a diverse manner in the short-run, they converge to a conjoint conduct in the long-run (that is, the long-run equilibrium) (Conforti, 2004). The basis of co-integration technique is the manner in which it deviates from condition of equilibrium for two non-stationary variables ought to be stationary (Abdulai, 2000). Co-integration techniques have acknowledged much emphasis since they solve the issues of statistical associated with nonstationary time series data (Conforti, 2004).

One solution to the problem associated with non-stationarity of data series is to distinguish the data series and to analyze the data generating process as an error correction mechanism in which the change in the dependent variable is interpreted as the result of contemporaneous variation in the independent variables and process adjustment to the long-run equilibrium (Getneta *et al*., 2005). In addition, the models of error correction offer an instrument to test co-integration among variables with nonstationary time series properties (Getneta *et al*., 2005).

According to Chisanga, (2012), the short-run adjustment parameter in in an ECM is inferred as a measure of the speed of price transmission, while the long-run multiplier is interpreted as a measure of the degree of price transmission of one price to the other. As opposed to an ordinary OLS model, the benefit of ECM is that it considers the dynamic association among the predictor and an independent variable which may span several periods (Chisanga, 2012).

The benefit of the test of co-integration is that it permits consistent inferences to be drawn in situations where the individual price series are non-stationary (Fackler and Goodwin, 2001). However, like other regression-based tests, co-integration tests are vulnerable to problems associated with spurious regression results and fail to account for transaction costs (Fackler and Goodwin, 2001). A fundamental shortcoming associated with the co-integration approach lies in the possibility that transaction costs may be non-stationary, this results in parameter estimates that have inconsistent standard errors estimates (Fackler and Goodwin, 2001). In addition, implications about the direction of causation between variables cannot be made by using co-integration (Ohen and Abang, 2011).

Engel and Granger's (1987) two-step residual-based co-integration procedure, and Johansen's (1990) variance autoregressive (VAR) method adopted in multivariate analyses are most common methods to analyze co-integration. Engle and Granger (1987), observed that the initial procedure involved other two approaches applied in testing individually the unit root in the price series using various tests of unit root like the Phillips-Perron (PP) test, and augmented Dickey-Fuller (ADF), and Dickey-Fuller (DF).

Engle and Granger recommended a two-step method for evaluating co-integration of economic time series (Goodwin and Schroeder, 1991). The first step involves estimating the parameters of the co-integrating regression using the OLS regression techniques (Goodwin and Schroeder, 1991). The second stage involves obtaining estimates of first-stage residual errors. Such that if the residuals are I (0), then the conclusion is that the two series are co-integrated (Goodwin and Schroeder, 1991).

However, the technique of Engle and Granger does not consent testing for the entire possible co-integrating vectors in a multivariate system which result to the development of the Johansen (1988) co-integration approach (Ankamah, 2012). The Johansen adopted maximum likelihood estimates to test for co-integration associations among various economic series (Ankamah, 2012). In evaluating the short-run dynamics Engle and Granger (1987) propose utilization of error correction approach in case there is the existence of co-integration relation between variables under consideration.

According to Abunyuwah (2007), correction of error shows sheds light on variation of price which normally imitates arbitrage and market efficiency based on the sensitivity of short-run and long-run. The utilization of the technique of correction of error will aid to discover more notions for instant, speed and asymmetry of price association, completeness, and the causality direction between two markets (Ankamah, 2012). Several amendments have been made to the above requirement to account for different aspects in examination of price transmission.

Conforti (2004) estimated the Auto Regressive Distributed Lag (ARDL) model that tests for the presence of a nonspurious long-run association between economic variables in case it is unknown *a priori* whether the variables are purely non-stationary, purely stationary or mutually co-integrated (Getneta *et al*., 2005). In addition, the approach of bounds testing discovered by Pesaran *et al*. (2001) for co-integration (long-run relationship) testing among variables in an unrestricted error correction model irrespective of the time series properties of the variables entering the model.

2.3 Empirical Studies Review

Several studies have examined the level of transmission of price between markets within a country, including quite a number for SSA. Minot (2011) used a VECM evaluating the global food price variations transmission into markets found in Africa and its effects on the welfare of household. The author used data for 1994 to 2008 period for maize, sorghum and rice in nine SSA countries, which was time series data type. From 62 price series, merely 13 was established from the study to have long-run association whereby the prices of domestic were impacted by the worldwide price of the similar product. Amongst the 13 local prices, only six had a significant long-term elasticity of transmission proposing that African maize prices are not closely linked to world markets.

The study concluded that the lack of integration between the domestic and international markets was due to the fact that most nations of SSA are near to self-sufficiency in maize, nonetheless imported rice was key in meeting the local demand. The current study analyzes price transmission of maize from internal to domestic markets in Kenya using VECM, in addition it analyzes domestic integration of five Kenyan maize markets.

A study on the assessment of South African maize prices transmission into Botswana market by Tebogo (2015), where the author used co-integration approaches and correction error technique on monthly price wholesale information for 2000 to 2013 period. The review established an existence of a long-run steady state equilibrium of prices of maize among Botswana and the South African. Estimation of 0.86 of price transmission long run elasticity was recorded, meaning pice of maize variations are transferred to the Botswana market by 86 percent from South Africa. To adjust maize price of Botswana to the price variations in South Africa it takes around 13 months. The same technique of Vector Error Correction was utilized by the current study, however, it varies from this study because it primary centered on the transmission of worldwide maize prices into Kenya's domestic market. The author mainly focused on regional price transmission, that is, the Southern African region.

Kirui (2019) evaluated the worldwide wheat prices transmission into Kenya's domestic market using an ECM. A data type of time series for 2002 to 2014 period for the local markets and international market was used by the study. The long-run steady state equilibrium was evidence of the study was existence of long-run equilibrium state of Kenya and the Ukrainian wheat prices. The estimation of 0.78 of price transmission long-run elasticity illustrate the variations in prices of wheat are transferred to domestic market of Kenya arose from Ukrainian by 78 percent. The adjustment speed of -0.08 was calculated which infers that to completely transmit wheat price changes from Ukraine to the Kenyan market it required around 13 months.

The study concludes that the Kenyan government should improve rural infrastructure and also create a conducive environment for local wheat production as well as create a competitive environment to reduce cost and time of grain handling. Price transmission was analyzed in the same manner in the current study. Nevertheless, primarily emphasizing on price transmission to Kenyan domestic markets from the world. The author considers only three markets, that is, two deficits and one surplus markets, the current study focuses on wider market coverage, two surplus and three deficit/consumption centers. The ongoing study primarily emphases on Kenya all in all. A landlocked Rwanda nation has a large portion of their products which goes through Kenya.

The assessment of world price transmission into Rwanda's rice was conducted by Tuyishime (2014). The author utilized a VECM method and time series periodic data for 2002 to 2012 period for Kigali, Ruhengeri, Umatara, and Butare. He noted the integration of world rice markets, and rice market in Rwanda. Furthermore, he observed 68 to 82 percent of the international prices are transmitted to domestic market ranged. To adjust to global prices Butare market takes 4 months whereas Kigali recorded 3 and half months. The price adjustment by Ruhengeri to world price is within 5 months whereas it requires 4 months for the adjustment of market of Umatara to price of the world. The author analyzed price transfer from worldwide prices to 4 other domestic markets. However, the current study applies related method in examining transmission of price. However, primarily emphasis on global prices transmission to the domestic maize markets in Kenya. The entire Kenya is the main focus of the current study.

Rapsomanikis *et al*. (2004) assessed integration of market and price transmission between international and domestic markets of selected food and cash crops in developing countries using the co-integration and error correction models with both symmetric and asymmetric adjustments. The specific crops under study were coffee as the cash crop and wheat as food crop. The countries under study were Ethiopia, Rwanda and Uganda in the case of coffee; and Egypt for wheat market study. The dataset covered the period 1990 to 2001 for coffee prices and 1969 to 2001 for wheat prices. They discovered that markets subjected to the speed of price adjustment, policies was relatively low. Hence policies impede the extend of price transmission.

Gitau and Meyer (2018), conducted a research on transmission of spatial price under different policy regimes in the Kenyan maize markets. The author used maize monthly prices for 2 maize surplus markets and 7 maize deficit markets for the years 2000 to 2016; and employed the Vector Error Correction Models (VECM) and co-integration in the study.

They found that there was extensive association and co-integration between surplus and deficit markets under regime with little or no policy interventions. A higher price transmission, faster correction of price shocks between surplus and deficit markets under the same regime was also established by the authors. Under policy implementation, there was price shocks taking longer to correct, low price transmission as shown by low speed of adjustment and higher half-life. The study concludes that the governments need to be cognizant of the counterproductive nature of the policies implemented in addressing the high food price dilemma.

The same method in the analysis of price transmission is adopted by ongoing study, yet basically centers on the worldwide price transmission to the domestic maize markets in Kenya. In addition to domestic integration of maize markets, the current study gives insights on whether international price changes are transmitted into domestic maize markets in Kenya.

From the foregoing review on the different approaches used to analyze market integration and price transmission, it is apparent that co-integration and error correction models are best suited for the task. Co-integration analysis techniques differentiate between the long-run and short-run dynamics of market and also aid testing for the law of one price (Listorti, 2009). Therefore, this study adopts the co-integration approach to analyze market integration. Thereafter, the ECM for price transmission analysis

CHAPTER THREE: METHODOLOGY

3.1 Theoretical Framework

The Law of one price is the basis for the analysis of market integration and price transmission forms. It postulates that at equilibrium the cost of a homogeneous product in two spatially separated markets that is equivalent to one another separately from the cost of conveying the products (Rapsomanikis, 2003).

Following Rapsomanikis (2003), the LOP can be specified as follows:

$$P_t^1 = \alpha_t + \beta P_t^2 + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

where P^1 and P^2 are prices in two different markets, α_t is the price differential between the two markets, which reflects transport costs and other transfer costs, and ε_t denotes error term. β is an unknown parameter to be measured. If β is stationary and unitary, it can be concluded that the markets are completely integrated and this implies that a change of price in a given market will be transferred to the other market (Nyongo, 2014). $\beta \neq 0$ shows integration of market to some level and exhibit an association with one another whereas $\beta=0$ implies absence of association between the prices (Rapsomanikis, 2003).

In this framework, the LOP is considered a condition of equilibrium after which there might be a divergence in the short-run. Given the explanation of LOP, prices might misbehave as a result of market distortions; that is, prices incline to exhibit co-movement between markets (Rapsomanikis, 2003). From the LOP, various approaches have emerged in testing for price transmission and market integration. One of such is the two-step Engel and Granger (1987) model for testing for co-integration of price series.

It involves the estimation of the following OLS regression of commodity prices in markets i and j at time t (Rapsomanikis, 2003):

$$P_t^i = a + bP_t^j + \varepsilon_t \quad \text{(3.2)}$$

The ADF test is applied to test for stationarity on the residuals from this regression. This involves estimating, below equation:

$$\Delta\varepsilon_t = \alpha + \beta\varepsilon_{t-1} + \gamma t + \sum_{j=2}^{n} \delta_j \Delta\varepsilon_{t-j} \quad \text{(3.3)}$$

Where t is a time trend, α-the constant term, β-coefficient on lagged residual, γ-coefficient on time trend, and n denotes lags number. In the case null hypothesis that $\beta = 0$ could be rejected, thus, implies that the series are co-integrated.

Asche *et al*. (1999) observed evidence of a long-run linear association between price series in spatially separated markets based on co-integration (If $\beta \neq 0$ in equation 3.1, long-run equilibrium relationship exists among the prices since prices are co-integrated. Therefore, there exists a co-integration vector (1,-β). However, whereas co-integration indicates that linear relationship of the reduced form occurs between two-time series, it is neither a necessary nor a sufficient condition for market integration (Barrett, 1996). When two-time series are co-integrated, the Granger representation theorem postulates that one of them must Granger cause the other- although prices need not be simultaneously determined. In this analysis causality tests are necessary since implications about the direction of causation between variables cannot be achieved using the co-integration.

3.2 Empirical Framework

3.2.1 Market Integration Analysis

To address first objective on whether maize markets in Kenya are integrated, the Johansen's (1990) maximum likelihood co-integration test was used. The two-stage procedure begins with tests for stationarity followed by a co-integration test.

3.2.2 Unit Root Tests

Vavra *et al*., (2005) termed stationarity as a method where statistical parameters (mean and standard deviation) of the process do not vary with time. Many economic time series are non-stationary, and some transformations such as differencing or detrending is needed to make them stationary (Vavra *et al*., 2005). Non-stationary variables produce spurious regressions which are characterized by stochastic trends and auto-correlated residuals, with variance of the residuals changing over time (Granger and Newbold, 1974). This leads to biased and inconsistent test results.

The initial procedure in analysis of co-integration involves testing stationarity of series. A non-stationarity null hypothesis is tested using any of available tests of unit root like test of ADF (Dickey and Fuller, 1979). Rejecting the null hypothesis entails that the prices being integrated of the similar order (I(1)), which means they could exist co-integration. In case they are both stationary or 'I(*0*)' they can be analyzed using OLS and the estimates will be BLUE (Greb *et al*. 2012). Engel and Granger (1987) or the Johansen's (1988) MLE utilized OLS in a two-step procedure to verify the no co-integration null hypothesis in case the series are both I(*1*). In this study, the Johansen MLE test was used.

3.2.2.1 Augmented Dickey-Fuller (ADF) Test

Following Dickey and Fuller (1979), the autoregressive formulation of the ADF test with a constant is specified as follows:

$$\Delta P_{it} = \alpha_0 + \alpha_1 t + \gamma P_{it-1} + \sum_{j=2}^{n} \beta_i \Delta P_{it-j+1} + \epsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

where P_{it} represents market price *i* at time *t*, $\Delta P_{it} = (P_{it} - P_{it-1})$, t denote variable of time trend, and α_0 is the intercept or constant term, . The joint hypothesis to check for unit root is: $H_0: \gamma = \alpha_0 = 0$ using $\emptyset_1$ statistic (see Annex 4 for critical values). By not rejecting the null hypothesis implies that the series is non-stationary. The unit root null hypothesis is rejected in contradiction of an alternative of stationarity if the test statistic (ADF statistic) of the estimated γ is higher compared to the critical value in absolute terms. For instance, a value of critical at the conventional significant level (usually the five percent significant level) is greater than that of the ADF statistic, thus, the series (P_t) is said to be stationary and vice versa.

The current study used the ADF regression with a time trend. Therefore, the test statistic was τ_τ (see Annex 4). The test was conducted at levels and first difference levels. Rejection of the null hypothesis at levels would mean that the prices series are stationary (that is, they are I(0)) and hence there is no integration of both price series in which case Granger causality test would be performed. (Rapsomanikis *et al*., 2004). Alternatively, the price series are non-stationary in which in case of the ADF test would be undertaken again at first difference to evaluate the integration order through a unit root null hypothesis not rejected (Minot, 2010).

In case at first difference the null hypothesis of a unit root is rejected, then the price series are integrated to degree 1 (that is, they are I(*1*)). It thus, means that at levels, the series follow a random walk and at first difference is stationary, I(*0*). Following Rapsomanikis *et al.* (2004), when the prices are I(*1*) at levels, they are integrated and thus tests of co-integration will have to be carried out between the price series using either the Johansen ML test or the two step Engel and Granger co-integration model.

3.2.2.2 Phillips Perron (PP) Test

A non-parametric test which is regard to be superior to the ADF test in small samples, because it uses consistent estimations of the variance is the PP test (Nkedah *et al.*, 2006). Therefore, this test is applied to assess the robustness of test of ADF. The Dickey-Fuller (DF) tests supported by distribution theory assumes that the errors are statistically independent and possess a constant variance (Enders, 2010). In utilizing this procedure, care should be taken to guarantee that the error terms are uncorrelated and their variance is constant. A generalization of the DF procedure which considers the nature of less restrictive of the error processes was developed by Phillips and Perron (1988). Phillips and Perron (PP) stationarity test considers the following (Enders, 2010):

$$X_t = c^* + \rho^* X_{t-1} + V_t \qquad (3.5)$$

$$X_t = c + \beta\{t - {}^{T}/_{2}\} + \rho X_{t-1} + V_t \qquad (3.6)$$

where X_t denotes respective price series, $\{t - {}^{T}/_{2}\}$ is the time trend and T is the sample size, V_t is the white noise error term. This procedure uses a non-parametric adjustment to the DF test statistic and allows for dependence and heterogeneity in the error term. Equation (3.6) also tests for the null of a unit root ($\rho = 0$) against the stationarity alternative of $\rho < 0$. The critical values for the PP statistics are precisely those given for the DF tests (see Annex 4).

3.2.3 Testing for Co-integration

The non-stationary in level of price series will demand the adoption of co-integration (Ikudayisi *et. al*., 2011). The test of Johansen co-integration is utilized by the current study by following Johansen and Juselius (1990) with critical values from Osternwald-Lenum (1992). The test is usually conducted to evaluate the co-integration of the two series, inferring to variable is I(*1*) and a linear combination of the two variables is I(*0*), respectively (Ikudayisi *et. al*., 2011). The co-integration method depends on an unrestricted method of VAR identified in error correction (EC) form. Following Johansen and Juselius (1990), the ECM is given as:

$$\Delta X_t = \pi X_{t-1} + \sum_{i-1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + V_t \ldots\ldots (3.7)$$

where X_t comprises the entire n model variable such as ~I(1), the π, Γ_i and Φ are parameters matrices to be measured, D_t denotes vector with elements of deterministic (trend, constant, and dummy) and V_t denotes random errors vector in line with a Gaussian white noise process. Equation (3.7) suggests that there cannot be different association between an I(0), and I(1) variable. Subsequently, if ΔX_t ~I(0), then π is a matrix of zeros, excluding if a linear combination of the variables in X_t is stationary (Ikudayisi *et. al*., 2011).

The Johansen test of co-integration assesses the rank (r) of the matrix Π (Ikudayisi *et. al*., 2011). Whether r = 0, then the entire variables are I(1). Thus, they are non-stationary (Ikudayisi *et. al*., 2011). If $0<r<N$, there exist r co-integrating vectors. Alternatively, in case r = N, then all the variables are I(0) and thus stationary, and any combination of stationary variables will also be stationary (Ikudayisi *et. al*., 2011). π is the extended response matrix and is well-defined as the product of two matrices: α and β', of dimensions (g x r) and (r x g) respectively (Ikudayisi *et. al*., 2011).

The β includes the co-integrating vector long-run coefficients; α is recognized as the adjustment parameter matrix and is the same as an error correction term. The linear combinations $\beta' X_{t-k}$ of this matrix will be I(0) in the case where the times series are co-integrated. In other words, if rank of π = r = K, the variables in levels are stationary meaning that no co-integration exists; if rank π = r = 0, denoting that all the elements in adjustment matrix have zero value, none of the linear combinations are stationary (Ikudayisi *et. al*., 2011).

The Johansen test of co-integration technique measures the π matrix through an unrestricted VAR and tests if one can reject the restriction implied by the reduced rank of π (Ikudayisi *et. al*., 2011). The co-integration of the system is tested through application of maximum likelihood $L_{max}(r)$ test, being co-integration rank function r. The reduced rank of π is tested by two methods; the trace test and the maximum eigenvalue, given respectively, by (Ikudayisi *et. al*., 2011):

$\lambda_{trace} = -T\sum_{i=r+1}^{n} \ln(1-\lambda_i^2)$……………………………………………..………..……… (3.8)

$\lambda_{max} = (r, r+1) = -Tln(1-\lambda_{r+1})$……………………………………..………………....(3.9)

where denotes vector of calculated values of the ordered eigenvalues attained from the calculated matrix and T denotes observations number after the lag adjustment, r =0,1,2,…,n-1.

The number of co-integrating vector in the equation (r) is determined by conduction the likelihood ratio (LR) test (Ikudayisi *et. al*., 2011). The trace statistics test the null hypothesis that the number of distinct co-integrating vectors (r) is less than or equal to r against a general alternative. The criterion for selection in this case is that the no co-integration null hypothesis, that is, H_o: r=0 denotes a five percent significance level being rejected if the observed statistic is greater than the critical value (critical values from Osternwald-Lenum (1992)).

The conclusion then is that the two-price series are co-integrated with r vectors of co-integrating vectors. The vector of co-integrating number is r denotes tested null hypothesis by optimal eigenvalue against the alternative of $r + 1$ co-integrating vectors, that is, if H_o: r=0 then H_1: r=1. If the critical value at the five percent level of significance is less than maximum eigen-value then the null hypothesis is rejected. Evidence against the null hypothesis of no co-integration indicates that markets are integrated since price co-move. In the event of accepting the null hypothesis, it implies that there is not integration among markets. Therefore, absence of price transmission.

In case of the presence of co-integration of price series, the tests progress by aiming on the error correction illustration, which aims to evaluate the short-run dynamics and the adjustment of price speed (Henry *et al*., 2012). The critical values for Johansen test are given in Annex 5 (that is, the critical values: with intercept in ECM). The Johansen ML tests is favored compared to test since it offers solutions issues of endogeneity and simultaneity related to other bivariate methods and its capability to test more than two variables at a time (Henry *et al*., 2012).

In this study, the Johansen ML co-integration test was carried out using Eviews 10 statistical software. The trace and the maximum eigenvalues were generated to determine whether the two price series, that is, the two domestic maize prices and the international and domestic price series were co-integrated. This process addressed the first aim of the current study that is assessment of the degree of integration of maize markets in Kenya towns like, Kisumu, Mombasa, Nairobi, Eldoret and Nakuru.

Thus, the evaluation of the magnitude of world market prices transmission into domestic markers of Kenya is the second objective of the current study. This involved employing the Johnsen ML procedure on each pair of the domestic maize markets and the international maize market to determine whether there were co-integrating price pairs so that an ECM could be specified for each price pair. The ECM was used to examine the short- and long-run price dynamics and speed of price adjustment.

3.2.4 Price Transmission Estimation

As per the theorem Granger illustration (Engel and Granger, 1987), ECM might be used to authentically represent their association might in case of the presence of co-integration of two variables. In the case prices in two spatially separated markets, P_{1t} and P_{2t}, thus, when they are co-integrated the vector error correction model (VECM) might represent their relationship (Engel and Granger, 1987).

The ongoing set of time series levels relates to their lagged values since the VECM is a re-parameterization of the standard VAR model (Engel and Granger, 1987). The VECM matrix of two spatially separate markets prices, P_{1t} and P_{2t} is given as (Engel and Granger, 1987):

$$\begin{bmatrix} \Delta P_{1t} \\ \Delta P_{2t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} (P_{1t-1} - \beta P_{2t-1}) + A_2 \begin{bmatrix} \Delta P_{1t-1} \\ \Delta P_{2t-1} \end{bmatrix} + \cdots + A_k \begin{bmatrix} \Delta P_{1t-k} \\ \Delta P_{2t-k} \end{bmatrix} + \begin{bmatrix} V_{1t} \\ V_{2t} \end{bmatrix} \ldots\ldots\ldots\ldots\ldots \quad (3.10)$$

For 3.10 equation, P_{1t} and P_{2t} along with respective changes, ΔP_{1t} and ΔP_{2t}, are the explanatory variables in the ECM. The matrices x containing A_2 to A_k measure the short-run effects of the model. The variables enter levels goes into the ECM combined as the single entity ($P_{1t-1} - \beta P_{2t-1}$), which reflects the divergence from equilibrium.

Vectors α_1 and α_2 contain the error correction coefficients which capture the speed of adjustment of P_{1t} and P_{2t} towards reestablishing the long-run equilibrium (Minot, 2010). The primary benefit of the VECM model over the approach of VAR is being able to isolates the long-term equilibrium (or 'co-integrating') association between P_{1t} and P_{2t}, that is seized by the ECterm ($P_{1t-1} - \beta P_{2t-1}$) in the short-term dynamics that guarantee other movement away from the long-run equilibrium are 'corrected' and, thus, temporary (Minot, 2010).

To model the price transmission from international to domestic maize markets in Kenya, the following VECM was used (Minot, 2010):

$$\left.\begin{array}{l}\Delta P_t^d=\mu_1+\alpha_1(P_{t-1}^d-\beta_1 p_{t-1}^w)+\delta_1\Delta P_{t-1}^w+\rho_1\Delta P_{t-1}^d+\varepsilon_{1t}(a)\\ \Delta P_t^w=\mu_2+\alpha_2(P_{t-1}^w-\beta_1 p_{t-1}^d)+\delta_2\Delta P_{t-1}^d+\rho_2\Delta P_{t-1}^w+\varepsilon_{2t}(b)\end{array}\right\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.11)$$

where, P_t^d denotes log of Kenyan domestic monthly maize price converted to real US dollars, P_t^w is the log of USA monthly maize prices in actual US dollars, Δ is the difference operator, so $\Delta P_t = P_t - P_{t-1}$, α, ρ, and δ are estimated parameters, and ε_t is the error term. The tests on the influence of the prices of the world on domestic prices (equation (a)), and the influence of domestic prices on world prices (equation (b)) will be done using Equation (12). However, only equation (a) was estimated in this study.

Equation (b) was dropped, as according to Minot (2010), most countries in SSA (including Kenya) might be regarded as "small countries" concerning the staple food crop markets. Therefore, they have little effect on world food prices. In addition, because the study calculated the global maize prices transmission to domestic maize prices, there was no need to estimate equation (b).

Accordingly, equation (12) was specified as follows (Minot, 2010):

$$\Delta P_t^d = \alpha + \theta(P_{t-1}^d - \beta p_{t-1}^w) + \delta \Delta P_{t-1}^w + \rho \Delta P_{t-1}^d + \varepsilon_t \text{ ....} (3.12)$$

where θ price adjustment speed to equilibrium; and all the other variables are as previously defined. Given that the expression of prices in logarithms, then the co-integration vector, β, is the long-run elasticity of price transmission from the world to the domestic market (Minot, 2010). The expected value in the case of foreign products is $0<\beta<1$, but it may be greater than one for exports.

Hence, in case $\beta=0.5$, then it suggests the transmission of domestic price in the long-run from worldwide price will be within a variation of 50 percent. The coefficient of EC θ represents the speed at which the system returns to equilibrium in case of a shock. The prediction was it lies between the range of $-1<\theta<0$ with $\theta = 0$ and $\theta = 1$implying no adjustment and rapid adjustment to deviations from long-run equilibrium, respectively (Nyongo, 2014).

The e_{t-1} represents deviations of error terms between previous period prices and in the long-run. A θ value of negative assists to precise the error creating it further possible that the ΔP_t^d is negative (Minot, 2010). The greater the θ in absolute value, the faster the prices of domestic P^d will go back to their long-term relationship or converge to the world prices P^w. The coefficient on variation in the world price, δ, is the short-run elasticity of the domestic price relative to the world price (Minot, 2010). Thus, representing the adjustment percentage of native price within 1 period later 1 percent shock in international price with an anticipated range of $0<\delta<\beta$ (Minot, 2010).

The variation on the lagged coefficient in the domestic price, the impact of individual international price change on variation in price of domestic in the subsequent period with an predictable range of -1<ρ<1 (Minot, 2010) is represented by autoregressive term ρ, $P_{t-1}^{d} - \beta p_{t-1}^{w}$ denotes the long-run co-integrating relationship representing the long-run association between the Kenyan domestic and international maize markets. (Minot, 2010).

Following equation 3.12, five ECM's were estimated each representing the relationship between each of the five Kenyan domestic markets and the international maize market (American number 2 yellow maize FOB Gulf of Mexico):

$$\Delta P_t^{eld} = \alpha + \theta(P_{t-1}^{eld} - \beta p_{t-1}^{usa}) + \delta \Delta P_{t-1}^{usa} + \rho \Delta P_{t-1}^{eld} + \varepsilon_t \ldots \quad (3.13)$$

$$\Delta P_t^{ksm} = \alpha + \theta(P_{t-1}^{ksm} - \beta p_{t-1}^{usa}) + \delta \Delta P_{t-1}^{usa} + \rho \Delta P_{t-1}^{ksm} + \varepsilon_t \ldots \quad (3.14)$$

$$\Delta P_t^{nkr} = \alpha + \theta\left(P_{t-1}^{nkr} - \beta p_{t-1}^{usa}\right) + \delta \Delta P_{t-1}^{usa} + \rho \Delta P_{t-1}^{nkr} + \varepsilon_t \ldots \quad (3.15)$$

$$\Delta P_t^{nrb} = \alpha + \theta\left(P_{t-1}^{nrb} - \beta p_{t-1}^{usa}\right) + \delta \Delta P_{t-1}^{usa} + \rho \Delta P_{t-1}^{nrb} + \varepsilon_t \ldots \quad (3.16)$$

$$\Delta P_t^{msa} = \alpha + \theta(P_{t-1}^{msa} - \beta p_{t-1}^{usa}) + \delta \Delta P_{t-1}^{usa} + \rho \Delta P_{t-1}^{msa} + \varepsilon_t \ldots \quad (3.17)$$

Where, msa-Mombasa, eld-Eldoret, nrb-Nairobi, ksm-Kisumu, nrb-Nairobi, and usa-USA. These are the maize markets under study.

3.3 Data Sources

Secondary data were used in this study. Monthly domestic wholesale maize prices for the January 2002 to March 2020 period were obtained from Kenya's Ministry of Agriculture (MOA) for five purposively selected domestic markets (Eldoret and Nakuru representing surplus production zones), and (Nairobi, Kisumu, and Mombasa representing deficit consumption zones). Global Information and Early Warning System (GIEWS) databank was the source of monthly price data for the U.S. Gulf of Mexico, No. 2 Yellow Corn since it is under the Food and Agriculture Organization of the United Nations (FAO) for similar period and used as the international reference maize prices.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Trends in maize prices

Table 4.1 presents the average maize prices in the international market and the five domestic markets over the January 2002 to March 2020 period. On average, maize prices were found to be low in Nakuru and Eldoret, with each market recording a mean price of USD 0.26/Kg. These two markets are located within the maize production areas and thus it would be expected that the maize prices in these regions to be low compared to other regions. Kisumu had the highest mean maize prices of USD 0.32 per Kg.

Table 4-1: Descriptive statistics for domestic and international maize prices (US$/Kg), January 2002 to March 2020

Market	Mean	Max	Min	SD	Obs
USA	0.17	0.33	0.09	0.06	204
Eldoret	0.26	0.52	0.07	0.09	204
Kisumu	0.32	0.59	0.10	0.11	204
Mombasa	0.27	0.53	0.10	0.09	204
Nairobi	0.29	0.52	0.10	0.09	204
Nakuru	0.26	0.50	0.09	0.08	204

N/B: Max-maximum, Min-minimum, SD-standard deviation, Obs-No of observations
Source: Author’s calculations

On average, USA had the lowest maize prices due to its position as a net exporter of the commodity (Table 4.1). According to Minot (2010), Sub-Saharan Africa staple grain prices are higher compared to the world costs of similar products. In order to measure price volatility, the standard deviation has been calculated on the price series. Domestically, there is high price variability in Kisumu, recording a high SD of 11 percent compared to other domestic maize markets prices series (Table 4.1).

The lowest price variability is exhibited in Nakuru (8 percent). This could be as a result of Nakuru being the maize producing zone and also a central market in terms of maize coming from the surplus regions of Eldoret must pass through here; also imports from international markets heading to Western and Nyanza deficit areas pass through this market. Hence such actions serve to stabilize maize prices. On average, domestic maize price variability is at 9.2 percent, compared to a low of 6 percent in the world price series. The low price volatility in the international markets is an expectation given the fact that US is a net exporter of maize.

4.2 Unit Root Test Results

The findings on unit root test results for the ADF and PP tests were presented in Table 4.2. The ADF and PP statistic for all the price series at levels are lower than their corresponding five percent critical value of 3.50 (Table 4.2). Therefore, the five percent significant level was not rejected in the unit root null hypothesis in these series in both models (Table 4.2). It can therefore be concluded, all the series price are non-stationary at levels. After first differencing of the price series, it is observed that both the ADF and PP test statistics are higher than their corresponding five percent critical value (Table 4.2).

Therefore, the null of non-stationarity is rejected and it is concluded all price series are integrated of order one, that is I(*1*). Since the series of wholesale prices of maize utilized in current work are entirely integrated in the similar order, I(*1*), they are jointly determined as predicted and thus might be co-integrated. After determination whether the price series are non-stationary, the next procedure in the analysis is to conduct co-integration test between the price series.

Table 4-2: Unit Root Tests for prices of Monthly Wholesale, January 2002 to March 2020

Series	**Level**			**First Difference**		
	ADF	**PP**	**Lags**	**ADF**	**PP**	***I*(d)**
Logarithm of Wholesale Maize Prices						
Log Eldoret Price	-3.38	-2.98	1	-11.19[c]	-10.88[c]	*I*(1)
Log Kisumu Price	-3.29	-3.33	1	-14.06[c]	-15.13[c]	*I*(1)
Log Mombasa Price	-3.19	-3.30	1	-13.98[c]	-14.40[c]	*I*(1)
Log Nakuru Price	-2.83	-2.78	1	-8.58[c]	-10.41[c]	*I*(1)
Log Nairobi Price	-3.02	-2.96	1	-14.93[c]	-15.67[c]	*I*(1)
Log USA Price	-1.77	-1.81	1	-11.46[c]	-11.60[c]	*I*(1)
5% Critical Values	-3.50	-3.50		-3.50	-3.50	

The Mackinnon critical values for 5% is -3.448. (c) Denotes rejection of the null hypothesis of a unit root at the 5 percent level (Mackinnon, 1996).

4.3 Co-integration Test

The findings co-integration test was presented in Table 4.3. This estimated trace test statistic values were greater than their corresponding critical values (for a null of zero, one and two co-integrating relationships) at the five percent level of significance; and less than the five percent critical value for a null of three association of co-integration. Trace test rejected the presence of zero null hypothesis, one, and two co-integrating relationships; but the presence of three co-integrating relationships null hypothesis is not rejected (Table 4.3).

Thus, the trace test indicated the presence of three co-integrating relationships at the five percent significance level within the Kenyan domestic maize markets (Table 4.3). Similarly, the maximum eigen statistic values were superior than their corresponding five percent critical values for the null hypothesis of the presence of zero and one co-integrating relationships (Table 4.3). Therefore, resulting to rejection of presence of zero null hypothesis, and one co-integrating relationship at 5 percent significance level. From Table 4.3 the maximum eigen test indicated presence of two co-integrating relationships was significance at five percent level.

Though the economy theory proposes application of the two tests in recognizing the number of co-integrating vectors, current studies such as Lutkepohl *et al*, (2001) indicates that the critical asymptotic values of the two tests tend to overstate the number of statistically significant co-integrating vectors in small samples. The more co-integrating vectors are usually reported by trace test compared to test of maximum eigenvalue (Lutkepohl *et al*, 2001). The findings of the authors showed that the statistic of maximum eigenvalue statistic are more dependable as opposed to the trace test.

Therefore, the current study employed test of maximum eigenvalue to decide on the number of co-integrating vectors for all individual price series. Thus, concluding that there are two co-integrating vectors in Kenya’s domestic maize prices. It can therefore be concluded that the Kenyan maize markets are integrated. The pair-wise co-integration tests analysis for domestic maize markets in Kenya was estimated and the results were presented in Table 4.4.

As shown in Table 4.4 the null trace test statistic and maximum eigen value tests of *r=n-1* were rejected the null hypothesis for the entire domestic price series; and the alternative hypothesis that *r=n* could not be rejected at the five and one percent level. The trace test statistic and the maximum eigen value statistic test provide evidence of at least one co-integrating relationship that is significant at both one and five percent level, in all the price pairs (Table 4.4). It can therefore be concluded that at least one co-integrating relationship exists in each of the price pairs

The results of tables 4.3 and 4.4 resulted to rejection of the first hypothesis; which stated that the markets for maize in Kenya are not integrated. Therefore, it is concluded that the maize markets in Kenya are co-integrated. This provides evidence of a long-run relationship in markets. Hence, their prices transfer together in the long-run.

Table 4-3: Johansen's Max-Eigen and trace test for the number of co-integrating vectors, January 2002 to March 2020

Maximum Likelihood Co-integration findings: A five-variable, one lag system.

Estimated Eigen values (λ's), Eigen vectors (β's) and Weights (α's)

	Eigen Values (λ's)				
Variable	0.186	0.157	0.090	0.046	0.020
Normalized Eigen vectors (β's)					
Eldoret	-0.045	12.468	-5.016	-6.208	-2.870
Kisumu	-7.818	-3.206	7.586	-1.118	-3.992
Mombasa	16.611	-0.911	4.000	-0.606	-4.187
Nairobi	-2.241	-9.104	-15.30	5.107	2.282
Nakuru	-5.752	0.730	8.303	6.056	7.522
Weights (α's)					
Eldoret	0.010	-0.028	0.008	-0.003	0.007
Kisumu	0.024	0.004	-0.010	-0.008	0.010
Mombasa	-0.011	-0.012	0.001	-0.019	0.004
Nairobi	0.015	0.001	0.018	-0.011	0.003
Nakuru	0.021	-0.019	-0.001	-0.011	-0.003

Number of Co-integrating Vectors

H_o	Trace statistic	Trace (0.95)	λ_{Max}	λ_{Max} (0.95)
r=0	115.12**	68.52	43.95**	33.46
r≤1	71.17**	47.21	36.56**	27.07
r≤2	34.60*	29.68	20.17	20.97
r≤3	14.43	15.41	10.08	14.07
r≤4	4.35	3.76	4.35	3.76

Note: The critical values are taken from Osterwald-Lenum. (1992). *(**) represents rejection of null at the 5%, (1%) level

Source: Author's Computations

The existence of food movement from surplus regions to deficit regions of the country is the implications of co-integrated domestic maize markets is that there is. Integrated markets mean that signal of prices are passed from one market to another; and thus all player of the market are able to make rational decisions based on these price signals. Producers for example in the maize growing areas of Nakuru and Eldoret will respond to maize demand in for example Nairobi or Mombasa as signaled by the high prices in these consumption centers.

Table 4-4. Pairwise Johansen's Co-integration test results for domestic maize markets:

Series	Null	Max-eigen	5% Critical	Trace test stat	5% Critical	I(*D*)
NRB-MSA	r=0	36.70**	14.07	26.77**	15.41	1
	r≤1	9.94**	3.76	9.94**	3.76	
NRB-NKR	r=0	24.06**	14.07	15.43*	15.41	1
	r≤1	8.64**	3.76	8.64**	3.76	
NRB-ELD	r=0	35.91**	14.07	24.94**	15.41	1
	r≤1	7.97**	3.76	7.97**	3.76	
NRB-KSM	r=0	22.19**	14.07	14.21*	15.41	1
	r≤1	7.99**	3.76	7.99**	3.76	
MSA-NKR	r=0	28.90**	14.07	20.27**	15.41	1
	r≤1	8.63**	3.76	8.63**	3.76	
MSA-ELD	r=0	38.52**	14.07	29.60**	15.41	1
	r≤1	8.91**	3.76	8.91**	3.76	
MSA-KSM	r=0	34.82**	14.07	26.53**	15.41	1
	r≤1	8.28**	3.76	8.28**	3.76	
NKR-ELD	r=0	18.49*	14.07	12.53	15.41	1
	r≤1	5.97*	3.76	5.97*	3.76	
NKR-KSM	r=0	17.29*	14.07	10.60	15.41	1
	r≤1	6.69**	3.76	6.69**	3.76	
ELD-KSM	r=0	33.68**	14.07	25.94**	15.41	1
	r≤1	7.74**	3.76	7.74**	3.76	

N/B: The critical values are the Osterwald-Lenum (1992) p-values. *(**) denotes rejection of the null hypothesis at 5% (1%) level of significance.

The co-integration tests between the domestic markets and the international reference (USA) maize markets were also carried out using the Johansen ML methodology. These results are shown in table 4.5.

The findings from trace test in Table 4.5 showed that at five percent significant level there were three co-integrating relationships between the Kenyan and the USA maize markets, whereas the max-eigen test indicate two co-integrating relationship significant at five percent level. The specifics of the actual markets will become clear when we look at the pairwise co-integration results (Table 4.8). The trace and max-eigen statistics in all the two null hypotheses (that is $r \leq 0$, and $r \leq 1$) are greater than their corresponding five percent critical values (Table 4.5). Thus the null of zero co-integrating vectors is rejected, also the null of presence of less than two co-integration vectors is rejected at the five percent level in the trace test.

Thereby resolving that there exist two co-integrating vectors in the relationship between Kenyan and USA markets. Both the domestic wholesale maize markets and the international maize market (USA) share long-run co-integrating association; hence, conjugation of these prices in the long run. The co-integration tests showed that the wholesale domestic maize markets and the international maize market (USA) share long-term relationship. Existence of co-integration in the two markets imply that changes in price policies in one market will directly affect the other market. The presence of at least one co-integrating vector allows for the estimation of an ECM in order to determine both the short-run and long-run price transmission dynamics between the two market regions.

Table 4-5. Johansen's max-eigen and trace test for the number of co-integrating vectors, January 2002 to March 2020

Maximum Likelihood Co-integration findings: A six-variable, one lag system.

Estimated Eigen values (λ's), Eigen vectors (β's) and Weights (α's)

	Eigen Values (λ's)					
Variable	0.215	0.156	0.091	0.077	0.027	0.021
Normalized Eigen vectors (β's)						
USA	1.885	-0.131	1.370	0.970	3.025	-1.610
Eldoret	2.194	-12.700	-2.875	-5.631	-4.169	-2.736
Kisumu	-8.270	2.257	7.764	2.759	-2.846	-2.936
Mombasa	16.504	3.178	1.518	4.327	-3.583	-2.567
Nairobi	-6.724	8.832	-16.482	-1.467	2.413	1.848
Nakuru	-4.701	-1.395	7.775	4.736	7.507	6.234
Weights (α's)						
USA	-0.001	0.001	-0.001	-0.005	-0.005	0.006
Eldoret	0.011	0.027	0.010	-0.003	0.006	0.006
Kisumu	0.032	-0.003	-0.005	-0.014	0.008	0.004
Mombasa	-0.003	0.007	0.013	-0.023	0.003	-0.003
Nairobi	0.022	-0.001	0.022	-0.005	-0.000	0.001
Nakuru	0.024	0.019	0.004	-0.007	-0.002	-0.006

Number of Co-integrating Vectors

H_o	Trace statistic	Trace (0.95)	λ_{Max} statistic	λ_{Max} (0.95)
r=0	136.05**	94.15	51.91**	39.37
r≤1	84.14**	68.52	36.26*	33.46
r≤2	47.88*	47.21	20.33	27.07
r≤3	27.54	29.80	17.09	21.13
r≤4	10.45	15.49	5.78	14.26
r≤5	4.67	3.84	4.67	3.84

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

Source: Author's Computations

4.4 Granger Causality Tests in Kenyan Maize Markets

The findings of co-integrated Johansen pairwise showed that all maize markets under study were integrated of degree C.I (1,1) on a pairwise basis (Table 4.4). Granger causality tests were performed for the co-integrated price series (Table 4.6).

The results related to the maize markets in Nairobi relative to other markets in Kenya implied Granger causality in at least one direction (Table 4.6). The test indicates a bilateral Granger causality between maize prices in Nairobi and Eldoret: in the long-run, maize prices in Nairobi and Eldoret affect each other (Table 4.6). A similar conclusion applies for maize prices in Nairobi and Kisumu, and Nakuru price pairs (Table 4.6).

However, long-run Granger causality test indicate that maize prices in Mombasa Granger-cause maize prices in Nairobi and not vice versa (Table 4.6). The results imply that maize prices in Nairobi strongly depend on maize prices in Mombasa.

The long-run Granger causality test results between Mombasa and each of the other domestic market, indicate at least one direction causality (Table 4.6). The test indicates a bilateral Granger causality between Mombasa and Eldoret, Kisumu, maize prices (Table 4.6). In the long-run therefore, maize prices in Mombasa and Eldoret, and Kisumu affect each other. However, Granger causality test between Mombasa and Nairobi, and Nakuru indicates causality in only one direction (Table 4.6). Maize prices in Nairobi and Nakuru strongly depend on prices in Mombasa maize market, and not vice versa.

Table 4-6. Granger Causality Test Results

Null Hypothesis	F-statistic	Prob.
Kisumu does not granger cause Eldoret	4.33***	0.0022
Eldoret does not granger cause Kisumu	5.33***	0.0004
Mombasa does not granger cause Eldoret	9.86***	3.E-07
Eldoret does not granger cause Mombasa	2.46***	0.0469
Nairobi does not granger cause Eldoret	6.08***	0.0001
Eldoret does not granger cause Nairobi	8.11***	4.E-06
Nakuru does not granger cause Eldoret	7.47***	1.E-05
Eldoret does not granger cause Nakuru	3.23***	0.0133
Mombasa does not granger cause Kisumu	7.44***	1.E-05
Kisumu does not granger cause Mombasa	4.75***	0.0011
Nairobi does not granger cause Kisumu	2.88**	0.0238
Kisumu does not granger cause Nairobi	7.92***	6.E-06
Nakuru does not granger cause Kisumu	3.23**	0.0134
Kisumu does not granger cause Nakuru	4.22***	0.0027
Nairobi does not granger cause Mombasa	0.69	0.5969
Mombasa does not granger cause Nairobi	11.55***	2.E-08
Nakuru does not granger cause Mombasa	1.32	0.2624
Mombasa does not granger cause Nakuru	7.60***	1.E-05
Nakuru does not granger cause Nairobi	5.25***	0.0005
Nairobi does not granger cause Nakuru	4.34***	0.0022

(*), (**), (***) denotes10%, 5%, 1% significance respectively. Decision criteria is rejecting null hypothesis if F-statistic is significant.
Source: Author's Computations

The Granger causality tests between Nakuru maize prices and other domestic maize prices, indicate causality in at least one direction (Table 4.6). There is a bilateral Granger causality between Nakuru-Eldoret, Nakuru-Kisumu, and Nakuru-Nairobi price pairs (Table 4.6). From the test results we can conclude that Nairobi and Nakuru prices affect each other. The same conclusion applies to Nakuru and Eldoret maize prices. However, for the Nakuru-Mombasa price pair, the test indicates Ganger causality in only one direction (Table 4.6). Mombasa prices Granger cause Nakuru maize prices only and not vice versa (Table 4.6). The results imply that maize prices in Nakuru strongly depend on maize prices in Mombasa.

4.5 Analysis of Price Transmission

4.5.1 Structural break Analysis

The Chow test of structural break was run for the five Kenyan maize markets, to determine whether there was any break in the series in the period 2007/2008. This was necessary in order to establish whether the 2007/2008 post-election violence caused a structural break in Kenyan maize markets.

The no structural break null hypothesis cannot be rejected in all the five cases (Table 4.7). The Wald statistic was not significant at the 5 and 10 percent level for entirely the five maize markets (Table 4.7). The conclusion was that all the five markets did not experience a structural break in the period 2007/2008. The 2007/2008 post-election violence did not cause a structural break in the Kenyan maize prices, as shown by the results in Table 4.7.

Table 4-7. Chow Break Point Test Results

Variable	Break date(s) Tested	Wald Statistic
Nairobi Price series	December 2007: January 2008	0.502 (0.778)
Nakuru Price series	December 2007: January 2008	0.155 (0.925)
Eldoret Price series	December 2007: January 2008	0.287 (0.866)
Kisumu Price series	December 2007: January 2008	0.049 (0.976)
Mombasa Price series	December 2007: January 2008	0.119 (0.941)

Note: ( ) are the chi-square probability values.
Source: Author’s Computations

After establishing that there was no structural break in the series, the analysis then proceeded with testing for pairwise co-integration between each of the Kenyan maize markets and the US price series. The results are as presented in Table 4.8.

4.5.2 Maximum Likelihood Estimates of the Pairwise Co-Integrating Vectors

The pair-wise co-integration test findings between each of the Kenyan domestic price series and the international reference maize market (price series of USA No.2 yellow maize) was offered in Table 4.8. The null hypothesis findings in table 4.8 show that *r=n-1* for the entire series was rejected and the alternative hypothesis that *r=n* was accepted at five percent significant level. The trace statistic for the Nairobi-USA market pair was 16.19 and the corresponding Osterwald-Lenum critical value was 14.07 for a null of r=0 (Table 4.8).

Table 4-8. Pairwise Johansen's Co-integration test results for domestic and international reference maize markets: January, 2002 to March, 2020

Series	Null	Max-eigen stat	5% Critical	Trace test stat	5% Critical	Var order
NRB-USA	r=0	16.19*	14.07	20.99**	15.41	1
	r≤1	4.80*	3.76	4.80*	3.76	
NKR-USA	r=0	16.38*	14.07	20.85**	15.41	1
	r≤1	4.48*	3.76	4.48*	3.76	
ELD-USA	r=0	19.86**	14.07	24.95**	15.41	1
	r≤1	5.09*	3.76	5.09*	3.76	
KSM-USA	r=0	16.11*	14.07	21.21**	15.41	1
	r≤1	5.09*	3.76	5.09*	3.76	
MSA-USA	r=0	17.48*	14.07	22.21**	15.41	1
	r≤1	4.73*	3.76	4.73*	3.76	

N/B: The critical values are the Osterwald-Lenum (1992) p-values. (*) (**) denotes rejection of the null hypothesis at 5% and 1% level of significance respectively. Where; NRB-Nairobi, NKR-Nakuru, ELD-Eldoret, KSM-Kisumu, MSA-Mombasa price series.

Thus, the null of no co-integration, that is r=0, was rejected at the five percent significance level and the alternative hypothesis of r=1 could not be rejected at the one percent significance level.

The conclusion was a presence of one co-integrating vector between USA and Nairobi maize markets. Therefore, Nairobi and USA maize market are integrated, which means that both markets share a common long-term association. In all the other four market pairs, both the max-eigen and trace static were greater than their corresponding five percent critical values (Table 4.8). Therefore, null of zero co-integrating vector was rejected at the five percent significance level; while the alternative hypothesis of the presence of one co-integrating vector at the five percent significance level was not rejected. Thus, concluding that the Kenyan wholesale maize markets are integrated with the international reference market (the USA maize market). This conclusion allows estimation of the error correction model, according to Gujarat (2004), in case the two variables X and Y are co-integrated, thus, the association between the two could be defined using the error correction instrument.

4.5.3 Optimal Lag Selection

Determining the number of lags is key and that will be integrated in each of the ECM equations to be estimated before the calculation of ECM. Johansen (1988) proposes lag selection criteria based on the Akaike Information criterion (AIC). This criterion involves choosing the lowest AIC value, and hence the lower the AIC value the better the model. Other lag selection criteria include the Schwarz information criterion (SIC), the Final Prediction error (FPE), the sequential modified LR test statistic (LR), and the Hannan-quinn information criterion (HQ). This study will apply the AIC to select the optimum lags for analysis. The findings based on the criteria of the lag selection are presented in Table 4.9.

Table 4-9. Lag selection criteria for the VAR Systems to be estimated

Eldoret-USA VAR System

Lag	LogL	LR	FPE	AIC	SC	HQ

0	-100.8600	NA	0.008925	0.956837	0.988192	0.969506
1	483.4904	1152.393	4.04e-05	-4.441771	-4.347707	-4.403765
2	498.9243	30.14983*	3.63e-05*	-4.548133*	-4.391359*	-4.484789*
3	500.6667	3.371350	3.71e-05	-4.527132	-4.307649	-4.438450
4	501.5916	1.772458	3.81e-05	-4.498527	-4.216334	-4.384508

Kisumu-USA VAR System

0	-84.84468	NA	0.007690	0.807858	0.839212	0.820526
1	460.8164	1076.094	4.98e-05	-4.230850	-4.136785*	-4.192843
2	467.5727	13.19848*	4.86e-05*	-4.256490*	-4.099717	-4.193146*
3	469.3154	3.371970	4.96e-05	-4.235492	-4.016009	-4.146811
4	470.4114	2.100091	5.10e-05	-4.208478	-3.926285	-4.094459

Mombasa-USA VAR System

0	-72.56585	NA	0.006860	0.693636	0.724991	0.706305
1	485.8819	1101.311	3.95e-05	-4.464018	-4.369953*	-4.426011*
2	491.6621	11.29163*	3.88e-05*	-4.480578*	-4.323804	-4.417234
3	492.1737	0.989777	4.01e-05	-4.448127	-4.228644	-4.359446
4	493.1800	1.928406	4.12e-05	-4.420279	-4.138086	-4.306260

Nairobi-USA VAR System

0	-63.45826	NA	0.006302	0.608914	0.640269	0.621583
1	485.8969	1083.379	3.95e-05	-4.464157	-4.370092*	-4.426150
2	493.9067	15.64716*	3.80e-05*	-4.501458*	-4.344684	-4.438114*
3	494.9101	1.941390	3.91e-05	-4.473582	-4.254099	-4.384901
4	495.9040	1.904613	4.02e-05	-4.445618	-4.163425	-4.331599

Nakuru-USA VAR System

0	-97.05239	NA	0.008614	0.921418	0.952772	0.934086
1	492.6383	1162.925	3.71e-05	-4.526868	-4.432804	-4.488862
2	506.0186	26.13825*	3.40e-05	-4.614127	-4.457353*	-4.550783*
3	510.4323	8.539874	3.38e-05*	-4.617974*	-4.398491	-4.529293
4	512.8201	4.575874	3.44e-05	-4.602978	-4.320785	-4.488959

*****indicates lag order selected by the criterion.
Source: Author's computations

Based on the AIC criteria for lag selection, a lag of 2 is selected for the Nairobi-USA VAR system (Table 4.9). At this lag, the value of the AIC is minimized, that is -4.501458 (Table 4.9). The Mombasa-USA VAR system chose a lag of 2, the lowest AIC value (-4.480578) was recorded at this lag (Table 4.9). The VAR systems of Eldoret-USA and Kisumu-USA, had their lags at 2; based on the minimized AIC values of -4.548133 and -4.256490 respectively (Table 4.9). A lag of 3 was chosen for the Nakuru-USA VAR system, based on a minimized AIC value of -4.617974

4.5.4 Estimates of the price transmission coefficients and the adjustment parameters

After starting that the markets were co-integrated according to the pairwise co-integration the results were presented in Table 4.8. The study adopted ECM to examine the price transmission signals among the markets pairs. The ECM analysis results are presented in Table 4.10. There was a substantial long-run relationship between all the five Kenyan markets and the world maize prices. The results from Table 4.10 showed that on average, around a percentage of 60 change in world prices is ultimately transmitted to the wholesale prices of maize in Kenya.

The results in Table 4.10 showed that the long-run price transmission elasticity had a range of 0.50 to 0.70. Thus, implying variation of 50 to 70 percent in world prices are transmitted into Kenyan wholesale maize prices. From Table 4.10 the highest long-run transmission elasticity was observed in Kisumu (0.70) that was at the five percent level significance. Implying that about a percentage of 70 change in world maize price is eventually transmitted to the wholesale maize prices in Kisumu.

It is followed closely by Nairobi and Eldoret both at 0.62, suggesting that a percentage of 62 change in world prices were transferred to the wholesale maize prices in Eldoret and Nairobi maize markets. On the other hand, Nakuru, a maize surplus town, had a long-run elasticity of 0.50, and was significant at five percent level. Thu, indicating that 50 percent of dissimilarity in world maize prices are transmitted to the wholesale maize prices in Nakuru.

Also implies that a 1 percent rise in international maize prices will result in a long-run rise in wholesale maize price of 0.50 percent in Nakuru market prices. The results in Table 4.10 showed that estimated long-run elasticity of Mombasa, Kenya's port of entry was 0.59, which was significant at one percent level. This low PT elasticity for Mombasa might be perhaps due to the fact that higher percentage of Kenya's maize imports comes from Tanzania through Nairobi, and also Uganda.

The larger long-run elasticities of price transmission (that is above 50 percent) imply that there is strong integration of international maize markets with the Kenyan domestic wholesale maize markets. However, the fact that these elasticities differ from unity considerably, indicate that price signals from international markets are not fully transmitted into Kenyan domestic markets.

Table 4-10. Transmission of World Maize Prices to Domestic Markets in Kenya

VECM Price pairs	Long-run Adjustment(β)	Speed of Adjustment (θ)	Short-run Adjustment(δ)	Lagged own price Coefficient(ρ)
	0.62***	-0.16***	-0.12	0.05

Nairobi & USA	(0.123) [-5.019]	(0.031) [-5.168]	(0.122) [-1.010]	(0.066) [0.763]
Mombasa & USA	0.59*** (0.143) -4.164]	-0.13*** (0.031) [-4.335]	-0.03 (0.126) [-0.277]	0.06 (0.068) [1.017]
Nakuru & USA	0.50*** (0.157) [-3.221]	-0.10*** (0.028) [-3.883]	0.15 (0.118) [1.262]	0.19*** (0.068) [2.819]
Eldoret & USA	0.62*** (0.139) [-4.483]	-0.13*** (0.026) [-5.089]	0.12 (0.122) 0.968]	0.29*** (0.065) 4.483]
Kisumu & USA	0.70*** (0.145) [-4.852]	-0.16*** (0.033) [-4.733]	-0.07 (0.139) [-0.519]	0.02 (0.066) [0.277]

(*), (**), (***) denotes10%, 5%, 1% significance respectively. Standard errors in () & t-statistic in [], t≥|2|.
Source: Author's computations

The results on price transmission elasticities also imply inelasticity of wholesale maize prices with respect to the world maize prices. The inelasticity could be explained by factors such as lack of good infrastructure, strict import requirements for maize/high tariffs to protect local producers. However, the short-run price adjustments are not significant, indicating that Kenyan markets do not respond to short-run variation in the world prices. This could be explained by the fact that agricultural products have inelastic demand and supply in the short run (Getnet *et al*., 2012).

4.5.5 Speed of Adjustments to the Long-run Equilibrium

Table 4.10 presents the relative speeds of adjustment for the five markets. The coefficients of the speed of adjustment were all at 5 percent level significant, demonstrating that maize prices in Kenya respond to changes in the international maize markets (Table 4.10). The speed of price adjustment ranges from -0.10 to -0.16. This adjustment speed is fast, as according to Rapsomanikis, *et al*., (2003), who found an error correction coefficient of -0.18, thus, concluding the adjustment to the long run relationship was quite fast between Ugandas' coffee market and international coffee markets.

Nairobi and Kisumu market recorded the highest adjustment speeds of 0.16 with the international maize market, which implies that on the average, it takes about 6 months for shocks in the international market to be transmitted into the domestic markets. Thus, taking around 6 months for price changes to fully transmit to Kisumu and Nairobi market[1].

Therefore, Nairobi and Kisumu appears to have a faster pass through of price signals, compared to the other three markets. Mombasa and Eldoret markets have the second highest pass through of price signals, recording a speed of adjustment of 0.13, implying it required around 7.7 months for variations in prices of the market in the world to be transmitted to Mombasa and Kisumu. Mombasa is an entry port for all Kenyan maize imports from outside EAC and is also one of the cities of Kenya, therefore, one would expect a faster response to world variation of price in this market.

The Lowest speeds of price adjustment were recorded in Nakuru (0.10), with 10 percent of the deviations from the long-run equilibrium being corrected for in one month (Table 4.10). Therefore, requiring around 10 months for the variations of global market prices to be transmitted to Nakuru. This is somewhat low compared to adjustment speeds in other centers. Following closely is

[1] To derive the speed of price adjustments in terms of the time it takes for a full price changes to be transmitted into domestic markets, the calculations were as follows: ($1/\theta$). Such that for instance, Nairobi = 1/0.16 = 6.25 months.

Mombasa and Eldoret which recorded a speeds of price adjustment of 0.13 each (Table 4.10). This means about 7.7 months is taken for the changes in world market prices to be transmitted to Mombasa and Eldoret markets. Nairobi is the capital city of Kenya and it's the headquarters to the maize controlling body, the NCPB.

A possible explanation of inadequate adjustment of price of short-run price, is that in the short-run, the NCPB, intervenes by releasing buffer stocks during maize deficits seasons and buying from farmers during surplus production seasons. This actions by NCPB thus functions to stabilize prices in the short-run.

CHAPTER FIVE: CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Conclusion

The transmission of world maize prices to Kenya's domestic market using wholesale monthly prices for the January 2002 to March 2020 period was evaluated by the current study. The United States of America number 2 price of corn of yellow in the Gulf of Mexico is applied as the international reference price. The market efficiency was evaluated by utilizing the co-integration tool. Prices co-integration in distinct markets is a signal of price transmission and market integration.

The descriptive analysis findings indicate that maize prices in Kenya appear to follow the same long-run trend as the world prices. However, Kenyan maize prices are significantly higher than the world price. The mean world price of maize is \$0.17 per Kg, while the average price in Kenya is \$0.28 Kg. Trend analysis showed that both international and domestic maize markets exhibited fairly constant prices between 2002 and 2006. Prices then began rising sharply in 2007 through to 2009; the prices rose again in 2012. This is the periods of the global food price crisis in which world food price index rose by more than 50 percent.

The long-term integration relationship between the domestic and world maize markets was pointed out from the findings of co-integration. This relationship is at the 5 percent level significant. All the five markets have statistically significant long term price transmission elasticity. These elasticities range from 0.50 to 0.70, with an average of 0.60, implying that a 60 percent variation in worldwide price would be transmitted to the domestic markets in Kenya. This provides evidence that international cereal prices changes are transferred faster to domestic markets in Kenya.

The evidence of a strong market integration between domestic and international maize markets offers an opportunity for both consumers and producers to benefit from price incentives. However, short-run integration is very low as shown by the price adjustment coefficients that are non-significant, inferring that it takes a longer period for domestic maize markets to respond to localized shocks. Therefore, it is essential that policy makers should consider market infrastructure development, though not explicitly analyzed, being vital to ensure linkages to international maize markets.

The results of the Granger Causality point to bidirectional causality in the Kenyan domestic market except for the Mombasa-Nairobi and Mombasa-Nakuru price pairs. This interdependence in prices implies that policies that target one market will eventually affect the entire maize market in Kenya. Therefore, shocks to one market price will have significant responses from the rest of the markets

The ECM calculated indicates that the adjustment process is quite fast with 13 percent of divergence from the long-run equilibrium being corrected each month. In terms of the time it takes for a full price changes to be transmitted, it suggests that it requires 7.7 months for the variations in the global market prices to completely conveyed to the Kenyan discount maize markets.

However, other studies in African food markets, have found partial or no price transmission between African and world food markets. These studies suggest poor infrastructure, high transaction costs, poor government policies, and lack of market information as some of the causes of partial or no transmission. Others suggest liberalization have improved transmission.

5.2 Policy Recommendations

The results from this study point towards three important policy implications. Firstly, the domestic markets appear to be well integrated and thus regions with high maize supplies such as, Nakuru and Eldoret, should respond to the price incentives in the maize deficit areas such as Kisumu, Nairobi and Mombasa. Through such responses, maize supply should be seen to be moving towards these deficit areas and finally experiencing lower prices as per the LOP analogy. However, what is observed over time is a persistence in high prices in these regions and also low food supplies in the deficit regions. This then necessitates policy makers to look into infrastructural issues and also ensure cartels are not in the chain to exploit both producers and consumers.

Secondly, is the fact that prices rose sharply in the 2007/2008 period necessitates the policy makers in the line ministry to develop policy that enhances food security including how to enhance domestic maize production, as well as ensuring there are enough maize reserves in the strategic grain reserves; early warning systems also need to be developed. One way of promoting pliability to instability in international grain prices, is diversification of essential foods diet of consumers. This would include staple foods such as cassava and Irish potatoes. Having broadened diet permits families to substitute towards more affordable other options, when the cost of one ascents. Staple food diversification through boosting of production by investing in high yielding, disease resistant varieties of the alternative staples crops would also provide a solution to food security.

Finally, the relatively fast speed of price adjustments, shown by adjustment parameters that are as high as 0.16, point towards a faster pass-through of international price changes. This offers an opportunity for the domestic producers to respond to any changes in international maize markets. Therefore, the government ought to give a reasonable and suitable environment that will enhance decision making among the traders.

Nonetheless, short run integration is extremely low, inferring that it takes a more period for maize markets to respond to localized shocks. Therefore, to allow a one on one price translation, the policy makers should work on reducing barriers to trade such as high tariffs on imported maize, generally reducing costs of maize trading in Kenya, and also develop better infrastructure in rural areas. All these will be aimed at enabling a complete pass through of international price signals into domestic markets.

References

Abdulai, A., (2000). “Spatial Price Transmission and Asymmetry in the Ghanaian Maize Market.” *Journal of Development Economics*, 63 (2000) 327-349

Alexander, C. & Wyeth., **(**1994). Co-integration and Market Integration: An Application to the Indonesian Rice Market. *Journal of Development Studies*, 30:303-328.

Ankamah-Yeboah, I. (2012). “Spatial Price Transmission in the Regional Maize Markets in Ghana.” *MPRA Paper No. 49720, posted 11 Sep 2013*.

Ardeni, P.G. (1989). Does the Law of One Price Really Hold for Commodity Prices? *American Journal of Agricultural Economics,* 71: 661-669.

Ariga, J., Jayne T.S., & Njukia, S., (2010). Staple Food Prices in Kenya. Prepared for the COMESA policy seminar on “Variation in Staple Food Prices: Causes, Consequences, and Policy Options”, Maputo, Mozambique, 25-26 January 2010

Asche, F., Bremnes, H. & Wessells, C. R., (1999) ‘Product Aggregation, Market Integration, and Relationships Between Prices: An Application to World Salmon Markets’, American Journal of Agricultural Economics, 81 (August), 568-581

Bob Baulch. (1997): Testing for food market integration revisited. *Journal of Development Studies, 33:4, 512-534*

Ceballos F., Hernandez M.A., Minot N., & Robles M., (2015). Grain Price and Volatility Transmission from International to Domestic Markets in Developing Countries. *Selected Paper prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July 26-28*

Chen B., & Saghaian S., (2016). Market Integration and Price Transmission in the World Rice Export Markets. *Journal of Agricultural and Resource Economics 41(3):444–457*

Chisanga Brian (2012). Efficiency and Integration in the Zambian Sugar Market: Analyzing Price Transmission, Price Formation and Policy. *An Msc thesis, University of Pretoria, 2012* (Unpublished)

Chris Ackello-Ogutu (2011). Managing Food Security Implications of Food Price Shocks in Africa. *Journal of African Economies*, Vol. 20, AERC Supplement 1, pp. i100–i141 doi:10.1093/jae/ejr010.

Conforti, P., (2004). "Price Transmission in Selected Agricultural Markets." *FAO Commodity and Trade Policy Research Working Paper No.7.* (Available at http://www.fao.org/es/ESC/)

Enders, W., & Granger, C.W.J., (1998). Unit-root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates. *Journal of Business and Economic Statistics 16 3, 304–311*

Enders, W., & Siklos P. L., (2000). Co-integration and Threshold Adjustments. Lowa State University, Working Paper, February 2000.

Enders, W., (2010). *Applied Econometric Time Series*. Third Edition. John Wiley & Sons Inc.

Fackler P. L., & Goodwin B. K., (2001). Spatial Price Analysis. *Handbook of Agricultural Economics, Volume 1, Chapter 17 @2001 Elsevier Science*.

FAO. (2009). "National Policy Responses to High Food Prices." *Economic and Social Perspectives Policy Brief 1. Food and Agriculture Organization of the United Nations. Rome*

FAO. (2003). "Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and applications", by Rapsomanikis, G., Hallam, D., and P. Conforti, in Commodity Market Review 2003-2004., Commodities and trade division, FAO, Rome.

FAO Giews food price data web page (http://www.fao.org/giews/pricetool/), *accessed on January, 2014*.

Friederike G., Nelissa J., Carolin M., von Cramon, T. S., & Nadine W., (2012). Cereal Price Transmission from International to Domestic Markets in Africa. Selected paper presented at the African Economic Conference 2012 Kigali, Rwanda. 30th October – 2nd November 2012.

Food security information for decision making. Web page (http://www.foodsec.org), *accessed on January, 2013*.

Gitau R., Meyer, F., (2018). Spatial Price Transmission under different Policy Regimes: A Case of Maize Markets in Kenya. Selected paper presented at the 56th Annual Conference of the Agriculture Economics Association of South Africa, Lord Charles Hotel, Somerset West, South Africa. 25th to 27th September 2018.

Getnet, K., Verbeke, W., & Viaene, J., (2005). Modelling Spatial Price Transmission in the Grain Markets of Ethiopia With an Application of ARDL Approach to White Teff. *Journal of Agricultural Economics 33 (2005) supplement 491-502.*

Ghoshray, A., (2011). "Underlying Trends and International Price Transmission of Agricultural Commodities." *ADB Economics Working Paper Series No. 257 | May 2011.*

Goodwin, B.K., & Holt M.T. (1999). Price Transmission and Asymmetric Adjustment in the US Beef Sector. *American journal of Agricultural Economics*, 81, 630-637.

Goodwin B. K and Schroeder T. C., (1991). Co-integration Tests and Spatial Price Linkages in Regional Cattle Markets. *American Journal of Agricultural Economics, Vol. 73, No. 2, pp. 452-464*

Gujarati D.N., (2004). *Basic Econometrics* (4th Ed.). Boston: The MacGraw-Hill Companies

Henry D. A., & Rebecca A., (2012). Spatial Market Integration and Price Transmission of Selected Plantain Markets in Ghana. *Journal of Sustainable Development in Africa,* Volume 14, No.5, 2012. ISSN: 1520-5509.

Ihle R., Von Cramon-Taubadel S., & Amikuzuno J., (2009). Price Transmission in the Eastern Africa Maize Market. “World Bank Report”, January 31, 2009

Ikudayisi A. A., & Salman K. K., (2011). Spatial Integration of Maize Market in Nigeria- A Vector Error Correction Model. *International Journal of Food and Agricultural Economics*. ISSN 2147-8988, Vol.2, No.3. pp. 71-80

Jayne, T.S., Yamano, T., Nyoro, J., & Awour, T., (2001). “Do Farmers Really Benefit from High Food Prices? Balancing Rural Interests in Kenya’s Maize Pricing and Marketing Policy.” *Tegemeo Institute of Agricultural Policy and Development Working Paper No 2B.*

Jayne, T. S., Robert J. M., & James N., (2005). The Effect of Government Marketing and Trade Policies on Maize Market Prices in Kenya.

Jayne, T.S., Robery J. M., & James N., (2008). The Effects of NCPB Marketing Policies on Maize Market Prices in Kenya, *Agricultural Economics,* 38(3): 313-325.

Kang’ethe, E., (2011). Situation Analysis: Improving Food Safety in the Maize Value Chain in Kenya. FAO report 2011

Karugia, T. J., Wambugu, K. S., & Kosura, O. W., (2003). "The Role of Infrastructure and Government Policies in Determining the Efficiency of Kenya's Maize Marketing System in the Post-Liberalization Era." *A Research Report Submitted to the International Food Policy Research Institute (IFPRI) 2020 Vision Network for East Africa.*

Kirimi L., Sitko N., Jayne T.S., Karin F., Muyanga M., Sheahan M., Flock J., & Bor J., (2011). A farm Gate-to-Consumer Value Chain Analysis of Kenya's Maize Marketing System. *Michigan State University International Development Working paper N. 111, January 2011*

Meyer, J., Von Cramon-Taubadel S., (2004). Asymmetric Price Transmission: A survey. *Journal of Agricultural Economics 55 (3), 581-611.*

Minot, N., (2010). "Transmission of World Food Price Changes to African Markets and its Effect on Household Welfare." *Paper presented at the Comesa policy seminar on "Food price variability: Causes, consequences, and policy options" on 25-26 January, 2010 in Maputo, Mozambique.*

Nkedah R., & Nzouessin C. B., (2006). Economic Analysis of the Spatial Integration of Plantain Markets in Cameroon. *A research paper presented to the African Economic Research Consortium (AERC).*

Odhiambo O. M., (2012). "The Kenyan Maize Sub-Sector Performance and Its Implications for Food Security Policy Dialogue." *Moi University Inaugural Lecture 14 Series No. 1, 2012*

Ohen S. B. and Abang S. O., (2011). Evaluation of price linkages within the supply chain of rice markets in Cross River State, Nigeria. *Journal of Stored Products and Postharvest Research Vol. 2(8), pp. 151 – 155, August 2011.*

Samuelson, P.A., (1952). Spatial price equilibrium and linear programming. *American Economic Review*, 42:560-580

Sexton, R. J., Kling, C. L., & Carman, H. F., (1991). Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery. *American Journal of Agricultural Economics 73 3, 569–580.*

Tebogo, T. (2015). An assessment of the transmission of South African maize prices to Botswana markets (Master's Thesis, University of Nairobi).

Tuyishime, N. (2014). An Assessment of the Transmission Of International Prices Into Rwanda's Rice Markets (Master's Thesis, University of Nairobi).

USAID (2010). Staple Foods Value Chain Analysis-Country Report Kenya. A report prepared by Chemonics International Inc. for review by the United States Agency for International Development, *The Competitiveness and Trade Expansion Program*.

USDA (2013). The 2013 Kenya Corn, Wheat and Rice Report. *Grain and Feed Annual*.

Vasciaveo M., Rosa F., Weaver R (2013). "Agricultural market integration: price transmission and policy intervention." *A paper presented at the 2nd AIEAA Conference – Between Crisis and Development: which Role for the Bio-Economy Parma, 6-7 June 2013.*

Vavra, P., & Goodwin B. K., (2005), "Analysis of Price Transmission Along the Food Chain", OECD Food, Agriculture and Fisheries Working Papers, No. 3, OECD Publishing.

Von Cramon-Taubadel, S., (1998) Estimating Asymmetric Price Transmission with the Error Correction Representation: An Application to the German Pork Market. *European Review of Agricultural Economics 25 (1998), pp. 1-18.*

Von Cramon-Taubadel, S & Loy, J.-P., (1996) "Price Asymmetry in the International Wheat Market: Comment", *Canadian Journal of Agricultural Economics, 44: 311-317*.

Wangia, C., Wangia S., & Hugo D.G., (2002). Review of Maize Marketing in Kenya: Implementation and Impact of Liberalization, 1989-1999.

Wooldridge, J., (2004). *Introductory Econometrics-A modern Approach*. Second Edition.

https://knoema.com/USDAPSD2020Feb/production-supply-and-distribution-of-agricultural-commodities-by-market-year-feb-2020. Accessed 24th May 2020

Appendices

Annex 1: Summary of the Critical Values for DF and ADF

Model	**Hypothesis**	**Test statistic**	**Critical Values**	
			95% C.I	**99% C.I**
$\Delta y_t = \alpha_0 + \theta y_{t-1} + \alpha_2 t + \varepsilon_t$	$\theta = 0$	τ_τ	-3.45	-4.04
	$\theta = \alpha_2 = 0$	Φ_3	6.49	8.73
	$\alpha_0 = \theta = \alpha_2 = 0$	Φ_2	4.88	6.50
$\Delta y_t = \alpha_0 + \theta y_{t-1} + \varepsilon_t$	$\theta = 0$	τ_μ	-2.88	-3.51
	$\alpha_0 = \theta = 0$	Φ_1	4.71	6.70
$\Delta y_t = \theta y_{t-1} + \varepsilon_t$	$\theta = 0$	τ	-1.95	-2.60

Note: Critical values are for a sample size of 100. Adapted from Enders (2010)

<u>Annex 2</u>: Johansen Critical Values

Critical Values for Johansen Test :Intercept in Cointegrating Vector

	$\lambda-$max						Trace					
p-r	50%	80%	90%	95%	97.5%	99%	50%	80%	90%	95%	97.5%	99%
1	3.40	5.91	7.52	9.24	10.80	12.97	3.40	5.91	7.52	9.24	10.80	12.97
2	8.27	11.54	13.75	15.67	17.63	20.20	11.25	15.25	17.85	19.96	22.05	24.60
3	13.47	17.40	19.77	22.00	24.07	26.81	23.28	28.75	32.00	34.91	37.61	41.07
4	18.70	22.95	25.56	28.14	30.32	33.24	38.84	45.65	49.65	53.12	56.06	60.16
5	23.78	28.76	31.66	34.40	36.90	39.79	58.46	66.91	71.86	76.07	80.06	84.45
6	29.08	34.25	37.45	40.30	43.22	46.82	81.90	91.57	97.18	102.14	106.74	111.01
7	34.73	40.13	43.25	46.45	48.99	51.91	109.17	120.35	125.58	131.70	136.49	143.09
8	39.70	45.53	48.91	52.00	54.71	57.95	139.83	152.56	159.48	165.58	171.28	177.20
9	44.97	50.73	54.35	57.42	60.50	63.71	174.88	198.08	196.37	202.92	208.81	215.74
10	50.21	56.52	60.25	63.57	66.24	69.94	212.93	228.08	236.54	244.15	251.30	257.68
11	55.70	62.38	66.02	69.74	72.64	76.63	254.84	272.82	282.45	291.40	298.31	307.64

Critical Values for Johansen Test :Intercept in ECM

	$\lambda-$max						Trace					
p-r	50%	80%	90%	95%	97.5%	99%	50%	80%	90%	95%	97.5%	99%
1	0.44	1.66	2.69	3.76	4.95	6.65	0.44	1.66	2.69	3.76	4.95	6.65
2	6.85	10.04	12.07	14.07	16.05	18.63	7.55	11.07	13.33	15.41	17.52	20.04
3	12.34	16.20	18.60	20.97	23.09	25.52	18.70	23.64	26.79	29.68	32.56	35.65
4	17.66	21.98	24.73	27.07	28.98	32.24	33.60	40.15	43.95	47.21	50.35	54.46
5	23.05	27.85	30.90	33.46	35.71	38.77	52.30	60.29	64.84	68.52	71.80	76.07
6	28.45	33.67	36.76	39.37	41.86	45.10	75.26	84.57	89.48	94.15	98.33	103.18
7	33.83	39.12	42.32	45.28	47.96	51.57	101.22	112.30	118.50	124.24	128.45	133.57
8	39.29	45.05	48.33	51.42	54.29	57.69	131.62	143.97	150.53	156.00	161.32	168.36
9	44.58	50.55	53.98	57.12	59.33	62.80	165.11	178.90	186.39	192.89	198.82	204.95
10	49.66	55.97	59.62	62.81	65.44	69.09	202.58	217.81	225.85	233.13	239.46	247.18
11	54.99	61.55	65.38	68.83	72.11	75.95	243.90	260.82	269.96	277.71	284.87	293.44

Critical Values for Johansen Test :Trend in ECM

	$\lambda-$max						Trace					
p-r	50%	80%	90%	95%	97.5%	99%	50%	80%	90%	95%	97.5%	99%
1	5.55	8.65	10.49	12.25	14.21	16.26	5.55	8.65	10.49	12.25	14.21	16.26
2	10.90	14.70	16.85	18.96	21.14	23.65	15.59	20.19	22.76	25.32	27.75	30.45
3	16.24	20.45	23.11	25.54	27.68	30.34	29.53	35.56	39.06	42.44	45.42	48.45
4	21.50	26.30	29.12	31.46	33.60	36.65	47.17	54.80	59.14	62.99	66.25	70.05
5	26.72	31.72	34.75	37.52	40.01	42.36	68.64	77.83	83.20	87.31	91.06	96.58
6	32.01	37.50	40.91	43.97	46.84	49.51	94.05	104.73	110.42	114.90	119.29	124.75
7	37.57	43.11	46.32	49.42	51.94	54.71	122.87	134.57	141.01	146.76	152.52	158.49
8	42.72	48.56	52.16	55.50	58.08	62.46	155.40	169.10	176.67	182.82	187.91	196.08
9	48.17	54.34	57.87	61.29	64.12	67.88	192.37	207.55	215.17	222.21	228.05	234.41
10	53.21	59.49	63.18	66.23	69.56	73.73	231.59	247.91	256.72	263.42	270.33	279.07
11	58.54	64.97	69.26	72.72	75.72	79.23	276.34	294.12	303.13	310.81	318.02	327.45

Critical Values for Johansen Test :Trend in Cointegrating Vector

	$\lambda-$max						Trace					
p-r	50%	80%	90%	95%	97.5%	99%	50%	80%	90%	95%	97.5%	99%
1	0.45	1.61	2.57	3.74	4.85	6.40	0.45	1.61	2.57	3.74	4.85	6.40
2	8.84	12.55	14.84	16.87	18.57	21.47	9.68	13.56	16.06	18.17	20.13	23.46
3	14.70	18.94	21.53	23.78	26.07	28.83	22.66	28.13	31.42	34.55	36.94	40.49
4	19.99	24.81	27.76	30.33	32.56	35.68	39.43	46.66	50.74	54.64	57.79	61.24
5	25.78	30.75	33.74	36.41	38.68	41.58	60.33	68.66	73.40	77.74	80.94	85.78
6	30.96	36.51	39.50	42.48	45.12	48.17	84.53	94.45	100.14	104.94	109.62	114.36
7	36.44	42.07	45.49	48.45	51.46	54.48	112.75	124.18	130.84	136.61	141.55	146.99
8	41.68	47.51	51.14	54.25	56.87	60.81	144.39	157.11	164.34	170.80	176.43	182.51
9	46.92	53.12	57.01	60.29	62.98	66.91	179.72	194.04	201.95	208.97	215.41	222.46
10	52.33	59.01	62.69	66.10	69.41	72.96	219.42	235.26	244.12	250.84	256.60	263.94
11	57.76	64.40	68.22	71.68	74.90	78.51	262.30	279.31	288.08	295.99	303.98	312.58

Source: Osternwald-Lenum, M. (1992). A note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Co-integration Rank Test Statistics. *Oxford Bulletin of Economics and Statistics*, 53:461-471.