AN ASSESSMENT OF THE TRANSMISSION OF INTERNATIONAL PRICES INTO RWANDA'S RICE MARKETS

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DECLARATION

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

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DEDICATION

This thesis is dedicated to the almighty God for His grace; to my beloved father and mother for their love and affection.

LIST OF ABBREVIATIONS AND ACRONYMS

ADF:	Augmented Dick-Fuller
AERC:	African Economic Research consortium
AIC:	Akaike Information Criterion
ARDL:	Autoregressive Distributed Lag
DF:	Dick-Fuller
ECM:	Error Correction Model
ESA:	Eastern and Southern Africa
FAO:	Food and Agriculture Organization of the United Nations
GDP:	Gross Domestic Product
HQC:	Hannan - Quinn Criterion
IMC:	Index of Market Connection
I(d):	Integrated of order d
I(1):	Integrated of order 1
JML:	Johansen Maximum Likelihood
Kg:	Kilogram
KM:	Kilometre
LOP:	Law of One Price
MINAGRI:	Ministry of Agriculture and Animal Resources
MINECOFIN:	Ministry of Finance and Economic Planning
MIS:	Market Information Systems
M-TAR:	Momentum Threshold Autoregressive
MT:	Metric Tons
NTB:	Non Tariff Barriers
OLS:	Ordinary Least Squares
PBM:	Parity Bound Models
PP:	Phillips-Perron
RADA:	Rwanda Agricultural Development Authority

RATIN: Regional Agricultural Trade Intelligence Network

RWF: Rwandan Franc

SRM: Switching Regime Models

SC: Schwarz Criterion

TAR: Threshold Autoregressive

VAR: Variance Autoregressive

VECM: Vector Error Correction Model

USD: United State Dollar

USAID: United States Agency for International Development

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This study evaluated the transmission of international rice market prices to the domestic Rwandan rice market using a vector error correction model that employs monthly time series data for four domestic markets Kigali, Umutara, Ruhengeri and Butare for the 2002 to 2012 period. The need for this study arose primarily because the relationship between world rice prices and Rwanda's domestic rice prices is not well understood. Thus, there is need to undertake empirical studies such as the current one that that shed light on this issue.

The findings of the study indicated that rice markets in Rwanda are integrated to world rice markets. The results also suggest a substantial transmission ranging between 68 to 82 percent of world prices change being transmitted into Rwanda's rice markets. In addition the study results suggest that it takes 4 months for Butare, 3.5 months for Kigali, 5 months for Ruhengeri and 4 months for Umutara rice prices to adjust to the international prices.

The high speed of transmission and adjustment could be attributed Rwanda reliance on imports in rice markets. The study recommends that the government should promote strategies that aim to increase self-sufficiency in rice production and in safety programs and rice storage strategies. The government of Rwanda should also promote resilience strategies to higher price transmission in international grain prices by diversifying the staple foods of consumers. Finally, Rwanda needs to invest in rural infrastructure and information systems to enable producers, traders and consumers to rationalize their decision of purchase and sale and the government

CHAPTER I: INTRODUCTION

1.1. Background information

Since 2006 the global prices of agricultural commodities have increased substantially. Between January 2006 and early 2008, the world prices of maize, wheat, and soybeans more than doubled, and rice prices tripled (Minot, 2010). The price increases were attributed to a number of causes. According to Ackello-Ogutu (2009) these causes include high petroleum prices, production of biofuel, increasing population and disposable income and weather related shocks. Moreover, the increase in international agricultural commodity prices raised concerns that the food price crisis will hurt economies especially those largely depending on the agriculture sector (Karugia *et al*, 2009 and Ackello-Ogutu, 2009).

Minot (2010) argues that the impact of the global food crisis may have been particularly severe in Sub-Saharan Africa (SSA) because a large percentage of households are net buyers of staple food crops, so they are hurt by higher food prices and as a consequence of the low incomes in the region, where food accounts for a large share of household budgets, often in the range of 50 to 70 percent. According to Shimiles (2010) the implication of that food price increase could significantly slow down the pace of poverty reduction in Rwanda, a country that has otherwise recorded remarkable growth in the last couple of years.

In Rwanda, rice is among preferred cereals especially in urban areas where rice consumption is higher than that of their rural counterparts and is highly preferred by institutions such as hospitals and schools, and in restaurants (MINAGRI, 2010). In the past 10 years, the total rice production has increased substantially from 11,949 Metric tons (MT) in 2000 to 40, 560 MTin 2008 (MINAGRI, 2010). This increase is mainly due to both national rice production program and Rwanda rice development strategy whose aim is to increase rice production to 170,000 MT by 2016 and make Rwanda self-sufficient in rice production (MINAGRI, 2011).

Table 1-1: Rice production, consumption and imports (MT) in Rwanda 2008-2012

Year	Production of milled rice	Consumption	Imports
2008	40,560	60,825	17,925
2009	52,780	84,440	31,660
2010	45,942	90,482	44,545
2011	47,996	93,227	45,231
2012	55,826	104,107	48,284

Source: MINAGRI (2011)

Despite these efforts the analyses of supply-demand from table 1 above reveals that rice production in Rwanda confronts two challenges (i) inadequate supply and (ii) increasing rice imports. According to MINAGRI (2011) with an average productivity of 5.8 tons /hectare, rice is grown over 12,400 hectares of marshlands in two seasons which made around 55,826 MT per year. Although there has been a rapid rise in rice production in the past decade, the country has not yet achieved self-sufficiency. Rwanda annually imports rose from an average of 17,925 MT in 2008 of milled rice to 48, 284 MT in 2012 mainly from countries such as Tanzania, Thailand and Vietnam.

These statistics clearly show how rice consumption has substantially increased or almost doubled from 60, 825 MT in 2008 to 104, 107 MT in 2012. With a population of 10.8 million in 2012, the per capita consumption of rice in Rwanda stands at 9.8 kg per year(MINAGRI,2011). Compared to other cereals per capita consumption rice consumption in Rwanda is ranked number two after whose per capita consumption is 14kg per year, while wheat and sorghum per capita consumption are 7.2 and 8.6 per year respectively MINAGRI(2011)

When international price of rice increased between March 2007 and March 2008, rice price in Rwanda increased substantially (Karugia *et al*, 2009). However that increase was more than in other regional markets. For example rice prices in Kigali markets were between US$ 1000 and US$ 1200 per Metric Ton(MT) throughout 2009 while rice prices in Dar es Salaam and Kampala trended only between US$ 800 and US$ 1000 in the same year (RATIN, 2009).

Price transmission refers to the co-movement shown by prices of the same good in different locations (Conforti, 2004). The concept is based on three components namely co- movement, the dynamics and speed of adjustment and asymmetry of response (Balcombe and Morisson, 2002). The co-movement and completeness of adjustment implies that changes in prices in one market are fully transmitted to the other; the dynamics and speed of adjustment is the process by, and rate at which, changes in prices in one market are filtered to the other market; and the asymmetry of response implies that upward and downward movements in the price in one market are symmetrically or asymmetrically transmitted to the other.

Conforti (2004) asserts that if price changes are not passed-through instantly, but after sometime, price transmission is incomplete in the short run, but complete in the long run, as implied by the spatial arbitrage condition. Changes in the price at one market may need some time to be transmitted to other markets for various reasons, such as policies, the number of stages in marketing and the corresponding contractual arrangements between economic agents, storage and inventory holding, delays caused in transportation or processing (Nkendah and Nzouessin, 2006).

Price transmission analysis uses price data to measure aspects of the relationship between the prices in the two markets. The analysis can be used to investigate the relationship between: world prices and local prices for a given commodity; local prices for the same commodity in different cities; and prices of two related commodities in the same market channel (Food security portal, 2012). Therefore studies on price transmission provides information on how shocks in one market are transmitted to another, reflecting the competitiveness of markets, effectiveness of arbitrage; efficiency of pricing and the extent to which domestic markets remain insulated from international markets (Abdulai, 2007).

Recent research in price transmission focused on two areas – vertical price transmission and spatial price transmission. Vertical transmission is a relationship between upstream and downstream market in the production chain (Minot, 2010). On the other hand spatial price transmission is a relationship between geographically distant markets for the same commodity. Spatial price transmission occurs when a commodity is traded between two regions or countries. For example, the price in the country that exports a given commodity affects the price of the same commodity in the importing country (Minot, 2010).

According to Keats et al, (2010) if markets are efficient and policies are not an obstacle to their operation, changes in the world price of any given commodity should be similarly reflected in changes in domestic prices – known as '*price transmission*'. There should be only a short lag – equivalent to the time taken to physically transfer the product between local and world markets. In reality, however, local prices may not change as expected in response to movements in the world market. Regarding the spatial transmission between markets factors the literature suggests at least six factors which affect the price transmission.

Keats et al, (2010) note that these include transfer costs, border policies, exchange rates, product differentiation, market power and returns to scale. Rapsomanikis *et al*, (2003) and Minot (2010) note that in case of high transportation cost which makes trade unprofitable, the presence of trade barriers, goods that are imperfect substitutes and when there is a lack of information about prices in other markets, price transmission may not occur. Conforti (2004) argues that an indicator of market efficiency, in perfectly competitive market, is the complete pass- through of price changes from one market to the other.

This study, therefore, is an attempt to assess the price transmission in rice markets for the case of Rwanda in particular. The result of this study will be used in formulating policies and programmes that address the transmission of rice prices from the world market to domestic markets in Rwanda. In the next section the research problem is undertaken

1.2 Statement of the problem

Widely traded commodities such as wheat and rice were the quickest to respond to world prices increase hence leading to rapid and dramatic price rises in many countries in 2008 Keats *et al*., (2010). This debate triggered the interest among researchers to understand how prices are transmitted from world to domestic markets. Because understanding of price movements within a country and the degree at which prices are transmitted across regions is of economic significance to a country as it provides forecast information on how producers and consumers in the domestic markets will react in response to price changes from external market (REPOA, 2013).

Several studies (Kilima, 2006, Minot, 2010; Kaspersen and Føyn , 2010) in Sub Saharan Africa have analyzed price transmission from world to domestic prices but there has not been any empirical study on price transmission in Rwanda. Thus, the relationship between world rice prices and Rwanda's rice prices is not well understood. This gap therefore raises the question on whether there is a price transmission from the world rice prices into Rwanda's rice prices.

The current study sought to answer that research question because understanding the relationship between world prices and Rwanda's prices will shed more light on the root causes of price increase in Rwanda and clarify the likely impact of rising world food prices on Rwanda's economy. Studying price transmission provides important information, how markets are integrated domestically, regionally and internationally and on how price shocks are transmitted from one market to another. Therefore enabling one to answer the question of how one market price shocks affect prices on another market.

1.3 Purpose and Objectives

The purpose of this study was to analyse the transmission of world rice prices to domestic rice markets in Rwanda

The specific objectives of this study were:

1. To evaluate the trends in rice prices in Rwanda
2. To assess the transmission of world rice prices to domestic rice markets in Rwanda

1.4 Hypotheses to be tested

The following hypotheses are tested:

1. That rice prices in Rwanda do not vary over years of the study
2. That domestic rice prices and international rice prices are not integrated

1.5 Justification of the study

Rwanda with almost 11 million people, has one of the highest population densities in sub-Saharan Africa of 365 per square kilometer and a rapid growth rate of 2.7 percent annually (MINAGRI, 2010). This rapid growing population has resulted in rapid increase of staple food consumption. For instance rice demand rose from 47.4 MT in 2005 to 70.8 MT in 2009; however, the country local rice supply increased only from 30.1 MT in 2005 to 38.8 MT in 2009 mainly because of low rice productivity which is a result of less efficient input usage systems, water availability and land availability (MINAGRI, 2010).

This imbalance in supply and demand increased the country reliance on increasing rice imports from 22, 887 MT in 2007 to 26, 736 MT in 2010. Rice prices have also been increasing in Rwanda local markets from 258 Rwanda Franc per kilogram (RWF/Kg) in 2005 to 513 RWF/Kg in 2009 (MINAGRI, 2010). Rice prices increase in international markets therefore raised concerns that Rwanda will suffer from higher international rice prices because not only will it divert countries' export revenues to pay a higher import bill but also will erode incomes of increasing rice consumers especially in urban areas.

Considering the magnitude of rice sector in feeding an ever increasing Rwandan population and on national economy. A comprehensive study of price transmission between international rice markets and Rwanda's rice markets is important because it attempts to ascertain whether there has been strong price transmission from world prices into Rwanda's rice prices. According to Kilima (2006) an understanding of price movements within a country is of economic significance to a country as it provides forecast information on how producers and consumers in the domestic markets will react in response to price changes from external market.

Therefore, the applied value of this study is that it helps Rwandan policy makers to acquire knowledge on how world rice price signals are transmitted to Rwanda rice market and an understanding of the performance of Rwanda rice markets in relations to world rice markets. Especially in the face of food price crisis policy makers need to be informed by evidence on the ability of Rwanda agricultural markets to respond to changes in international prices of agricultural commodities hence become more effective in developing strategies to address challenges raised by higher domestic prices.

1.6 Organization of the study

The thesis is organised into five chapters. Chapter one covers the introduction and includes the background information, problem statement, objectives, hypotheses and justification of study. Chapter two undertakes a theoretical and literature review. Chapter three presents on the methodology applied in the study; it includes the theoretical framework, the empirical model, and data sources and data analysis. Chapter four discusses the findings of the study and chapter five provides the summary, conclusion, policy implications of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Literature Review

2.1.1 The notion of Price Transmission and Market Integration

The theory of price transmission is premised on the Law of One Price (LOP), which follows from the spatial arbitrage condition that transfer cost adjusted prices are the same across spatially separated markets (Fackler and Goodwin 2002). Following Fackler and Goodwin (2002), the Spatial Arbitrage condition, can be specifiedas follows;

$$P_j - P_i \leq R_{ij} \quad (2.1)$$

Where P indicates the price in the two spatially separated locations i and j, and R_{ij} is the cost of moving the good considered from i to j.

The spatial arbitrage condition implies that the difference between prices in different locations will never exceed transport costs, or otherwise the profiting opportunities would be immediately exploited by arbitrageurs: they would buy the goods in the market in which the price is lower, and sell them in the one where it is higher (Goodwin and Piggott, 2001). Other things being equal, the price would then go up in the first market due to the increased demand, and go down in the second one because of the increase of supply, towards equilibrium. In the short-run, actual prices may diverge from the spatial arbitrage condition, but the actions of the arbitrageurs are expected to make it valid in the long-run, moving the price spread towards the transport cost (Goodwin and Piggott, 2001).

The law of One Price (LOP) directly follows from the spatial arbitrage condition: in markets linked by trade and arbitrage, prices will be equalized, net of transport costs. The LOP is based on international commodity arbitrage, implying that "*in the absence of transport costs* *and trade restrictions, perfect commodity arbitrage ensures that each good is uniformly priced throughout the world*" (Fackler and Goodwin 2002). Two forms of LOP have been distinguished: a weak and a strong LOP. The weak LOP is the same as the arbitrage condition, while strong LOP can be represented as below (2.2):

$$P_j = P_i + R_{ij} \qquad (2.2)$$

If a relationship such as (2.2), holds, the markets can be said to be integrated and hence price transmission will occur (Rapsomanikis, *et al*. 2003).

Price transmission also follows from market integration, such that when two markets are integrated, price transmission is will occur. Two markets are then said to be integrated if changes in price of one market are translated into changes in another market and vice versa. In the case of spatial market integration, two product markets are said to be integrated if, when trade takes place between them, price in the importing market equals price in the exporting market plus the transportation and other costs of moving the product between the two markets (Baulch, 1997). Sexton, *et al.* (1991) summarizes three factors that may contribute to a lack of market integration.

Firstly, markets may not be integrated when they are not linked by arbitrage i.e. they are autarkic as transaction costs are prohibitive in relation to price differences or due to public market protection. Secondly, presence of impediments to efficient arbitrage, such as trading barriers, imperfect competition, or risk aversion. Finally markets may not be integrated due to imperfect information in one or more of the markets, arising from collusion among traders or preferential access to scarce resources, that may result in higher price differences between markets than can be attributed to transaction costs.

The distinction between short run and long run price transmission is important and the speed by which prices adjust to their long run relationship is essential in understanding the extent to which markets are integrated in the short run. Changes in the price at one market may need some time to be transmitted to other markets for various reasons, such as policies, the number of stages in marketing and the corresponding contractual arrangements between economic agents, storage and inventory holding, delays caused in transportation or processing, etc. (Nkendah and Nzouessin, 2006).

Price transmission measures, therefore, are important as they indicate how price changes move from one market to another or from one stage of a marketing channel to another stage. Although the markets could be for related commodities (such as maize and soybeans) or for products at different points in the supply chain (for example, wheat and bread), in this case the focus is on markets for the same commodity in several locations. The section that follows reviews some of the approaches that have been used in studying price transmission and gives an in depth discussion in terms of their pros and cons.

2.1.2 Approaches used in the Analysis of Price Transmission

A number of approaches have been used to analyze price transmission, either linear or non linerar approaches. Linear approaches include the correlation coefficient and regression models, Granger causality, Ravallion model and the co-integration and error correction mechanism approaches. However, there are other approaches that recognize the non-linear nature of price transmission; these include the threshold model and the parity bound models. In the following paragraphs, these approaches are discussed in detail.

Earlier studies on price transmission used simple correlation coefficient and regression approaches of contemporaneous prices. The correlation coefficient indicates the degree of relationship between two variables (Abdulai, 2007). The correlation coefficient ranges between 0 and 1 where 0 means no relationship, and 1 means perfect correlation. Such that a high correlation coefficient is evidence of co-movement and was interpreted as a sign of an efficient market. Abdulai (2007) notes that the advantage of this method is that it is easy to calculate and understand because the coefficient of determination R^2 indicates share of variation in one variable explained by other variables, but it has a serious disadvantage of only considering relationship between prices at same time hence does not take into account lags.

The limit of this approach is that it is founded on strong hypothesis of the permanence of commercial flows between the markets; the fixity of the costs of transfer and the fact that on a market, the prices are supposed to be given in an exogenous way (Nkendah and Nzouessin, 2006). Another limitation recognized with this approach is that the coefficient can be high and even equal to 1 whereas no trade exists between the two markets. This can be the case if the prices in the two markets are affected by the same factors namely the inflation and seasonal movements (Nkendah and Nzouessin, 2006).

According to Nkendah and Nzouessin (2006) the approach based on the estimate of a model of regression is founded on the hypothesis: of linearity between the prices of the various markets. The method of regression comprises a static regression approach. Static regression analyses are used to find the equation that best fits the data (Nkendah and Nzouessin, 2006). One of the cited advantages is that the approach gives information to calculate transmission elasticity that can take into account effects of inflation, and seasonality however on the negative side the methods is believed to give misleading results if data are non-stationary (Nkendah and Nzouessin, 2006).

In regression framework Granger (1969) proposed causality approach, which improves greatly on the simple bivariate correlation and regression tests. Granger (1969) causality test provides evidence of whether price transmission is occurring between two markets, and in which direction. The price in market A is said to granger-causes the price in market B if both the current and the lagged values of price in market A improve the forecasting of price in market B. The Granger causality concept refers to the notion of causality in terms of lead and lag relationships: significant coefficients of the lagged prices imply that shocks to prices in one market induce significant responses in another after some lags (Granger, 1969).

Granger causality tests have some advantage over correlation coefficients as they allow for lagged or leading effects in price inter-relationships. However, the inferences from Granger causality tests do not reveal the nature of the relationship and results can still be spurious since they did not take into account seasonality and other implications of non-stationarity (Kilima, 2006). Hence the development of the Ravillion's model. In general, Ravallion's model was an improvement compared to the bivariate correlation/regression and Granger causality as it made provisions for other variables that affect prices (Rapsomanikis, *et al*. 2003).

Ravallion's (1986) model specifies a framework of numerous rural markets linked to a central market, and the test for market integration determines whether the price of a commodity in a given producer market is influenced by its price in a central market. The model indicates that the price in the central market is influenced by contemporary and lagged prices in all other markets and its own lags, while the price in any of the other rural markets is influenced by the contemporary and lagged values of the price in the central market and its own lagged values, only (Fackler and Goodwin, 2002).

Rapsomanikis, *et al*. (2003) note that various hypotheses can be tested using this model, which includes, the market segmentation, central market, short-run and long-run market integration hypotheses. This model became the standard tool as it provided more comprehensive assessment of markets inter-relationships and resolved many of the shortfalls of the previous approaches. It also gave rise to a series of extension for instance Timmer in 1987 extended the usefulness of Ravallion's approach through an index of market connection (IMC) that gives an easily comprehensible measure of short-run market integration between two markets.

However, the interpretation of the IMC is still ambiguous; because a larger value of IMC, for example, might indicate that markets are not integrated or that markets are integrated but transport costs exhibit a higher degree of persistence. In the same way, a low IMC suggests that markets are not isolated but it is unclear how connected the markets are (Kilima, 2006). Another major shortfall of the Ravallion approach stems from its underlying assumption of radial markets system in which market prices are exogenous is deemed abstract. Again ignoring the impact of trade amongst local markets seems a very strict assumption (Fackler and Goodwin, 2002).

While these various approaches and their extensions reflected some improvements in analyzing price transmission, namely, elasticity of transmission, direction of influence, dynamic adjustment structure, and multi-market considerations; they did not address the problem of spurious regression associated with non-stationary series as raised by Granger and Newbold (1974). This led Engel and Granger in 1987 to develop the technique of co-integration of time series data. Co-integration between the price series implies that although two prices may behave in a different way in the short run, they converge toward a common behavior in the long run a process called long run equilibrium (Conforti, 2004). Unlike the Ravillion's model, cointegration establishes long run equilibrium between series without requiring the series to be stationary and does not require any assumptions, or any restrictions on the market structure like the radial market structure (Granger and Lee, 1989).

Engel and Granger (1987) defined a long-run equilibrium relationship between the price in a given market P_t^1 and the price in another market P_t^2 in the equation 3 below:

$$P_t^1 = \alpha_0 + \alpha_1 P_t^2 + \mu_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.3)}$$

The above representation is estimated using Ordinary Least Squares (OLS) and the residuals from (2.3) are used to test for co-integration in the following representation:

$$\Delta\mu_t = \rho\mu_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.4)}$$

Such that the null of $\rho = 0$ is tested against an alternative of $\rho \neq 0$. If the null is rejected, then the two price series are co-integrated and thus a long-run relationship exists between the two markets, and hence price transmission can occur between the two markets.

If a long-run relationship exists, the characteristics of the dynamic relationship between the prices can be described by an Error Correction Model (ECM) (Barrett and Li, 2002; Rapsomanikis *et al.*, 2003), the short-run adjustment parameter of this type of model can be interpreted as a measure of the speed of price transmission, while the long run multiplier can be interpreted as a measure of the degree of price transmission of one price to the other

(Rapsomanikis *et al.*, 2003). The advantage of ECM over an ordinary OLS model is that it accounts for dynamic relationships that may exist between a dependent variable and explanatory ones, which may span several periods(Rapsomanikis *et al.*, 2003).

According to Rapsomanikis *et al.*, (2003) two commonly employed approaches to co-integration analysis are Engel and Granger (1987) used for bivariate analyses and the Johansen (1994) variance autoregressive (VAR) approach used in multivariate analyses. Where the first step in employing any of the two approaches is testing for unit roots in the price series individually under a null hypothesis of unit roots using the Dickey-Fuller (DF), augmented Dickey-Fuller (ADF), Phillips-Perron (PP) or other tests. Phillips and Perron (1988) developed a generalization of the Dickey-Fuller procedure that allows for fairly mild assumptions concerning the distribution of the errors. Hence the PP test, unlike the ADF test, allows the disturbances to be weakly dependent and heterogeneously distributed. (Enders, 2004).

Abunyuwah (2007) notes that the ECM representations have brought considerable insight into long-run market relationships/price dynamics with great policy interest in commodity markets. However, Barrett and Li (2002) criticized the cointengration and ECM methods. Because first, they do not incorporate trade flow and transfer data into market integration concept. Second, Co integration and error correction modeling techniques also assume linear relationships between market prices therefore these methods tend to violate consistent market integration condition of discontinuities in trade, implied by spatial arbitrage conditions (Barrett and Li, 2002).

The realization that price relationships may be nonlinear due to transactions costs motivated the introduction of a class of models called switching regime models (SRM) namely Threshold Autoregressive (TAR) models and Parity Bound Models (PBM) (Meyer, 2003). TAR models and PBM integrate price and transactions costs series and are quite widely applied to agricultural price series (Rapsomanikis *et al.*, 2003). In Africa, these models have been applied to test for spatial arbitrage in grain markets in Mozambique, Ethiopia, Tanzania and Madagascar (Abdulai, 2007).

Threshold models were introduced by Enders and Silkos in 1999 to explicitly recognize the influences of transactions costs faced by traders on spatial market integration and account for them without necessarily using actual transactions costs data (Conforti, 2004). The idea is that, inter-market price differentials must exceed thresholds bands arising from transactions costs, before provoking existing market equilibrium and causing price adjustment to ensure market integration. Meyer (2003) argues that spatial markets, transportation costs limits the transmission of price shocks below a critical level because potential gains from trade cannot offset these costs and hence a perfect price adjustment will not take place.

Takayama and Judge (1971) predicts patial equilibrium theory where short run price adjustments due to arbitrage will take place only if the difference between international and domestic prices exceeds a threshold that is determined by transport and transaction costs. If the difference between prices is less than this threshold, there is no incentive for traders to engage in arbitrage, and prices can move independently of one another (Barrett and Li, 2002). The specification of the threshold models starts with the estimation of the the Engel-Granger relationship below:

$P_t^1 = \alpha_0 + \alpha_1 P_t^2 +$

μ_t ....(2.5)

Where μ_t is a random error term with constant variance that can be contemporaneously correlated. Therefore, Engel and Granger (1997) introduced asymmetric adjustments by letting the deviations from the long-run equilibrium in equation (2.5) behave as a Threshold Autoregressive (TAR) process:

$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \varepsilon_t$ ....(2.6)

Where It is the heaviside indicator function so that:

$I_t = \begin{cases} 1 \; if \; \mu_{t-1} \geq 0 \\ 0 \; if \; \mu_{t-1} < 0 \end{cases}$ .... (2.7)

Assuming the system is convergent, $\mu_{t-1} = 0$ can be considered as the long-run equilibrium value of the sequence. If μ_{t-1} is above its long-run equilibrium value, the adjustment is $\rho_1\mu_{t-1}$, while the adjustment is $\rho_2\mu_{t-1}$ if below its long-run equilibrium. The adjustment is symmetric if $\rho_1 = \rho_2$. Instead of estimating equation (2.7) with the heaviside indicator equation (2.8) depending on the level of μ_{t-1}, the decay could also be allowed to depend on the previous period's change in μ_{t-1}. The heaviside indicator could then be specified according to the following rule:

$I_t = \begin{cases} 1 \; if \; \Delta\mu_{t-1} \geq 0 \\ 0 \; if \; \Delta\mu_{t-1} < 0 \end{cases}$ … (2.8)

According to Engel and Granger (1987), replacing (2.7) by (2.8) is particularly useful when adjustment is asymmetric to the degree that the series exhibits more "momentum" in one direction than the other. Models estimated using Equations (2.6), (2.7), and (2.8) are termed momentum threshold autoregression (M-TAR) models. If $|\rho_1| > |\rho_2|$, the M-TAR model exhibits little decay for negative $\Delta\mu_{t-1}$ but substantial decay for for positive $\Delta\mu_{t-1}$. Thus, decreases tend to persist but increases tend to revert quickly toward the attractor. The heaviside indicator of (2.8) can be used in a dynamic model augmented by lagged changes in μ_t.

The test statistic for the null hypothesis using the TAR specification of (2.5) and (2.6) and the M-TAR specification of (2.7) and (2.8) are called Φ_μ and Φ_μ^*, respectively. Three main factors determine the distributions of Φ_μ and Φ_μ^*. These are the number of lags in the augmented equation (8), the number of variables and the type of deterministic elements included in the cointegrating relationship. The appropriate critical values for Φ_μ and Φ_μ^* Enders and Granger (1998) and Enders and Siklos (1999).

Finally, the analysis of symmetry will proceed by estimating the market integration relation in equation 2.5 and then tested for asymmetric adjustment using specifications 2.6, 2.7 and 2.8. In other words both the TAR and the M-TAR specifications will be estimated. As in other studies (Alderman, 1993; Alexander and Wyeth, 1994), constant costs are assumed between markets. Any other assumption about costs, would make the analysis dependent both on assumptions about variation of costs with quantities transacted and on the variation of transaction costs across agents (Dwyer and Wallace, 1992).

Baulch in 1997 introduced the PBM to price transmission and market integration analysis, while Barrett and Li (2002) made significant extension to it. The PBM explicitly consider transaction costs and trade flow data, in addition to price series, in analyzing market integration. PBM have the advantage of allowing for a variety of inter-market price relationships within the range of perfect market integration and complete market segmentation unlike dynamic approaches, which rigorously accept price transmission or reject a null hypothesis at a given significance level (Kilima, 2006).

TAR and PBM methods have their drawbacks too, Barret (2005) notes that they rely heavily on inherently arbitrary distributional assumptions in estimation and typically ignore the time series properties of the data, not permitting analysis of the dynamics of inter-temporal adjustment to short-run deviations from long-run equilibrium and potentially important distinctions between short-run and long-run integration. Moreover, these sophisticated techniques are inherently difficult to model and are data intensive and require specific computer skills or software (Kilima, 2006).

Other important models in price transmission analysis are the impulse response models. These measure the spread of a price shock and provide additional information regarding the dynamic time-path of price adjustments (Kilima, 2006). Goodwin and Piggot (2001) notes that the most important aspect of the impulse response analysis is the possibility of checking whether the price series converge quickly after an isolate, exogenous shock to one of them. Because impulse response analysis has been interpreted as both dynamic disequilibrium adjustments and equilibrium adjustments they cause ambiguity in interpreting their results (Fackler and Goodwin, 2002).

Today, the majority of the price transmission studies use the econometric techniques of time series especially of cointegration analysis and ECM. Rapsomanikis *et al.*, (2003) and Kilima (2006) argue that they provide good results concerning the transmission of the prices if a methodological framework of suitable test is used and correctly interpreted the results. Moreover, these approaches of time series require small amount of data compared to other econometric models, by considering only the series of price easily available in the developing countries.

2.2 Empirical review

Several studies have focused on price transmission in SSA. These studies have analyzed price transmission in a number of selected food and cash crop markets and found that price transmission in African markets are characterized by more incomplete transmission or African domestic markets well poorly linked to international ones. They emphasize that across Africa very high increase in prices were seen but they did not correlate with international prices. Further they say it is likely that higher prices observed in Africa responded more to local factors and perhaps to inflation imported through rising oil prices.

Baffes and Gardner (2003) examined the transmission of world commodity prices to domestic markets under policy reforms in eight countries: Chile, Ghana, Madagascar, Indonesia, Egypt, Mexico, Argentina and Columbia. The study used error correction mechanism to analyze price transmission in 10 commodities: namely maize, wheat, cocoa, rice, sugar, palm oil, sorghum, soybeans and coffee hence a total of 31 country/commodity pairs for the period from 1970 to 1997. The study found that of the eight countries examined, only Mexico, Chile, and Argentine prices had a significant pass through of world price movements.

For the remaining five countries Ghana, Madagascar, Indonesia, Egypt, and Colombia the transmission was either low or non-existent, and the variability of world prices is not reflected in domestic price movements in any important way. The study concluded that the political desire to insulate domestic markets from world commodity markets is remarkably persistent even in the most liberalized countries. The present study is different in that it does not introduce structural breaks as the above study did to account for trade policies hence the current focuses more on effect of world price transmission into domestic prices solely.

Conforti (2004) analyzed price transmission in selected markets in sixteen countries - Argentina, Brazil, Chile, Costa Rica, Egypt, Ethiopia, Ghana, India, Indonesia, Mexico, Pakistan, Senegal, Thailand, Turkey, Uganda, and Uruguay - primarily for basic food commodities. The analysis were done using an ECM on a price database collected from various sources. Results show that African countries normally have lower degree of price transmission compared to that of other countries in Asia and Latina America. Secondly analysis showed that vertical transmission is generally higher than spatial transmission of changes in the world reference prices.

The study however revealed mixed results suggesting that it is difficult to draw definite generalizations on price transmission when analyzing many different commodities within different countries. The study was also constrained by many missing data especially in African countries hence the study results did not allow for a rigid conclusion. This study uses the same methodology similar to the present study but they differ in a way the current focus the analysis in one country, and one commodity rice. This seeks to avoid therefore weaknesses of not having firm results due to lack of relevant data.

Kilima (2006) analyzed the extent to which world market price changes are transmitted through border prices into local producer prices for four Tanzanian markets namely sugar, cotton, wheat and rice commodities for the period between 1994 and 2005. The study used co-integration and causality techniques to test for price linkages. For the analyzed commodity prices (sugar, cotton, wheat, and rice), the co-integration results indicate that the prices in Tanzania were not well integrated with commodity prices in the world market. However, Granger-causality tests revealed the existence of a unidirectional- causal relationship, whereby commodity prices in the world market Granger-caused prices in Tanzania.

The two methodologies taken together imply that commodity prices in the world market and local markets in Tanzania drifted apart, but some shocks from the world market passed through to Tanzania but not the reverse. The present study uses VECM instead of co-integration hence test not only if markets are integrated but also the magnitude of price transmission and the speed of adjustment. In addition the current study does not test granger causality because it assumes only world prices influences domestic prices as Rwanda is a small country therefore does not have influence on world prices.

Kaspersen and Føyn (2010) investigated price transmission for agricultural commodities in Uganda. The prices of Robusta coffee and sorghum were examined using an empirical vector autoregressive(VAR) model for the period from June 2000 to September 2006 for sorghum while for coffee the period analyzed was January 1986 to April 2006. The study found that sorghum price are not integrated with world markets, However, for the cash crop, Robusta coffee, especially, in the period of 1990's with high coffee prices on the world market, coffee prices in Uganda were strongly connected to world prices.

The study concluded that price transmission from world markets has only been evident in the case of rising prices of an exported commodity, but otherwise agricultural commodity markets in Uganda are poorly linked to world markets. The current study is similar to this in the manner that it seeks also to establish whether there is price transmission of world prices into Rwanda's markets but it differs from this study as it uses a different method, VECM instead of VAR. Second it analyzes the price transmission of a highly traded food commodity, rice compared to sorghum thus minimizing the effect the non-tradability.

Minot (2010) studied the transmission of world food price changes to African markets African countries: Ethiopia, Ghana, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda and Zambia. The study used a vector error-correction model approach. The data consisted of 62 domestic price series for maize, rice, and wheat for the period of five years. Only 13 of the 62 price series show a long-run relationship in which the domestic price is influenced by the international price of the same commodity. Indeed, of these 13 domestic prices that show a long-run relationship with international prices, only six have a long-term elasticity of transmission that is statistically significant.

The study found also that the degree of price transmission differs across commodities, for example for the case of maize only 10 percent of tested domestic prices were significantly related to world maize prices while almost 50 percent of the domestic rice prices were related to world rice prices. The study argued that it is not astonishing for such differences because most SSA countries are close to self-sufficient in maize, but rely heavily on imported rice to meet local demand. The current study uses similar methodological approaches. However, it focuses on single country and commodity hence the present study is more specific to the case of Rwanda.

Amikuzino (2012) reviewed the contribution of agricultural economics to rice transmission analysis and market policy in SSA. The study used a meta database obtained from 45 price transmission studies published between 1978 and 2011. The study used meta- regression analysis to provide an overall assessment of the potential impact of selected, study-specific attributes on estimated price transmission coefficients and in identifying asymmetric price transmission. Results indicated large dispersion of estimated price transmission coefficients between 2.5 percent and 94.2 percent.

The study established that in general the extent of price transmission in SSA is comparatively low and asymmetric price transmission differ consistently across the attributes in SSA. This study uses different methodology of VECM instead of meta regression analysis and does not attempt to measure asymmetry of price transmission.   They differ in a way the current focus the analysis in one country, Rwanda while the above was a price transmission study across many countries hence the current study seeks to give quantitative evidence of price transmission in Rwanda markets.

Chisanga (2012) conducted an analysis of efficiency and integration of Zambian sugar markets. Analyses involved vertical and spatial price transmission between world and Zambian sugar prices and testing for price transmission asymmetry using an ECM from 1996 to 2010 period. Findings show low integration between world and Zambian sugar price. Results also showed that the adjustment process is asymmetric between world and Zambian sugar prices hence suggesting low market efficiency. However, vertical price transmission analysis revealed that Zambian sugar markets are relatively more integrated and efficient.

These results suggest that there are distortions in the sugar market, which may include transaction costs, high concentration in the market structure as well as inappropriate policies such as high taxation, high interest rates and import bans. The current study does not analyze market efficiency hence does not conduct price transmission asymmetry and analysis of vertical price transmission of producer, wholesale and retail prices relations . Instead both study are similar in the manner that both studies use ECM approach to establish quantitative relationship between world markets and domestic markets.

Acharya, *et al.* (2012) studied world rice and wheat price transmission to the Indian domestic markets for the period from 1996 to 2011. Tests were done using Johansen methodology of estimating a VECM. Results showed that domestic prices during the crisis period did increase but the increase was considerably lower than the increase in global prices. In addition the results suggest that the transmission from international prices to farm-gate prices is asymmetric, which shows that farm-gate prices respond differently in rising and falling phases of international prices.

Because price transmission is influenced by the marketing and price policies, the paper also reviewed domestic policies related to marketing of rice and wheat in India. The study established that government interventions in rice and wheat markets, were major factors that impacted the price transmission of global prices to Indian markets. The present study though it quantifies transmission of international prices into Rwanda's rice markets, does not review price policies in Rwanda and their influence on the transmission process. However both studies use similar econometric approach, the VECM.

Greb *et al*. (2012) conducted a study on the extent and speed of transmission of international cereal(rice, maize and wheat) price changes to the domestic retail and wholesale level in developing and emerging countries with a focus on African countries. The study employed the extensive FAO GIEWS price data set from 1995 to 2011 using VECM approach. The study found that the share of co-integrated commodity markets is higher in African countries compared with the other countries in the sample (49 percent compared to 35 percent). In addition in most case domestic prices adjusted to deviations from the long-run price relationship, but international did not.

The study further analyzed how much the variation in the samples of price transmission estimates can be explained by country- or product-specific factors (economic, political, geographical, as well as infrastructure and trade variables using meta regression analysis. The analysis found that an increasing ratio of net imports is associated with slower price transmission leading to the conclusion of increased intervention on politically more sensitive markets. The current study uses similar methodological approaches but does not conduct regression analysis. In addition it focuses on single country and commodity contrary to the study under review hence the present study provides more specificity to the case of Rwanda.

The foregoing analysis seems to indicate that the most widely used empirical mode to study price transmission is the Vector Error Correction Model (VECM). The VECM which is an extension of co-integration techniques has an intuitive appeal for the study of price transmission, since it allows separating short and long run market dynamics (Conforti, 2004). The distinction between short run and long run price transmission is important and the speed by which prices adjust to their long run relationship is essential in understanding the extent to which markets are integrated (Conforti, 2004). For these reasons, this study uses the same approach to study price transmission in Rwanda.

In addition this study uses VECM because time series models have small data requirements compared to other methodologies. They simply rely on price series only, which are easily obtained for developing countries where data availability is still a main challenge. This study contributes to the body of knowledge in price transmission. Its uniqueness is that it assesses the transmission of international prices into Rwanda’s rice markets. Hence provides quantitative evidence of price transmission in Rwanda.

CHAPTER 3: METHODOLOGY

This chapter aims at developing a general understanding of stationarity, co-integration and the vector error correction model approaches used to analyze price transmission. First, a theoretical background of the VECM is presented. The analytical framework highlights tests that are used to test for non-stationarity of time series data, approaches that are used to test for co-integration of variables and the VECM empirical model of testing parameters of price transmission are highlighted in the second part of this chapter. Finally, data sources and data analysis are outlined in the last part of the chapter.

3.1 Theoretical framework

The Law of One Price (LOP) provides the theoretical base for spatial price transmission. The LOP following Fackler and Goodwin (2002) states that prices of homogenous goods will, in equilibrium, equal each other, apart from the cost of moving the goods from one place to another. The LOP is supposed to regulate spatial price relations: in markets linked by trade and arbitrage, prices expressed in the same currency will be equalized, net of transport costs. This is a basic economic law with simple equation: market price one at certain time P_t^1 should be equal to market price two at the same time P_t^2 allowing for transfer costs *c*, for transporting the commodity from market 1 to market 2 Fackler and Goodwin (2002).

Following Fackler and Goodwin (2002), the relationship between the prices can be specified as follows;

$$P_t^1 = P_t^2 + c \qquad (3.1)$$

Minot (2010) argues that if the cost of transportation (c) is large, this will create a large band within which each price can fluctuate without inducing trade and reconnecting the two prices.

The author also documents that the full cost of transportation will be larger in case: the distance between the markets is large, the infrastructure is poor, the tariffs and other trade taxes are high, and if trading is particularly risky. And as long as there is no trade, there will be no price transmission. If the relationship between two prices, such as (3.1), holds, the markets can be said to be integrated.

The LOP is expected to regulate spatial price relations in an undistorted world; the premises of full price transmission and market integration correspond to those of the standard competition model (Conforti, 2004). Even though prices may not behave as explained by the LOP due to market distortions, prices do tend to have a co-movement between markets and prices might be connected in very complex ways and might behave differently in the short and in the long-run Conforti (2004). Therefore, in this framework, the Law of One Price can be thought of as an equilibrium condition, from which there might be discrepancy in the short-run.

Fackler and Goodwin (2002) refer to the relationship (3.2) below as the spatial arbitrage condition. The spatial arbitrage condition implies that market integration lends itself to a co-integration interpretation;

$P_{1t} = P_{2t} + m$, LOP...(3.2)

$P_{1t} - P_{2t} \leq m$, weak form of LOP..(3.3)

If two prices in spatially separated markets P_{1t} and P_{2t} contain stochastic trends and are integrated of the same order, say Integrated of order d(d), the prices are said to be co-integrated if:

$P_{1t} - \beta P_{2t} = \mu_t$ ………………………………………………………………………………...........(3.4)

Where:

u_t: is stationary*;* and

β: is the co-integrating parameter

By the Granger Representation Theorem (Engle and Granger, 1987); if two trending, say *Integrated of order one (1),* variables are co-integrated, their relationship may be validly described by a Vector Error Correction (VECM) model as follows:

$\Delta P_t = \alpha + \pi P_{t-1} + \sum_{k=1} \Gamma_k \Delta P_{t-k} + \varepsilon_t$ …………………………………………….............(3.5)

Where:

$\boldsymbol{P_t}$is an $nx1$vector of *n* price variables,

Δ is the difference operator, so that, $\Delta P_t = P_t - P_{t-1}$,

$\varepsilon_t$is an $nx1$ vector of error terms, and

$\alpha$is an $nx1$ vector of estimated parameters that describe the trend component

$\pi$is an nxn matrix of estimated parameters that describe the long-term relationship and the error correction adjustment, and

$\Gamma_k$is a set of nxn matrices of estimated parameters that describe the short-run relationship between prices, one for each of q lags included in the model.

3.2 The Empirical Models

In order to operationalize this study three steps of analyses are undertaken. The first step in estimation of a price transmission is to determine whether the individual price series are non-stationary (also referred to as ‘integrated of I(1). This is done using the Augmented Dickey-Fuller test and the Phillips-Perron test by testing for unit roots. These two sets of tests test the null hypothesis that a time series is I(1). Therefore, conclude the order market integration.

If the series have a diverse order of integration then it is concluded that there is absence of integration, thus no price transmission (Phillips-Perron, 1988).

Secondly, If the series are both I(1), the null hypothesis of no co-integration can be tested using a two-step OLS procedure proposed by Engel and Granger (1987) or a maximum likelihood procedure developed by Johansen (1988). One can test the null hypothesis of non-co-integration against the alternative hypothesis of one co-integrating vector applying the Johansen procedure (Johansen, 1994). Thirdly, in case markets are co-integrated, a Vector Error Correction Model (VECM) is estimated to assess the transmission of international prices to domestic prices. It is for these reasons that the following sections give an in depth understanding of these three steps in estimating price transmission are discussed in the next sections in details.

3.2.1 Stationarity Tests

Non stationarity is tested using both the ADF and the PP test. If the prices are not both I(1), they cannot be co-integrated. If they are both stationary or 'I(0)' they can be studied using an Autoregressive Distributed Lag (ARDL) models (Greb, *et al*. 2012). However in case the price series are non stationary both ADF and PP tests are able to determine the order of that integration for instance I(1), I(2), I(n). These tests are necessary before the specification of an ECM.

The ADF test is one of the most commonly use tests for stationarity. The null hypothesis is that the series has a unit root. In other words, the ADF tests for the null hypothesis of non-stationarity against the alternative hypothesis of stationarity condition. Rejecting the null hypothesis means that the stationary condition is achieved. The ADF consists of estimating the following regression:

$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Y_{t-1} + \varepsilon_t$ ....(3.6)

where ε_t is a pure white noise error term which is independently and identically distributed as a normal distribution with zero mean and constant variance and is assumed to be homoskedastic, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2}) \Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$e.t.c (Dickey and Fuller, 1979). m is the number of lags which are included in the model to ensure that the residuals ε_t have zero mean and constant
variance.

The ADF therefore tests the null hypothesis that $\delta = 0$; that is the variable in question contains a unit root against the alternative that $\delta < 0$ that is, the time series is stationary. The actual estimation procedure of the ADF test is to difference a variable and regress it on its lagged value e.g. $\Delta Y_t = \delta Y_{t-1} + \mu_t$. Then divide the estimated coefficient of ΔY_{t-1} by its standard error to compute the t (tau) statistic, and refer to the DF tables. If tau statistic exceeds the DF or MacKinnon critical tau values, the null hypothesis that $\delta = 0$ is rejected. On the other hand, if the computed absolute value of tau does not exceed the critical tau value, we fail to reject the null hypothesis that the time series is non- stationary (Gujarati and Sangetha, 2007).

The Phillips and Perron is a non-parametric test to check for serial correlation. Ng and Perron (1995) argue that PP test statistics can be viewed as Dickey–Fuller statistics that have been made robust to serial correlation by using the Newey–West (1987) heteroskedasticity- and autocorrelation-consistent covariance matrix estimator. Because under the null hypothesis that $\delta = 0$, the PP statistics have the same asymptotic distributions as the ADF t-statistic and normalized bias statistics. Another advantage of PP over ADF is that the user does not have to specify a lag length for the test regression (Ng and Perron, 1995).

Both ADF and PP tests determine the order of difference at which the series becomes stationary, hence allowing the determination of order of integration which suggests if price series are integrated of the same order or not. However, before conducting the stationarity tests, it is important to carry a graphical analysis which involves plotting the data in query on a graph. Gujarati and Sangetha, (2007) note that before pursuing the formal unit root tests, it is always advisable to plot the time series under study because such plots give an initial hint about the probable nature of the time series.

Most statistical softwares used in econometric analysis have the ADF and PP procedures in built, so that the task of the analyst is to choose whether to include a trend, intercept, or both in estimation. As mentioned earlier on, in order to perform the ADF it is necessary to include the number of lagged variables, which is selected following the Akaike Info Criterion (AIC), and/or Hannan-Quinn Criterion (HQC), and/or Schwarz Criterion (SC) (Greb, *et al*. 2012). In this study, All series are trended and with intercept and the chosen lag lengths in both tests are based on the Akaike Information Criterion (AIC).

3.2.2 Market Integration Analysis

If the non- stationarity tests reveal that the series are integrated of the same order I (1), the second step is to test for co-integration of price series. There are two possible procedures that might be applied on price series, these approaches are highlighted in the lines below.

First, the Engle and Granger (1987) approach of estimating co-integration among price series. Utkulu (1994) notes that the concept of co-integration was first introduced by Granger in 1981 afterwards, Engle and Granger (1987) provided a solid theoretical base for representation, testing, estimating of co-integrated non stationary time-series variables in a two steps approach. Utkulu (1994) notes that this approach has an advantage that the long-run equilibrium relationship can be modeled by a simple regression involving the levels of the variables.

Following Utkulu (1994), in the first step, the approach estimate the long-run (co-integrating) regression:

$C_t = \beta Y_t + \mu_t$ ....(3.7)

where both C_t and Y_t are non-stationary variables and integrated of order one (i.e. C_t~ I(1) and Y_t ~I(1)). Hence, In order for C_t and Y_t to be cointegrated, the necessary condition is that the estimated residuals from equation 15 above should be stationary (i.e. μ_t ~ I(0)). The analysis, therefore, involves testing the residuals of the co-integrated regression for a unit root using ADF or Phillip PP tests. The second step involves estimating a short-run model with an ECM by the OLS (Engle and Granger, 1987). If the residuals of the co-integrating regressions are found to be stationary, then it implies that co-integration exists (Engle and Granger, 1987). The second step involves specifying an ECM.

The second approach of estimating co-integration is the Johansen Maximum Likelihood (JML) method. This is a means of testing for co-integration in a multivariate context, where there is the possibility of more than one co-integrating vector being present (Johansen and Juselius, 1990). According to Utkulu (1994) The JML follows the same principles as the Engle-Granger approach to co-integration, as the order of integration of the variables are first assessed, if the variables are I(1) the Johansen Maximum Likelihood (ML) procedure can then be used to determine whether a stable long-run relationship exists between the variables.

Johansen (1988) relies on the relationship between the rank of a matrix and its characteristic roots hence the rank of matrix π is equal to the number of independent co-integrating vectors. According to Greb *et al*. (2012) the Johansen procedure is a multivariate generalization of the Dickey-Fuller test and is formulated as follows:

$P_{it} = A_1 P_{it-1} + \varepsilon_t$……………………………………………………..........................(3.8)

So that: $\Delta P_{it} = A_1 P_{it-1} - P_{it-1} + \varepsilon_t$…………………………………..........................(3.9)

$\Delta P_{it} = (A_1 - I) P_{it-1} + \varepsilon_t$…………………………………………….........................3.10)

$\Delta P_{it} = \Pi P_{it-1} + \varepsilon_t$…………………………………………………........................(3.11)

Where P_{it} and ε_t are $(nx1)$ vectors;

A_1 is an (nxn) matrix of parameters;

I = an (nxn) identity matrix; and $\Pi = (A_1 - I)$ matrix.

Such that the rank of (A_1-I) matrix equals the number of co-integrating vectors. The crucial thing to check is whether (A_1-I) consists of all zeros or not. If it does, that implies that the ΔP_{it} in the above model are unit root processes, and there is one linear combination of (P_{it}) which is stationary, and hence the variables are not co-integrated (Johansen, 1988). The technique produces two statistics, one is the test based on trace of the stochastic matrix, second is the likelihood ratio test based on maximal eigenvalue of the stochastic matrix.

According to Utkulu (1994) the standard approach to the Johansen ML procedure is to first calculate the Trace and Maximum Eigen value statistics, then compare these to the appropriate critical values.

These tested can be represented as follow as in Utkulu (1994):

$\lambda_{trace}(r) = -T\sum_{j=r+1}^{n} \ln(1-\hat{\lambda}_j)$..(3.12)

$\lambda_{Max^{r,r+1}} = -T \ln(1- \hat{\lambda}_{r+1}$ ....(3.13)

Where $\hat{\lambda}_j$ is the estimated values of the characteristic roots (eigenvalues) obtained from the estimated π matrix; and *T* is the number of usable observations. The Trace statistic tests the null hypothesis that co-integration rank is equal to *r* against the alternative that the co-integration rank is equal to *r*+1. While the maximum Eigen-value statistic tests the null hypothesis of *r* co-integrating vectors against the alternative of *r* +1 co-integrating vectors. Both tests have the null hypothesis that there are at most *r* co-integration vectors and the procedure for determining the number of co-integrating vectors follows a sequential procedure.

First, the null hypothesis H_0 ($r_0 = 0$) against alternative hypothesis H_1 ($r_0 > 0$) is tested. If this null is not rejected then it is concluded that there are no co-integrating vectors among the n variables. If H_0 ($r_0 = 0$) is rejected then it is concluded that there is at least one co-integrating vector and the process proceeds to test H_0 ($r_0 = 1$) against H_1($r_0 > 1$). If this null is not rejected then it is concluded that there is only one co-integrating vector. According to Alexander (2001) when a test is not rejected, stop testing there and that value of r is the commonly-used estimate of the number of co-integrating relations.

It is important to note that the asymptotic null distribution of likelihood ratio trace(r_0) and likelihood ratio max(r_0) follow a non-standard distribution but instead a multivariate version of the Dickey-Fuller unit root distribution which depends on the dimension $n-r_0$ and the specification of the deterministic terms (Utkulu, 1994). Critical values for this distribution are tabulated in Osterwald-Lenum (1992) for $n-r_0$ =1,...,10 and are usually given by computer programmes. In some cases Trace and Maximum Eigen-value may yield different results and Alexander (2001) indicates that in such cases the results of trace test should be preferred.

The JML approach has an advantage over the Engle-Granger approach because it provides a systems-based approach instead of single equation-based approaches to estimate the long-run equilibrium (Johansen,1988 and Johansen and Juselius, 1990). In addition, the JML method provides not only the direct estimates of the co-integrating vectors but also enables to construct tests for the order (or rank) of co-integration, r and it is commonly acknowledged that the statistical properties of the JML are generally better and of higher power compared to the Engle and Granger procedure (Utkulu, 1994). Therefore, This study uses the Johansen's Maximum Likelihood method as in Greb *et al*. (2012) and Minot (2010) .

3.2.3 Analyzing Price Transmission

In case Johansen test indicates that there is a long-run relationship between the two variables then there will exist an ECM relating these variables. The vector error-correction model (VECM) is an extension of the VAR models which relates the current levels of a set of time series to lagged values of those series (Engle and Granger, 1987). According to Minot (2010) and (Greb, *et al*. 2012) the interactions between international or world prices and domestic price take the following VECM form:

$$\Delta P_t^d = \alpha_1 + \theta_1\left(P_{t-1}^d - \beta_1 P_{t-1}^w\right) + \delta_1 \Delta P_{t-1}^w + \rho_1 \Delta P_{t-1}^d + \varepsilon_t \text{.......................................(3.14a)}$$

$$\Delta P_t^w = \alpha_1 + \theta_1\left(P_{t-1}^w - \beta_1 P_{t-1}^d\right) + \delta_1 \Delta P_{t-1}^d + \rho_1 \Delta P_{t-1}^w + \varepsilon_t \text{.......................................(3.14b)}$$

In matrix form and allowing for more than one lag of the price difference terms, the above VECM equations can be written as:

$$\begin{bmatrix} \Delta P_t^d \\ \Delta P_t^w \end{bmatrix} = \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix} \begin{bmatrix} 1 & \beta_1 \end{bmatrix} \begin{bmatrix} P_{t-1}^d \\ P_{t-1}^w \end{bmatrix} + \sum_{t=1}^{k} \begin{bmatrix} \delta_{1t} & \rho_{1t} \\ \delta_{2t} & \rho_{2t} \end{bmatrix} \begin{bmatrix} \Delta P_{t-i}^w \\ \Delta P_{t-i}^d \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{1t} \end{bmatrix} \text{.........................(3.15)}$$

Where; P_t^d is the domestic price; P_t^w is the world price; and α, θ, δ, and ρ are the parameters to be estimated. Following Minot (2010) the values and expected signs of the coefficients in the error-correction model above can be interpreted as follows:

The co-integration factor (β) is the long-run elasticity of the domestic price with respect to the international price. β is the long-run elasticity of price transmission. The expected value for imported commodities is 1>β>0, Thus, if β=0.5, this implies that 50 percent of the proportional change in the international price will be transmitted to the domestic price in the long run.

The error-correction coefficient (θ) reflects the speed of adjustment. It is normally expect to fall in the range of -1< θ <0. The term in parentheses represent the deviation or “error” between the prices in the previous period and the long-run relationship between the two prices. If the error is positive (the domestic price is too high given the long-term relationship), then the negative value of θ helps “correct” the error by making it more likely that the$\Delta P_t^d$is negative. The larger θ is in absolute value (that is, the closer to -1), the more quickly the domestic price (p^d) will return to the value consistent with its long-run relationship to the world price (p^w).

The coefficient on change in the world price (δ) is the short-run elasticity of the domestic price relative to the world price. In this case, it represents the percentage adjustment of domestic price one period after 1 percent shock in international price. The expected value is $0<\delta<\beta$.

The coefficient on the lagged change in the domestic price (ρ) is the autoregressive term, reflecting the effect of each change in the domestic price on the change in domestic price in the next period. The expected value is $-1<\rho<1$.

From the perspective of empirical price transmission analysis, (Greb, *et al*. 2012) argue that the main advantage of the VECM over the standard VAR model is that it separates the long-run equilibrium (or 'co-integrating') relationship between P^d and P^w which is captured by the error correction term$\left(P_{t-1}^{d} - \beta_1 P_{t-1}^{w}\right)$ from the short-run dynamics ensuring that any deviations from this long run equilibrium are only temporary. In order words, The VECM indicates that any short term fluctuations between independent and dependent variable will give rise to a stable long run relationship between the variables (Alexander, 2001).

Because most SSA countries, Rwanda included, are considered to be "small countries" in the staple food crop markets hence are price takers in the world staple food market there is little importance in testing the effect of domestic prices on world prices (Minot, 2010). Thus the part of the VECM that is interesting in the context of this study is the equation (3.14a), which estimates only the effects of the world prices on domestic markets. Following Minot (2010) methodology such that from the above general form (3.14a), following four models are estimated and all prices are converted into logarithms, so that coefficients can be interpreted as elasticities.

$$\Delta P_t^{Butare} = \alpha_1 + \theta_1\left(P_t^{Butare} - \beta_1 P_t^{Thai}\right) + \delta_1 \Delta P_t^{Thai} + \rho_1 P_t^{Butare} + \varepsilon_{1t} \ldots\ldots\ldots \text{(3.16a)}$$

$$\Delta P_t^{Kigali} = \alpha_2 + \theta_2\left(P_t^{Kigali} - \beta_2 P_t^{Thai}\right) + \delta_2 \Delta P_t^{Thai} + \rho_2 P_t^{Kigali} + \varepsilon_{2t} \ldots\ldots\ldots \text{(3.16b)}$$

$$\Delta P_t^{Ruheng} = \alpha_3 + \theta_3\left(P_t^{Ruheng} - \beta_3 P_t^{Thai}\right) + \delta_3 \Delta P_t^{Thai} + \rho_3 P_t^{Ruheng} + \varepsilon_{3t} \ldots\ldots\ldots \text{(3.16c)}$$

$$\Delta P_t^{Umutara} = \alpha_4 + \theta_4\left(P_t^{Umutara} - \beta_4 P_t^{Thai}\right) + \delta_4 \Delta P_t^{Thai} + \rho_4 P_t^{Umutara} + \varepsilon_t \ldots\ldots\ldots \text{(3.16d)}$$

Where:

P_t^{thai} : is the log of Thailand rice prices at time t

P_t^{Ruheng}: is the log of Ruhengeri rice prices at time t

P_t^{Butare} : is the log of Butare prices at time t.

P_t^{Kigali} : is the log of Kigali of prices at time t.

3.3 Data sources

Price transmission was analyzed using 12 year monthly data from January 2000 to December 2012 for both international and Rwanda rice prices. Rwanda rice prices were, monthly domestic wholesale prices collected for a sample of markets from northern, eastern, southern and central parts of Rwanda. These were four wholesale markets for rice namely Umutara, Kigali, Ruhengeri and Butare. These monthly prices for all the selected markets were obtained from the Directorate of Economics and Statistics, Ministry of Agriculture, Government of Rwanda, which is the official agency for collecting, compiling and maintaining the price statistics for agricultural commodities.

On the other hand, international rice price series data on the same period of January 2000 to December 2012 is from Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization (FAO). GIEWS is an online database that collect countries' basic staples prices around the word. The international rice prices reference used is the Thailand 5 percent broken milled white rice Free On Board (FOB) Bangkok. Thailand prices were chosen   In addition, in order for domestic and international monthly rice prices to be analyzed; Rwanda rice prices in RWF were converted into US dollars using monthly exchange rate collected from the Central Bank of Rwanda. These were monthly exchange rates for the period of January 2000 to December 2012.

3. 5 Data analysis

Descriptive analysis was carried out in this study to characterize rice price patterns in Rwanda. Econometric analyses of stationarity, co-integration and VECM involve the usage of econometric software packages EVIEWS 7 which allows performing different tests on the time series data. In the next chapter descriptive and econometric analyses results are presented and discussed.

CHAPTER 4: RESULTS PRESENTATION AND INTERPRETATION

This chapter presents and discusses the descriptive and econometric results of the study. The descriptive results are presented in the first part of this chapter. The second part presents and discusses the results of the unit root tests, co-integration tests and VECM analysis and the final part discuss the findings in relation to findings of similar studies in the SSA region.

4.1 Description of domestic and international rice markets (objective one)

This section examines the trends in nominal monthly wholesale rice prices in four major rice markets in Rwanda namely Kigali, Umutara, Ruhengeri and Butare and one international rice market (Thailand). The monthly price series for these domestic markets and world reference (Thailand) prices cover the period from January 2000 up to December 2012 which corresponds to 156 observations. The prices are quoted in US Dollars per metric ton (USD/MT).

The table 1 below highlights the mean, standard deviation, minimum values and maximum values of the variables used to assess the international price transmission into rice markets in Rwanda. The mean of Thailand rice price is $332.15 per MT while the mean price of rice in Rwanda ranges between $806.89 USD/MT, $831.83 USD/MT, $ 854.94 USD/MT and $ 835.94 USD/MT for Butare, Kigali, Ruhengeri and Umutara wholesale rice prices respectively. The maximum prices range from $ 800.40 USD/MT Thailand to $ 2172. 79 USD/MT for Kigali.

The minimum prices are $ 147.82 USD/MT, $ 255.40 USD/MT, $389. 87 USD/MT, $425. 68 USD/MT, and $ 480.88 USD/MT for Thailand, Kigali, Butare, Umutara and Ruhengeri respectively. The standard deviation for Thailand is $151.78 USD/MT. The measure of the spread of the distribution is high in the Butare market comparatively to the other Rwanda price series which ranges between $264.99 USD/MT and $ 277.29 for Kigali and Umutara respectively. Examining the mean, maximum and minimum values of the Rwanda and Thailand price series it can be observed that rice prices in Rwanda are more than twice as huge as the world reference price.

Table 4-1: Descriptive statistics for Rice Prices in International and Domestic Markets

Markets	Mean	Max	Min	SD	N
Butare (US$/MT)	806.89	1335.00	389.87	299.66	156
Kigali (US$/MT)	831.83	2172.79	255.40	264.99	156
Ruhengeri (US$/MT)	854.94	1483.93	480.88	273.44	156
Umutara (US$/MT)	835.69	1335.00	425.68	277.29	156
Thailand (US$/MT)	332.15	800.40	147.82	151.78	156

N/B; Max-maximum, min-minimum, SD-standard deviation, Obs-No of observations

Source: Author’s calculations.

As shown in Figure 2 below the trend in rice prices in the five markets show a significant volatility. These fluctuations along the years follow a similar upward trend much of the time in the period of the analysis. However, it is important to note from the figure 1 below, the coincidence of the sharp increase in both international rice prices and domestic prices in 2007 and early 2008. The graph shows that although the series do appear to move together, Rwanda prices appear to experience much often sharp fluctuations than to Thailand ones. In addition, the times Rwandan rice prices are higher than Thailand prices.

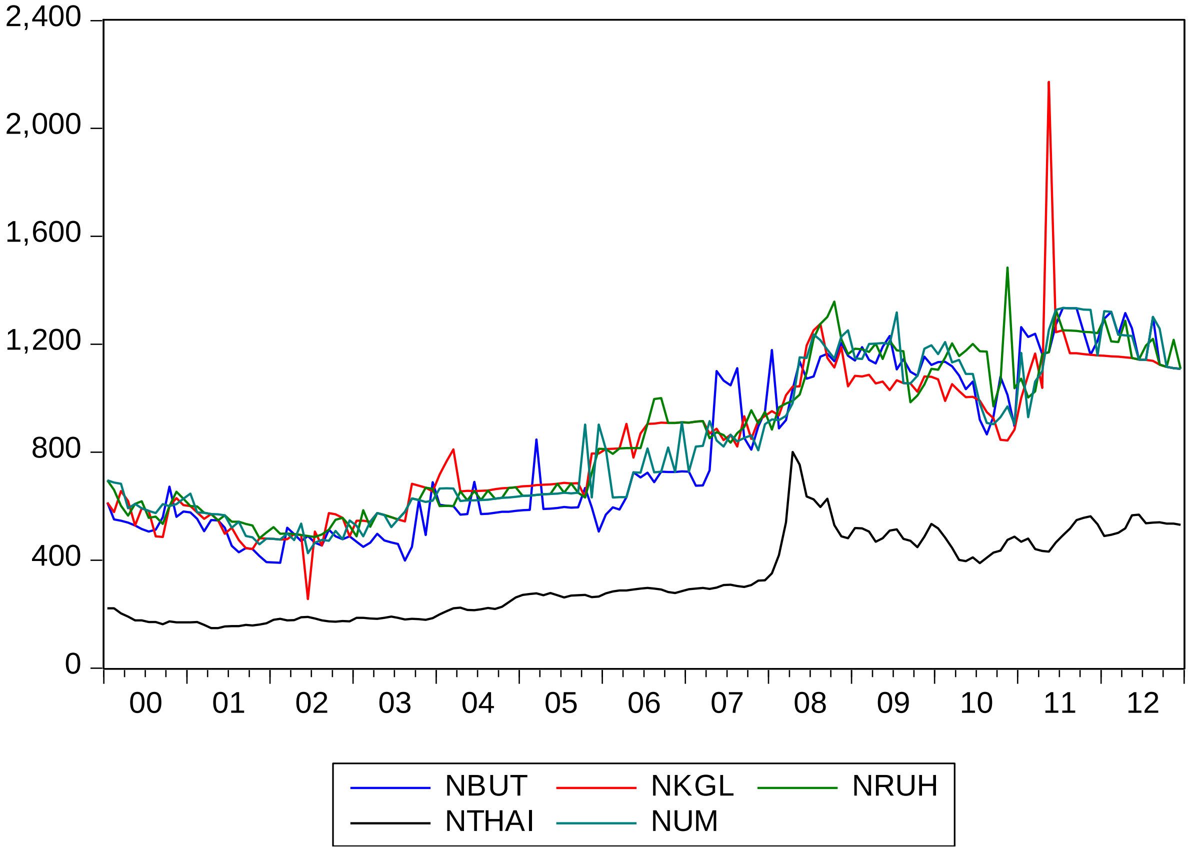

Figure 1: Graph of trend in Domestic and International Prices

The descriptive analysis provides the pattern of rice market prices in Rwanda as compared to international rice prices. However, at this stage, the emerging evidence does not provide any conclusive relationship in the price series. The conclusion from the descriptive analysis and trend analysis of wholesale rice prices in four markets in Rwanda is that these prices are all time higher than international rice prices and are volatile before and after the world food crisis of 2007 and 2008.

4.2 Econometric Analysis of Price Transmission (objective two)

4.2.1 Unit root tests (ADF and Phillips & Perron tests)

Table 4-2: Unit Root Tests (ADF & PP), January 2000 to December 2012

SERIES	Level Series			First Difference		*I*(d)
	ADF	PP	Lags	ADF	PP	
Logarithm of wholesale Rice prices						
Ruhengeri price	-3.39	-3.32	1	-11.55	-17.52	*I*(1)
Kigali price	-3.33	-4.85	1	-20.68	-25.51	*I*(1)
Butare price	-3.05	-3.58	1	-12.04	-20.92	*I*(1)
Umutara price	-3.21	-3.64	1	-20.65	-21.44	*I*(1)
Thailand price	-2.94	-2.82	0	-6.33	-7.50	*I*(0)
5% Critical Values	-3.43	-3.43		-3.43	-3.43	

Source: Author's compution

To test for stationarity in the price series, ADF and PP tests were applied at level and first difference to the logarithmically transformed monthly prices of rice including the constant and the trend. First table 2 above, reports results in levels. the ADF t- statistics results are -3.39 for Ruhengeri, -3.33 for Kigali, -3.05 for Butare, -3.21 for Umutara and -2.94 for Thailand. The PP t- statistics results are -3.32 for Ruhengeri, -4.85 for Kigali, - 3.58 for Butare, -3.67 for Umutara. These results in levels fail to reject the null hypothesis of a unit root at five percent level of significance of -3.45, thus indicating that all the four variables are non-stationary at levels. It can therefore be concluded that both the ADF and PP tests indicate that all five markets have unit roots. the exception was for Thailand which were found to be stationary in level thus integrated of order zero, I(0).

When data series is differenced once, table 2 above shows that ADF statistic became -11.55 for Ruhengeri, -20.68 for Kigali, -12.04 for Butare, -20.65 for Umutara and -6.33 for Thailand. On the other hand PP statistic became -17.52, -25.51, -20.92, -21.44, -7.50 for Ruhengeri, Kigali, Butare, Umutara and Thailand respectively. With five percent level of significance of -2.88, both ADF and PP tests reject the null hypothesis of unit root. The fact that the null hypothesis of the unit root cannot be rejected when the series are in level but can be rejected when the series are in first difference indicate that the series are integrated of order one. This means that each variable is a random walk and integrated of the same order I (1). This is a necessary but not sufficient condition for co-integration. In the next step co-integration analyses of the price variables are undertaken.

4.2.2 Co-integration Analysis (Johansen ML)

The possible co-integrating long run relationship between international rice prices and Rwanda rice prices were carried out using Eviews 7.0. The bivariate analysis consists of testing the number of co-integration vectors. The existence of r number of co-integrating vectors means that the two variables have a long run relationship the absence of which means otherwise. The results of the Johansen ML are given in the table below. In both cases if the statistic is greater than the critical value the null hypothesis is rejected. Referring to section 3.2.2 only when the null hypothesis of no co-integrating vector is rejected that the next null of at least one co-integrating is tested.

Table 4-3: Johansen's Maximun Eigen value and trace test for the number of co-integrating vectors, January 2000 to December 2012.

Butare, Kigali, Ruhengeri and Umutara Rice Markets

H_o	Trace statistic	Trace (95%)	λ_{max}	λ_{max} (95%)
r=0	131.13**	68.52	49.26**	33.46
r≤1	81.86**	47.21	33.34**	27.07
r≤2	48.51**	29.68	31.17**	20.97
r≤3	17.33*	15.41	16.90*	14.07
r≤4	0.43	3.76	0.43	3.76

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

Domestic rice prices co-integration results for the null of no co-integrating vector are Trace test 131.13 and 49.26 for Maximum eigen value. Because both Trace and Maximum eigen statistics are greater than the critical values of 68.52 and 33.46 for Trace and Max tests respectively. The null of no co-integrating vector against the alternative of existence of at least one co integrating vector is rejected. The process proceeds to test the null of one, two or three co-integrating vectors. The tests again reject the null hypotheses of one, two or three co-integrating vectors because the statistic for both tests are greater than the critical values, figures showed in table 3 above.

However, table 3 above shows that the null hypothesis of r = 4, implying the presence of four co-integrating equations among domestic markets against the alternative hypothesis of the presence of four co-integrating equations is not rejected because the statistic for both Trace and Max eigen tests of 0.43 are less than the critical value of 3.76. Based on the co-integration tests, it can be concluded that Rwanda rice markets namely Kigali, Butare, Ruhengeri and Umutara rice prices are co-integrated with presence of three co integrating equations.

Table 4-4: Johansen's Maximun Eigen value and trace test for the number of co-integrating vectors, January 2000 to December 2012.

H_o	Trace statistic	Trace (95%)	λ_{max}	λ_{max} (95%)
1. Butare and Thailand Rice Markets				
r=0	20.56**	15.41	20.14	14.07
r≤1	0.62	3.76	0.62	3.76
2. Kigali and Thailand Rice Markets				
r=0	28.11**	15.41	27.56**	14.07
r≤1	0.55	3.76	0.55	3.76
3. Ruhengeri and Thailand Rice Markets				
r=0	23.24*	15.41	22.9*	14.07
r≤1	0.43	3.76	0.34	3.76
4. Umutara and Thailand Rice Markets				
r=0	22.9*	15.41	22.39*	14.07
r≤1	0.5	3.76	0.5	3.76

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

Butare and Thailand rice prices co-integration results for the null of no co-integrating vector are Trace test 20.56 and 20.14 for Maximun eigen value. Because both Trace and Maximum eigen statistics are greater than the critical values of 15.41 and 14. 07 for Trace and Max tests respectively. The null of no co-integrating vector against the alternative of existence of at least one co integrating vector is rejected. The process proceeds to test the null of one co-integrating vector, the test fails to reject the null hypothesis of one co-integrating vector because the statistic for both tests of 0.62 is less than the critical value of 3.76. Since, the rank is equal to one which is more than zero Butare and Thailand prices are co-integrated.

Kigali and Thailand rice prices co-integration results are 28.11 for Trace test and 27.56 for Maximum eigen value. The null of no co-integrating vector is rejected because both Trace and Max eigen statistics are greater than the critical values of 15.41 and 14. 07. The null of one co-integrating vector against the alternative of at least two co-integrating vectors is tested. The statistic result in table 3 above is 0.55 for both Trace and Max test. The test fails to reject the null hypothesis of one co-integrating vector because the statistics for both tests are less than the critical value of 3.76. Since, the rank is equal to one which is more than zero the conclusion is that Kigali and Thailand prices are co-integrated.

Ruhengeri and Thailand rice prices co-integration results are 23.24 and 22.9 for Trace test and and Maximum eigen value test respectively. The null of no co-integrating vector is rejected because both Trace and Max eigen statistics are greater than the critical values of 15.41 and 14. 07. The test for null of one co-integrating vector against the alternative of at least two co-integrating vectors is therefore tested. The statistic results in table 3 above are 0.43 and 0.34 for Trace and Max test respectively. Because the statistics for both tests are less than the critical value of 3.76, the null hypothesis of one co-integrating vector is not rejected. Since, the rank is equal to one which is more than zero the conclusion is that Ruhengeri and Thailand prices are co-integrated.

Finally, co-integration results for Umutara and Thailand rice prices are 22.9 and 22.39 for Trace test and and Maximum eigen value respectively. Therefore, the null of no co-integrating vector is rejected because both Trace and Maximum eigen statistics are greater than the critical values of 15.41 and 14. 07. The statistic result in table 3 above for the null of one co-integrating vector is 0.5 for Trace and Max test respectively. Because the statistic for both tests is less than the critical value of 3.76, the null hypothesis of one co-integrating vector is not rejected. Since, the rank is equal to one which is more than zero the conclusion is that Ruhengeri and Thailand prices are co-integrated.

Based on the co-integration tests, it can be concluded that the international and Rwanda rice prices are co-integrated. The integration between the international and Rwanda rice prices is possibly due to increased trade (imports) between Rwanda and the world as discussed in chapter one. Some of the policies Rwanda implemented such as regional integration (trade liberalization) account for observed co-integration. In the next section the VECM model is estimated. The presence of only one co integrating vector suggest that though Rwanda rice prices are integrated to international ones that integration is weak. This lead to the estimation of the VECM to quantify how these prices are related.

4.2.3 Transmission of international prices into Rwanda's rice markets

Since domestic rice prices are co-integrated with international prices, an attempt is made to capture long- run and short-run dynamics between international and domestic rice prices by estimating VECM. The long run relationship between Rwanda rice markets namely Butare, Kigali, Ruhengeri, Umutara and the world reference rice prices (Thailand) in the period 2000-2012 is displayed.

Table 4-5: VECM model results

	β_i	θ_i	δ_i	Adj R^2	Fstatistic	AIC
Butare_Thailand	0.82(-15.06)	-0.25(4.29)	0.10(0.78)	0.16	7.01	-3.43
Kigali_Thailand	0.69(-13.61)	-0.28(4.18)	0.19(1.38)	0.29	22.28	-3.29
Ruhengeri_Thailand	0.72(-16.19)	-0.20(4.31)	0.13(1.48)	0.14	9.86	-4.26
Umutara_Thailand	0.74(-16.78)	-0.25(4.54)	0.12(1.15)	0.30	23.43	-3.95

The β_i, θ_i and δ_i are the long-run elasticity of price transmission, the price adjustment, and short-run elasticity of price transmission parameters respectively. The figures in paranthesis are the t-statistic. Source: Author's computation

All wholesale rice markets in Rwanda appear to be linked to world rice markets. The coefficients of the long-run co-integrating equations are all statistically significant indicating that there is a long-run equilibrium relationship between international and domestic prices for those markets. About 82%, 69%, 72% and 74% respectively for Butare, Kigali, Ruhengeri and Umutara represent the variation in the world rice price transmitted. As the estimation is done in logarithms, the percentages from table 6 above can also be interpreted as the long-run elasticities of price transmission(β). These elasiticities suggest that a one percent increase in the world rice prices increases Butare, Kigali, Ruhengeri and Umutara rice prices by 0.82 percent, 0.69 percent, 0.72 percent and 0.74 percent respectively.

The coefficients of the speed of adjustment (θ) are negative for all four markets and statistically significant which confirms the validity of the model. It confirms that the domestic rice prices have an automatic adjustment mechanism by responding to deviations from equilibrium in a balancing manner. These results suggest that it takes 4 months for Butare, 3.5 months for Kigali, 5 months for Ruhengeri and 4 months for Umutara rice prices to adjust to the international prices.

The short-run shocks in international prices (δ) do not have any significant influence on domestic prices because the coefficients of short run adjustments are not significant in all four markets suggesting international prices have no influence on Rwanda's rice markets in the short-run.

4.3 Discussion of the findings

This study findings have support from studies in Africa by Benson, Mugarura, and Wanda 2008; Cudjoe, Breisinger, and Diao 2010; Minot 2011, who found in general a fairly higher price transmission in some African commodity markets and relatively rapid speed of adjustments. The co-integration showed that Rwanda rice prices are integrated among themselves and to international rice price and finally, the VECM analysis showed a higher long run coefficients of transmission are significant.

Abbott and Borot de Battisti (2011) also identify certain patterns, such as much greater price transmission for highly traded commodities (for instance rice) compared to non-tradable ones (millet and sorghum), and higher price transmission rates for import dependent countries, including rice in Senegal, Mali, Burkina Faso, Niger, Malawi and wheat in Ethiopia. This forms the basis for the reason of a near complete pass over of price changes between Rwanda rice markets and international rice prices evidenced by a higher long-run price transmission elasticity between 0.69 a and 0.82.

Many price transmission studies in SSA notably in Ethiopia and Malawi, showed that food prices grew more rapidly than on the world market (Minot 2011). This suggests that other shocks than the world market prices were at play. Similarly, Benson *et al.;* (2008) argue that the increasing food prices in SSA could be better explained by domestic factors rather than by the global food crisis. Similarly to these findings the current study descriptive and trend price analysis shows higher domestic rice prices in Rwanda before, during and after the global food crisis of 2007–2008 which can not solely be attributed to price transmission.

A limited number of warehouses too form part of the poor harvesting. Warehouse owners opt to charge higher storage costs due to demand, thereby leaving out a significant portion of the farmers. Therefore the combination of limited domestic production and tones of rice that decay due to poor post-harvest handling of the crop leaves a big gap between supply and demand hence no option for farmers but to charge a higher price in order to recover the costs they incurred in production. Traders also are compelled to set price quite high due to overwhelming demand from the consumers. Another factor responsible for the high rice prices is the high transportation costs.

Rwanda is still quite undeveloped and consequently has poor feeder roads and rural transport infrastructure generally. This causes the farmers to incur high costs in carrying their produce to the market and also to warehouses. To make matters worse, Rwanda also imports rice because of being unable to meet the country demand. The transports costs are thus bound to be high especially because it is landlocked. Past studies show that it takes five more days to ferry goods to landlocked states compared to coastal countries. In addition, there are delays which are unforeseen and inevitable because rice imports have to pass through several countries where some of areas might be in political volatile situation, hence hindering smooth flow of transport.

Lastly is the situation in which the market is regulated. A regulated market implies that the government or a major value chain actor intervenes in setting prices. Rwanda is to some extent a regulated market and this has contributed to the high price of rice. This is partly due to the factor that rice value chain in Rwanda has big and small players. the former being the millers and traders and the later being farmers. While the government might intervene to protect farmers while millers and traders may have special interest all these intervention impede the efficiency of markets but have little impact on price transmission

Also, during the food crisis, some African countries like Tanzania banned the export of rice to neighbouring countries. Although the effect is difficult to quantify, these restrictions by Tanzanian government could have probably raised rice prices in Rwanda because the country imports a large quantity of rice from Tanzania. In light of the above findings, the conclusion is that international rice prices are well transmitted in Rwanda rice markets . However, Rwanda high rice prices are dominantly the effect of conditions that affect domestic rice supply namely poor harvest, higher transport costs and market regulations not solely a result of price increase in world rice prices.

CHAPTER FIVE

This chapter presents a summary of the study draws some conclusions and makes recommendations. A brief summary of the study is outlined, thereafter conclusions drawn and recommendations made for policy makers in the Rwanda rice market.

5.1 Summary of the study

The study made an assessment of the transmission of international rice prices into the Rwanda's rice market. Thailand was used to represent the international prices owing to its large production of the crop. It was found that rice was the staple food in Rwanda, with the urban population having the higher consumption compared to their rural counterparts. The rapid growth of Rwandan population, their changing lifestyles and rising incomes have caused a rapid increase in rice demand that far outstrip supply because rice production in Rwanda faces a lot of hurdles such poor harvest, high production costs, and inferior quality.

The increase of rice prices in Rwanda before and after the global food crisis which was the highest in Rwanda compared to other regional markets and international markets formed the reason of evaluating whether world prices had a hand in higher rice prices in Rwanda. Because the escalation of prices diverts government funds to purchasing expensive imports (rice) as well as erodes the purchasing power of increasing consumers . Therefore, price transmission analysis which assess the co-movement, dynamics and speed of adjustment and asymmetry of response between price series was necessary in determining if there was relationship between the world prices and rice prices in Rwanda

Price transmission was analyzed using 12 year monthly data from January 2000 to December 2012 for both international and Rwanda rice prices. Four wholesale markets in Rwanda were included in the study : Kigali, Umutara, Ruhengeri and Butare while Thailand prices were used as world reference. The analysis consisted of descriptive and econometric analysis. The descriptive involved the generation of minimum, maximum, mean and graph analysis of the price series. The econometric analysis consisted of three steps. The stationarity test using ADF and PP tests; Co-integration test using the JML approach; and price transmission test using the VECM.

In descriptive analysis, The average price of rice in Rwanda ranges between $ 806.89-854.94 per MT whereas it was only $332.15 per MT for Thailand. Graph analysis showed that rice prices in Rwanda are also all time higher and experiences sharp fluctuations than Thailand prices international prices. The conclusion from the descriptive analysis and trend analysis of wholesale rice prices in four markets in Rwanda is that these prices are all time higher than international rice prices and experience frequent fluctuations before and after the world food crisis of 2007 and 2008. Indicating that insufficiency in supply in domestic markets might be the reason of higher rice prices in Rwanda.

After the descriptive analysis, the econometric analysis was undertaken. First, the stationarity test revealed that the null hypothesis of the unit root cannot be rejected when the series are in level but can be rejected when the series are in first difference indicate that the series were integrated of order one. Second, the co-integration tests, showed that the international and Rwanda rice prices are co-integrated. Such integration is possibly due to increased trade(imports) between Rwanda and the world. however, The study found that even though co-integration existed between the four Rwandan markets and Thailand, but the cointegration was stronger for the domestic markets than between international and Rwanda rice markets.

The VECM established the existence of a long run equilibrium relationship between international prices and domestic prices of the four wholesale markets. About 82 percent, 69 percent, 72 percent and 74 percent respectively for Butare, Kigali, Ruhengeri and Umutara represent the variation in the world rice price transmitted. In addition VECM results suggest that it takes 4 months for Butare, 3.5 months for Kigali, 5 months for Ruhengeri and 4 months for Umutara rice prices to adjust to the international prices. Finally, there was no significant influence of short run shocks in international prices on the domestic markets.

5.2 Conclusion and recommendations

Following the findings of this study below we draw policy recommendations:

1. That Rwandese domestic market prices are integrated among themselves however not well integrated due to the existing of only one co-integrating vector suggesting there is still room to improve that integration and make these markets more efficient. Hence, Rwanda needs to invest in rural infrastructure and information systems such Market Information Systems(MIS) to enable producers, traders and consumers to rationalize their decision of purchase and sale which is a condition of food security of Rwanda populations in various areas.

2. That International rice prices are transmitted to Rwanda domestic markets at a higher rate. This finding has a policy implication because changes in world markets have significant effects to Rwanda markets and reflects high dependency to rice imports. to

promote diversification programs to other staple foods. Diversifying will allow households to substitute toward less expensive staples when the price of rice rises.

3. That the speeds of adjustment are about 3 months. This high speed of adjustment reflects the removal of trade barrier policies and other distortions hence any shock in worked markets is transferred faster requiring the government of Rwanda to promote resilience measures such as safety programs for venerable population and also invest in rice storage to cater for periods of shocks to ensure food security in the country.

5.4 Further Research

Future research is required to include more rigorous methods such as threshold autoregressive and switching regime models. This will give more information regarding how price transmission varies in various trade and policy regimes and give an accurate evaluation of any program or policy intended to capture some structural changes. This was beyond the scope of this study. There is also need to determine the welfare impact of price transmission.

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