SPATIAL INTEGRATION FOR FRESH CASSAVA MARKETS IN CENTRAL MALAWI

BY

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DECLARATION BY CANDIDATE

I declare that this thesis is my own work and effort that it has not been submitted anywhere for any other award. Where other sources of information have been used, they have been acknowledged.

Signature: ____

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CERTIFICATE OF APPROVAL

We declare that this thesis is the student's own work and effort and where he has used other sources of information it has been acknowledged. This thesis has been submitted with our approval.

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DEDICATION

To Emma and Michael for the joy they bring in my life and to my parents for the spirit of hard work and dedication instilled in me.

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ABSTRACT

Over the past decade, there has been an increase in cassava production in Malawi. The overall objective of this study was to examine extent of spatial integration of fresh cassava market in central Malawi and its underlying hypothesis was that fresh cassava markets in central Malawi are not well integrated and not efficient in transmitting price information across spatially located markets.

An analysis was conducted over 17 markets in central Malawi using a co-integration approach (as developed by Engle and Granger, 1987) and a distributed-lag model (introduced by Ravallion, 1986). The study further employed the Granger Causality Error Correction Mechanism and an Index of Market Connectedness to examine the degree of market integration between integrated market links.

Results indicate presence of market integration across spatially located market. However, it is observed that the market is not perfectly efficient in transmitting price information across spatially separated markets. It is further observed that the fresh cassava market within central Malawi is divided into 3 economic markets: [(Chimbiya, Thete, Mitundu, Lilongwe and Nanjiri), (Salima, Mtakataka, Sharpvalley), (Ntcheu and Lizulu)].

The study recommends promotion of farmer’ associations and specialisation in cassava production i.e. producers to specialise either in cassava stem production or root production in order to improve pricing efficiency and that future efforts to analyse efficiency of the marketing system should not isolate stems which would influence a lot in pricing and marketing decision making by producers handling both stems and fresh roots. The study also recommends that any price stabilisation policy interventions by government can be concentrated on one market in each of the economic markets and the effects would be transmitted in the long run to other markets within the same economic market.

1 INTRODUCTION

1.1 Background information on Malawi: socio-economic context

Malawi's economy is highly dependent on agriculture and is constrained by limited natural resources and a rapidly expanding population. The country is land-locked and lacks mineral resource endowments as compared to its neighbouring countries. The country's population is estimated at 12.3 million (UNDP/GoM, 2003). Agriculture accounts for about 34.7 % of GDP (RBM, 2005) and employs about 85 % of the country's population. Agriculture contributes to more than 90 % of the country's foreign exchange earnings. Tobacco, tea and sugar which are the three main agricultural export products, make an average contribution of about 80 % to Malawi's export earnings. Agricultural GDP grew at an average of 2.27 % over the past five years with large swings ranging from -6 % in 2001 to 5.9 % in 2003. The five-year average growth rate is below the officially estimated population growth of 3 % (NEC, 2005).

The agricultural sector is dualistic, consisting of small holder farmers and an estate sub-sector. The two sub-sectors have been historically distinguished on the basis of legal and institutional rules regulating land tenure, type of crops and marketing arrangements. The smallholder sub-sector is based on a customary land-tenure system and is primarily subsistence, providing the bulk of food production. Approximately 80 % of the rural workforce is employed in the smallholder sub-sector and 11 % in estates. However, small land holdings, low productivity, high costs of inputs relative to price received for outputs, erratic rainfall and low levels of income in farm employment are among the factors that affect the sector's ability to feed the population and meet human needs.

Malawi is consistently placed among the poorest 10 countries in the world according to the UNDP Human Development Index (HDI). Poverty is widespread and severe with more than 52.4% of the population considered poor and 22.4 % of the poor reportedly living in extreme poverty according to the 2004-2005 Integrated Household Survey (NSO, 2005). The level of inequality is highly significant with the richest 5 % of the population consuming more than 26 % of GDP and the bottom 20 % consuming about 4.5 % of GDP (UNDP, 2003) during the period from (2001-2004). In 2005, the Gini coefficient was estimated at 0.48 and 0.34 for urban and rural areas respectively. The same year, the country's GDP comprised of mainly agriculture (39 %); manufacturing (11.2 %) and services (43 %). GDP per capita growth rate over the past five years (2001 – 2005) averaged just over 2 %, below the officially estimated population growth rate of 3 %. Consumer price inflation has come down from nearly 45 % in 1999 to the current level of about 15 %, but this is up by 5 % compared with the same time in year 2004.

Administratively, the country is divided into three regions: northern, central and southern regions with Mzuzu, Lilongwe and Blantyre as the respective main regional centres for commerce, trade and government affairs. There are a total of 28 districts in the country. Ministry of Agriculture in Malawi is administratively divided into 8 Agricultural Development Divisions (ADD). The ADD is further divided into Rural Development Projects that are based in each District. Within the RDP, there are Extension Planning Areas which are further divided into Sections that are manned by Extension workers to cover a specific geographical area.

1.2 Spatial pattern of cassava production, consumption and trade in Malawi

Cassava in Malawi is produced mainly for household consumption; as a staple[1] diet to about 30% of the country's population and as a snack or substitute to bread among most households including those in high income category. However the crop has a lot of utilitarian value in confectionary, wood, textile and animal feed industries (Phiri, 2001). Additionally, cassava flour can be processed into high quality starch, which can further be processed into glucose, fructose and glue. A research conducted by Home Economics/Human Nutrition Department at Bunda College (1999) [2] showed that cassava could be used in preparation of child feeding formulas.

Two broad cassava types exist in Malawi, sweet and bitter varieties. Bitter varieties are mostly grown in the northern region of the country while central and southern regions mostly grow sweet cassava varieties. At household level, bitter cassava is usually, consumed in form of flour. Peeled fresh roots are soaked in earthenware or stationary pond water to soften and ferment. After fermentation, the roots are rinsed with clean water and lignified fiber is removed from the pulp. The pulp is then broken into small pieces or smashed and sun dried. Once dry, they are pound into flour which is used for *nsima*[3] or brewing beer. On the other hand, sweet cassava is either consumed raw, boiled, roasted or sun dried into *makaka*. Fresh roots are peeled before consumption. Dried cassava (*makaka*) is then pound into flour for *msima* in areas where cassava is a staple food. In a study by Phiri (2001) it was observed that about 83% of the fresh cassava is consumed

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[1] Just like most southern Africa countries, maize is the major staple crop for Malawi such that the problem of food insecurity has been for many years analyzed in relation to maize.
[2] One of the constituent colleges of the University of Malawi
[3] A traditional recipe where by cassava or maize flour is cooked in boiling water into a 'dough' and is consumed as main dish alongside vegetables or meat

boiled and eaten as a complement to tea. As such the best attributes for fresh boiled cassava ought to be sweet, starchy and fast cooking.

In recent years, droughts have been persistent and Malawi has been experiencing increased cost of inputs used on traditional food and cash crops especially maize and tobacco. As a result, cassava has been receiving greater attention from many stakeholders mainly because of its ability to tolerate drought, wide geographical suitability, minimum requirement of inorganic fertilizers and environmental friendliness. National production of cassava increased significantly during 1990-2006 period. Malawi Government's promotion of production of drought tolerant food crops is one of the major contributing factors. Cassava production in year 2006 was estimated at 3, 082, 997MT (wet weight) as compared to 2, 794 617 MT in year 2001 while planted area was estimated to have increased from 166, 129 hectares in 1999 to 169, 485 hectares in 2006 (FEWS, 2007). The government, NGOs and research institutions such as IITA/SARRNET intensified an extension campaign for increased production of cassava during this period. Significant research work on the crop has been done in the country especially on the supply side, i.e. development and distribution of improved varieties and agronomic practices. Since 1990's IITA/SARRNET in collaboration with department of extension in the Ministry of Agriculture and also in collaboration with a number of NGOs and civil society have seriously been involved in distributing improved varieties of cassava to farmers.

Despite the increase in production of cassava, its contribution to Malawi's economy remains marginal relative to tobacco, tea and sugar largely due to the subsistence nature of its production and lack of linkage to the industry. According to Phiri (2001), more than 67% of farmers in the country grow cassava. However, the production pattern is not only haphazard and scattered, but the areas grown by individual farmers are on average, small relative to other major cash crops (e.g. tobacco, etc).

Fresh cassava marketing season starts around August and ends around February. Just like most agricultural products, the market is affected by seasonality whereby there is shortage of supply at certain periods of the year. Generally, cassava prices are lower in the middle of the season when supply is high and prices tend to rise towards end of the season when supply is low (Phiri, 2001). As harvesting and marketing season progresses, traders drive long distances to transport cassava from deeper rural production areas to urban centres. This is translated into high cassava prices. However producers do not benefit form this seasonality and price variation because cassava is highly perishable and cannot be stored in its fresh form for a long period of time.

1.3 Problem statement

Since 1990s, efforts to improve cassava production in Malawi have been mainly in improving production of cassava and improvement of product quality through development and dissemination of processing technologies. A lot of research has been conducted on supply side of cassava especially development and distribution of improved varieties and agronomic practices. Subsequently, there has been an increase in cassava production in Malawi. However, despite this increase in production over the past decade, contribution of the crop to Malawi's economy remains marginal. This is mainly attributed to its lack of linkage to industries and haphazard production.

In late 1990s, some of the problems affecting cassava marketing were-small scale and fragmented production units, lack of marketing information among producers and lack of established grades and standards for processed cassava[4]. Strides have been made in formulating standards for processed cassava with Malawi Bureau of Standards introducing Standards for cassava flour. Malawi Government and several NGOs like IDEAA and FEWS have set up market information systems and databases in order to facilitate easy access to prevailing market prices.

Recent research efforts by stakeholders like IITA/SARRNET are to understand the demand side of cassava. Efforts were made to apply a sub-sector analysis on production of cassava in the country. The study utilized cross-sectional data on characteristics and behaviors of players in the cassava commodity chain. This analysis observed that a great bulk of cassava is being traded on the fresh market and is consumed fresh. The analysis further observed that prices for cassava have been rising in Malawi over the past decade. This was attributed to rise in price of bread and other confectionaries which people in urban areas mostly use for breakfast. Resulting from this analysis, further efforts have been put to develop and disseminate processing technologies so as cassava could fill a niche in industrial utilization.

Another study by Mataya *et al* (2001) focused on review of policy on cassava processing, marketing and distribution in Malawi. The study also explored the cassava marketing chain and performance of the cassava market by conducting gross margin analysis as the commodity moves along the chain. The study observed that the cassava market is not characterised, such that at the time of making production decisions, farmers do not have precise information regarding size of the market, range of prices they have to expect and how to locate such markets. It described that production decisions are driven by subsistence

[4] See Proceedings of a workshop on 'Cassava Commercialisation for Economic Development in Malawi' held in May 2001 in Blantyre, Malawi.

concerns. The study further observed that even though the cassava marketing chain is long, there is fair distribution of marketing proceeds among the players in the chain.

Although several studies[5] have been conducted to understand performance of cassava market and transfer of incentives along the commodity chain, all previous studies did not analyze transfer of price incentives across different spatially located markets. An accompanying priority to the understanding of the process of transmission of incentives across the marketing chain is the understanding of how well developed is the cassava market and how incentives are transmitted across spatially different markets, hence this study. The study draws up policy inferences from conclusions arrived at upon analyzing spatial market integration for fresh cassava in central Malawi via co-integration, distributed-lag model, Granger causality and Index of Market Connectedness approaches. Key questions answered by the study are: what is the degree of spatial integration identified with fresh cassava markets in central Malawi? Are fresh cassava markets efficient in transmitting price information from one market to another?

1.4 Justification

The main objective for Malawi government in promoting cassava production is to find a food security crop to address problems experienced with variability of maize production. For over a decade now, significant resources and effort has been put by government, NGOs, international and local research institutions to promote cassava production and marketing in Malawi. Already, the crop provides staple diet to over 30% of the country's population. Resultantly, production and consumption of cassava has significantly increased during the same period.

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[5] Examples include the study by Phiri (2001) and Mataya, *et al.* (2001)

As part of the process, several studies aimed at understanding the factors affecting production, marketing and consumption of the crop have been conducted. Despite these efforts, empirical attestation of some assertions has been scanty especially with reference to cassava in Malawi. One of the key general observations by these studies is that lack of market information by players in the commodity chain has negatively affected production of the crop. Literature on marketing of agricultural commodities has cited price inefficiency as one of the major causes of stagnation of production and lack of competitiveness of most agricultural products. A key aspect in marketing information and price efficiency is the transfer of price signals across spatially located markets.

It was therefore relevant to conduct this study so that the generated empirical evidence provides an insight into fresh cassava market in general and offer particular inferences on how to influence efficiency in the marketing system of fresh cassava. This is necessary as an accompaniment to the efforts applied to improve production of the crop. Testing for spatial market integration enabled identification of groups of integrated market so that further interventions aimed at improving production and marketing of cassava are well focused and directed without duplication.

Since a great bulk of the cassava is traded on the fresh market, this study focused on spatial market integration as distinguished from temporal or vertical market integration. Cassava is harvested from its point of production to urban markets to be sold whilst still fresh. The commodity passes through various middle men at different markets in different geographical locations as it moves from point of production to point of consumption. There is relatively less storage time and processing between point of harvest to point of consumption to warrant effective temporal and vertical integration. Thus, the study was interested to understand the process of transmission of price information from one location to another within the cassava market network in central Malawi.

Majority of the fresh cassava traded on the fresh market is of sweet variety. Within the country, sweet cassava is mostly produced from central and southern regions. However, the study concentrated on spatially distinct markets within the central region because markets in the major cassava producing hotspots of the region had consistent price data series unlike most markets from the southern region.

Literature provides several methodologies for testing spatial market integration. Due to different policy implications of each of the methodologies, this study employed two methodological approaches to examine spatial market integration for fresh cassava root in central Malawi. Firstly, a co-integration approach as suggested by Engle and Granger (1987) aimed at determining long run price relationships between spatially different markets and secondly; a distributed-lag model as developed by Ravallion (1986) providing a restrictive definition of market integration to test a one to one co-movement of prices if price differentials are equal to transfer costs either instantaneously or with lags.

1.5 Objectives of the study

The overall objective of this study was to understand the process of transmission of price information from one distinct spatially located fresh cassava market to another within the cassava market network in central Malawi. Specifically, the following were the objectives of the study:

i. To determine the extent of fresh cassava spatial market integration;
ii. To test causal relationship across spatially separated markets; and
iii. To estimate the degree of integration for the cassava markets.

1.6 Hypotheses of the study

The general hypothesis underlying the study was that fresh cassava markets in central Malawi are not well integrated. The study achieved its objectives by testing the following hypotheses:

i. There is no long run spatial integration of cassava markets;
ii. The cassava market is not efficient in transmitting price information across spatially integrated markets; and
iii. There is no causal relationship among fresh cassava markets

1.7 Thesis Layout

This thesis is organized as follows. In chapter 2, a literature review describing the structure and conduct of fresh cassava market based on previous studies in Malawi is provided. The chapter further describes relevance of understanding spatial market integration, some previous work and theories regarding measuring market integration, linking this to why choice of the two methodological approaches used in this study. Finally, the chapter provides theoretical underpinnings of the two methodological models used in this study. Chapter 3 presents the methodology used to achieve objectives and test hypotheses of this study. The chapter initially describes the study area, followed by sampling frame used, data collection and handling methods; a brief overview of some properties of time series and analytical techniques used to empirically arrive at the conclusions drawn from this study. The chapter also presents some of the limitations of the study. Chapter 4 presents results of estimations for spatial market integration. Chapter 5 draws major conclusions from results of estimations carried out in the study and their policy implications; and finally; Chapter 6 presents recommendations on further analysis of efficiency of the cassava market and policy considerations.

2 LITERATURE REVIEW

2.1 Introduction

Pertinent to the understanding of integration of fresh cassava market in central Malawi is how, in particular, the cassava market is structured and how it is functioning within central region of Malawi. This chapter describes the structure and conduct of fresh cassava market based on previous studies in the country. Thereafter, the chapter describes relevance of understanding spatial market integration[6], some previous work and theories regarding measuring spatial market integration, linking this to why the choice of two methodological approaches used in this study. Lastly, the chapter provides theoretical underpinnings of the two methodological models used in this study.

2.2 Cassava marketing in Malawi

Cassava provides a staple diet to over 30% of the population in Malawi (Phiri, 2001); however, its contribution to Malawi's economy has been marginal relative to tobacco, tea and sugar. According to Mataya *et al* (2001), fresh cassava or its various processed forms have only been marketed domestically, as a substitute to bread among most low to middle income households in both the rural and urban areas of Malawi.

Two main market channels for cassava in Malawi exist. First channel is the fresh market where the bulk of marketed cassava falls. In 1999, it was estimated that the fresh cassava market takes up about 80% of market share whilst industrial utilization takes up the remaining 20% share (Moyo, Benesi and Sandifolo, 1998).

[6] It should be noted that market integration can be understood from three forms: spatial market integration; temporal market integration; integration across price form and integration across product form. For the purposes of this study, interest is on spatial market integration.

Marketing systems for cassava comprises of producers, traders (middlemen/wholesalers, retailers), transporters and consumers. Fresh cassava moves from producers to traders (along side transporters) and then to consumers. In the fresh market, farmers are the producers who are involved in cassava cultivation. Middlemen/wholesalers perform all functions and activities that involve movement of fresh cassava from the producers to consumers. This movement is facilitated by transporters who offer public transports, vehicles and oxcarts for hire (Phiri, 2001). According to the same study by Phiri (2001), once cassava is on the market, retailers normally buy small quantities from the middlemen/wholesalers or producers and resell in local markets, roadsides or at working premises. The cassava is sold either raw or boiled. Some producers act as retailers whereby they harvest cassava and sell it by themselves on the fresh market in urban and rural market centers. Transport systems used by middlemen to move cassava from local areas (rural areas) to the urban markets include head-loads, bicycles, oxcarts and vehicles.

Mataya *et al* (2001) observed that due to the involvement of a lot of people in the marketing chain, fresh market for cassava provides a lot of employment opportunities. He further observed that even though the cassava marketing chain is long, there is fair distribution of marketing proceeds among the players in the chain. For example, based on price data collected from two markets in 1995 and 2000, it was estimated that producers earned 61.5% and 57.1% of the final consumer price for cassava in 1995 and 2000 respectively. The traders margin as been estimated at 25% for both years.

2.3 Geographical markets and the concept of market integration

Market integration concerns free flow of goods and information-and thus prices-over form, space and time and this is thus closely related to concepts of efficiency

(Barrett, 1996). Vertical market integration involves stages in marketing and processing channels; spatial integration relates spatially distinct markets, and inter-temporal integration refers to arbitrage across periods.

In agriculture, geographic markets are of particular importance because agricultural products are typically bulky and/or perishable. Often times, areas of production and consumption are separated and transportation is costly. According to Sexton, Kling and Carman (1991), the geographical boundaries of a market are important in measurement of supply and demand, in price discovery and in the structure of competition. As indicated by Sexton, Kling and Carman (1991) contemporary studies of economic markets (and definitions of a market) are usually based on the fundamental definitions of Cournot and Marshall whereby; two regions are in the same economic market for a homogeneous good if prices for that good differ by exactly the inter-regional transportation cost.

Other authors describe this same arbitrage concept as an indication that the law of one price holds between the two regions (Carter and Hamilton, 1989) or that the regional markets are integrated (Goodwin and Schroeder, 1990). A more direct description is provided by Baulch (1997) as follows: two product markets within a country are said to be spatially integrated if; when there is trade between these markets, price in the importing market equals the price in exporting market plus transport and other transfer costs of moving the product between these two markets, without implying that the markets are competitive. Goletti, Ahmed and Naser (1994) define spatial market integration as the co-movement of prices, and more generally, spatial market integration refers to the smooth transmission of price signals and information across spatially separated markets. If two markets are integrated, a shock to the price in one market should be manifested in the other market's price as well. Among perfectly segmented markets, price series should be independent (Barrett, 1996).

Failure of two or more regions to adhere to the law of one price may be explained by several reasons. According to Ravallion (1986) there are impediments to efficient arbitrage such as trade barriers, imperfect information or risk aversion. Spiller and Huang (1986) describes the regions not to be linked by arbitrage i.e. they represent autarkic markets while Faminow and Benson (1990) suggest that there is imperfect competition in one or more of the markets. Sexton, Kling and Carman (1991) pointed out that existence of imperfect competition is of relevance because a normative conclusion often drawn from market integration analysis is that observance of the Marshallian arbitrage condition across markets implies existence of efficient, competitive arbitrage forces though this conclusion is justified only for the proto-type point-space trading model wherein effectively, all buyers and sellers (within a region) are located at a single point (Faminow and Benson, 1990).

Several authors have advanced different reasons for studying market integration. According to Goletti, Ahmed and Naser (1994), studies on market integration makes it possible to identify groups of integrated markets, so as to avoid duplication of intervention. They argue that; if locations A, B and C are well integrated, government may think of withdrawing or reducing its efforts to influence the price process in those locations. A scarcity in A will be quickly be transmitted to B and C, making it redundant to duplicate the same program in all three locations. Furthermore, if the areas where market A is located experiences a bad harvest, prices will suddenly increase. In market B, there is no reason to assume that a bad harvest has also happened. In the absence of communication flows between the two markets, prices in B would not show any movement. On the other hand, if A and B were integrated, the price in B would also increase. This is because some food would flow from B to A decreasing the available supply in B. At the same time the price in A would be lower than in the absence of market integration. According to Ravallion (1986), if price transmission does not occur, the localised scarcities and abundances may result in excessive strain on the population.

Information on market integration may also provide specific evidence as to the competitiveness of markets: the effectiveness of arbitrage (Carter and Hamilton, 1989) and the efficiency of pricing (Buccola, 1985). According to Delgado (1986), a well-integrated market system is essential to household food security in both food deficit rural areas and those witnessing a rise in the relative importance of non-food cash cropping. He further argues that market integration is key to sustained success of extension of food production technologies, which might otherwise flood stagnant local markets with unusable surpluses. In food grain markets, the degree of market integration determines whether equity-oriented production policies in less favoured food producing areas should be oriented toward food or some alternative activity (Delgado, 1986). Baulch (1997) explains that without spatial integration of markets, price signals will not be transmitted from urban food deficit to rural food surplus areas, prices will be more volatile, agricultural producers will fail to specialise according to long-term comparative advantage, and the gains from trade will not be realised.

2.4 Measures of spatial market integration

Spatial market relationships can be described by prices, trade volumes or both. Sometimes economists establish appropriate aggregation of spatial units by reference to trade volumes; other times they use co-movement among prices from spatially distinct markets (Barrett and Li, 2002). The traditional methodology to study market integration relies on correlations between prices in pairs of regions (Sexton, Kling and Carman, 1991). Past research identified various measures of integration derived from transformation of time series of prices. According to Goletti, Ahmed and Naser (1994), measures for market integration include correlation coefficients; short and long term tests of adjustment; long term multipliers and times to adjust; causality and centrality tests; and co-integration coefficients.

Intuitively, the use of correlation coefficients is related to the idea that integrated markets exhibit prices that move together. This test considers correlation of price series for different markets to indicate an extent to which the markets are integrated (Goletti, Ahmed and Naser (1994). Timmer (1974) and Harris (1979) advanced criticisms of this approach that it masks presence of other synchronous factors such as general price inflation, seasonality, population growth, procurement policy, etc. Goletti, Ahmed and Naser (1994) suggests that one way to take care of this criticism is to consider correlation of price differences, which has the attractive property of interpreting market integration as interdependence of price changes in different markets. Furthermore, Goletti, Ahmed and Naser (1994) contend that price change would largely eliminate common trends that introduce spurious correlations. However, besides problems of spurious correlation, there are other serious problems related to the often non stationary nature of the price series involved. To overcome these problems, a co-integration approach was developed.

Co-integration analysis is concerned with the existence of a stable relation among prices in different localities. According to Engle and Granger (1987), a time series wander extensively. Prices move from time to time, and their margins are subject to various shocks. When a long run linear relation exists among different series, these series are said to be co-integrated (Engle and Granger, 1987). The presence of co-integration is an indicative of interdependence; its absence indicates market segmentation. According to Goletti, Ahmed and Naser (1994), a segment link is one where co-integration is rejected in both directions a long which a link can be traced, where as an integrated link is one where co-integration is accepted in both directions. In order to overcome the problems of non stationary in the price series, Engle and Granger (1987) suggests de-trending the series through differencing to make it stationary i.e. the series not to have systematic trend, no systematic change in variance and strictly no periodic variations or seasonality (see Engle and Granger, 1987).

Ravallion (1986) observed that there are inferential dangers in the bivariate modelling of static price series taking the form of correlations described above where by bivariate or regression coefficients are estimated between time series of spot prices for an otherwise identical good or bundle of good. It is not enough to say that markets are integrated; one would like to know the extent of integration (Goletti, Ahmed and Naser, 1994). According to Goletti, Ahmed and Naser (1994), the main issue becomes that of measuring magnitude of price transmission. The authors argue that immediate impact of price shocks should be distinguished from the impact that builds over time. Ravallion (1986) contends that the same data, the static bivariate method can be readily extended into a dynamic model of spatial price differentials. He argues that by permitting each local price series to have its own dynamic structure (and allowing for any correlated local seasonality or other characteristics) as well as an inter-linkage with other local markets, the main inferential dangers of the simpler bivariate model can be avoided. The dynamic model has the advantage that one can distinguish between the concepts of instantaneous market integration and the less restrictive idea of integration as a long run target of the short run dynamic adjustment (Ravallion, 1986).

Further research studies on spatial integration of markets suggested that the above considered approaches to testing of market integration confuse market equilibrium and market integration (Barrett and Li, 2002). These authors argue that analysis of prices tell little or nothing about actual trading behaviour. They contend that a further complication that arises with respect to co-integration, error correction and Granger causality methods is that the methods are unreliable under a variety of commonly occurring conditions, such as when trade is discontinuous or bidirectional or when transaction costs are non stationary. According to Barrett (1996), simple bivariate correlation coefficients require filtering to eliminate bias towards spurious integration due to common exogenous trends (e.g. general inflation) common periodicity (e.g. agricultural seasonality) or autocorrelation. On the other hand, contemporaneous correlation tests may overestimate segmentation is lags in information, delivery or contract expiration produce a natural lag in the price response between markets (Barrett, 1996). He further argues that these approaches fail to recognise heteroskedasticity common in price data of reasonably high frequency. Delgado (1986) observed that methodologies still being used in measuring market integration are based on pair-wise comparison of price series, albeit with greater attention to de-trending and weighting of observations. He then argues that what matters is that the system of markets is integrated and not that particular pair be integrated at any one time.

Baulch (1997) contends that measures of market integration based on co-movement of prices fail to recognise the pivotal role played by transfer costs. He observed that many researchers make erroneous assumption concerning the continuity of trade flows between markets and the nature of price formation in multi-market systems. In consequence, food markets that are well-functioning are often diagnosed as exhibiting incomplete and/or lagged price adjustment (Baulch, 1997). Gonzalez-Rivera and Hefland (2001) argued that prices in an integrated spatial market are determined simultaneously in numerous locations such that using bivariate correlation of prices would be difficult to determine which locations belong to the same market and the exercise may lead to inconclusive results.

The main inference from arguments against bivariate correlation of price series is that the methodology disregards trade flow data and transfer costs which are necessary in explaining the relationship between spatially located markets experiencing discontinuous or bi-directional trade. Based on these arguments, several methodologies have been suggested to measure integration of spatial markets. Barrett and Li (2002) proposed a methodology based on maximum likelihood estimation of a mixture distribution model incorporating price, transfer cost and trade flow data. They argue that: since traditional spatial price analysis methods typically confuse *market integration* reflecting tradability of products between spatially distinct markets, irrespective of existence or absence of spatial market equilibrium and *competitive market equilibrium* in which extraordinary profits are exhausted by competitive pressures regardless of whether this results in physical trade flows between the two markets; the maximum likelihood estimation will distinguish the two concepts (Barrett and Li, 2002).

According to Baulch (1997), transfer costs (comprising transportation, loading and unloading costs and trader's nominal profit) determine parity bounds within which prices of a homogeneous commodity in two geographically distinct markets can vary independently. He therefore suggests Parity Bound Models (PBM) to assess the extent of market integration by distinguishing three possible trade regimes: Regime 1 at the parity bounds (in which spatial price differentials equal transfer costs); Regime 2 inside the parity bounds (in which price differentials are less than transfer costs); and Regime 3 outside the parity bounds in which price differentials exceed transfer costs (Baulch 1997). Considering scarcity of time series data on transportation charges and other elements of trader's transfer costs, Baulch (1997) argues that inter-market price spreads can be compared with exact information on transfer costs obtained from structure-conduct-performance study or by interviewing traders, and it is possible to establish probabilistic limits within which the spatial arbitrage conditions can are likely to be binding in other periods.

Nevertheless, each approach (based on price or trade flow) has important shortcomings. Analysis based on trade volumes can not establish whether spatial equilibrium conditions hold and thus whether trade exhausts all rents to arbitrage so as to ensure Pareto efficiency while analysis of prices tells little or nothing about actual trading behaviour (Barrett and Li, 2002). Sexton, Kling and Carman (1991) observed that arbitrage models must be chosen and interpreted carefully relative to the trade and market structure characteristics of the product under study.

Given the cassava market structure in central Malawi as described above, there are a lot of unobservable and immeasurable transaction costs in marketing of fresh cassava. This; coupled with unavailability of time series data on trade flows and transfer costs among cassava markets under study, employment of suggested methods incorporating this data was not possible. Following Baulch (1997), it was inadvisable to estimate transfer costs based on inter-market price differentials in case trade flows between two markets were infrequent but occurred regularly between each of the two markets and a third market. In such circumstances, price differentials between the first two markets do not reflect cost of moving produce between them (Baulch, 1997). The Co-integration approach as suggested by Engle and Granger (1987) and distributed lag model proposed by Ravallion (1986) were therefore used in this study to evaluate extent of market integration in fresh cassava markets in central Malawi. Consideration was made on differences in policy inferences made from results of the two approaches and availability of relevant time series data. It is deemed necessary to cautiously use available data series than guess extend of market integration for such an important crop to Malawi.

2.5 Theoretical Definition of Co-integration Model: Engel and Granger[7] (1987)

Co-integration analysis is concerned with the existence of a stable relation among prices in different localities. According to Engle and Granger (1987), a time series wander extensively, yet some series may be expected to move so that they do not drift too far apart. When a long run linear relation exists among different series, these series are said to be co-integrated (Engle and Granger, 1987). It is of interest to measure if a set of variables are co-integrated because of the economic implications such as whether some system is in equilibrium in the long run and it might be sensible to test such hypothesis before estimating a multivariate dynamic model (*ibid*).

If each element of a vector of time series x_t first achieves stationary after differencing, but a linear combination $\alpha' x_t$ need not to be differenced, the time

[7] Literature suggests two main approaches for testing of a co-integrating relation between time series. First, proposed by Engle and Granger (1987) using a two stage-step procedure to test for co-integration using Augmented Dickey-Fuller test. Second is the maximum likelihood procedure of Johansen (1988) which relies on the relationship between the rank of a matrix and its characteristic roots. This study employed the Engle and Granger procedure due to its simplicity in estimation and its wide usage

series are said to be co-integrated with co-integrating vector α (Engle and Granger, 1987). In presenting the same concept, Greene (2003) states that if a series X_t is non-stationary but its first difference is stationary, then it is said to be integrated of order one or simply integrated, and could be represented as $X_t \sim I(1)$[8]. Otherwise, if the X_t is stationary, it is said to be integrated of order zero and denoted as $X_t \sim I(0)$. If two time series X_t and Y_t are both I(1), then in most cases the linear combination $Y_t - \alpha - \beta X_t = \mu_t$ is also I(1). But it is possible that μ_t is stationary or I(0). If the two series are both I(1), then there may be β such that, $\mu_t = Y_t - \beta X_t$ is I(0).

Interpreting $\alpha' x_t = 0$ as a long run equilibrium, co-integration implies that deviations from equilibrium are stationary, with finite variance, even though the series themselves are non stationary and have infinite variance (Engle and Granger, 1987). Intuitively, if the two series are both I(1), then this partial difference between them might be stable around a fixed mean. The implication would be that the series are drifting together at roughly the same rate. Two series that satisfy this requirement are said to be co-integrated (Greene, 2003). Granger and Weiss (1983) state that a necessary and sufficient condition for co-integration is that the coherence between the two series is one at zero frequency. Presence of co-integration between two series is indicative of interdependence; its absence indicates market segmentation. In particular, a segmented link is one where co-integration is rejected in both directions along which the link can be traced, where as an integrated link is one where co-integration is accepted in at least one direction[9]. This argument follows Engle and Granger (1991).

[8] Integration or economic integration here means the number of times the series needs to be differentiated before attaining stationarity

[9] See also Ngugi (1991) edited by Edriss, A. (2003)

Once presence of co-integration between two cassava price series is established, then the relationship between the two series can be represented as an Error Correction Mechanism (ECM) (Engle and Granger, 1991). The idea is simply that a proportion of the disequilibrium from one period is corrected in the next period (Engle and Granger, 1987). For example, the change in price in one period may depend upon the degree of excess demand in the previous period. Such schemes can be derived as optimal behavior with some types of adjustment costs or incomplete information (Engle and Granger, 1987).

For a two variable system, a typical error correction model would relate the change in one variable to past equilibrium errors, as well as to past changes in both variables. According to Engle and Granger (1987) for a multivariate system, a general error correction representation in terms of B, the backshift operator, can be defined as follows:

$$A\ (B)\ (1\text{-}B)\ x_t = -yz_{t-1} + u_t \qquad [2.1]$$

Where u_t is a stationary multivariate disturbance, with $A(0) = I$, $A(1)$ has all elements finite, $z_T = \alpha' x_T$, and $y \neq 0$.

In this representation, only the disequilibrium in the previous period is an explanatory variable. However, by re-arranging terms, any set of lags of the z can be written in this form, permitting any type of gradual adjustment toward a new equilibrium (Engle and Granger, 1987).

A number of authors have used the co-integration analysis in the study of market integration. Goletti, *et al*. (1994) employed the co-integration techniques by Engle and Granger (1987) to study integration of wheat and flour markets in Pakistan.

They used retail and wholesale monthly prices for the commodities at various markets in the country. It was found that flour markets are more integrated than wheat markets. It was also found out that magnitude of long term price transmission is over 60% for flour as compared to a low magnitude of 40% for wheat.

Goletti and Babu (1994) also used the same co-integration technique in their analysis of market integration in Malawi. The authors worked with data that covered both the period before and after market reforms. The Augmented Dickey Fuller (ADF) test revealed that all series were I(1) and that most of the markets were integrated with the period after reform having more integrated markets than the period before.

Thapa (2002) also used the co-integration technique to analyze the impact of Real Effective Exchange Rate (REER) on economic activities in Nepal. Based on the standard theories of aggregate demand and aggregate supply in an economy, the author tested the relationship between REER and the Gross Domestic Product (GDP). ADF test revealed that the time series data used for the study were not stationary at log levels but at first log differences and that the series had significant time trend. The results further showed that interest rate is not important to boost economic activities while international competitiveness and labor costs are more significant variables in influencing economic activities in Nepal.

2.5.1 Weaknesses of the Co-integration model

Several authors have criticized the co-integration to be unreliable if: (i) the transaction costs are non-stationary (see Barrett, 1996; and Barrett and Li, 2002; Fackler and Goodwin, 2002). And (ii) if there are reversals in trade flows across markets (Barrett and Li, 2002 and Baulch, 1997). The argument is that if transaction cost is non-stationary, failure to find co-integration between two price series may be consistent with market integration i.e. rejection of co-integration hypothesis may not necessarily mean lack of market integration, it can just be reflection of transfer costs being non-stationary (Barrett, 1996). However, conclusions of available co-integration based studies largely go against this contention. Instead of finding lack of integration, most of the studies conclude in favor of market integration. And these studies conform for countries with very different level of development, including Brazil (Gonzalez-Rivera and Hafland, 2001), Indonesia (Alexander and Wyeth, 1994); Ethiopia, (Dercon, 1995) Kenya, (Ngugi, 1991) Ghana, (Rashid, 2004) and Malawi (Goletti and Babu, 1994). There are some cases, such as Ngugi, (1991) where one or two locations in a given set of markets lack integration, but it is hard to attribute them entirely to the non stationary transaction costs.

Goletti *et al*. (1994) observed that other weaknesses of the co-integration method are that the methodology is not able to say anything about strength of the relationship between the prices series considered as pair of integrated markets; the length of time it takes for a shock to be transmitted from one market to another and the symmetry of transmission of upward and downward price changes. Dynamic representation of spatial market integration as suggested by Ravallion (1986) addresses some of the weaknesses raised against this methodology.

2.6 Theoretical underpinnings of the Distributed-Lag model: Ravallion approach

The distributed-lag model aims at dynamic representation of market integration in order to supplant the imprecision and inferential dangers of static bivariate measures such as co-integration method described above. Literature on market integration such as Blyn (1973) and Harris (1979) argue that suppose that trade is infinitely costly between two market locations but that the time series of prices at the two locations are synchronously, identically and linearly affected by another variable (e.g. price of a related third good traded in a common market or shared dynamic seasonal structure in production), then one can readily express price in one market as a linear function of the price in the other market, with slope of unity, even though the markets are segmented. Ravallion (1986) further observes that any measurement errors or omitted variables would yield imprecision in a test equation based on a static bivariate model, but under those conditions, the static model fails as a test for market integration.

Ravallion (1986) observed that using the same data, a static bivariate method, can be readily extended into a dynamic model of spatial price differentials by permitting each local price series to have its own dynamic structure (and allowing for any correlated local seasonality or other characteristics) as well as an inter-linkage with other local markets. This can assist to avoid main inferential dangers of simpler bivariate model. Furthermore, spurious correlations can also be avoided by filtering the price series prior to calculating pair wise correlations by testing for residual cross correlations amongst univariate ARIMA models of each price series (Haugh, 1976). However, Ravallion (1986) proposed testing market integration conditions as nested hypothesis within an explicit multivariate model of spatial market structure such that alternative hypotheses of market integration and market segmentation are encompassed within a more general model and so tested as restricted forms.

The distributed-lag model targets at distinguishing concepts of instantaneous market integration as a long run target of the short run dynamic adjustments. Ravallion (1986) argues that this distinction is important because in many settings, it will be implausible that trade adjusts instantaneously to spatial price differentials and so one would be reluctant to accept short run market integration as an equilibrium concept. However, given enough time, the short run adjustments might exhibit a pattern which converges to such equilibrium. If the short run integration is rejected, then it would be nice to know if there is any long-run tendency towards market integration.

The Ravallion model makes two assumptions about characteristics of spatial market structure. First, it assumes that there exists a group of local (rural) markets and a single central (urban) market. While there might be some trade among the local markets, it is trade with the central market which dominates local price formation. However, depending on number of local markets and their size, one can also posit that the central market price is influenced by various local prices. Second assumption of the model is that the econometric version representing the first assumption such that it should embody a suitable dynamic structure, as it is well known; dynamic effects can arise from a number of conditions in the underlying behavioral relations including expectation formation and adjustment costs (see also Hendry *et al*. 1984 for a survey of possibilities). Taking into consideration the two assumptions, the basic Ravallion model takes the following form:

$$P_{it} = \sum_{j=1}^{n} a_{ij} P_{it-j} + \sum_{j=0}^{n} b_{ij} P_{1t-j} + X_{it} c_i + \varepsilon_{it}$$

$$(i = 2, \ldots\ldots N) \qquad [2.2]$$

where P_{it} is the price in localized market i in time t; P_{1t} is the price in the central market in time t, P_{1t-j} is the price in the central market in time $t-j$, X_1 is a vector of other influences on the central market, and X_i is a vector of other influences (e.g. inflation index, seasonal dummies) and the ε's are white noise processes.

Ravallion (1986) used this technique in a study on price differentials for rice markets in Bangladesh. The methodology was applied to monthly district level rice price data and was observed that Dhaka appeared to have dominant influence on inter-district rice trade in Bangladesh. The study also suggested quite significant departures from the conditions for both short run and long run market integration; these are not revealed by tests using static correlations.

The Ravallion model was also used in a study of structural market integration for wheat and rye in North and Baltic seas by Jacks (2000). The methodology permitted a clear distinction between short run market integration and integration as a long run tendency in the short run adjustment process. Some markets were identified to be integrated in the long run but rejected short run integration.

In a study on inter-commodity price transmittal for food markets in Ghana, Alderman (1992) expanded the dynamic model of market integration as introduced by Ravallion, (1986). Alderman (1992) investigated one property of an efficient market: the full use of available information. He investigated whether maize prices would be independent of prices of locally produced substitutes. By including price series of commodities that are substitutes to maize, it was observed that in some regions, lagged maize prices do not convey information that is not contained in commodities such as sorghum whilst in other regions, lagged millet prices help to predict market prices for maize particularly during drought periods.

2.6.1 Weaknesses of Ravallion (1986) approach

Ravallion model's radial structure [equation 2.2] assumes price shocks originate from one central (urban) market whose prices are weakly exogenous from those of other markets. Barrett (1996) argues that although market demand shocks may originate in cities, agricultural supply shocks generally have rural roots. Furthermore, inter seasonal flow reversals and direct links between regional markets also violate the radial markets assumption.

Ravallion's model, like most 'Law of One Price' tests also assume constant inter market transfer costs that are either additive or proportional. If transfer costs are actually more complex or time-varying, inference will be biased in favor of accepting the hypothesis of segmented (un-integrated) markets (Barrett, 1996).

3 METHODOLOGY

3.1 Introduction

This chapter describes methods that were used to achieve objectives and test hypotheses of this study. The chapter initially describes the study area, followed by sampling frame used, data collection and handling methods, a brief overview of basic properties of time series and analytical techniques used to empirically arrive at the conclusions drawn from this study. Lastly, this chapter presents some of the limitations of the study.

3.2 The study area

The study focused on fresh cassava markets in central region of Malawi[10]. The region comprises 9 districts and is covered by 3 Agricultural Development Divisions[11] (ADDs) under the Ministry of Agriculture namely: Kasungu ADD, Salima ADD and Lilongwe ADD. The central region covers some of the major cassava producing hot spots producing majority of sweet cassava varieties that are traded on major fresh cassava markets in the country. Markets under this study were: Salima, Dowa, Mponela, Ntchisi, Kasungu, Mchinji, Nsundwe, Lilongwe, Mitundu, Nanjiri, Mkhoma, Sharpvalley, Thete, Mtakataka, Chimbiya, Lizulu and Ntcheu. Choice of these markets was based on availability of plausible price series data with minimal gaps. Figure 3.1 shows special location of the markets under study.

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[10] Malawi is administratively divided into three regions: north, central and south.

[11] Ministry of Agriculture in Malawi is administratively divided into 8 ADDs. The ADD is further divided into Rural Development Projects that are based in each District. Within the RDP, there are Extension Planning Areas which are further divided into Sections that are manned by Extension workers to cover a specific geographical area.

3.3 Sample frame

Secondary data on cassava prices collected over 17 markets listed above, were used in this study. These markets are some of the designated markets by Agro-Economic Survey[12] to collect prices of various agricultural commodities across the country. Price data were collected from January 2004 – January 2006 period. The data were collected using Ministry of Agriculture extension workers based at Extension Planning Areas situated close to these markets. The Agro-Economic Survey is also collecting production figures for various commodities around the same markets. Cassava price data is collected per kilogram of fresh weight. Data series are available on weekly basis from 1989 for some markets; however, the period from January 2004 has consistent series for markets in question.

[12] Agro-Economic Survey works hand in hand with Famine Early Warning System department of economic planning and development. Currently Agro-economic survey is conducting market surveys, collecting price data for various agricultural produce in local markets, production of various agricultural commodities, etc across the county

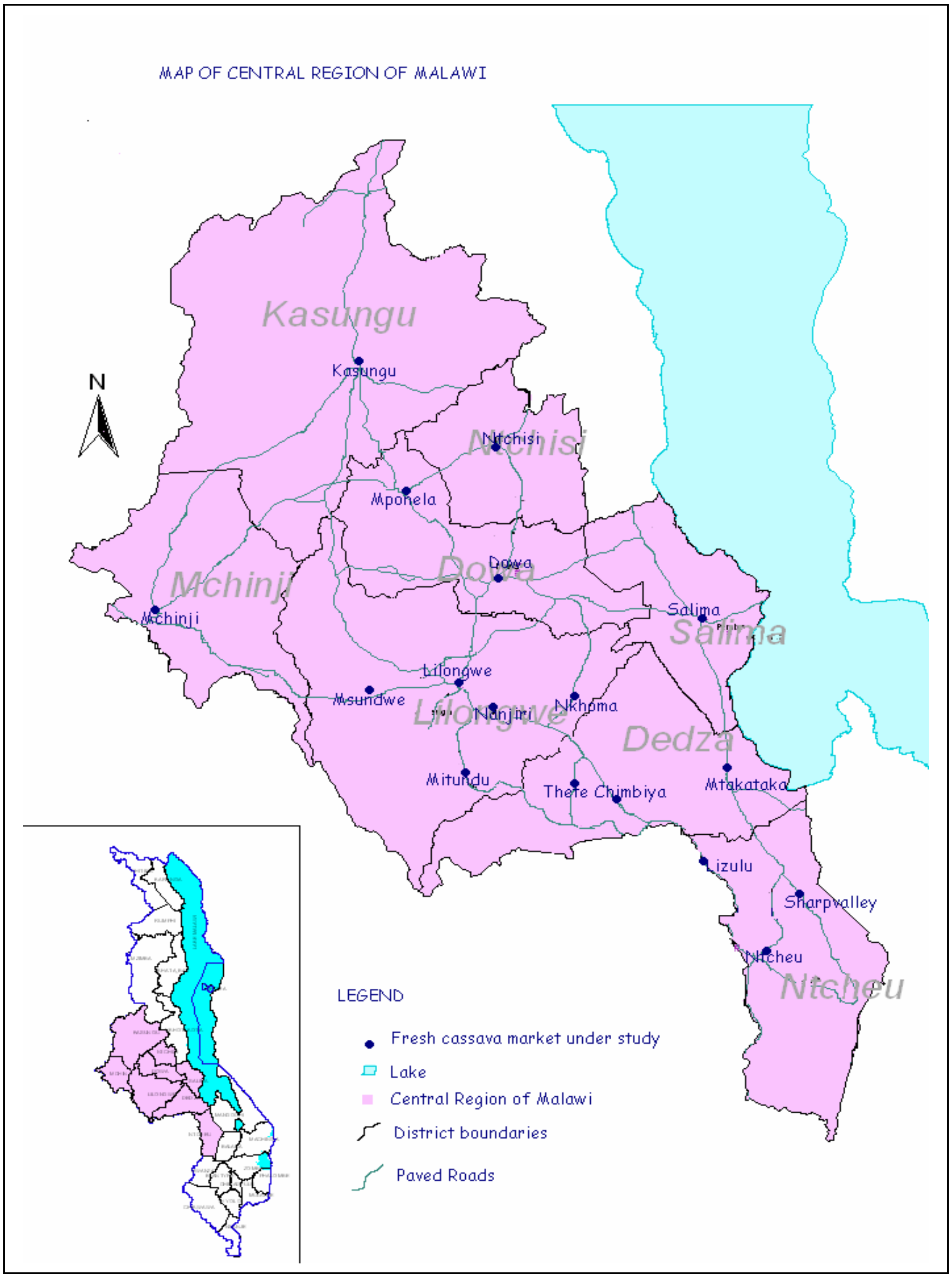

Figure 3.1: Map of central Malawi showing spatial location of fresh cassava markets

3.4 Data collection and handling

After secondary data sets were collected from Agro-Economic Survey, individual series were plotted over time and plots were used to clean the data by adjusting[13] data points more than two standard deviations away from the weekly mean. Within the data sets, existing few missing observations were approximated by linearly interpolating and extrapolating[14] (see Goetz and Weber, 1986) values from a complete nearby market by comparing trend of the adjacent plots.

Price series were further deflated using 2006 Consumer Price Index (year 2000=100) obtained from National Statistical Office in Zomba. Deflation of the price series was carried out for several reasons. Firstly it enabled the analysis to deal with "real prices" i.e. cassava prices relative to the price of other commodities in the economy. This was also carried out to determine if the nominal price series contained significant trend and to know if it was caused by inflation or by a natural trend in the real prices. Secondly, deflation fulfilled some statistical standards. Considering that standard regression analysis with least squares assumes homoscedasticity[15] of the random error term, two offsetting factors could have affected variance of the error term in the data series; on one hand, improved price measurement techniques and consistency of measurement of cassava weight by data collectors could reduce variance of the error term (difference in measurements by different people and inconsistency in price collection could affect/increase variance of the error term). On the other hand, if the prices rose over time, then the higher absolute deviations of prices from the

[13] The period understudy (January 2004 to January 2006) was fairly short due to unavailability of "clean" data. It was therefore better to adjust outliers than flagging them as missing values.
[14] Though subjective, it was acceptable to hypothesize that prices of the same commodity in adjacent market tend to be moving in unison based on concept of spatial arbitrage. This was used to interpolate where two to three missing variables were present.
[15] i.e. the variance of the random error term is constant and not correlated with the independent variables

trend line would also have led to a higher variance of the error term. Deflating of the price series therefore in general reduced the magnitude of the prices, thereby reducing also the variance of the error term. Further more; deflation was carried out to adjust for auto-correlation[16] among error terms of the time series.

However, it should be mentioned that preliminary assessment of the price series included assessment of both nominal and real prices due to the market extension nature of the preliminary price series assessment. Deflated prices only would have been meaningless to farmers and other marketing agents who understandably are more concerned with current or "inflated" prices because that is the price they receive today for their commodities.

The study was interested in distinguishing between inter-year variability and intra-year variability. In the first case, interest was in measuring fluctuations around some long-term trend of prices while in the second case, interest was in understanding what happens in each year, season or month. As it is well known, most agricultural production is characterized by seasonality related to agronomic cropping patterns, it was necessary to have a clear idea of how variability was differing over time and space. This insight was useful in order to understand price behavior within the study period. Data series were used to construct an aggregate series for the whole central region of Malawi. This involved averaging of weekly prices over time and space. The aggregate series is presented in this report as "mean regional price."

In order to have a preliminary picture of efficiency of arbitrage over space, correlation of price series from the different markets was performed. Based on the

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[16] Whereby error terms in one period depend on errors on another period; this could have lead to bias in estimated variance of regression coefficient in subsequent analyses.

concept of arbitrage, if markets are indeed competitive, efficient and integrated, the expectation is that prices for the same product in two different markets within the region will exhibit similar patterns of price behavior (Golleti *et al*. (1994).

Several studies have used correlation of price series between different markets to test for market integration. In a study on integration of wheat markets in Pakistan, Golleti *et al*. (1994) applied this technique to test for correlations of wheat and flour at wholesale and retail level. They found that retail flour prices exhibited a higher correlation of price differences than at wholesale level. Golleti *et al* (1994) also used the same technique to study rice markets in Bangladesh. Ngugi (1991) also employed the methodology to assess integration of Kenyan maize markets and observed that 91% and 100% of the market links showed significant correlation during pre-liberalization and post liberalization period respectively. However, using the co-integration model, only 14% and 19% of the links were found to be co-integrated.

According to Golleti *et al*. (1994), correlation coefficients are not however, a proof of market integration but rather rough indicators of integration and efficiency. Early criticism of this approach was advanced by Blyn (1973), Timmer (1974) and Harris (1979). Some of the recent criticisms of the methodology were advanced by Ravallion (1986) and Delgado (1986) whereby they argue that testing of market integration based on correlation of coefficients of local prices mask presence of other synchronous factors such as general price inflation, seasonality and population growth, etc. Other authors such as Golleti *et al* (1994) argue that this problem can be overcome by computing correlation coefficients based on price differences since price differences would largely eliminate the technical problems related to spurious correlation arising from presence of common trends.

3.4.1 Brief overview of some properties of time series

In simple terms, time series are time dependent processes. These models are generated by stochastic (or random) processes with a structure that can be characterised and described. In other words, a time series model provides a description of the random nature of the stochastic process under study that generated the sample of observations under study. The description is given not in terms of a *cause-and-effect relationship* as would be the case in a regression model; but in terms of how that randomness is embodied in the process. The assumption is that each value e.g. y_0, y_1, …….y_t in the series is drawn randomly from a joint probability distribution (Roche, 2001). It is usually possible to construct a simple model of the time series that may be reasonable approximation to the actual distribution. For example, consider the first order autoregressive process *AR* (1) with drift:

$$y_t - \mu \ = \phi\,(y_{t-1} - \mu) + \upsilon_t$$

$$y_t = \mu\ (1 - \phi) + \phi\, y_{t-1} - \mu + \upsilon_t$$

$$y_t = \alpha + \phi\, y_{t-1} - \mu + \upsilon_t$$

This is a simple example of a stochastic process where the uncertainty is due to υ_t and y_t is modeled solely as a function of its lagged value. Assuming $\upsilon_t \sim NIID\ (0, \sigma^2)$ and if $|\ \phi\ | < 1$, the observations fluctuate around unconditional mean μ. According to Pyndick and Rubbenfield (1998), under these assumptions, μ and ϕ can be estimated by Ordinary Least Squares (OLS).

In developing the time series model, of interest is whether or not the underlying stochastic process that generated the series can be assumed to be invariant with respect to time. By constraining ϕ to be between the interval [-1, 1], it implies that the process is stationary. In this case, a stationary process is one whose joint distribution and conditional distribution are both invariant with respect to displacement in time. In other words, a time series is considered stationary if its mean fluctuates around a constant long-run mean and the variance is finite. A good example of a stationary process is Gaussian white noise whereby it has a zero mean and constant variance.

If $\phi = 1$ in (4.1), then the variable y_t is said to have a unit root and it is an indication that the series are non stationary. The case where $\phi = 1$ is referred to as a random walk. When $\phi > 1$ the AR (1) process is explosive (Roche, 2001). Chapter 3, section 3.5.1 of this thesis briefly describes some of the methodologies to test for unit roots [See also Roche, (2001) for measures of unit roots and tests for non-stationary in time series]. The need to have some formal analysis for handling unit roots arises from economic interpretation of relationships between data that contain unit roots and the importance of non stationary data when attempting to avoid the problem of spurious regressions in estimation[17]. Many aggregate economic time series (examples include: consumption, income, prices, interest rates etc) display strong persistence with sizeable fluctuations in both mean and variance over time (Greene, 2003). Classical hypothesis testing is based on the assumption that the first two population moments (unconditional) are constant over time (covariance stationary) and hence unit roots pose a challenge for usual estimation procedures (Roche, 2001).

A non stationary series can be made stationary by taking first differences [Maddala, *et al*. (1992); Greene (2003); Roche (2001)]. If after differencing a time series d times the series is stationary, then the series is said to be integrated

[17] According to Pyndick and Rubenfield (1998), the standard regression models such as OLS cannot be applied to perform regression analysis because under presence of unit root, they lead to spurious and inconsistent results. In addition, if variables are non-stationary, it is difficult to conduct hypothesis testing as the classical assumptions on the property of the error term, namely that it has zero mean, constant variance, and is non-auto correlated is violated.

of order d and it is denoted I(d) (Greene, 2003). If however, a time series is already stationary so that it is I(0), then the equilibrium error υ_t has no distinctive property. It could be that υ_t ~ I(-1), so that its spectrum is zero at zero frequency and if the series has measurement error, this property in general cannot be observed and so the series is of little realistic interest (Engle *et al*., 1987). According to Engle and Granger (1987), an I(1) process has several important properties:

> If $y_t \sim I(1)$ with $y_0 = 0$, then (i) variance y_t goes to infinity as t goes to infinity; (ii) an innovation has a permanent effect on the value of y_t, as is the sum of all previous changes; (iii) the spectrum of y_t has an approximate shape $f(\omega) \sim A\omega^{-2d}$ for small ω so that in particular $f(0) = \infty$; (iv) the expected time between crossing of $y = 0$ is infinite; (v) the theoretical autocorrelations, $\rho_k \to 1$ for all k as $t \to \infty$

3.5 Analytical Techniques

This study employed two methodological approaches to examine spatial market integration for fresh cassava in central Malawi. This is due to different policy implications of each of the methodologies.

i. A co-integration approach as suggested by Engle and Granger (1987) aimed at determining long run price relationships between spatially different markets. Literature suggests two main approaches for testing of a co-integrating relation between time series. First, proposed by Engle and Granger (1987) using a two stage-step procedure to test for co-integration using Augmented Dickey-Fuller test. Second is the maximum likelihood procedure of Johansen (1988) which relies on the relationship between the rank of a matrix and its characteristic roots. This study employed the Engle and Granger procedure due to its simplicity in estimation and its wide usage.

ii. A distributed-lag model as developed by Ravallion (1986) providing a restrictive definition of market integration to test a one to one co-movement of prices if price differentials are equal to transfer costs either instantaneously or with lags.

3.5.1 Engle and Granger Co-Integration model specification

As earlier stated, examining degree of integration between any pair of markets; *i* and *j* is to test whether or not there is any systematic relationship between the price series of the two markets. This can be done by applying OLS regression on one of the price series, say P_{it} on another price series, say P_{jt} plus a constant. This is represented as follows:

$$P_{it} = \alpha + \beta P_{jt} + \mu_t \qquad [3.1]$$

where, P_{it} and P_{jt} denotes prices at time *t* and at markets *i* and *j* for a given commodity; α and β are the parameters to be estimated and μ is the error term.

However, the relationship in (3.1) has interest only if the error term, μ_t, is stationary, implying that price changes in market *i* do not drift far apart in the long run from price changes in another market *j*. When this occurs, the two series are said to be co-integrated. To estimate long run market integration and assess whether fresh cassava prices moved in fixed band, the Engle and Granger co-integration model employs a two step-residual based test.

3.5.1.1 Step 1: Testing for order of economic integration

Price series in individual markets are tested separately for order of econometric integration i.e. the number of times each series needs to be differenced before transforming it into a stationary[18] series. To test for the order of economic integration, stationarity test is applied. Literature provides two tests for stationarity: correlogram method[19] and unit root test. This study used the unit root test because of its wide application. Several unit root tests are available[20]. The study used the Augmented Dickey-Fuller (ADF) procedure due to its widespread usage and availability of relevant critical values in most econometric and statistical software used during this study. Finding of a unit root in the price series indicated non-stationary.

3.5.1.2 Specification of ADF procedure

According to the ADF procedure[21]; for a given price series, P_{it}; two forms of ADF regression equations can be estimated to test for a unit root:

$$\Delta P_{it} = \delta_0 + \delta_1 P_{i\,t-1} + \Sigma\, \phi_h\, \Delta P_{i\,t-h} + \nu_t \qquad [3.2]$$

$$\Delta P_{it} = \delta_0 + \delta_1 P_{i\,t-1} + \delta_2 t + \Sigma\, \phi_h\, \Delta P_{i\,t-h} + \varepsilon_t \qquad [3.3]$$

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[18] A time series is considered stationary if its mean fluctuates around a constant long-run mean and the variance is finite. If a series is non stationary, it is said to have a unit root. According to Pyndick R and D L Rubinfield (1998), the standard regression models such as OLS cannot be applied to perform regression analysis because under presence of unit root, they lead to spurious and inconsistent results. In addition, if variables are non-stationary, it is difficult to conduct hypothesis testing as the classical assumptions on the property of the error term, namely that it has zero mean, constant variance, and is non-auto correlated is violated..

[19] Correlogram method is pictorial and gives the autocorrelation coefficients at various lags of the series. A non stationary series starts with a very high coefficient and the coefficients taper off slowly. A non stationary time series has also very high Ljung-Box Q statistics with low ρ-values (Thapa, 2002). According to Johnston and Dinardo (1997) it involves subjective judgment applied to the time series.

[20] Other unit root tests include: Dickey-Fuller (AD) test; Phillips-Perron test; Johannsen and Juselius test; and co-integration regression Durbin-Watson test.

[21] See Dickey, D. A. and Fuller, W. A. (1979 and 1981)

where v_t and ε_t for $t = 1, \ldots\ldots, n$ are assumed to be Gaussian white noise[22]; Δ is the difference operator; h is the number of lags; and the δ's and the ϕ's are the parameters to be estimated. Equation 3.2 is with constant and no trend while equation 3.3 has a constant and trend. The number of lagged term h[23] is chosen to ensure that the error process in the estimating equation is residually uncorrelated and captures the possibility that P_{it} is characterized by a higher order autoregressive process. The ADF test statistic has a null hypothesis of a unit root process (i.e. $\delta_1 = 0$) against an alternative of a stationary ($\delta_1 < 0$ and $\delta_{2t=1} = 0$) or trend stationary (($\delta_1 < 0$ and $\delta_{2t=1} \neq 0$) process.

3.5.1.3 Step 2: Testing for stationarity of residual (μt) of the OLS regression [3.1]

The residual, μ_t of the OLS regression [3.1] between a given pair of local cassava price series is in turn tested for stationarity using the same ADF test method. This time, the test for stationarity serves the purpose of establishing the stability of the patterns of the relationship between the two series. Presence of co-integration between two price series is indicative of interdependence between their respective markets. In other words, the presence of co-integration is indicative of non segmentation between a considered pair of cassava market.

3.5.2 Specification of the Causality Error Correction model

Once presence of co-integration between two cassava price series is established, then the relationship between the two series can be represented as an Error Correction Mechanism (ECM) (Engle and Granger, 1991). The test of Granger

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22 By v_t *and* ε_t being Gaussian white noise, it is ensured that they are series of uncorrelated random variables with mean zero and constant variance.

23 The weakness in ADF test is that the power of the test may be adversely affected by mis-specifying the lag length.

causality in the ECM would follow a two step procedure. First is to test, by looking at the coefficients of the short-run part of ECM i.e. $\phi_h = 0$ implying Granger non-causality. Secondly is to look at speed of adjustment. The Engle-Granger methodology assumes that the regressor is weakly exogenous implying that causality runs from the regressor to the dependent variable[24]. The use of ECM in this study was therefore to test for causality. The idea was to examine if there exists a central market that is influencing fresh cassava prices in the whole central region, hence concentration of the analysis on testing for causality than testing for speed of adjustment.

The following model was therefore used to fulfill the second objective of testing causal relationship between spatially located markets and the second hypothesis that cassava markets in central Malawi are not efficient in transmitting price information:

$$\Delta P_{it} = \Upsilon_0 + \Upsilon_1 P_{i\,t-1} + \Upsilon_2 P_{j\,t-1} + \sum \delta_k \Delta P_{i,t-k} + \sum \phi_h \Delta P_{j,t-h} \qquad [3.4]$$

Where Δ is the difference operator, P_i and P_j are prices series for market *i* and *j*; *k* and *h* are number of lags and the Υ, δ and ϕ are the parameters to be estimated.

The ECM is provided by the sum of the third and fourth terms with their joint coefficient representing the EC term (Engle and Granger, 1991). Following Goletti and Babu (1994) the null hypothesis of causality from market *j* to market *i* was tested as follows:

$$H_0: \Upsilon_2 = 0 \qquad \phi_h = 0 \qquad h = 1, 2, \ldots\ldots, n$$

[24] This may not be the case. See Johansen (1988)

The above test is used to establish the existence of a central market for fresh cassava in central Malawi, defined as a market whose prices have one-way influence on prices in other markets. A weaker version of centrality would involve causation within certain region, so that a regional center can be defined, consisting of a market whose prices affect prices in all markets within that region without being affected by them.

3.5.3 Distributed-Lag model specification: Ravallion Model and Testing Hypotheses

The Ravallion model makes two assumptions about characteristics of spatial market structure. First, it assumes that there exists a group of local (rural) markets and a single central (urban) market. While there might be some trade among the local markets, it is trade with the central market which dominates local price formation. However, depending on number of local markets and their size, one can also posit that the central market price is influenced by various local prices. This is summarized by models of the following forms:

$$P_1 = f_1(P_1, P_2, \ldots\ldots\ldots\ldots P_N, X_1) \qquad [3.5]$$

$$P_i = f_i(P_i, X_i) \qquad (i = 2, \ldots\ldots\ldots N) \qquad [3.6]$$

where P_1 is the central market price, X_i $(i = 1, \ldots\ldots\ldots N)$ is a vector of other influences on local markets. The functions of f_i $(i = 1, \ldots\ldots\ldots N)$ can be thought of as solutions of the appropriate conditions for market equilibrium, taking into account of the main spatial choices and the costs of adjustment facing traders when deciding where to sell.

Since spatial price differentials become more aggregated, the above specification produces inferential difficulties when investigating the linkage location of any revealed impediment of trade. If there are a large number of local market linkages, then (depending on what other relevant local non price variables) it may become impossible to identify even the indirect radial linkage (Ravallion, 1986). However, since the main aim in estimating the model is to test alternative hypothesis to do with market integration, Ravallion (1986) suggests that its econometric specification should not prejudice the outcome. He therefore proposes incorporation of alternative hypotheses regarding market integration in such a way as to allow for their nesting within a general model so as to be tested as restrictive forms[25].

Second assumption of the model is that the econometric version of equations 3.5 and 3.6 should embody a suitable dynamic structure, as it is well known; dynamic effects can arise from a number of conditions in the underlying behavioral relations including expectation formation and adjustment costs[26]. This results into the following structural form for T-period series of prices for N markets:

$$P_{1t} = \sum_{j=1}^{n} a_{1j} P_{1t-j} + \sum_{k=2}^{N} \sum_{j=0}^{n} b_{1j}^{k} P_{kt-j} + X_{1t} c_1 + \varepsilon_{1t} \qquad [3.7]$$

$$P_{it} = \sum_{j=1}^{n} a_{ij} P_{it-j} + \sum_{j=0}^{n} b_{ij} P_{1t-j} + X_{it} C_i + \varepsilon_{it} \qquad (i = 2, \ldots\ldots N) \; [3.8]$$

[25] Ravallion (1996) further suggests that for estimation, it is convenient to assume that the function can be given a linear representation by introducing an appropriate stochastic term.

[26] For a survey of possibilities, see Hendrey, D., Pagan, A. R. and Sargan, J.D. (1984)

where P_{1t} is the price in the central market in time t, P_{1t-j} is the price in the central market in time $t - j$, P_{kt-j} [or P_{it-j} in (3.8)] is the price in localized market k (or i) in time t-j, X_1 is a vector of other influences on the central market, P_{it} is the price in localized market i in time t and X_i is a vector of other influences on localized market i.

In this way, prices in the central market are determined by past values in the central market and all localized markets and concurrent values in the localized market while prices in the localized market are determined by past values in the central and respective localized markets and concurrent values in the central market. Worth mentioning, however is that interest lies in the transmission mechanism evident in the greater economy and not with the structure of price formation within the central market such that, the study safely disregarded equation 3.7 (Ravalion, 1986).

Due to the considerations made above and correcting for collinearity, an error correction mechanism[27] allows estimation of equation [3.8] to take the following form:

$$\Delta P_{it} = (\alpha_{i1} - 1)(P_{it-1} - P_{1t-1}) + b_{i0}\Delta P_{1t} + (\alpha_{i1} + b_{i0} + b_{i1} - 1) P_{1t-1} + C_i X_{it} + e_{it} \qquad [3.9]$$

where, ΔP_{it} equals the change in price in the i-th (local) market in time t, $(P_{it-1} - P_{1t-1})$ is the difference between the price in the i-th market and the reference market in time t-1, ΔP_{1t} is the change in the price in reference market in time t, P_{1t-1} is the lagged value of the reference market, X_{it} c_i is a vector of other influences

[27] See Alexander, C. and J Wyeth, (1994). See also Baulch (1997); Adelman and Shively (1991)

on the i-th market and e_{it} is the error term. In which case, the following hypotheses are tested:

Market segmentation: Central market prices do not influence prices in the *i*th local market if

$$b_{ij} = 0 \qquad (j = 0, \ldots\ldots\ldots n) \qquad (i)$$

Short run market integration: A price increase in the central market will be immediately passed on in the i-th market price if

$$b_{i0} = 1 \qquad (ii)$$

There will be lagged effects on future prices unless in addition to *(ii)*,

$$\alpha_{ij} = b_{ij} = 0 \qquad (j = 1, \ldots\ldots\ldots n) \qquad (iii)$$

If *(ii)* and *(iii)* are accepted as parameter restrictions, then one can say that market i is integrated with central market within one time period. A weaker form of market integration will also be tested in which the lagged effects need only to vanish on average:

$$\sum_{j=1}^{n} \alpha_{ij} + b_{ij} = 0 \qquad (iv)$$

Long run market integration: Long run equilibrium is one in which market prices are constant over time, undisturbed by any local stochastic effects, such that

$$\sum_{j=1}^{n} \alpha_{ij} + \sum_{j=0}^{n} b_{ij} = 1 \qquad (v)$$

It should be mentioned however that when unlike Ravallion, this study did not assume existence of a central market given that there is no specific central fresh cassava market covering all of central Malawi. Therefore, the Ravallion model (equation 3.9) was performed on each market becoming a reference market (see annex III).

3.5.4 Specification of the Index of Market Connection (IMC) analysis

Timmer (1987) observed that while the Ravallion model (equation 3.9) allows the testing of various hypotheses about market efficiency, it does not provide and easily accessible statistic about the degree of integration between polar cases. Following this observation, Timmer (1987) decomposed the following formula to calculate IMC[28]

$$\text{IMC} = (1 + a)/(c-a) \qquad [3.10]$$

Timmer (1987) suggests that, markets are fully integrated if $a = -1$ and IMC = 0, While the markets are completely isolated if $a = c$ and IMC = ∞. IMC is generally greater than 0. When IMC is closer to 0, the degree of integration between markets is higher and vice versa. IMC < I indicate high degree of market integration and IMC > 1 imply low degree market integration.

[28] See Alderman (1992) and Lapping Wu (1990) for derivation of IMC (equation 3.10) from the Ravallion model (equation 3.9). More details are also presented in Annex I.

3.6 Limitations of the study

Major limitation of this study was frequency of data used in this study. This study used weekly prices obtained from the markets understudy. The markets usually have weekly market days[29] during which these prices are collected. The prices may not reflect price changes in a rather short period of time such as days. Cassava marketing is done by middlemen/producers who transport their cassava on bicycles from areas of production to market centers such that it only takes a day to transfer the commodity from point of production to market and price differentials could be transmitted within a day than weeks. Furthermore, cassava is marketable when fresh as such has to be sold within few days after harvesting to protect its quality. Unfortunately, daily price series for fresh cassava are not available in Malawi. Not withstanding this concern, empirical results of this analysis provides a significant attempt to measure the extent to which fresh cassava markets are spatially integrated in central Malawi. The analysis is justifiable and deemed preferable to cautiously use existing data rather than 'guess' the state of market development for an economically important crop to which much effort and resources are being put to develop and already about 30% of the population is relying upon as a staple food.

[29] Most of the markets are rural or semi-urban markets whereby there is either one or two days a week designated as market days. Prices used in this study are collected from those particular market days.

4 RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, results of estimations for spatial market integration using analytical techniques described in chapter 3 are presented. Initially, the chapter presents results of preliminary analysis of aggregate price behaviour for cassava in central Malawi.

4.2 Results of preliminary analysis of fresh cassava price behavior in central Malawi

4.2.1 Aggregate behavior of cassava prices in central Malawi

Tables 4.1 and 4.2 below provide variability statistics for nominal and real cassava prices respectively. The tables show that nominal prices had a higher price variability of 0.254 while real prices indicated an average variability of 0.179. This implies that nominal variation contributed more to instability of cassava prices experienced during this period. It is further observed that all markets under study except Dowa and Kasungu have high price variability above regional variability in nominal terms. On average, Kasungu market has low price variability below the regional variability. There is one possible explanation to this observation. Starting from year 2000, Malawi government, various research institutions and NGOs initiated programs on multiplication, distribution and purchasing of clean cassava planting material[30] from local farmers. These programs were mainly operated in Lilongwe and Salima districts from which the

[30] Cassava planting material refers to fresh and mature stems of the plant. In order to sell them, planting material is harvested and sold whilst fresh to facilitate sprouting when planted by the next farmer. In most cases, farmers uproot the roots within the next one or two days after harvesting of planting material so as to preserve its quality. This result in oversupply of fresh cassava on the market leading to price fluctuation particularly because they would like to sell roots whilst they are still fresh.

rest (except Kasungu and Dowa where the programs were not in effect during the period understudy) of the markets are located or are in close proximity. Fluctuations in supply of fresh cassava on the market facilitated by these programs may have contributed to high variability of prices in the corresponding markets unlike Kasungu and Dowa. This point is further explained and expanded in the later sections.

Table 4.1: Variability statistics for nominal cassava prices

	Count	Minimum	Maximum	Mean	Sample Variance	Standard Deviation	Standar d Error	Coefficient Of Variation
Salima	100	11.760	33.000	22.332	36.222	6.018	0.602	0.269
Mtakataka	100	8.330	32.500	18.529	33.579	5.795	0.579	0.313
S. Valley	100	8.050	30.000	15.881	23.868	4.885	0.489	0.308
Dowa	100	3.280	15.100	6.464	1.853	1.361	0.136	0.211
Mponela	100	6.810	29.520	15.077	34.547	5.878	0.588	0.390
Ntchisi	100	3.740	25.000	10.660	19.222	4.384	0.438	0.411
Kasungu	100	10.830	25.000	17.695	12.362	3.516	0.352	0.199
Mchinji	100	3.000	28.080	13.325	24.973	4.997	0.500	0.375
Nsundwe	100	5.500	40.000	18.073	56.217	7.498	0.750	0.415
Lilongwe	100	8.130	30.730	19.374	40.369	6.354	0.635	0.328
Mitundu	100	5.610	29.460	14.223	41.263	6.424	0.642	0.452
Nanjiri	100	5.000	27.780	14.682	26.232	5.122	0.512	0.349
Nkhoma	100	7.080	31.720	14.969	54.632	7.391	0.739	0.494
Thete	100	4.000	21.900	11.448	30.914	5.560	0.556	0.486
Chimbiya	100	4.560	41.770	17.672	55.139	7.426	0.743	0.420
Lizulu	100	7.290	32.230	17.406	27.426	5.237	0.524	0.301
Ntcheu	100	4.230	37.830	14.586	41.357	6.431	0.643	0.441
Mean Nominal Prices	100	10.145	25.008	15.435	15.368	3.920	0.392	0.254

Table 4.2: Variability statistics for real cassava prices

	Count	Minimum	Maximum	Mean	Sample Variance	Standard Deviation	Standard Error	Coefficient of Variation
Salima	100	6.668	16.921	11.860	6.775	2.603	0.260	0.219
Mtakataka	100	4.419	16.730	9.950	8.847	2.974	0.297	0.299
Sharp Valley	100	4.473	14.349	8.428	4.523	2.127	0.213	0.252
Dowa	100	1.656	7.544	3.494	0.650	0.806	0.081	0.231
Mponela	100	3.643	15.136	7.995	7.745	2.783	0.278	0.348
Ntchisi	100	2.230	11.638	5.631	3.673	1.916	0.192	0.340
Kasungu	100	6.628	14.904	9.435	2.181	1.477	0.148	0.157
Mchinji	100	1.492	13.071	7.057	5.239	2.289	0.229	0.324
Msundwe	100	3.136	18.620	9.502	11.342	3.368	0.337	0.354
Lilongwe	100	4.847	16.155	10.324	9.120	3.020	0.302	0.293
Mitundu	100	3.199	14.317	7.481	8.678	2.946	0.295	0.394
Nanjiri	100	2.897	15.153	7.844	6.605	2.570	0.257	0.328
Nkhoma	100	4.333	16.018	7.790	10.424	3.229	0.323	0.414
Thete	100	2.361	11.585	5.990	6.590	2.567	0.257	0.429
Chimbiya	100	2.678	18.430	9.391	12.090	3.477	0.348	0.370
Lizulu	100	4.281	16.761	9.298	6.475	2.545	0.254	0.274
Ntcheu	100	2.522	18.094	7.712	8.513	2.918	0.292	0.378
Mean Real Prices	100	5.958	11.641	8.187	2.138	1.462	0.146	0.179

Aggregate series for both nominal and real prices were plotted over time and are presented below in Figures 4.1 and 4.2 respectively. Prices of fresh cassava increased both in nominal and real values over the period of the analysis. Nominal prices increased at a trend of 12.1% while real prices increased at a trend of 4.04% and both series hitting their lowest values in the third week of March 2005 (week 59). From the graphs, it can also be observed that both nominal and real prices fluctuated considerably around the trend lines. Tables 4.1 and 4.2 above also show variance of 15.37 for nominal prices while real prices have variance of 2.14.

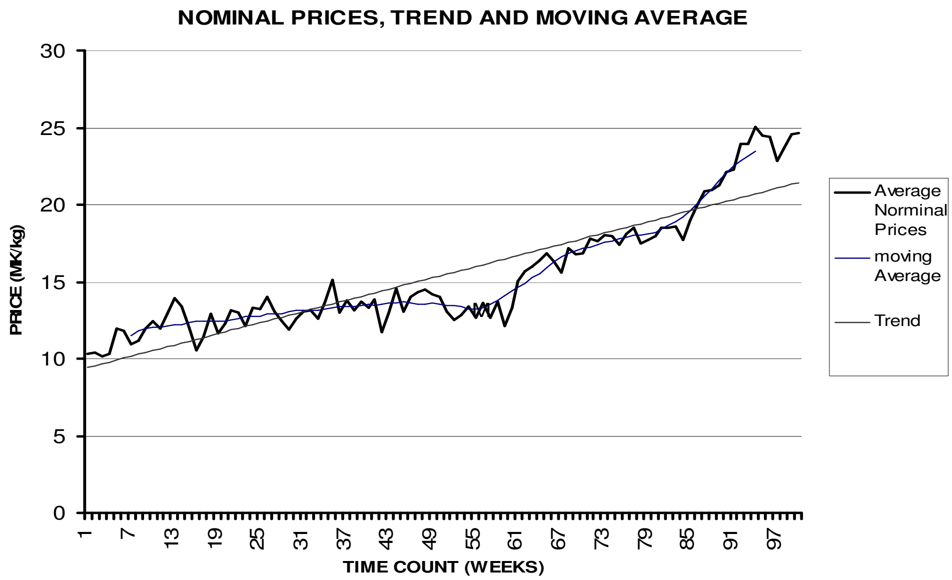

Figure 4.1: Nominal prices, trend and moving average for fresh cassava in central Malawi

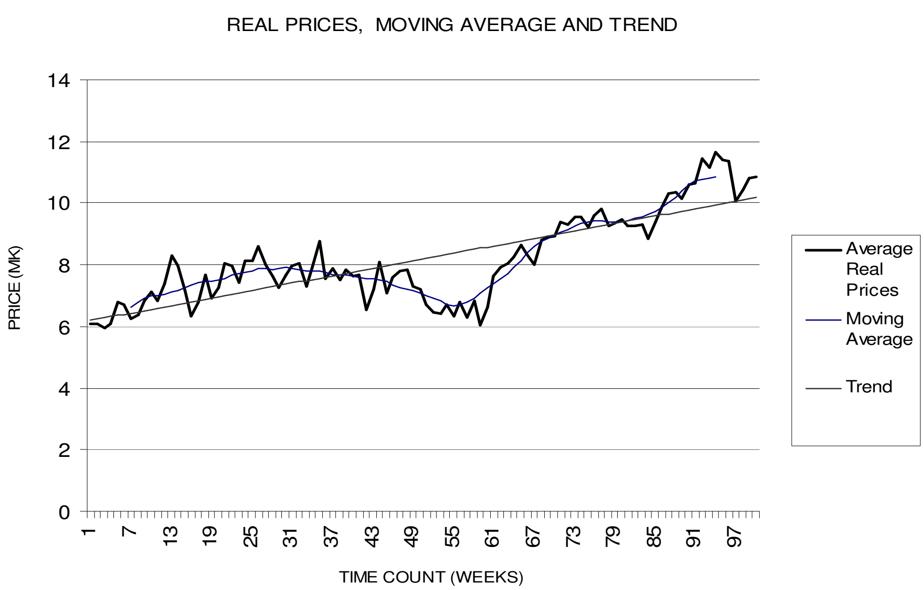

Figure 4.2: Real prices, trend and moving average for fresh cassava in central Malawi

A seasonal analysis was further applied to the aggregate series. Firstly, individual series were regressed on a simple trend variable (starting with and incremented by 1 for each week) in order to obtain trend. Results are presented in table 4.3 below. From the table, trend for regional nominal and real prices were 0.121 and 0.040 respectively. This implies that over the 100 week period trend is present for both nominal and real prices and was increasing nominal prices by MK0.12 per kg and real prices by MK0.04 per kg each week. The t-statistics of 20.050 and 13.238 for nominal and real price series respectively indicate that the trends are significantly different from zero. Individual markets also displayed significant increasing trend for both nominal and real terms except for Dowa market

Table 4.3: Linear trend for real and nominal prices

Market	Nominal Price Linear Trend	t-Statistic of Nominal Linear Trend	R-Square of Nominal Trend Equation	Real Price Linear Trend	t-statistic of real price trend	R-square of real price trend equation
Salima	0.156	11.333	0.563	0.050	6.684	0.313
Mtakataka	0.062	3.232	0.087	0.003	0.249	0.001
S. Valley	0.114	9.130	0.454	0.036	5.527	0.230
Dowa	0.001	-1.157	-0.010	0.010	-3.824	0.121
Mponela	0.140	9.510	0.475	0.052	6.414	0.288
Ntchisi	0.101	8.866	0.439	0.035	6.235	0.277
Kasungu	0.069	6.915	0.321	0.021	1.994	0.029
Mchinji	0.134	12.194	0.599	0.052	8.687	0.429
Nsundwe	0.191	10.884	0.543	0.074	8.238	0.403
Lilongwe	0.135	7.773	0.375	0.042	4.322	0.152
Mitundu	0.121	6.424	0.289	0.044	4.800	0.182
Nanjiri	0.073	4.485	0.162	0.017	1.916	0.026
Nkhoma	0.222	17.580	0.757	0.094	15.882	0.717
Thete	0.162	15.717	0.713	0.069	12.251	0.601
Chimbiya	0.145	6.831	0.316	0.046	4.074	0.136
Lizulu	0.105	7.118	0.334	0.028	3.367	0.095
Ntcheu	0.129	7.089	0.332	0.044	4.816	0.183
Mean Regional Prices	0.121	20.050	0.804	0.040	13.238	0.638

A centered 12 month moving average was calculated for each series. Individual observations in the time series were replaced by the average of 12/2 values in the preceding period and 12/2 values in the subsequent period. As a result of this averaging, individual observations that were unusually large or small values were brought more inline with the other values in the series. This assisted to remove fluctuations of the series and this allowed outlining longer term factors particularly cycles and trends of the series. The calculated trend and moving average were used to calculate seasonal and cyclic indices for average cassava prices. Resulting from calculation of the centered moving average, there is no moving average for first and last six observations in the series and therefore, seasonal and cyclical indices also have no corresponding values for these weeks. Figures 4.1 and 4.2 above further shows the moving average plotted overtime together with actual prices. The moving average has eliminated most of the irregular fluctuations in the nominal and real prices. Similarly, though short, the seasonal index series in Figures 4.3 and 4.4 below shows a clearly repetitive seasonal pattern while the cyclical index in Figures 4.5 and 4.6 closely follow a sine-wave, with no apparent consistent yearly pattern.

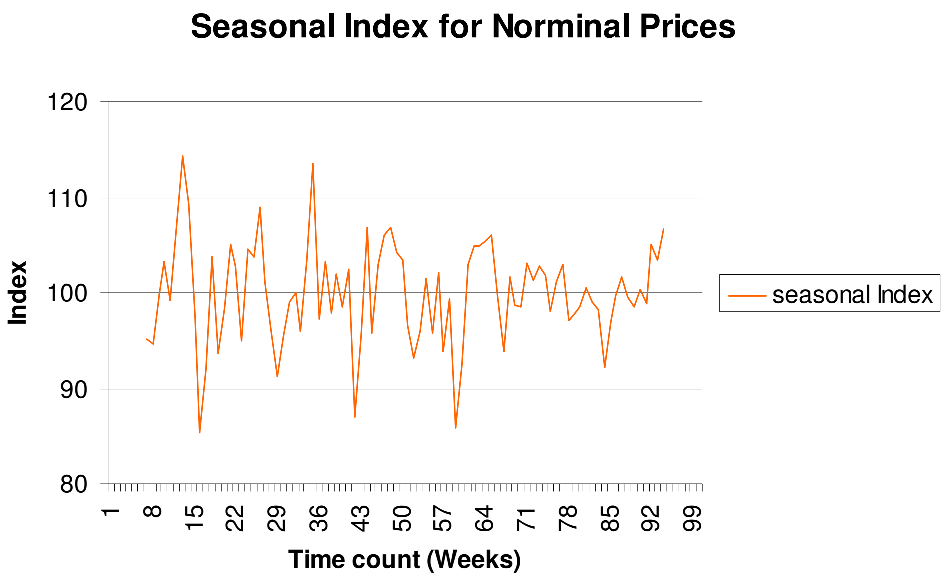

Figure 4.3: Seasonal index for nominal prices for fresh cassava in central Malawi

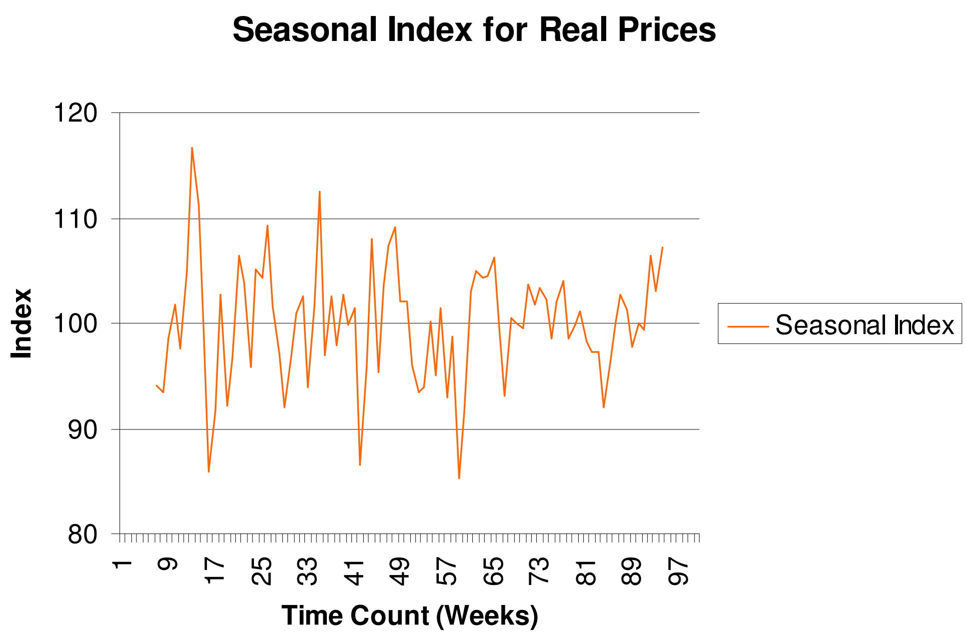

Figure 4.4: Seasonal index for real prices for fresh cassava in central Malawi

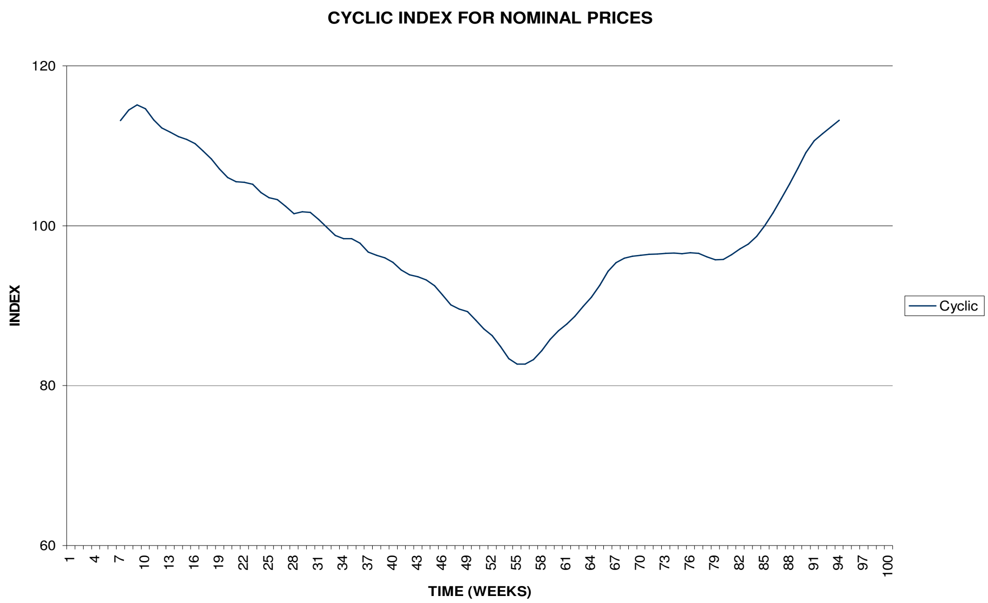

Figure 4.5: Cyclical effect on nominal prices for fresh cassava in central Malawi

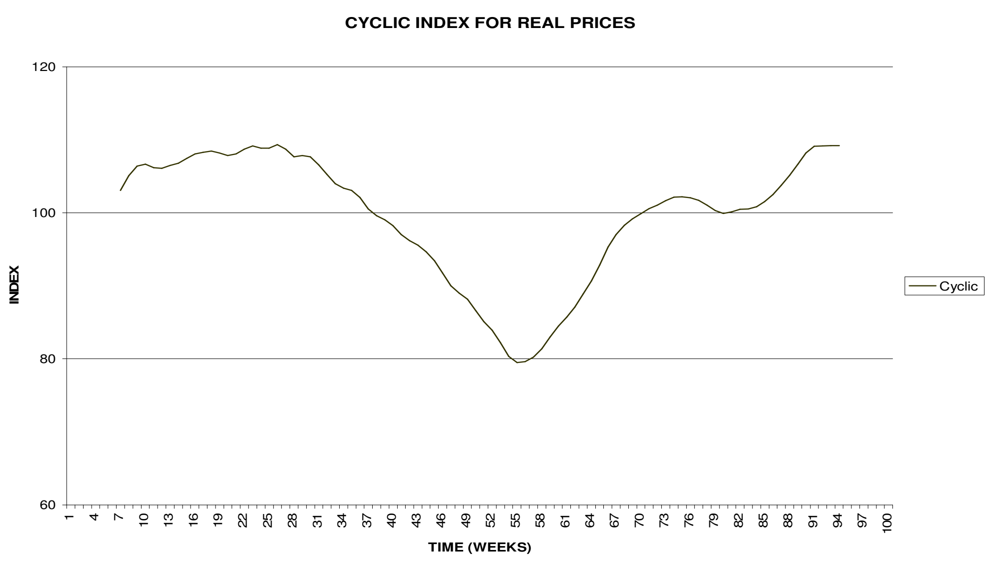

Figure 4.6: Cyclical effect on real prices for fresh cassava in central Malawi

It is interesting to note that week 59 (third week of March, 2005) where both the nominal and real prices experienced their lowest values, both the seasonal and cyclic indices also experienced lowest values for both real and nominal values. The seasonal and cyclic indices showed almost the same low values of 85% implying that the low prices experienced this period could be due to both seasonal and cyclic factors. During this period, the region still is experiencing rains and quality of cassava roots is not good for fresh consumption. These two factors could contribute to the phenomenon.

Table 4.4 below shows that the coefficient of variation for the seasonal indices for both nominal and real prices to be 0.56. As earlier indicated, producers do not benefit from this seasonality and price variation because cassava is highly perishable and cannot be stored in its fresh form for a long period of time. This study did not manage to carry out a further analysis of the seasonal index due to shortage of the data set. A further analysis of the seasonal index was required to understand the phenomenon expressed above. This would have involved analysis of trend in the monthly seasonal values by presenting the seasonal index weekly table by month basis, then calculating the mean, trend and t-statistics for same months. This could have showed whether prices are increasing or decreasing over time over particular weeks in a given month. However the data set was short which implied 2 observations per month for the period where seasonal indices were available.

During the weeks around October to February, cassava prices for both years under the study showed an increase in prices (refer to figures 4.1 and 4.2). This agrees with findings of a study on sub-sector analysis of cassava and sweet potatoes conducted by Phiri (2001), whereby it was indicated that prices of fresh cassava tend to rise towards the end of marketing season. It was observed in the mentioned study that fresh cassava tends to be expensive during this period due to high transportation cost. Around this period, fresh cassava is usually supplied from distant sources and cheaper mode of transport such as bicycles are not convenient.

Table 4.4: Seasonal variation of fresh cassava prices

	Mean	Standard Error	Standard Deviation	Coefficient of Variation	Sample Variance	Minimum	Maximum	Count
Real Prices	99.992	0.596	5.594	0.056	31.298	85.221	116.634	88
Norminal Prices	99.957	0.563	5.279	0.053	27.870	85.322	114.256	88

Analysis of variability of weekly cassava prices for each month of the year was carried out in order to arrive at the seasonality of price variability. Figure 4.7 shows seasonality of variability of the nominal prices. November, December and January indicated high variability in prices (see also table 4.5 below). Two reasons may explain this observation. First, it could be as a result of scarcity of good quality cassava (mealy) resulting from too much water from rain affecting quality of the roots since these months, the country receives rain. Second, this period is the opportune time of cassava planting when farmers source and plant cassava. As mentioned earlier, the period understudy coincided with programs targeting multiplication and procurement of cassava planting material from farmers by NGOs and Malawi government. Most producers harvested planting material in order to sell on this new niche as a result, supply of fresh cassava to markets increased. Since fresh cassava favors to be sold whilst in its fresh form, this might have contributed to the high nominal price variability during these months.

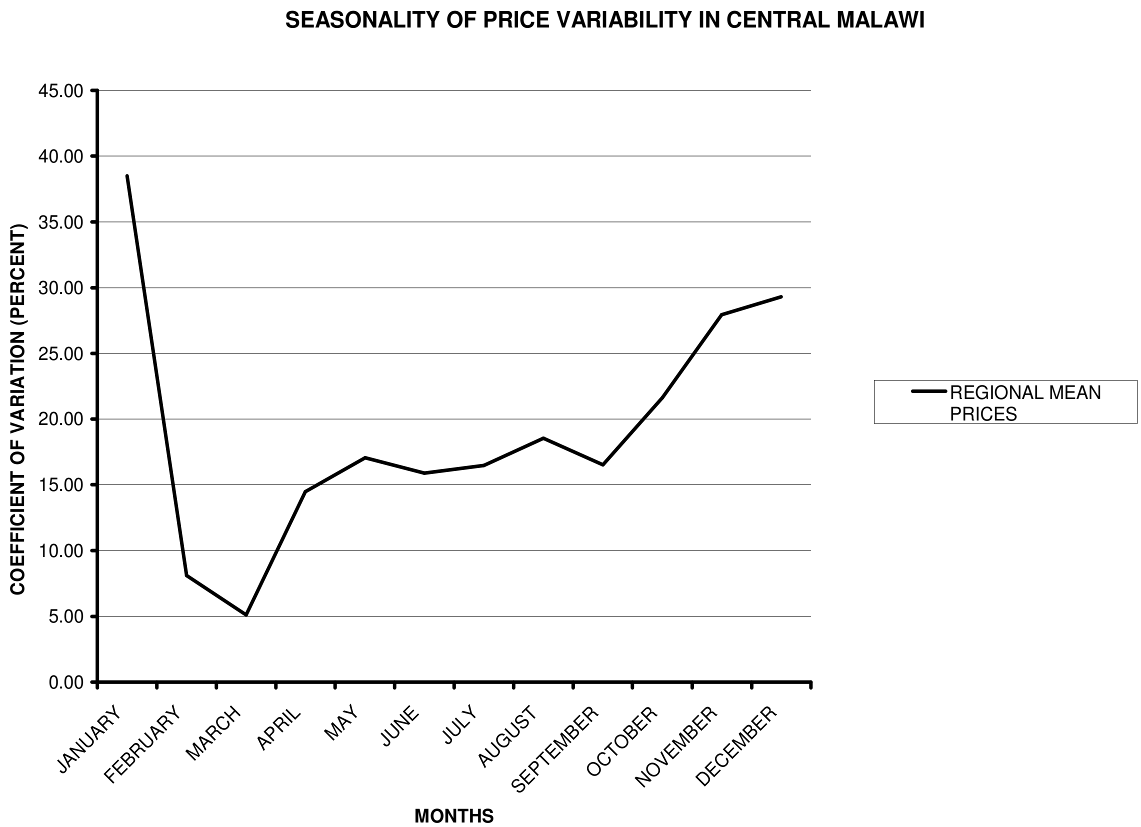

Figure 4.7: Seasonality of price variability of nominal fresh cassava price

Table 4.5: Coefficient of variation of weekly nominal fresh cassava prices in central Malawi (percent)

Market/Month	January	February	March	April	May	June	July	August	September	October	November	December
Salima	24.89	19.77	24.48	32.03	42.37	16.78	13.65	26.27	32.39	22.26	27.88	13.05
Mtakataka	40.82	37.96	28.76	16.38	20.15	16.75	34.12	22.59	16.35	39.33	41.62	36.33
S. Valley	43.11	14.22	20.31	17.18	32.58	23.94	33.63	15.20	23.86	21.14	37.72	24.66
Dowa	16.31	13.36	12.09	21.10	15.18	13.58	13.57	4.15	36.23	14.45	10.39	14.18
Mponela	39.43	11.35	21.05	27.18	52.21	44.15	24.16	29.94	24.82	41.38	18.80	39.37
Ntchisi	48.77	13.26	20.82	31.11	33.05	26.32	10.86	18.55	19.72	34.47	39.51	50.61
Kasungu	20.94	4.40	11.31	16.67	13.55	26.94	28.22	23.98	13.88	14.42	27.11	17.96
Mchinji	19.71	21.27	36.75	17.03	19.18	29.17	38.19	35.69	30.42	31.67	21.02	34.12
Nsundwe	47.55	54.81	26.26	15.76	34.61	45.22	23.34	45.12	40.46	24.10	22.94	30.50
Lilongwe	29.55	30.44	26.93	31.49	18.26	34.52	35.04	21.43	33.02	28.87	37.86	30.19
Mitundu	50.82	56.46	55.52	16.09	35.65	30.93	20.67	18.69	6.62	7.42	21.81	13.42
Nanjiri	51.32	39.87	32.89	22.21	8.72	16.63	19.15	20.55	30.93	26.50	25.92	20.38
Nkhoma	62.69	20.67	25.13	58.56	45.97	49.38	37.11	31.57	45.36	36.67	45.34	55.28
Thete	63.58	26.43	19.17	61.76	24.79	25.95	51.67	55.63	52.75	45.88	41.50	56.66
Chimbiya	83.87	19.20	11.55	14.53	16.45	22.34	24.68	17.48	8.61	22.81	38.24	55.68
Lizulu	52.06	10.79	16.38	19.51	10.78	12.39	17.03	18.22	16.14	19.09	24.56	26.95
Ntcheu	33.77	9.92	23.73	27.57	32.71	25.02	26.81	24.22	24.39	40.15	54.67	44.22
Regional Mean Prices	38.51	8.11	5.11	14.49	17.06	15.90	16.48	18.55	16.53	21.64	27.94	29.28

4.2.2 Price correlations

Results of correlation of price series are presented in tables 4.6 and 4.7 below. As earlier discussed, price series for markets understudy showed substantial inflation as such; only deflated series were used to carry out this analysis. This was done to eliminate effect of co-variation in the series on the correlation coefficients.

Correlation coefficients calculated at price levels are higher than correlation coefficients at price differences. This could be due to picking up of co-variations in the series resulting from time trend, and seasonality components. Price differences have those components taken out. Sixty nine percent of correlations at price levels show significant correlation at 5% and 1% level of confidence. Forty percent of the correlations at price differences are significant at the same level of confidence. Generally, the price differences show lower correlations ranging from 2.8% between Dowa and Mponela markets to the highest correlation between Ntchisi and Dowa at 11% while correlations at price levels range from 3.2% between Chimbiya and Salima markets to 44.2% between Lilongwe and Mchinji market. Following an argument by Timmer (1974), the low correlation of prices observed between any two markets may indicate either poor flow of information or economic inefficiency. The observation may also be indicative of competitive trade and linked markets which are seasonally separated due to high transport cost.

An interesting correlation in the price differences is between Ntcheu and Lilongwe considering that in between the direct route linking the two markets, there are two other markets, Lizulu and Chimbiya which do not show significant correlation with either Lilongwe or Ntcheu. Another interesting link is between Nkhoma and Dowa markets whereby there is no direct link in terms of road (paved, secondary or foot path) to facilitate arbitrage between these two markets. These could be examples of spurious results by the correlations or the markets could be indirectly linked by prices of another commodity traded directly or indirectly (through another third market) between these markets. Negative correlations in the markets indicate some degree of segmentation between those markets. The correlation coefficients indicate the general picture of integration and efficiency of the cassava markets. However, it is important to view these results bearing in mind that the correlations are not a proof of market integration and efficiency of markets for the reasons earlier explained. In the next two sections, a co-integration analysis and a dynamic dimension of the interdependence between prices in different markets is presented by conducting and dynamic modeling of the price relationships.

Table 4.6: Correlation coefficients for fresh cassava prices in central Malawi (price levels)

	Salima	Mtakataka	S. Valley	Dowa	Mponela	Ntchisi	Kasungu	Mchinji	Nsund we	Lilong we	Mitundu	Nanjiri	Nkhom a	Thete	Chimbiy a	Lizulu	Ntcheu
Salima	1																
Mtakataka	0.184*	1															
Valley	0.350**	0.403**	1														
Dowa	-0.314**	0.036	-0.093	1													
Mponela	0.525**	0.297**	0.414**	0.025	1												
Ntchisi	0.287**	0.370**	0.506**	0.003	0.417**	1											
Kasungu	0.004	0.172*	0.355**	-0.106	0.204*	0.049	1										
Mchinji	0.427**	0.197*	0.422**	-0.034	0.497**	0.380**	0.211*	1									
Nsundwe	0.239**	0.021	0.370**	-0.294**	0.272**	0.315**	0.278**	0.511**	1								
Lilongwe	0.377**	0.467**	0.437**	0.008	0.512**	0.361**	0.334**	0.666**	0.265**	1							
Mitundu	0.091	-0.461**	-0.050	-0.316**	-0.083	0.041	-0.055	0.086	0.461**	-0.179*	1						
Nanjiri	0.155	-0.066	0.070	-0.229*	0.114	0.224*	-0.223*	-0.047	0.224*	-0.159	0.446**	1					
Mkhoma	0.623**	0.198*	0.519**	-0.359**	0.665**	0.588**	0.240**	0.475**	0.442**	0.422**	0.143	0.183*	1				
Thete	0.581**	0.165	0.432**	-0.234**	0.525**	0.386**	0.217*	0.656**	0.406**	0.594**	0.046	-0.049	0.743**	1			
Chimbiya	0.180*	0.417**	0.341**	0.002	0.283**	0.611**	0.030	0.261**	0.266**	0.324**	0.003	0.320**	0.392**	0.424**	1		
Lizulu	0.138	0.345**	0.463**	0.086	0.231*	0.442**	-0.025	0.401**	0.349**	0.365**	-0.035	0.177*	0.228*	0.320**	0.609**	1	
Ntcheu	0.337**	0.414**	0.512**	-0.089	0.220*	0.605**	0.197*	0.474**	0.310**	0.402**	-0.035	-0.004	0.406**	0.381**	0.483**	0.434**	1

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Table 4.7: Correlation coefficients for fresh cassava prices in central Malawi (first difference)

	Salima	Mtakataka	S. Valley	Dowa	Mponela	Ntchisi	Kasungu	Mchinji	Nsundwe	Lilongwe	Mitundu	Nanjiri	Nkhoma	Thete	Chimbiya	Lizulu	Ntcheu
Salima	1																
Mtakataka	0.145*	1															
S. Valley	-0.001	0.187*	1														
Dowa	-0.222*	-0.107	0.102*	1													
Mponela	0.002	-0.082	0.025	0.169*	1												
Ntchisi	-0.199*	-0.09	-0.041	0.346**	0.026	1											
Kasungu	-0.06	-0.085	0.014	0.139*	0.192*	-0.042	1										
Mchinji	0.114	0.124*	0.005	0.143*	-0.015	-0.035	0.119*	1									
Nsundwe	-0.016	0.011	0.026	0.008	0.12	-0.086	0.054	0.055	1								
Lilongwe	0.182*	0.164*	0.017	-0.188*	-0.227*	-0.005	-0.202*	0.081	0.054	1							
Mitundu	-0.055	0.017	0.091	0.136*	0.123	0.095	0.072	0.115*	0.138*	0.105	1						
Nanjiri	0.082	0.009	0.081	0.011	0.038	0.173*	0.092	0.105*	0.077	0.178*	0.292**	1					
Nkhoma	0.108	-0.007	0.003	-0.224*	0.089	0.011	0.079	-0.148	-0.079	0.012	-0.161	0.196*	1				
Thete	0.248**	-0.174*	0.026	-0.096	0.001	-0.003	-0.079	0.064	0.006	0.077	-0.122	0.063	0.238**	1			
Chimbiya	0.07	-0.056	-0.281**	0.081	0.161*	0.028	0.027	0.064	0.103*	-0.089	0.04	-0.035	-0.063	0.128	1		
Lizulu	-0.059	0.05	0.138*	-0.005	-0.091	-0.279**	-0.055	0.021	0.230*	0.074	0.054	-0.131*	-0.034	-0.144	-0.171*	1	
Ntcheu	0.283**	0.191*	0.300**	-0.067	0.095	-0.08	-0.002	-0.008	-0.087	0.213*	-0.069	0.033	0.099	-0.024	-0.051	0.088	1

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

4.3 Estimated results of market integration: Engle and Granger co-integration model

4.3.1 Results of stationary test: testing for unit roots using Augmented Dickey-Fuller (ADF) test

Price series from the 17 markets under study were tested individually if they are stationary. Thus, price series were tested for presence of unit root. The ADF test was used to carry out this test. Of paramount importance in the ADF test, is the choice of lag (choice of *h* in equation 3.2 and 3.3), as earlier mentioned, power of ADF test may be adversely affected by mis-specifying the lag length. Choice of lag length in this study was based on Schwartz Information Criterion (SIC) whereby the lag length with smallest SIC was chosen.[31] The resulting residuals follow white noise process. Results of ADF tests are presented in table 4.8 below. The table summarizes the number of times a series had to be differenced to become stationary, the number of lags with or without trend and the t-statistic for testing significance of estimated δ_2 coefficients.

[31] Other strategies for choice of the lag include lag selection such as Akaike Information Criterion or choosing lags whose coefficients are significantly different from zero i.e. the highest lag with a significant coefficient (for an example, see Hendry and Doornik, 2001). Other econometric software such as E-Views permits manual specification of the number of lags or to use automatic lag selection criterion. See also Johnson R R (2000). *Using Econometrics, A practical guide,* University of San Diego

Table 4.8: Results of ADF test for presence of unit roots

Market	Number of Differences	ADF Statistic						Order of Integration
		Without trend			With trend			
		t-Statistic	Lags	MacKinnon Critical Values (5%)	t-Statistic	Lags	MacKinnon Critical Values (5%)	
Salima	1	-4.679	5	-2.894	-4.661	5	-3.461	I (1)
Mtakataka	1	-3.928	8	-2.894	-4.47	8	-3.46	I (1)
Sharpvalley	1	-5.994	4	-2.892	-6.118	4	-3.458	I (1)
Dowa	0	-4.888	2	-2.891	-4.897	2	-3.456	I (0)
Mponela	0	-3.976	10	-2.894	-4.054	10	-3.46	I (0)
Ntchisi	0	-3.527	10	-2.894	-3.875	10	-3.46	I (0)
Kasungu	1	-3.877	4	-2.892	-3.858	4	-3.458	I (1)
Mchinji	1	-5.865	4	-2.892	-5.826	4	-3.458	I (1)
Msundwe	1	-4.568	4	-2.892	-4.541	4	-3.458	I (1)
Lilongwe	1	-8.287	2	-2.892	-8.298	2	-3.457	I (1)
Mitundu	1	-5.122	5	-2.893	-5.318	5	-3.458	I (1)
Nanjiri	1	-5.177	3	-2.892	-5.107	3	-3.457	I (1)
Nkhoma	0	-3.217	10	-2.894	-3.297	10	-3.46	I (0)
Thete	1	-4.871	4	-2.892	-4.875	4	-3.458	I (1)
Chimbiya	1	-5.243	4	-2.892	-5.511	4	-3.458	I (1)
Lizulu	1	-4.636	7	-2.893	-4.851	7	-3.459	I (1)
Ntcheu	1	-5.423	4	-2.892	-5.404	4	-3.458	I (1)

At price levels, Dowa, Ntchisi, Mponela and Nkhoma markets reject the null hypothesis of unit root with or without inclusion of deterministic trend. This shows that trend has no effect in the price series of these markets and the series are I(0) with or without trend. It follows that ν_t and ε_t from equation (3.2) and (3.3) respectively have no distinct property for Dowa, Ntchisi, Mponela and Nkhoma series and there is no realistic economic interest in these series. This finding could be a result of measurement errors in price data collection. As explained earlier, data is collected by different people at different times in different locations such that any inconsistency in price collection could affect variance of the series. Given the prior consideration of properties of time series, these four series are not included in subsequent estimations for market integration.

A different scenario is observed from Kasungu, Msundwe and Sharpvalley markets whereby the price series from these markets reject the null hypothesis of unit root at price levels without deterministic trend and they fail to reject the hypothesis at price level with trend. This shows that there is an effect of deterministic trend on the price series of these markets. The rest of the markets, do not reject the null hypothesis that there is a unit root at price levels independent of the inclusion of a deterministic trend. However, the tests significantly reject the null hypothesis of a unit root for these series in first differences with or without inclusion of deterministic trend. The same is observed for the three markets, Kasungu, Msundwe and sharpvalley. This shows that the series are I(1). These series exhibit important properties of time series and they satisfy necessary condition for testing for co-integration among the series. Therefore, price series from the 13 markets identified to be I(1) were regressed over each other using equation 3.1 to test for co-integration.

4.3.2 Results on testing for co-integration

Equilibrium relationships in economics are expected that, at least in the long run, certain combination of economic variables should not diverge from each other. In an efficient marketing system, the expectation is that prices of a homogeneous commodity traded in spatially located markets should not drift apart in the long run. According to Roche (2001) in the short run, variables may drift apart according to seasonal factors but if they continue drifting too far apart in the long run, then economic forces such as market mechanisms or government intervention should bring them back together. Among price data series from the 13 markets whose price series are I(1), testing for co-integration involved applying OLS regression on one price series from one market, $P_{i,}$ on another price series from another market, P_j taking the form in equation (3.1). If P_i and P_j co-move in the long run, then μ_t must be I(0), otherwise P_i and P_j would just drift apart. The null hypothesis of no co-integration between variables in (3.1) was tested by testing for a unit root using ADF test in the residual of the OLS estimation i.e.

H_0: P_i and P_j are not co-integrated

H_1: P_i and P_j are co-integrated

Figure 4.8 below shows that only 28.8% of the tested links indicate co-integration among the price series i.e. these links reject the null hypothesis that series in the tested link are not co-integrated. Among co-integrated series, 84.4% of the links indicate co-integration in both directions i.e. co-integrating coefficients for residuals are significant when P_{it} is regressed on P_{jt} or when P_{jt} is regressed on P_{it}. It therefore can be concluded that fresh cassava prices from co-integrated series co-move together in the long run such that even though each series wander and their margins differ due to seasonal and other various shocks, in the long run the prices do not drift apart. Assuming there is bad harvest in location of market $P_{i,}$ and fresh cassava prices suddenly increase, cassava prices in market $P_{j,}$ will also increase because these markets do relate and there is a communication flow whereby some cassava will flow from market P_j to market $P_{i,}$ there by decreasing supply in P_j. Links accepting the null hypothesis of no co-integration imply the markets are segmented and there is no communication flow between those links. Incase of price changes in market P_i, there is no reason to expect that prices in market P_j will also change. Table 4.9 summarizes results of ADF test on residuals from OLS regression of pairs of price series identified to be I(1)[32]. The study used Mac Kinnon critical[33] values to determine significant tests.

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[32] For space and clarity, the table only presents results of links indicating co-integration. The rest of the estimations are provided in annex II of this thesis. M

[33] For further information see Mac Kinnon, J. G (1991) 'Critical Values for Co-integration tests' In long run equilibrium relationships: Reading in Co-integration, R. F. Engle and G. W. J. Granger (eds), Oxford: Oxford University Press

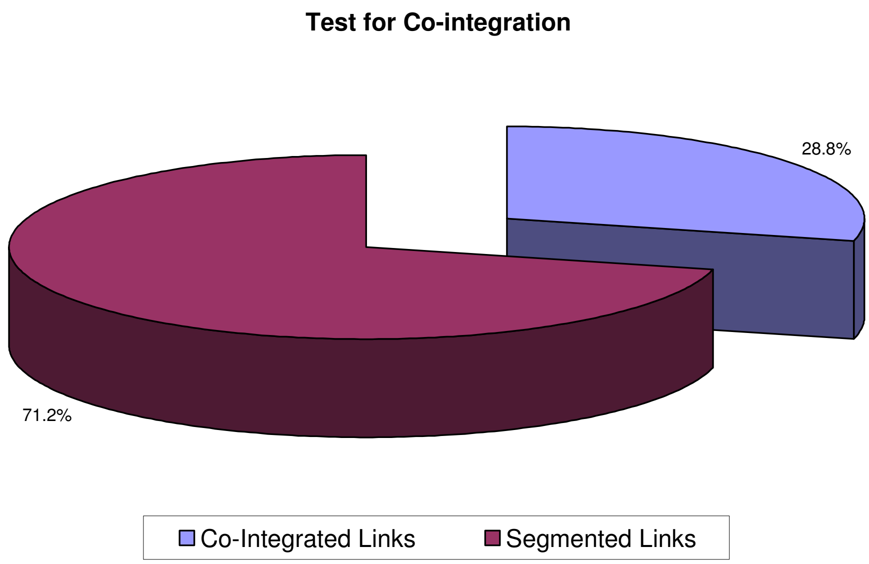

Figure 4.8: Percentage of co-integrated and Segmented links

Table 4.9: Results of ADF test for unit roots in OLS regression residual (μ_t)

Market *i*	Market *j*	Error term (μ_t) ADF statistic				Order of Integration
		d_2 Coefficient	t-Statistic	Lags	MacKinnon Critical Values (5%)	
Thete	Lilongwe	-0.49	-3.594	3	-3.503	I (0)
Thete	Mitundu	-0.662	-3.828	1	-3.501	I (0)
Thete	Msundwe	-0.804	-3.658	6	-3.509	I (0)
Thete	Nanjiri	-0.6	-4.063	1	-3.499	I (0)
Thete	chimbiya	-0.502	-3.87	4	-3.505	I (0)
Sharpvalley	Lizulu	-0.925	-3.829	5	-3.514	I (0)
Sharpvalley	Mtakataka	-0.965	-3.784	2	-3.511	I (0)
Sharpvalley	Ntcheu	-0.649	-3.597	3	-3.503	I (0)
Nanjiri	Lilongwe	-0.395	-3.572	1	-3.407	I (0)
Nanjiri	Mitundu	-0.403	-3.638	2	-3.509	I (0)
Nanjiri	chimbiya	-0.471	-3.772	4	-3.516	I (0)
Msundwe	chimbiya	-0.632	-3.901	1	-3.499	I (0)
Msundwe	Lilongwe	-0.514	-3.813	2	-3.501	I (0)
Msundwe	Mitundu	-0.693	-4.106	1	-3.501	I (0)
Msundwe	Nanjiri	-0.521	-3.839	2	-3.501	I (0)
Msundwe	Thete	-0.528	-3.824	2	-3.501	I (0)
Mtakataka	Salima	-0.759	-3.533	2	-3.516	I (0)
Mtakataka	Sharpvalley	-0.83	-3.725	2	-3.509	I (0)
Mtakataka	Lizulu	-0.803	-3.47	2	-3.509	I (0)
Mtakataka	Ntcheu	-0.54	-3.953	2	-3.509	I (0)
Mitundu	Nanjiri	-0.419	-3.752	2	-3.503	I (0)
Mitundu	Thete	-0.591	-3.837	2	-3.503	I (0)
Mitundu	chimbiya	-0.382	-3.652	1	-3.501	I (0)
Mitundu	Lilongwe	-0.589	-3.732	1	-3.501	I (0)
Mitundu	Msundwe	-0.528	-3.578	2	-3.503	I (0)
Ntcheu	Mtakataka	-0.46	-3.535	2	-3.509	I (0)
Chimbiya	Mitundu	-0.272	-3.875	3	-3.505	I (0)
Chimbiya	Nanjiri	-0.332	-3.771	2	-3.501	I (0)
Chimbiya	Lilongwe	-0.271	-3.803	2	-3.501	I (0)
Chimbiya	Msundwe	-0.279	-3.837	2	-3.501	I (0)
Chimbiya	Nanjiri	-0.332	-3.771	2	-3.501	I (0)
Chimbiya	Thete	-0.276	-3.939	2	-3.501	I (0)
Lilongwe	Mitundu	-0.579	-3.747	1	-3.501	I (0)
Lilongwe	Nanjiri	-0.577	-3.569	2	-3.499	I (0)
Lilongwe	Chimbiya	-0.463	-3.966	2	-3.501	I (0)
Lilongwe	Msundwe	-0.483	-3.588	2	-3.501	I (0)
Lilongwe	Thete	-0.386	-3.966	3	-3.499	I (0)
Lizulu	Mtakataka	-0.546	-3.802	1	-3.507	I (0)
Lizulu	Ntcheu	-0.502	-3.629	1	-3.505	I (0)
Lizulu	Salima	-0.647	-3.523	2	-3.516	I (0)

Market *i*	Market *j*	Error term (μ_t) ADF statistic				Order of Integration
		d_2 Coefficient	t-Statistic	Lags	MacKinnon Critical Values (5%)	
Lizulu	Sharpvalley	-0.456	-3.570	2	-3.507	I (0)
Kasungu	Mchinji	-0.657	-3.626	3	-3.507	I (0)
Mchinji	Kasungu	-0.743	-4.554	2	-3.501	I (0)
Salima	Mtakataka	-0.557	-3.644	1	-3.514	I (0)
Salima	Ntcheu	-0.536	-3.583	3	-3.519	I (0)
Salima	Sharpvalley	-0.557	-3.597	1	-3.514	I (0)

Figure 4.9 summarizes integrated links as identified by co-integration analysis. Three economic markets can be observed i.e. a group of markets that are co-integrating. Firstly, significant co-integration coefficients from Salima, Mtakataka, Sharpvalley, Lizulu and Ntcheu show that these markets are in one economic market. A second economic market is observed comprising Lilongwe, Mitundu, Chimbiya, Thete Nanjiri and Msundwe. A third economic market observed comprise Mchinji and Kasungu markets. This implies that any price change in one market; in the long run, similar changes will be reflected in the other markets within the same economic market and there will be no reason to expect price changes in markets from a different economic market. In case of any policy intervention (such as price stabilization using either trade or storage policies) by government that would influence prices for fresh cassava, concentration can be on one market in each of the economic markets and the effects would be transmitted in the long run to other markets within the same economic market.

Map of Central Malawi

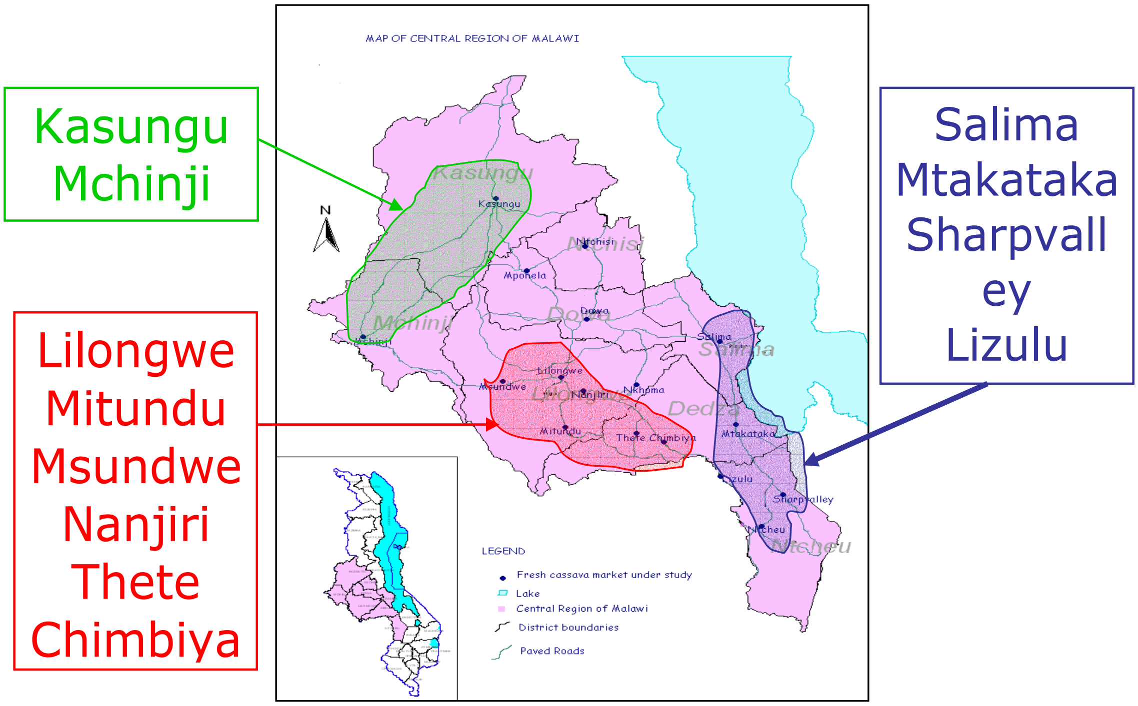

Figure 4.9: Map of Central Malawi showing Economic markets observed by applying co-Integration analysis

These results therefore indicate that central region is divided into several economic regions. The results agree with spatial location of the cassava markets under study. The markets are forming an economic region located within the area (See figure 4.9) and are linked with various roads[34] that could be facilitating integration. However, it should be borne in mind that it can be argued that the trading practice for fresh cassava in central Malawi is not necessarily that one market is directly supplying fresh cassava to another market i.e. there is limited physical flow of fresh cassava from one market to another. For example, producers and middlemen around and near to Mitundu and Nanjiri markets collect fresh cassava at farm gate and transport it directly to Lilongwe market without trading it on any of the former markets. In this case, neither Mitundu nor Nanjiri markets perform the function of transmitting/handling fresh cassava (Nanjiri or Mitundu do not physically transfer fresh cassava) between producers in Mitundu or Nanjiri and consumers at Lilongwe market.

However, the markets under study are the main cassava trading centers, surrounded by large number of producers who sell to consumers and smaller retailers selling cassava in streets usually by bicycle, by head, or by foot. In this case, the interaction of retailers/producers and middlemen who trade between producers and consumers contribute to price transmission between spatially located markets because middlemen and producers have a choice of where to sell their commodity. On the other hand, there are smaller markets such as Linthipe whereby different producers bring together their cassava and are bought by middlemen who transport this cassava to distant markets such as Lilongwe. This

[34] This study did not test structural determinants affecting market integration however, results from studies such as Golleti et al. (1994) and Escobal (2005) on the role of public infrastructure such as roads on market integration indicate that presence of paved roads connecting various markets facilitate market integration because they reduce transaction costs to move products from one market to another.

is also playing a big role in transmission of price information from one market to another.

Although some literature[35] argues that existence of the co-integration relationships is neither a necessary nor sufficient condition for market integration, Ismet *et al*. (1998) in a study on Indonesia rice market using co-integration analysis and Goletti *et al.* (1994) in a study of maize market in Malawi, observed that stable long run relationships that exist between spatial price series are an indication of strong price dynamics, indicating that the exchange locations are in the same economic markets and are integrated. The implication here is that since there is no deliberate policy process that is fettering cassava prices in the central region of Malawi; results of this analysis are reliable.

4.4 Estimated results of market integration: Distributed-Lag model

The distributed-lag model aims at dynamic representation of market integration in order to supplant the imprecision and inferential dangers of static bivariate measures such as co-integration. Using the same data used in co-integration analysis, the model permits each local price series to have its own dynamic structure (and allows for any correlated local seasonality or other characteristics) as well as an inter-linkage with other local markets. The dynamic model has an advantage that one can distinguish between the concepts of instantaneous market integration and the less restrictive idea of integration as a long run target of the short run dynamic adjustment. Unlike Ravallion (1986), this study did not assume existence of a central market given that there is no specific central fresh cassava market covering all of central Malawi. Therefore, the Ravallion model (equation 3.9) was performed on each market becoming a reference market (See annex III).

[35] See for example Barrett (1996)

Following Ravallion (1986), three key hypotheses can be tested: market segmentation; short-run market integration and long-run market integration.

4.4.1 Testing for market segmentation

A null hypothesis that fresh cassava markets in the central region of Malawi are segmented and that they are entirely unrelated was tested. Thus:

$$H_o: \quad b_{ij} = 0 \qquad (j = 0, \ldots\ldots\ldots n)$$

Results are summarised in table 4.10[36] below. The results show that 88.8% of the tested 156 links are segmented from each other. From the markets indicated to be segmented, this implies that none of the prices from a central market, P_{1t}, under consideration significantly influence prices in the local market, P_{it} under consideration. For example, the null hypothesis of segmentation between Mitundu market and Sharpvalley market is rejected whether Mitundu or Sharpvalley is taken as a central market. In a segmented link, fresh cassava prices from the reference central market are therefore independent from prices in the local market. The high number of segmented links as observed by the distributed-lag model is in agreement with results of correlation coefficients of price series and co-integration based on Engle and Granger (1987) approach as presented above. Percentage of non segmented links observed by distributed-lag model is lower than the percentage of long term co-moving links of cassava prices as shown by correlation coefficients of price series and co-integration based on Engle and Granger (1987) approach. Possible reasons to explain the low percentage of non-segmented links are provided in chapter 5.

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[36] In the interest of space, this table only indicates the significant links rejecting the hypothesis of market segmentation. The rest of the results for all tested market links are presented in annex III of this thesis

Table 4.10: Results of tests for market integration using distributed lag model

Market *i*	Market *j*	a_{ij}	*F*-Statistic	b_{i0}	*t*-statistic	$a_{ij} + b_{ij}$
Chimbiya	Thete	0.843	5.253	0.199	1.833	1.043
Lilongwe	Chimbiya	0.912	4.264	0.162	2.953	1.074
Lilongwe	Mitundu	0.941	3.199	0.155	2.745	1.097
Lilongwe	Nanjiri	0.944	3.725	0.074	2.461	1.018
Lizulu	Ntcheu	0.780	6.185	-0.171	-1.623	0.609
Mitundu	Lilongwe	0.713	3.806	0.274	2.744	1.047
Mitundu	Nanjiri	0.834	2.929	0.031	2.253	0.865
Mitundu	Thete	0.463	9.086	0.641	3.448	1.103
Mtakataka	Salima	0.591	5.772	0.479	2.311	1.070
Mtakataka	Sharpvalley	0.982	3.561	0.112	1.704	1.094
Nanjiri	Chimbiya	0.823	2.779	0.065	2.183	0.888
Nanjiri	Lilongwe	0.750	2.865	0.070	2.461	0.820
Nanjiri	Mitundu	0.821	3.623	0.174	2.377	0.995
Ntcheu	Lizulu	0.690	4.892	0.480	2.256	1.170
Salima	Sharpvalley	0.825	2.748	0.153	1.761	0.977
Salima	Mtakataka	0.867	3.308	0.229	1.712	1.096
Sharpvalley	Mtakataka	0.593	10.367	0.326	3.449	0.919
Sharpvalley	Salima	0.585	5.144	0.353	1.693	0.938
Thete	Chimbiya	0.686	6.023	0.478	2.618	1.164

Note: The critical value for F-Test with N_1= 3 and N_2= 48 at the 95% Significance level is 2.61.
Critical value for 1-tailed t-test with N+48 at the 95% Confidence level is 1.677

4.4.2 Testing for short-run market integration

A price change in the central market will be immediately passed on in *i*-th market if b_{i0} = 1 i.e. price movement in one market depends on instantaneous price movement in the other market. On the basis of the results (table 4.10 above), the distributed-lag model rejects any short run market integration between any of the markets. Thus the Ravallion model fails to detect for immediate transfer or 'one-on-one' transfer of cassava prices from one market to another within the central region of Malawi. This means that among non segmented fresh cassava markets, if there is a price change in reference central market, say Salima; the price change will not be immediately reflected on prices in a local market say Mtakataka. The following are probable reasons to explain absence of short run market integration in the price series:

The first reason could be frequency of data used in this study. The study used weekly prices which could not reflect the price changes in a rather short time. In a study by Phiri (2001), it was observed that cassava marketing is done by middlemen/producers who transport their cassava on bicycles from areas of production to market centres such that it only takes a day to transfer the commodity from point of production to market and price differentials could be transmitted within a day than weeks. Unfortunately, daily price series for cassava are not available in Malawi. Furthermore, fresh cassava is marketable when fresh as such has to be sold within few days after harvesting to preserve its quality.

The second reason could be a result of characteristics of fresh cassava marketing taking place within the central region. In the same study by Phiri (2001) it was observed that within the fresh cassava market chain, there are mainly producers and middlemen participating at the farm gate. Most of the trade is done at farm gate level whereby producers sell to middlemen who take the cassava directly to urban markets. As earlier stated the trading practice for fresh cassava in central Malawi is not necessarily that one market is directly supplying fresh cassava to another market i.e. there is limited physical flow of fresh cassava from one market to another. For example, producers and middlemen around and near to Mitundu and Nanjiri markets collect fresh cassava at farm gate and transport it directly to Lilongwe market without trading it on any of the former markets. In this case, neither Mitundu nor Nanjiri markets perform the function of transmitting/handling fresh cassava (Nanjiri or Mitundu do not physically transfer fresh cassava) between producers in Mitundu or Nanjiri and consumers at

Lilongwe market. This therefore prevents immediate transmission of price information and immediate response to price changes by the traders.

4.4.3 Testing for long-run market integration

Lastly, the distributed-lag model tested the hypothesis of long run integration among the fresh cassava markets. As earlier stated, attainment of unity in the measures fulfils the condition for perfect market integration. There is no specific central market for cassava covering the whole central region such that price series from all non segmented markets were regressed over each other to test for long-run integration. All results are presented in Annex III. Table 4.10 above provides a summary of integrated links as identified by the distributed-lag model.

Immediately emerging from the table is high degree of long run market integration evident for the entire period under study. The average deviation from unity is 6.9% pointing to the inescapable fact that strong forces towards integration are present. Considering that the price series used in the analysis were already tested for unit roots and were identified to be stationary; then the inferences drawn from the results in the table are valid.

As noted earlier, the percentage of links indicating long run market integration remain low at 11.2% as compared to 28.8% by co-integration model. Additionally, a similar general picture of economic markets/regions as indicated by the co-integration analysis is observed showing four economic markets. Unlike co-integration analysis, Kasungu and Mchinji markets do not indicate market integration in the long run. In the economic market comprising of Mitundu, Lilongwe, Nanjiri, Chimbiya, Msundwe and Thete markets; only Msundwe does not indicate integrated to the rest of the markets. While in the economic group comprising Salima, Mtakataka, Sharpvalley, Lizulu and Ntcheu market; Ntcheu and Lizulu does not indicate integrated with the rest of the markets. However, Ntcheu and Lizulu are integrated between themselves. A possible explanation for the difference in composition of the observed economic groups is provided in chapter five. These results therefore means that past values of prices for fresh cassava in the reference central market together with past values of prices in local market influenced present price P_t in local market. A summary of observed economic markets is provided in figure 4.10.

The conclusion of economic markets as observed by the distribution-lag model follows rejection of null hypotheses of no long-run integration by a group of markets when price series of a local market (for example Mitundu market) is regressed over its own lagged values and lagged values of prices from a reference central market (for example Lilongwe market). Similarly, the null hypothesis is rejected when the same regression is done between price series from Mitundu market (as a local Market) and price series from Nanjiri market (as a central market). Furthermore, the null hypothesis is rejected when series from Nanjiri (local market) is regressed over prices from Lilongwe market (central market). An argument such as the one advanced by Sexton, Kling and Carman (1991) that this type of measure tests a pair of price series for integration can arise. This study did not test if the identified group of markets within the same economic group simultaneously share the same long-run information[37]. As argued by Ravallion (1986), the interest of this distributed–lag model lies in the transmission mechanism evident in the greater economy and not with the structure of price

[37] A multivariate analysis such as the one proposed by Gonzalez-Rivera and Hefland (2001) can be employed to analyze if markets within the same economic group simultaneously share both the same commodity (fresh cassava) and same long run information.

formation within the central market[38]. In this case, the conclusion of economic markets is valid.

Map of Central Malawi

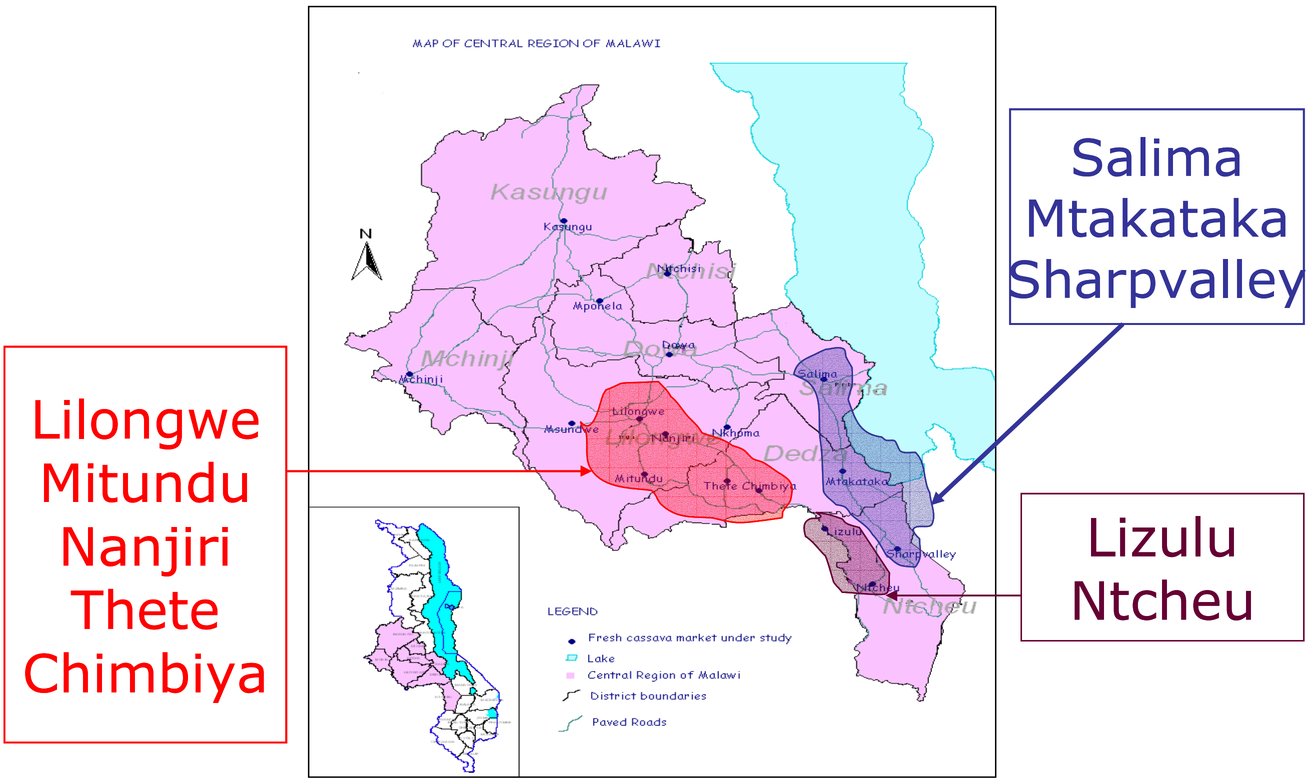

Figure 4.10: Map of Central Malawi showing Economic markets observed by Distributed-lag model

[38] See Ravallion (1986) for further explanation

4.5 Results of Causality Error Correction Mechanism

The causality error correction mechanism was used to test for the response of price variable (the dependent variable) to shocks/changes in price from another market (independent variable). This was achieved by regressing equation (3.4) among co-integrated markets. According to Engle and Granger (1987), a bivariate co-integrated system must have a causal ordering in at least one direction. Just like the ADF tests, of critical importance in the causality test is the specification of lag length, *k* and *h* in the equation. Again, Schwartz Information Criterion[39] (SIC) was employed to determine the optimum lag length. Following Goletti and Babu (1994) market *j* is said to Granger cause market *i* if Υ_2^i is significant and $\sum\phi^i_h$ is not significant. Table 4.11 presents results of causality tests. Direction of the arrow indicates direction of causality and causality is bi-directional where arrows face both directions. Zero indicates lack of causality in either direction. Significant level of 5% was used in hypothesis testing (t-statistic). Causality tests showed a 2-8 weeks lag in price movement

[39] The notion of an information criterion is to provide a measure of information that strikes a balance between measure of goodness of fit and parsimonious specification of the model. Different information criteria differ in how to strike this balance. To select appropriate lag length, the study chose lag length with the smallest Schwartz Information Criterion.

Table 4.11: Results of causality test based on causality Error Correction Mechanism

Market *i*	Market *j*	Υ_2 Coefficient	t-Statistics	$\sum \phi^{h}$ $\Delta P_{j,t-h}$ Coefficient	t-statistics	Market *j*	Market *i*	Υ_2 Coefficient	t-Statistics	$\sum \phi^{h}$ $\Delta P_{j,t-h}$ Coefficient	t-statistics	Direction of Causality
Thete	Lilongwe	0.196	2.331*	0.112	1.539	Lilongwe	Thete	0.019	0.360	0.016	1.106	←
Thete	Mitundu	-0.318	-2.789*	-0.026	-1.340	Mitundu	Thete	-0.098	-1.339	0.002	0.119	←
Thete	Msundwe	0.017	0.214	0.014	0.921	Msundwe	Thete	-0.035	-0.400	0.011	0.384	0
Thete	Nanjiri	-0.167	-2.228*	0.019	0.439	Nanjiri	Thete	-0.065	-0.065	-0.037	-2.155	←
Sharpvalley	Lizulu	0.203	2.532*	0.004	1.258	Sharpvalley	Lizulu	0.203	2.532*	0.004	1.258	←→
Sharpvalley	Mtakataka	0.179	2.687*	0.002	1.389	Mtakataka	Sharpvalley	0.239	1.563	0.029	1.079	←
Sharpvalley	Ntcheu	0.113	1.986*	0.014	1.022	Ntcheu	Sharpvalley	-0.062	-0.534	-0.015	-0.651	←
Nanjiri	Lilongwe	-0.046	-0.667	0.010	0.173	Lilongwe	Nanjiri	-0.009	0.165	-0.004	-0.158	0
Nanjiri	Mitundu	0.028	0.353	-0.016	-1.090	Mitundu	Nanjiri	0.105	1.702*	0.008	0.942	→
Msundwe	chimbiya	-0.017	-0.245	-0.035	-1.065	Chimbiya	Msundwe	-0.001	-0.020	0.004	0.303	0
Msundwe	Lilongwe	0.059	0.659	-0.106	-1.156	Lilongwe	Msundwe	-0.064	-1.281	-0.008	-0.851	0
Msundwe	Mitundu	0.113	1.117	-0.014	-0.609	Mitundu	Msundwe	-0.079	-1.437	0.013	-1.297	0
Msundwe	Nanjiri	0.002	0.994	0.012	0.830	Nanjiri	Msundwe	-0.005	-0.104	-0.010	-1.107	0
Mtakataka	Salima	0.164	1.050	0.001	0.000	Salima	Mtakataka	-0.008	-0.179	0.000	-0.122	0
Mitundu	chimbiya	0.030	0.780	0.013	0.753	Chimbiya	Mitundu	-0.083	-1.491	-0.034	2.598	0
Mitundu	Lilongwe	-0.113	-1.704	-0.068	-1.364	Lilongwe	Mitundu	-0.043	-0.660	0.006	0.517	0
Ntcheu	Mtakataka	0.142	1.578	0.002	1.070	Mtakataka	Ntcheu	0.064	0.651	0.018	0.909	0
Chimbiya	Lilongwe	0.131	2.224*	0.057	1.052	Lilongwe	Chimbiya	-0.021	-0.811	0.006	0.367	←
Chimbiya	Nanjiri	-0.117	-2.135*	-0.019	-0.552	Nanjiri	Chimbiya	0.069	1.601	-0.005	-1.000	←
Chimbiya	Thete	0.104	1.812*	0.009	0.526	Thete	Chimbiya	-0.024	-0.423	-0.020	-0.752	←
Lizulu	Mtakataka	0.066	1.110	-0.001	-0.898	Mtakataka	Lizulu	-0.339	3.101	0.011	2.926	0
Lizulu	Ntcheu	0.081	1.361	-0.010	-0.709	Ntcheu	Lizulu	0.352	3.441	0.008	2.441	0
Lizulu	Salima	0.044	0.413	-0.005	-0.379	Salima	Lizulu	-0.059	-0.979	-0.044	1.938	0
Kasungu	Mchinji	0.099	2.449	-0.032	-2.036	Mchinji	Kasungu	0.185	1.973	0.085	2.158	0
Salima	Ntcheu	0.035	0.793	0.019	1.742	Ntcheu	Salima	0.052	0.368	-0.017	-0.948	0
Salima	Sharpvalley	-0.053	-0.751	-0.033	-2.265	Sharpvalley	Salima	0.170	2.558*	0.035	0.489	□

NB: Market *j* is said to Granger cause market *i* if Υ_2^{i} is significant and $\sum \phi^{i}_{h}$ is not significant. Significant level of 5% was used in hypothesis testing in this analysis and is indicated by * where the t-statistic is significant.

From table 4.11 above, results of the causality test do not indicate a distinct central market for fresh cassava during the period under study. Out of 23 pairs of co-integrated markets tested for causal relationship, only one pair (Sharpvalley and Lizulu) indicate bi-directional causal price relationship. Nine pairs indicated causal relationship in at least one direction. Nanjiri market indicated central to 3 other markets: chimbiya, Thete and Mitundu. Lilongwe market indicated central to two other markets: Chimbiya and Thete, while Thete, Ntcheu, Mtakataka, sharp valley and Mitundu indicated central to one market each. These results also explain the co-integration between Salima and Lizulu markets whereby there is bidirectional causality of Lizulu and Sharpvalley; the causality between Salima and Sharpvalley also indicated significant. It therefore can be concluded that there is a stable long run linear relationship between the prices from markets indicating co-integration and causality such that one series say, P_i can be used to linearly forecast prices in another market say, P_j.

The results are similar to findings of causality among cassava markets in Ghana during the period of 1997-2000 in a study by Aderman and Shively (2002) whereby plantain and cassava markets showed no significant causality unlike grain markets. As earlier discussed, majority of fresh cassava marketing is largely marketed from points of production to urban markets by middlemen and producers. Due to distances between district markets, limited flow of cassava flows directly from one district market to another. This could possibly affect the results displayed here. Price data is hardly available for smaller markets within districts such as Area 25, Area 23 markets, etc which could be supplied by Lilongwe market.

4.6 Results of the Index of Market Connectedness analysis

In order to measure price relationship between integrated markets based on the distributed-lag model, equation 3.10 was calculated. As already indicated, markets are fully integrated if $a = -1$ and IMC = 0, While the markets are completely isolated if $a = c$ and IMC = ∞. IMC is generally greater than 0. When IMC is closer to 0, the degree of integration between markets is higher and vice versa. IMC < I indicate high degree of market integration and IMC > 1 imply low degree of market integration.

IMC results are presented in table 4.12. From the table, results indicate that among the integrated markets based on the Ravallion model, Mitundu and Thete markets have the lowest degree of market integration. This implies that the degree of market integration observed between Mitundu and Thete is low. Mtakataka versus Sharpvalley; and Lilongwe versus Nanjiri indicate the highest degree of market integration. This implies that these market links are highly integrated. The results furthermore indicate an average IMC of 0.371 implying that among the integrated links, the degree of market connectedness is high.

Table 4.12: Results of IMC

Market *i*	**Market *1***	a_{i1}	$(a_{i\,-1})$	*c*	$(c- a_{i1})$	***IMC = (ai1- 1)/(c- ai1)***
Sharpvalley	Mtakataka	0.593	-0.407	-0.018	-0.611	0.666
Sharpvalley	Salima	0.585	-0.415	-0.002	-0.587	0.707
Salima	Mtakataka	0.867	-0.133	-0.012	-0.879	0.151
Nanjiri	chimbiya	0.823	-0.177	0.006	-0.817	0.217
Nanjiri	Lilongwe	0.750	-0.250	0.009	-0.741	0.337
Mtakataka	Salima	0.590	-0.410	0.016	-0.574	0.714
Mtakataka	Sharpvalley	0.981	-0.019	0.013	-0.968	0.020
Mitundu	Lilongwe	0.738	-0.262	0.013	-0.725	0.361
Mitundu	Nanjiri	0.834	-0.166	0.002	-0.832	0.200
Mitundu	Thete	0.463	-0.537	0.005	-0.458	1.172
Ntcheu	Lizulu	0.690	-0.310	-0.013	-0.703	0.441
Chimbiya	Mitundu	0.868	-0.132	-0.001	-0.869	0.152
Chimbiya	Thete	0.843	-0.157	0.021	-0.822	0.191
Lilongwe	Chimbiya	0.912	-0.088	-0.026	-0.938	0.094
Lilongwe	Mitundu	0.941	-0.059	-0.019	-0.960	0.061
Lilongwe	Nanjiri	0.944	-0.056	-0.022	-0.966	0.058

Note: IMC = (ai1 -1)/(c-a)

In calculating IMC, this study did not include the variables of transportation, policy, seasonal factors and time trend. Therefore there was no $c_i X_{it}$ in the model (3.9). The omission of those variables is based on the following reasons:

i. It was not possible to get detailed and accurate data on transportation costs between regional markets and reference markets.

ii. Policy factors are important influence on market integration. However, during the period under study, there has been no clear cassava marketing policy interventions in the country to be incorporated in the model.

iii. As described in chapter three, prices were deflated during the preliminary and seasonal analysis. Therefore seasonal factors and time trend were not retained in the series and eventually not included in the model because their coefficients could not be significant.

5 CONCLUSION

The study draws conclusions on spatial market integration of cassava markets in central Malawi based on analysis conducted using two analytical procedures: a co-integration approach (as developed by Engle and Granger, 1987) and a distributed-lag model (Ravallion (1986) approach). The study further employed the Causality Error Correction Mechanism to determine causality between co-integrated market links and Index of Market Connectedness to examine the degree of market integration between integrated market links as identified by the distributed-lag model.

Results from both co-integration and distribution-lag model point to unescapable fact that forces of market integration are in play in the fresh cassava market in the central region of Malawi. However, very low percentages of integrated links in the long run (28.8% and 11.2% for co-integration and distribution lag model respectively) indicate that the market is not perfectly efficient in transmitting price information across spatially separated markets. Two possible explanations can be provided. As described earlier, the trading practice for fresh cassava in central Malawi is not necessarily that one market is directly supplying fresh cassava to another market i.e. there is limited physical flow of fresh cassava from one major market to another major market. For example, producers and middlemen around and near to Mitundu and Nanjiri markets collect fresh cassava at farm gate and transport it directly to Lilongwe market without trading it on any of the former markets. In this case, neither Mitundu nor Nanjiri markets perform the function of transmitting/handling fresh cassava (Nanjiri or Mitundu do not physically transfer fresh cassava) between producers in Mitundu or Nanjiri and consumers at Lilongwe market. This therefore may prevent immediate transmission of price information and immediate response to price changes by the traders in different located markets.

The second reason is that cassava was initially promoted mainly for food security realising the variability of maize production in Malawi. In the process, it was realised that one of the constraints to cassava production is lack of clean planting material for cassava. As a result, Government of Malawi, NGOs and research institutions initiated programs on multiplication, distribution and purchasing of clean cassava planting material from local farmers. The period understudy coincided with these programs where by selling prices of planting material went as high as MK7 per 1m cutting of planting material. This provided a new market niche for cassava producers to generate higher incomes from the crop. Considering that planting material is harvested and sold whilst fresh and that in most cases farmers uproot cassava roots within the next one or two days after harvesting of planting material so as to preserve its quality, a question on selling and pricing decisions for fresh cassava by producers is raised: what dominates a farmer's decision on what time to sell and what price to set for fresh cassava - fresh roots or fresh stems?

The impact of cassava stems on pricing and marketing decisions is not proved in this study. However, pricing and marketing decisions will differ between those handling both commodities and those handling only one commodity taking into consideration gains from trade. Those handling both commodities may base their decision on gains from both stems and roots while those not handling stems may base their decision relative to prices of other substitutes such as maize particularly in areas where cassava is a staple food or in areas where cassava is consumed as a meal during maize shortages. These differences will therefore contribute to fresh cassava roots pricing inefficiency and might have affected prices recorded during the period understudy and subsequently affecting the results displayed here.

From the results presented here, it is inevitable that fresh cassava market within central Malawi is divided into economic markets. Co-integration analysis indicates three economic markets [(Salima, Mtakataka, Sharpvalley, Lizulu and Ntcheu); (Lilongwe, Mitundu, Chimbiya, Thete Nanjiri and Msundwe); (Mchinji and Kasungu)] while dynamic representation of price series from the same markets also indicates three economic markets but with different composition [(Chimbiya, Thete, Mitundu, Lilongwe and Nanjiri), (Salima, Mtakataka, Sharpvalley), (Ntcheu and Lizulu)]. The difference could be a result of differences in econometric specifications of the two measures. The underlying assumptions of Ravallion (1986) model that "spatial arbitrage conditions must always bind and trade flows must occur in every period" are restrictive for co-movement of price series. Baulch (1997) observed that these conditions will not always hold under conditions of differing demand and supply shocks in the marketing system. The period under study (January, 2004 to January, 2006) coincided with a national disaster in maize production[40] significantly below the national requirements. Kasungu and Mchinji districts were among the most hit areas with severe maize shortages. This could have disturbed cassava price formation and transmission within the markets. On the other hand, this could have enhanced market integration due to flow of cassava from surplus areas to Maize/Cassava deficit areas. Given the integration test results at hand, the former could hold.

[40] Maize is the main staple food for Malawi particularly the central region of Malawi. See Malawi Vulnerability Assessment Report, May, 2005 by Ministry of Economic Planning and Development.

6 RECOMMENDATIONS

Based on results and conclusions drawn from the analysis carried out in this study and bearing in mind that the main objective for Malawi government in promoting cassava production is to find a food security crop to address problems experienced with variability of maize production, the following key recommendations are made:

In the past decade, there has been increase in production of cassava. In order to improve its contribution to household food security, it is being recommended that efforts should be made to support farmers producing cassava planting material to specialise in production of planting material alone. In the process of promoting cassava as a food security crop, selling of cassava stems become a major undertaking for most cassava growers, this is believed to contribute to inefficiency in fresh cassava pricing. Farmers handling cassava solely for consumption are being negatively affected. Promotion of specialization in cassava production will provide an opportunity to enhance pricing efficiency based on commodities.

Furthermore, it is recommended that efforts should be made to facilitate organization of cassava producers into co-operatives or associations that will support in regulation of pricing and marketing of cassava commodities. Given the characteristics of cassava marketing being practiced in the region, pricing and marketing decisions by farmers are being made subjectively and largely based on subsistence needs of the producers. Organisation of farmers would enhance pricing and marketing capacity for fresh cassava and other cassava products particularly stems. Although efforts have been made to establish some market information systems and collection of agricultural commodity prices particularly cassava, there is a weak feedback system to cassava producers. There is no clear analysis and dissemination of the price information to producers to enable them make informed choices on when and where to sell their commodities. It is therefore recommended that periodic analysis and dissemination of collected cassava prices be developed so that there is regular feedback to producers that could assist them in making pricing and marketing decisions.

Although fresh cassava constitutes bigger market share of traded cassava, it is being recommended that efforts to analyse efficiency of the marketing system of fresh cassava roots should not be looked and analysed in isolation from other cassava products particularly stems (planting material) which would influence a lot in pricing and marketing decision making by producers handling both stems and fresh roots. Further analysis on gains from trade in each channel (fresh roots, fresh stems and processing industry) is recommended. Each potential market can then be linked to the season in which agronomical attributes of cassava can suit. This will ensure efficiency in production and marketing of cassava while at the same time making the desirable contribution to food security. The recommended analysis can therefore include investigation of transmittal of information across commodities: cassava roots and cassava stems; to determine efficiency in pricing and decision making on when to uproot and sell cassava. For example, in this study, it could have been possible to include price series on cassava stems as an exogenous factor in the distributed–lag model. However price information on cassava stems was not available to enable such analysis.

This study identified economic markets in which fresh cassava is marketed within central Malawi. Price stabilisation policy interventions by government can be concentrated on one market in each of the economic markets and the effects would be transmitted in the long run to other markets within the same economic market. Nevertheless, one might be interested to analyse further if the identified group of markets within the same economic group simultaneously share the same long-run information. Multivariate analysis methodologies such as the one proposed by Gonzalez-Rivera and Hefland (2001) can be employed to analyze if markets within the same economic group simultaneously share both same commodity (fresh cassava) and same long run information. However, such efforts to carry out further analysis could be hindered by limited availability appropriate time series data. It is therefore recommended that organizations collecting and monitoring price information such as Agro Economic Survey and FEWSNET should include collection of other economic/marketing data such as transfer costs. This would facilitate further detailed analyses to understand marketing efficiency of commodities such as cassava.

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Annex I: Timmer (1987) Derivation of Index of Market Connectedness (IMC)

Timmer (1987) observed that while the Ravallion model (equation 3.9) allows the testing of various hypotheses about market efficiency, it does not provide and easily accessible statistic about the degree of integration between polar cases. To deal with this issue, Timmer (1987) made two modifications of the model. First, he worked in logarithm of prices. This implies ad valorem marketing costs rather than a fee per quantity handled (Alderman, 1992). According to Alderman (1992), this innovation is however, not essential to their second modification which is the assumption of a single lag structure for price formation rather than the six lags that Ravallion uses. This simplifies subsequent interpretation since a little algebraic manipulation allows one to reformulate the model as:

$$(P_{it} - P_{1t-1}) = (\alpha_{i-1}) (P_{it-1} - P_{1t-1}) + b_{i0} (P_{1t} - P_{1t-1}) + (\alpha_i + b_{i0} + b_{i1} - 1) P_{1t-1} + c_i X_{it} + e_{it} \quad [A.1]$$

With this expression, one sees that the temporal change in a peripheral (local) market is a function of the spatial price spread in the last period, the temporal change in the central, or reference market and the price level in the reference market in the last period. Again, seasonal and policy variables are included[41]. Equation (A.1) can further be manipulated to derive

$$P_{it} = (1 + a) P_{it-1} + b (P_{1t} - P_{1t-1}) + (c-a) P_{1t-1} + c_i X_{it} + e_{it} \quad [A.2]$$

Where;

$a = \alpha_{i-1}$; $b = b_{i0}$; $c = \alpha_i + b_{i0} + b_{i1} - 1$;

In long-run equilibrium conditions, $(P_{1t} - P_{1t-1}) = 0$. If one assumes also that $c_i = 0$, then $(1 + a)$ and $(c-a)$ are, respectively, the contribution of local and central market price history to current prices. If the prices are well integrated, the latter will have a comparatively strong influence on the local price level. Timmer suggests that the

[41] These are bivariate dummy variables. As such it is useful to include an intercept as well.

relative magnitude of the two influences can be indicated by their ratio. He the defines this as the Index of Market Connectedness (IMC) with values less than 1 as indicating high market integration in the short-run.

Ravallion (1986) and Heytens (1986) used these models to test for the existence any seasonal patterns in market integration. This is important as it is possible that in some seasons the cost of transport exceeds the difference in production or import prices between the two markets. At such times, the price in one market could appear not to be linked with movements of the other (Alderman, 1992).

Annex II: Results of All Co-integration tests

As discussed earlier, the concept of co-integration states that, if a series X_t is non-stationary but its first difference is stationary, then it is said to be integrated of order one or simply integrated, and could be represented as X_t ~ I(1). Otherwise, if the X_t is stationary, it is said to be integrated of order zero and denoted as X_t ~ I(0). If two time series X_t and Y_t are both I(1), then in most cases the linear combination $Y_t - \alpha - \beta X_t = \mu_t$ is also I(1). But it is possible that μ_t is stationary or I(0). According to Greene, W (2003), if the two series are both I(1), then there may be β such that,

$$\mu_t = Y_t - \beta X_t$$

is I(0). Intuitively, if the two series are both I(1), then this partial difference between them might be stable around a fixed mean. The implication is that the series are drifting together at roughly the same rate. Co-integration test therefore involves applying OLS regression between a given pair of price series taking the form: $P_{it} = \alpha + \beta P_{jt} + \mu_t$, where, P_{it} and P_{jt} denotes prices at time t and at locations i and j respectively for a given commodity, α and β are the parameters to be estimated and μ is the error term. Subsequently, the test involves testing the residual μ_t of the OLS regression for stationarity. This study employed the ADF test to test for stationarity. All the results of ADF tests on residuals are presented in the table below:

		Error term ADF statistic				MacKinnon Critical Values for hypothesis of unit root		
		With Trend						
Market *i*	Market *j*	d_2 Coefficient	t-Statistic	Lags	Order of Integration	1%	5%	10%
Salima	Chimbiya	-0.521	-2.735	2	NI	-4.190	-3.519	-3.190
Salima	Kasungu	-0.564	-2.659	2	NI	-4.184	-3.516	-0.188
Salima	Lilongwe	-0.515	-2.649	2	NI	-4.184	-3.516	-3.188
Salima	Lizulu	-0.539	-2.776	3	NI	-4.190	-3.519	-3.190
Salima	Mchinji	-0.481	-2.604	2	NI	-4.184	-3.516	-3.188
Salima	Mitundu	-0.534	-2.784	3	NI	-4.190	-3.519	-3.190
Salima	Msundwe	-0.571	-2.723	3	NI	-4.190	-0.519	-3.190
Salima	Mtakataka	-0.557	-3.444	1	I (0)	-4.178	-3.514	-3.187
Salima	Nanjiri	-0.536	-2.816	3	NI	-4.190	-3.519	-3.190
Salima	Ntcheu	-0.536	-3.283	3	I (0)	-4.190	-3.519	-3.190
Salima	Sharpvalley	-0.557	-3.497	1	I (0)	-4.178	-3.514	-3.190
Salima	Thete	-0.534	-2.801	3	NI	-4.190	-3.519	-3.190

Market *i*	Market *j*	Error term ADF statistic			Order of Integration	MacKinnon Critical Values for hypothesis of unit root		
		With Trend						
		d_2 Coefficient	t-Statistic	Lags		1%	5%	10%
Thete	chimbiya	-0.502	-3.870	4	I (0)	-4.158	-3.505	-3.182
Thete	Kasungu	-0.407	-3.038	4	NI	-4.158	-3.505	-3.182
Thete	Lilongwe	-0.490	-3.194	3	I (0)	-4.154	-3.503	-3.180
Thete	Lizulu	-0.441	-3.069	4	NI	-4.173	-3.511	-3.185
Thete	Mchinji	-0.522	-3.090	4	NI	-4.154	-3.503	-3.180
Thete	Mitundu	-0.662	-3.828	1	I (0)	-4.150	-3.501	-3.179
Thete	Msundwe	-0.804	-3.258	6	I (0)	-4.168	-3.509	-3.184
Thete	Mtakataka	-0.450	-2.948	2	NI	-4.168	-3.509	-3.184
Thete	Nanjiri	-0.600	-4.063	1	I (0)	-4.146	-3.499	-3.178
Thete	Ntcheu	-0.556	-3.022	2	NI	-4.150	-3.501	-3.179
Thete	Salima	-0.558	-3.108	3	NI	-4.190	-3.519	-3.190
Thete	Sharpvalley	-0.506	-2.941	3	NI	-4.154	-3.503	-3.180
Sharpvalley	chimbiya	-0.601	-2.822	3	NI	-4.154	-3.503	-3.180
Sharpvalley	Kasungu	-0.665	-2.111	1	NI	-4.146	-3.499	-3.178
Sharpvalley	Lilongwe	-0.824	-2.822	1	NI	-4.146	-3.499	-3.178
Sharpvalley	Lizulu	-0.925	-3.829	5	I (0)	-4.178	-3.514	-3.187
Sharpvalley	Mchinji	-0.206	-2.661	1	NI	-4.146	-3.499	-3.178
Sharpvalley	Mitundu	-0.263	-2.052	2	NI	-4.158	-3.505	-3.182
Sharpvalley	Msundwe	-0.457	-2.871	3	NI	-4.154	-3.503	-3.180
Sharpvalley	Mtakataka	-0.965	-3.784	2	I (0)	-4.173	-3.511	-3.185
Sharpvalley	Nanjiri	-0.440	-3.054	3	NI	-4.154	-3.503	-3.180
Sharpvalley	Ntcheu	-0.649	-3.397	3	I (0)	-4.154	-3.503	-3.180
Sharpvalley	Salima	-0.747	-3.041	2	NI	-4.184	-3.517	-3.188
Sharpvalley	Thete	-0.475	-3.000	2	NI	-4.150	-3.501	-3.179
Nanjiri	chimbiya	-0.471	-3.772	4	I (0)	-4.184	-3.516	-3.188
Nanjiri	Kasungu	-0.386	-2.510	6	NI	-4.168	-3.509	-3.184
Nanjiri	Lilongwe	-0.395	-3.272	1	I (0)	-4.142	-3.407	-3.177
Nanjiri	Lizulu	-0.415	-2.469	6	NI	-4.184	-3.516	-3.188
Nanjiri	Mchinji	-0.480	-3.138	2	NI	4.150	-3.501	-3.179
Nanjiri	Mitundu	-0.403	-3.638	2	I (0)	-4.168	-3.509	-3.184
Nanjiri	Msundwe	-0.206	-1.770	3	NI	-4.154	-3.503	-3.180
Nanjiri	Mtakataka	-0.273	-1.976	4	NI	-4.178	-3.514	-3.187
Nanjiri	Ntcheu	-0.264	-1.889	6	NI	-4.173	-3.511	-3.185
Nanjiri	Salima	-0.269	-1.701	4	NI	-4.196	-3.522	-3.191
Nanjiri	Sharpvalley	-0.252	-0.966	4	NI	-4.158	-3.505	-3.182
Nanjiri	Thete	-0.042	-3.926	2	I (0)	-4.150	-3.501	-3.179
Msundwe	chimbiya	-0.632	-3.901	1	I (0)	-4.150	-3.499	-3.178
Msundwe	Kasungu	-0.696	-3.152	2	NI	-4.150	-3.501	-3.179
Msundwe	Lilongwe	-0.514	-3.813	2	I (0)	-4.150	-3.501	-3.179
Msundwe	Lizulu	-0.529	-2.804	2	NI	4.163	-3.507	-3.183
Msundwe	Mchinji	-0.590	-3.054	2	NI	-4.150	-3.501	-3.179
Msundwe	Mitundu	-0.693	-4.106	1	I (0)	-4.150	-3.501	-3.179

Market i	Market j	Error term ADF statistic			Order of Integration	MacKinnon Critical Values for hypothesis of unit root		
		With Trend						
		d_2 Coefficient	t-Statistic	Lags		1%	5%	10%
Msundwe	Nanjiri	-0.521	-3.839	2	I (0)	-4.150	-3.501	-3.179
Msundwe	Ntcheu	-0.549	-2.986	2	NI	-4.150	-3.501	-3.179
Msundwe	Salima	-0.663	-2.843	3	NI	-4.190	-3.519	-3.190
Msundwe	Sharpvalley	-0.321	-2.856	2	NI	-4.150	-3.501	-3.179
Msundwe	Thete	-0.528	-3.824	2	I (0)	-4.150	-3.501	-3.179
Mtakataka	chimbiya	-0.627	-3.114	2	NI	-0.168	-3.509	-3.184
Mtakataka	Kasungu	-0.600	-2.922	2	NI	-4.168	-3.509	-3.184
Mtakataka	Lilongwe	-0.403	-3.638	2	I (0)	-4.168	-3.509	-3.184
Mtakataka	Lizulu	-0.803	-3.470	2	I (0)	-4.168	-3.509	-3.184
Mtakataka	Mchinji	-0.625	-3.028	2	NI	-4.168	-3.509	-3.184
Mtakataka	Mitundu	-0.587	-3.041	2	NI	-4.168	-3.509	-3.184
Mtakataka	Nanjiri	-0.528	-2.922	2	NI	-4.168	-3.509	-3.184
Mtakataka	Ntcheu	-0.540	-3.953	2	I (0)	-4.168	-3.509	-3.184
Mtakataka	Salima	-0.759	-3.533	2	I (0)	-4.184	-3.516	-3.188
Mtakataka	Sharpvalley	-0.830	-3.725	2	I (0)	-4.168	-3.509	-3.184
Mtakataka	Thete	-0.609	-3.128	2	NI	-4.168	-3.509	-3.180
Mitundu	chimbiya	-0.382	-3.382	1	I (0)	-4.150	-3.501	-3.179
Mitundu	Kasungu	-0.345	-2.845	2	NI	-4.154	-3.503	-3.180
Mitundu	Lilongwe	-0.589	-3.732	1	I (0)	-4.150	-3.501	-3.179
Mitundu	Lizulu	-0.431	-2.639	3	NI	-4.168	-3.509	-3.184
Mitundu	Mchinji	-0.402	-3.152	1	NI	-4.150	-3.501	-3.179
Mitundu	Msundwe	-0.528	-3.278	2	I (0)	-4.154	-3.503	-3.180
Mitundu	Mtakataka	-0.411	-2.657	2	NI	-4.168	-3.509	-3.184
Mitundu	Nanjiri	-0.419	-3.752	2	I (0)	-4.154	-3.503	-3.180
Mitundu	Ntcheu	-0.454	-2.866	2	NI	-4.154	-3.503	-3.180
Mitundu	Salima	-0.279	-2.564	2	NI	-4.184	-3.516	-3.188
Mitundu	Sharpvalley	-0.429	-2.608	2	NI	-4.154	-3.503	-3.180
Mitundu	Thete	-0.591	-3.837	2	I (0)	-4.154	-3.503	-3.180
Ntcheu	chimbiya	-0.482	-3.048	2	NI	-4.150	-3.501	-3.179
Ntcheu	Kasungu	-0.518	-2.424	6	NI	-4.168	-3.509	-3.184
Ntcheu	Lilongwe	-0.466	-3.082	2	NI	-4.149	-3.499	-3.178
Ntcheu	Lizulu	-0.580	-3.150	2	NI	-4.163	-3.507	-3.183
Ntcheu	Mchinji	-0.433	-3.120	2	NI	-4.150	-3.501	-3.179
Ntcheu	Mitundu	-0.482	-2.993	2	NI	-4.154	-3.503	-3.180
Ntcheu	Msundwe	-0.562	-2.934	4	NI	-4.150	-3.505	-3.182
Ntcheu	Mtakataka	-0.460	-3.335	2	I (0)	-4.168	-3.509	-3.184
Ntcheu	Nanjiri	-0.431	-2.637	4	NI	-4.158	-3.505	-3.182
Ntcheu	Salima	-0.615	-2.973	4	NI	-4.958	-3.522	-3.191
Ntcheu	Sharpvalley	-0.439	-3.004	2	NI	-4.150	-3.501	-3.179
Ntcheu	Thete	-0.532	-2.690	4	NI	-4.158	-3.505	-3.182
Chimbiya	Kasungu	-0.258	-2.483	2	NI	-4.150	-0.501	-3.179
Chimbiya	Lilongwe	-0.271	-3.803	2	I (0)	-4.150	-3.501	-3.179

Market *i*	Market *j*	Error term ADF statistic			Order of Integration	MacKinnon Critical Values for hypothesis of unit root		
		With Trend						
		d_2 Coefficient	t-Statistic	Lags		1%	5%	10%
Chimbiya	Lizulu	-0.412	-2.746	2	NI	-4.163	-3.507	-3.183
Chimbiya	Mchinji	-0.289	-3.039	2	NI	-4.150	-3.501	-3.179
Chimbiya	Mitundu	-0.272	-3.875	3	I (0)	-4.158	-3.505	-3.182
Chimbiya	Msundwe	-0.279	-3.837	2	I (0)	-4.150	-3.501	-3.179
Chimbiya	Mtakataka	-0.318	-2.262	2	NI	-4.168	-3.589	-3.184
Chimbiya	Nanjiri	-0.332	-3.771	2	I (0)	-4.150	-3.501	-3.878
Chimbiya	Ntcheu	-0.366	-3.041	2	NI	-4.150	-3.501	-3.878
Chimbiya	Salima	-0.275	-2.306	2	NI	-4.186	-3.516	-3.188
Chimbiya	Sharpvalley	-0.264	-3.038	2	NI	-4.150	-3.501	-3.179
Chimbiya	Thete	-0.276	-3.939	2	I (0)	-4.150	-3.501	-3.179
Lilongwe	Chimbiya	-0.463	-3.966	2	I (0)	-4.150	-3.501	-3.179
Lilongwe	Kasungu	-0.456	-2.221	1	NI	-4.146	-3.499	-3.178
Lilongwe	Lizulu	-0.464	-2.584	3	NI	-4.168	-3.509	-3.184
Lilongwe	Mchinji	-0.588	-3.163	2	NI	-4.150	-3.501	-3.179
Lilongwe	Mitundu	-0.579	-3.747	1	I (0)	-4.150	-3.501	-3.179
Lilongwe	Msundwe	-0.483	-3.488	2	I (0)	-4.150	-3.501	-3.179
Lilongwe	Mtakataka	-0.362	-2.352	2	NI	-4.168	-3.509	-3.318
Lilongwe	Nanjiri	-0.577	-3.369	2	I (0)	-4.146	-3.499	-3.178
Lilongwe	Ntcheu	-0.266	-3.143	1	NI	-4.146	-3.499	-3.178
Lilongwe	Salima	-0.277	2.368	2	NI	-4.184	-3.516	-3.188
Lilongwe	Sharpvalley	-0.925	-2.672	2	NI	-4.150	-3.501	-3.179
Lilongwe	Thete	-0.386	-3.966	3	I (0)	-4.146	-3.499	-3.178
Lizulu	Chimbiya	-0.372	3.409	3	I (0)	-4.158	-3.505	-3.182
Lizulu	Kasungu	-0.480	-3.113	2	NI	-4.163	-3.507	-3.183
Lizulu	Lilongwe	-0.441	-2.939	2	NI	-4.163	-3.507	-3.183
Lizulu	Mchinji	-0.434	-2.862	2	NI	-4.163	-3.507	-3.183
Lizulu	Mitundu	-0.425	-2.892	2	NI	-4.163	-3.507	-3.183
Lizulu	Msundwe	-0.483	-3.021	2	NI	-4.163	-3.507	-3.183
Lizulu	Mtakataka	-0.546	-3.802	1	I (0)	-4.163	-3.507	-3.183
Lizulu	Nanjiri	-0.497	-3.050	2	NI	-4.163	-3.507	-3.183
Lizulu	Ntcheu	-0.502	-3.329	1	I (0)	-4.158	-3.505	-3.182
Lizulu	Salima	-0.647	-3.323	2	I (0)	-4.184	-3.516	-3.188
Lizulu	Sharpvalley	-0.456	-3.470	2	I (0)	-4.163	-3.507	-3.183
Lizulu	Thete	0.428	-3.070	1	NI	-4.150	-3.505	-3.182
Kasungu	Chimbiya	-0.206	-2.122	5	NI	-4.163	-3.507	-3.183
Kasungu	Lilongwe	-0.257	-2.041	5	NI	-4.163	-3.507	-3.183
Kasungu	Lizulu	-0.229	-2.189	5	NI	-4.163	-3.507	-3.183
Kasungu	Mchinji	-0.657	-3.626	3	I (0)	-4.163	-3.507	-3.183
Kasungu	Mitundu	-0.240	-2.415	5	NI	-4.163	-3.507	-3.183
Kasungu	Msundwe	-0.279	-1.994	4	NI	-4.163	-3.507	-3.183
Kasungu	Mtakataka	-0.178	-1.407	4	NI	-4.178	-3.514	-3.187

Market i	Market j	Error term ADF statistic With Trend d_2 Coefficient	t-Statistic	Lags	Order of Integration	MacKinnon Critical Values for hypothesis of unit root 1%	5%	10%
Kasungu	Nanjiri	-2.944	-2.700	5	NI	-4.168	-3.507	-3.183
Kasungu	Ntcheu	-0.197	-2.068	4	NI	-4.158	-3.505	-3.182
Kasungu	Salima	-0.308	-2.086	3	NI	-4.190	-3.519	-3.190
Kasungu	Sharpvalley	-0.340	-2.754	5	NI	-4.163	-3.507	-3.188
Kasungu	Thete	-0.228	-2.381	4	NI	-4.158	-3.505	-3.182
Mchinji	Chimbiya	-0.358	-2.823	2	NI	-4.150	-3.501	-3.179
Mchinji	Kasungu	-0.743	-4.554	2	I (0)	-4.150	-3.501	-3.179
Mchinji	Lilongwe	-0.490	-3.011	1	NI	-4.146	-3.499	-3.178
Mchinji	Lizulu	-0.262	-2.050	3	NI	-4.168	-3.088	-3.184
Mchinji	Mitundu	-0.302	-2.195	3	NI	-4.158	-3.505	-3.182
Mchinji	Msundwe	-0.431	-3.063	2	NI	-4.150	-3.501	-3.179
Mchinji	Mtakataka	-0.333	-2.390	2	NI	-4.168	-3.509	-3.184
Mchinji	Nanjiri	-0.459	-2.547	2	NI	-4.150	-3.501	-3.179
Mchinji	Ntcheu	-0.291	-2.495	2	NI	-4.150	-3.501	-3.179
Mchinji	Salima	-0.331	-2.898	2	NI	-4.184	-3.576	-3.188
Mchinji	Sharpvalley	-0.277	-2.504	2	NI	-4.150	-3.501	-3.179
Mchinji	Thete	-0.415	-3.141	1	NI	-4.146	-3.499	-3.178

Annex: III: Results of All Distributed-lag Model tests

Model specification:

$$\Delta P_{it} = (\alpha_{i1} - 1)(P_{it-1} - P_{1t-1}) + b_{i0}\Delta P_{1t} + (\alpha_{i1} + b_{i0} + b_{i1} - 1) P_{1t-1} + X_{it} c_i + e_{it}$$

Where, ΔP_{it} equals the change in price in the *i*-th (local) market in time *t*, $(P_{it-1} - P_{1t-1})$ is the difference between the price in the *i*-th market and the reference market in time *t-1*, ΔP_{1t} is the change in the price in reference market in time *t*, P_{1t-1} is the lagged value of the reference market, $X_{it} c_i$ is a vector of other influences on the *i*-th market and e_{it} is the error term.

Note: The critical value for F-Test with N_1= 3 and N_2= 48 at the 95% Significance level is 2.61. Critical value for 1-tailed t-test with N=48 at the 95% Confidence level is 1.677

Market *i*	Market *1*	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Thete	chimbiya	2.525	-0.182	-2.424	0.322	1.534	-0.030	-1.383
Thete	Dowa	7.190	-0.210	-2.546	-0.306	-1.527	-0.017	-0.838
Thete	Kasungu	6.729	-0.278	-3.267	-0.510	-1.415	-0.007	-0.344
Thete	Lilongwe	2.693	-0.289	-2.951	0.364	1.583	-0.011	-0.533
Thete	Lizulu	1.409	-0.155	-1.612	0.064	0.369	-0.026	-1.112
Thete	Mchinji	6.114	-0.353	-3.497	0.135	0.638	-0.032	-1.518
Thete	Mitundu	5.876	-0.186	-1.630	0.261	1.804	-0.016	-0.684
Thete	Mkhoma	2.986	-0.309	-3.124	0.204	1.533	-0.007	-0.322
Thete	Mponela	2.271	-0.192	-1.900	-0.016	-0.706	-0.016	-0.706
Thete	Msundwe	3.660	-0.132	-1.943	-0.117	-2.107	-0.019	-0.876
Thete	Mtakataka	2.805	-0.227	-2.296	0.159	1.321	-0.028	-1.177
Thete	Nanjiri	3.045	-0.123	-2.225	0.153	1.843	-0.024	-1.084
Thete	Ntcheu	2.560	-0.233	-2.215	0.148	1.123	-0.034	-1.483
Thete	Ntchisi	2.459	-0.188	-2.052	0.219	1.247	-0.023	-1.043
Thete	Salima	3.914	-0.257	-2.740	0.172	0.843	-0.021	-0.895
Thete	Sharpvalley	3.539	-0.258	-2.637	0.115	0.687	-0.022	-0.995
Sharpvalley	chimbiya	2.257	-0.151	-1.913	0.226	1.479	-0.016	-0.831
Sharpvalley	Dowa	6.193	-0.338	-3.071	0.382	1.518	0.001	0.074
Sharpvalley	Kasungu	8.773	-0.449	-3.689	0.297	1.637	0.018	0.979
Sharpvalley	Lilongwe	6.408	-0.224	-2.595	-0.153	-1.165	-0.003	-0.172
Sharpvalley	Lizulu	4.402	-0.179	-1.932	-0.484	-2.623	-0.015	-0.818
Sharpvalley	Mchinji	5.793	-0.366	-3.390	0.216	1.159	-0.015	-0.875
Sharpvalley	Mitundu	1.166	-0.062	1.058	0.257	1.262	-0.012	-0.615
Sharpvalley	Mkhoma	7.120	-0.327	-3.774	0.146	0.798	0.012	0.649
Sharpvalley	Mponela	6.250	-0.268	-3.126	0.201	1.509	0.011	0.585
Sharpvalley	Msundwe	3.767	-0.186	-2.294	0.203	1.230	-0.004	-0.238
Sharpvalley	Mtakataka	10.367	-0.407	-3.928	0.326	3.449	-0.018	-1.041
Sharpvalley	Nanjiri	1.689	-0.080	-1.260	-0.143	-0.885	-0.009	-0.469
Sharpvalley	Ntcheu	5.781	-0.238	-2.800	0.257	2.618	-0.017	-0.954
Sharpvalley	Ntchisi	4.761	-0.263	-3.036	0.037	0.215	-0.011	-0.594
Sharpvalley	Salima	5.144	-0.415	-3.089	0.353	1.693	-0.002	-0.108
Sharpvalley	Thete	3.990	-0.226	-2.818	0.031	0.687	0.001	0.059
Ntchisi	chimbiya	2.391	-0.159	-2.178	0.157	1.073	-0.018	-1.020
Ntchisi	Dowa	2.789	-0.157	-1.873	-0.071	-2.480	-0.008	-0.440
Ntchisi	Kasungu	2.830	-0.121	-1.794	-0.423	-1.346	-0.005	-0.268

Market *i*	Market *j*	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Ntchisi	Mponela	3.182	-0.080	-1.026	-0.551	-2.634	-0.010	-0.580
Ntchisi	Msundwe	1.903	-0.111	-1.996	0.038	0.434	-0.009	-0.573
Ntchisi	Mtakataka	4.056	-0.190	-2.233	0.132	1.349	-0.019	-1.070
Ntchisi	Nanjiri	3.182	-0.045	-0.898	-0.185	-1.554	-0.011	-0.680
Ntchisi	Ntcheu	5.400	-0.213	-2.720	-0.060	-0.612	-0.019	-1.148
Ntchisi	Salima	2.034	-0.167	-1.989	0.004	0.023	-0.013	-0.659
Ntchisi	Sharpvalley	1.991	-0.170	-1.908	0.031	0.215	-0.010	-0.560
Ntchisi	Thete	3.249	-0.171	-2.470	0.141	1.246	-0.003	-0.143
Nanjiri	chimbiya	2.779	-0.177	-1.173	0.065	2.183	0.006	0.377
Nanjiri	Dowa	2.639	-0.124	-2.186	-0.005	-0.036	0.018	1.040
Nanjiri	Kasungu	3.572	-0.116	-2.094	0.487	1.577	0.022	1.277
Nanjiri	Lilongwe	2.865	-0.250	-1.164	0.070	2.461	0.009	0.474
Nanjiri	Lizulu	2.530	-0.173	-2.252	0.082	0.631	0.012	0.709
Nanjiri	Mchinji	1.988	-0.092	-1.911	0.103	0.595	0.012	0.698
Nanjiri	Mitundu	3.183	-0.253	-2.514	0.043	2.253	0.021	1.203
Nanjiri	Mkhoma	3.815	-0.045	-1.016	-0.405	-0.247	0.003	0.196
Nanjiri	Mponela	0.540	-0.044	-1.033	0.009	0.058	0.007	0.369
Nanjiri	Msundwe	3.623	-0.179	-1.825	0.174	2.377	0.014	0.824
Nanjiri	Mtakataka	1.387	-0.068	-1.299	-0.054	-0.555	0.007	0.422
Nanjiri	Ntcheu	2.237	-0.084	-1.878	0.190	-0.427	0.008	0.514
Nanjiri	Ntchisi	4.028	-0.071	-1.532	-0.273	-1.454	0.003	0.199
Nanjiri	Salima	4.663	-0.227	-2.940	0.003	0.018	0.040	1.966
Nanjiri	Sharpvalley	2.721	-0.098	-1.888	-0.011	-0.885	0.013	0.804
Nanjiri	Thete	4.331	0.051	-1.645	0.019	2.033	0.013	0.767
Msundwe	chimbiya	3.968	-0.644	-2.726	0.028	1.677	-0.030	-1.032
Msundwe	Dowa	9.042	-0.478	-3.577	0.126	0.291	-0.008	-0.029
Msundwe	Kasungu	13.234	-0.636	-4.661	0.246	0.904	0.019	0.705
Msundwe	Lilongwe	2.045	-0.439	-2.790	0.426	1.222	-0.015	-0.516
Msundwe	Lizulu	10.728	-0.556	-4.628	0.130	0.664	-0.028	-1.046
Msundwe	Mchinji	9.168	-0.504	-4.278	0.082	0.301	-0.030	-1.132
Msundwe	Mitundu	2.714	-0.581	-2.305	0.182	1.989	-0.022	-0.749
Msundwe	Mkhoma	3.566	-0.243	-2.509	0.342	1.428	-0.003	-0.102
Msundwe	Mponela	3.975	-0.243	-2.820	0.137	0.542	-0.006	-0.188
Msundwe	Nanjiri	4.487	-0.303	-2.994	0.209	2.877	-0.033	-1.142
Msundwe	Ntcheu	8.616	-0.317	-3.791	-0.136	-0.931	-0.031	-1.160
Msundwe	Ntchisi	2.648	-0.212	-2.290	0.102	0.434	-0.022	-0.750
Msundwe	Salima	5.952	-0.508	-3.305	0.197	0.673	-0.018	0.598
Msundwe	Sharpvalley	7.239	-0.396	-3.455	-0.208	-1.108	-0.016	-0.571
Msundwe	Thete	4.664	-0.307	-2.384	0.258	2.227	-0.014	-0.492
Mtakataka	chimbiya	6.571	-0.442	-3.583	0.318	1.298	-0.035	-1.427
Mtakataka	Dowa	3.598	-0.311	-2.390	0.019	0.072	0.001	0.033
Mtakataka	Kasungu	7.283	-0.470	-3.789	0.297	0.654	0.026	0.913

Market *i*	Market *j*	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Mtakataka	Nanjiri	2.905	-0.179	-2.159	-0.126	-0.555	-0.023	-0.849
Mtakataka	Ntcheu	7.789	-0.344	-3.214	0.407	2.838	-0.017	-0.695
Mtakataka	Ntchisi	6.316	-0.342	-3.032	0.072	0.349	0.000	-0.007
Mtakataka	Salima	5.772	-0.410	-3.365	0.479	2.311	0.016	0.571
Mtakataka	Sharpvalley	9.086	-0.537	-3.787	0.641	3.448	0.005	0.186
Mtakataka	Thete	4.832	-0.326	-3.058	0.234	1.321	0.012	0.434
Mkhoma	chimbiya	2.504	-0.105	-2.182	0.014	0.125	-0.023	-1.630
Mkhoma	Dowa	2.474		-1.980	0.159	1.427	-0.020	-1.422
Mkhoma	Kasungu	3.524	-0.115	-1.920	-0.320	-1.359	-0.015	-1.111
Mkhoma	Lilongwe	0.742	-0.075	-0.879	0.004	0.041	-0.017	-1.233
Mkhoma	Lizulu	2.440	-0.153	-2.189	0.097	0.725	-0.028	-1.753
Mkhoma	Mchinji	0.900	-0.073	-1.043	-0.003	-0.022	-0.022	-1.498
Mkhoma	Mitundu	1.865	-0.072	-1.976	0.090	0.670	-0.017	-1.186
Mkhoma	Mponela	1.020	-0.107	-0.990	0.136	1.035	-0.016	-1.177
Mkhoma	Msundwe	3.001	-0.109	-2.340	0.091	1.429	-0.018	-1.314
Mkhoma	Mtakataka	4.764	-0.195	-2.380	0.201	2.666	-0.030	-1.840
Mkhoma	Nanjiri	4.500	-0.055	-1.540	-0.226	-0.247	-0.015	-1.140
Mkhoma	Ntcheu	2.817	-0.143	-2.381	0.052	0.683	-0.027	-1.932
Mkhoma	Ntchisi	5.045	-0.314	-0.178	0.026	1.496	-0.026	-2.157
Mkhoma	Salima	2.130	-0.174	-1.961	0.152	1.076	-0.023	-1.381
Mkhoma	Sharpvalley	1.709	-0.136	-1.742	0.088	0.798	-0.022	-1.562
Mkhoma	Thete	1.549	-0.111	-1.592	0.085	0.933	-0.018	-1.285
Mitundu	chimbiya	2.547	-0.538	-1.701	0.126	1.570	0.010	0.668
Mitundu	Dowa	1.325	-0.081	-1.602	0.061	0.056	0.015	1.039
Mitundu	Kasungu	1.641	-0.074	-1.542	0.228	0.913	0.018	1.194
Mitundu	Lilongwe	3.806	-0.262	-1.817	0.274	2.744	0.013	0.860
Mitundu	Lizulu	3.906	-0.091	-1.802	-0.164	-1.579	0.010	0.734
Mitundu	Mchinji	1.758	-0.071	-1.732	0.001	0.006	0.012	0.817
Mitundu	Mkhoma	3.293	-0.028	-2.756	0.103	0.669	0.015	0.985
Mitundu	Mponela	0.562	-0.034	-0.980	-0.003	-0.023	0.016	1.009
Mitundu	Msundwe	4.314	-0.148	-2.812	0.157	1.890	0.015	1.092
Mitundu	Mtakataka	2.201	-0.053	-1.346	0.041	0.826	0.015	0.992
Mitundu	Nanjiri	2.929	-0.166	-1.959	0.031	2.253	0.002	0.103
Mitundu	Ntcheu	1.366	-0.049	-1.395	0.052	0.682	0.012	0.786
Mitundu	Ntchisi	0.789	-0.030	-0.812	0.126	1.136	0.013	0.896
Mitundu	Salima	1.610	-0.090	-1.631	0.178	1.363	0.023	0.563
Mitundu	Sharpvalley	1.653	-0.058	-1.385	0.130	1.261	0.014	0.964
Mitundu	Thete	3.561	-0.019	-2.546	0.112	1.704	0.013	0.875
Dowa	chimbiya	2.920	-0.147	-2.370	0.143	1.049	-0.016	-0.926
Dowa	Kasungu	5.485	-0.332	-3.187	0.372	1.265	0.004	0.252
Dowa	Lilongwe	1.322	-0.047	-0.601	-0.144	-1.070	-0.119	-0.658
Dowa	Lizulu	4.549	-0.310	-2.979	0.091	0.728	-0.023	-1.357
Dowa	Mchinji	5.443	-0.277	-2.656	0.063	1.497	-0.018	-1.065

Market *i*	Market *j*	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Dowa	Ntcheu	9.066	-0.237	-3.825	0.075	-0.875	-0.022	-1.358
Dowa	Ntchisi	3.030	-0.183	-2.305	0.166	2.480	-0.015	-0.864
Dowa	Salima	3.229	-0.276	-2.443	0.255	1.489	-0.001	-0.036
Dowa	Sharpvalley	7.050	-0.338	-3.329	0.121	1.518	-0.012	-0.736
Dowa	Thete	5.135	-0.118	-1.691	0.208	-1.265	-0.009	-0.517
Ntcheu	chimbiya	2.426	-0.239	-2.166	0.266	1.216	-0.013	-0.536
Ntcheu	Dowa	2.219	-0.128	-1.204	-0.205	-0.875	-0.005	-0.173
Ntcheu	Kasungu	3.480	-0.254	-2.537	-0.091	-0.201	-0.017	0.620
Ntcheu	Lilongwe	6.049	-0.230	-2.857	-0.196	-1.147	-0.006	0.258
Ntcheu	Lizulu	4.892	-0.310	-3.033	0.480	2.256	-0.013	-0.572
Ntcheu	Mchinji	5.210	-0.298	-3.054	0.332	1.325	0.000	0.016
Ntcheu	Mitundu	0.668	-0.064	-1.002	0.186	0.682	-0.014	-0.497
Ntcheu	Mkhoma	4.382	-0.291	-2.960	0.183	0.683	0.022	0.809
Ntcheu	Mponela	3.655	-0.231	-2.623	0.312	1.370	0.016	0.598
Ntcheu	Msundwe	1.697	-0.080	-0.926	-0.128	-0.931	-0.108	-0.412
Ntcheu	Mtakataka	5.410	-0.255	-2.434	0.372	2.838	-0.007	-0.307
Ntcheu	Nanjiri	1.202	-0.091	-1.282	-0.095	-0.428	-0.017	-0.431
Ntcheu	Ntchisi	5.655	-0.299	-2.778	-0.125	-0.612	-0.001	-0.033
Ntcheu	Salima	2.638	-0.223	-2.249	0.163	2.538	0.004	0.154
Ntcheu	Sharpvalley	6.023	-0.314	-2.876	0.478	2.618	0.008	0.328
Ntcheu	Thete	7.892	-0.376	-3.971	0.170	1.122	0.025	1.029
Chimbiya	Dowa	1.834	-0.114	-1.867	0.153	1.049	0.012	0.639
Chimbiya	Kasungu	3.491	-0.155	-12.586	-0.100	-0.327	0.022	1.160
Chimbiya	Lilongwe	4.092	-0.126	-2.698	0.173	1.953	0.018	1.030
Chimbiya	Lizulu	3.109	-0.227	-2.508	0.185	1.286	0.011	0.064
Chimbiya	Mchinji	4.731	-0.138	-2.675	-0.191	-1.097	0.007	0.424
Chimbiya	Mitundu	2.680	-0.132	-1.679	0.213	2.150	-0.001	-0.064
Chimbiya	Mkhoma	3.822	-0.144	-2.638	0.023	0.125	0.021	1.111
Chimbiya	Mponela	1.861	-0.090	-1.745	-0.010	-0.061	0.012	0.651
Chimbiya	Msundwe	2.721	-0.094	-1.729	0.029	2.257	0.009	0.513
Chimbiya	Mtakataka	2.513	-0.167	-2.207	0.113	1.298	0.006	0.416
Chimbiya	Nanjiri	2.998	-0.088	-1.654	0.172	1.683	0.002	0.097
Chimbiya	Ntcheu	7.207	-0.242	-3.739	0.109	1.217	0.005	0.297
Chimbiya	Ntchisi	3.984	-0.184	-2.784	0.147	1.073	0.011	0.658
Chimbiya	Salima	2.359	-0.125	-2.022	-0.067	-0.463	0.008	0.489
Chimbiya	Sharpvalley	4.037	-0.176	-2.669	0.189	1.479	0.014	0.816
Chimbiya	Thete	5.253	-0.157	-2.968	0.199	1.833	0.021	1.200
Lilongwe	Chimbiya	4.264	-0.088	-1.374	0.162	2.953	-0.026	-1.241
Lilongwe	Dowa	6.818	-0.255	-3.396	-0.158	-1.070	-0.017	-0.895
Lilongwe	Kasungu	1.903	-0.177	-1.852	0.014	0.038	-0.014	-0.649
Lilongwe	Lizulu	1.966	-0.149	-1.840	0.172	1.102	-0.032	-1.478
Lilongwe	Mchinji	3.922	-0.287	-2.807	0.141	0.686	-0.030	-1.506
Lilongwe	Mitundu	3.199	-0.059	-2.219	0.155	2.745	-0.019	-0.883

Market i	Market j	F-Statistic	$(a_{i1}- 1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik} + b_{i0} + b_{i-1})$ coefficient	t-statistic
Lilongwe	Ntchisi	4.018	-0.223	-2.871	0.083	0.556	-0.022	-1.144
Lilongwe	Salima	5.106	-0.646	-3.202	0.112	0.572	-0.041	-1.802
Lilongwe	Sharpvalley	6.448	-0.248	-2.617	-0.176	-1.165	-0.022	-1.154
Lilongwe	Thete	4.597	-0.211	-2.191	0.029	2.583	-0.014	-0.715
Lizulu	Chimbiya	5.344	-0.297	-3.255	0.188	1.286	-0.015	-0.084
Lizulu	Dowa	4.621	-0.341	-3.002	0.125	0.728	0.018	0.902
Lizulu	Kasungu	5.315	-0.275	-3.097	-0.299	-0.898	0.020	0.997
Lizulu	Lilongwe	2.705	-0.151	-2.218	0.150	1.102	0.011	0.545
Lizulu	Mchinji	3.718	-0.246	-2.710	0.171	0.868	0.002	0.081
Lizulu	Mitundu	2.625	-0.072	-1.033	-0.313	-1.579	0.000	0.013
Lizulu	Mkhoma	2.850	-0.203	-2.364	0.188	0.925	0.020	0.892
Lizulu	Mponela	2.355	-0.141	-1.937	-0.071	-0.402	0.009	0.412
Lizulu	Msundwe	1.182	-0.155	-1.509	0.073	0.664	-0.002	-0.092
Lizulu	Mtakataka	3.244	-0.174	-2.090	-0.040	-1.760	-0.002	-0.099
Lizulu	Nanjiri	0.112	-0.195	-2.140	0.105	0.631	-0.013	-0.668
Lizulu	Ntcheu	3.093	-0.200	-2.375	0.030	1.656	-0.009	-0.464
Lizulu	Ntchisi	2.646	-0.179	2.115	0.211	1.381	0.002	0.106
Lizulu	Salima	3.920	-0.271	-2.737	0.204	2.161	0.021	0.978
Lizulu	Sharpvalley	6.185	-0.220	-2.649	-0.171	-1.623	0.003	0.138
Lizulu	Thete	4.566	-0.211	-3.003	0.046	0.369	0.015	0.768
Mponela	Chimbiya	4.695	-0.140	-3.042	-0.007	-0.061	-0.028	-1.773
Mponela	Dowa	5.286	-0.207	-2.713	0.279	2.276	-0.023	-1.508
Mponela	Kasungu	2.322	-0.138	-2.390	0.036	0.121	-0.020	-1.210
Mponela	Lilongwe	3.222	-0.178	-1.934	-0.074	-0.575	-0.014	-0.827
Mponela	Mchinji	2.248	-0.155	-1.994	0.075	0.430	-0.031	-1.857
Mponela	Mitundu	1.241	-0.065	-1.594	-0.004	-0.023	-0.019	-1.118
Mponela	Mkhoma	14.156	-0.486	-5.278	0.151	1.035	-0.003	-0.226
Mponela	Msundwe	1.274	-0.076	-1.427	0.044	0.542	-0.025	-1.496
Mponela	Mtakataka	1.686	-0.153	-1.718	0.028	0.284	-0.030	-1.559
Mponela	Nanjiri	1.430	-0.070	-1.739	0.007	0.058	-0.021	-1.269
Mponela	Ntcheu	3.973	-0.165	-2.763	0.118	1.370	-0.033	-2.035
Mponela	Ntchisi	7.982	-0.215	-3.190	-0.199	-1.664	-0.020	-1.289
Mponela	Salima	2.192	-0.134	-1.571	0.272	1.535	-0.024	-1.218
Mponela	Sharpvalley	6.782	-0.246	-3.283	0.084	1.509	-0.028	-1.838
Mponela	Thete	6.166	-0.231	-3.429	0.000	-0.002	-0.022	-1.452
Kasungu	Chimbiya	0.119	-0.006	-0.178	-0.022	-0.327	-0.002	-0.255
Kasungu	Dowa	1.188	-0.072	-1.295	0.085	1.265	-0.003	-0.417
Kasungu	Lilongwe	2.309	-0.078	-2.087	0.002	0.038	-0.003	-0.355
Kasungu	Lizulu	0.481	-0.003	-0.071	-0.058	-0.898	-0.002	-0.235
Kasungu	Mchinji	3.761	-0.185	-2.720	0.172	2.516	-0.015	-1.672
Kasungu	Mitundu	0.434	-0.010	-0.316	0.075	0.913	-0.003	-0.333
Kasungu	Mkhoma	2.301	-0.045	-1.227	-0.113	-0.136	-0.003	-0.360
Kasungu	Mponela	2.083	-0.066	-1.994	0.008	0.121	-0.001	-0.169

Market *i*	Market *j*	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Kasungu	Sharpvalley	4.299	-0.136	-2.210	0.056	0.237	-0.008	-0.912
Kasungu	Thete	1.217	0.000	-0.009	-0.077	-1.415	-0.003	-0.330
Mchinji	Chimbiya	1.092	-0.022	-0.479	-0.125	-1.097	-0.008	-0.620
Mchinji	Dowa	4.927	-0.193	-2.486	0.111	0.497	-0.003	0.219
Mchinji	Kasungu	2.020	-0.272	-2.421	0.279	1.252	-0.015	0.878
Mchinji	Lilongwe	1.965	-0.138	-1.992	0.067	0.686	0.000	-0.020
Mchinji	Lizulu	1.769	-0.133	-1.849	0.094	0.868	-0.014	-1.034
Mchinji	Mitundu	0.291	-0.024	-0.588	0.001	0.006	-0.011	-0.774
Mchinji	Mkhoma	4.321	-0.169	-2.951	-0.003	-0.022	-0.006	0.425
Mchinji	Mponela	3.565	-0.156	-2.699	0.050	0.430	-0.004	0.286
Mchinji	Msundwe	0.701	-0.076	-1.109	0.022	0.301	-0.007	-0.478
Mchinji	Mtakataka	2.719	-0.163	-2.299	0.102	1.328	-0.010	-0.726
Mchinji	Nanjiri	0.533	-0.039	-0.930	0.070	0.595	-0.010	-0.754
Mchinji	Ntcheu	1.290	-0.075	-1.250	0.104	1.325	-0.010	-0.763
Mchinji	Ntchisi	2.961	-0.092	-1.874	-0.124	-1.181	-0.008	0.552
Mchinji	Salima	1.884	-0.181	-1.940	0.095	0.661	-0.002	0.153
Mchinji	Sharpvalley	2.596	-0.190	-2.262	0.124	1.159	-0.002	0.155
Mchinji	Thete	0.937	-0.094	-1.335	0.061	0.638	-0.003	-0.231
Salima	Chimbiya	0.916	-0.082	-1.071	-0.076	-0.463	-0.013	-0.731
Salima	Dowa	4.139	-0.274	-2.788	0.197	1.489	-0.005	-0.334
Salima	Kasungu	6.645	-0.459	-3.582	0.079	0.299	-0.004	-0.279
Salima	Lilongwe	0.404	-0.118	-1.355	0.007	0.572	-0.003	-0.156
Salima	Lizulu	2.748	-0.175	-1.774	0.153	1.761	-0.019	-1.047
Salima	Mchinji	2.820	-0.244	-2.374	0.109	0.661	-0.015	-0.889
Salima	Mitundu	2.883	-0.152	-2.235	0.238	1.363	-0.017	-1.016
Salima	Mkhoma	2.540	-0.192	-2.176	0.177	1.076	-0.116	-0.627
Salima	Mponela	3.028	-0.145	-2.055	0.220	1.635	-0.009	-0.516
Salima	Msundwe	6.264	-0.288	-3.395	0.054	0.673	-0.017	-1.072
Salima	Mtakataka	3.308	-0.133	-1.656	0.229	1.712	-0.012	-0.683
Salima	Nanjiri	1.222	-0.126	-1.416	0.003	0.072	-0.020	-0.987
Salima	Ntcheu	2.974	-0.095	-1.692	0.151	1.688	-0.011	-0.606
Salima	Ntchisi	1.010	-0.103	-1.394	0.003	0.023	-0.007	-0.390
Salima	Sharpvalley	5.054	-0.327	-3.071	0.211	1.840	-0.009	-0.576
Salima	Thete	0.613	-0.067	-0.940	0.097	0.843	-0.002	-0.111

Market i	Market j	F-Statistic	$(a_{i1}-1)$ coefficient	t-statistic	b_{i0} coefficient	t-statistic	$(a_{ik}+b_{i0}+b_{i-1})$ coefficient	t-statistic
Ntchisi	Lilongwe	1.094	-0.107	-1.453	0.073	0.556	-0.007	-0.417
Ntchisi	Lizulu	2.752	-0.181	-2.179	0.189	1.381	-0.018	-0.992
Ntchisi	Mchinji	2.163	-0.090	-1.333	-0.224	-1.181	-0.016	-0.890
Ntchisi	Mitundu	1.241	-0.056	-1.225	0.208	1.136	-0.017	-0.909
Ntchisi	Mkhoma	5.481	-0.292	-2.602	0.246	1.596	-0.010	0.533
Mtakataka	Lilongwe	8.545	-0.393	-3.573	-0.104	0.552	0.019	0.655
Mtakataka	Lizulu	6.138	-0.337	-3.154	-0.072	-2.360	-0.017	-0.675
Mtakataka	Mchinji	5.653	-0.414	-3.318	0.369	2.328	-0.006	-0.234
Mtakataka	Mitundu	2.853	-0.132	-1.837	0.088	1.522	-0.025	-0.894
Mtakataka	Mkhoma	8.490	-0.446	-3.545	0.079	1.566	0.043	1.418
Mtakataka	Mponela	6.583	-0.397	-3.595	0.065	0.285	0.030	0.992
Dowa	Mitundu	2.838	-0.146	-2.404	0.088	0.506	-0.015	-0.856
Dowa	Mkhoma	4.863	-0.268	-2.990	0.257	1.427	0.003	0.190
Dowa	Mponela	4.631	-0.209	-2.514	0.342	2.276	0.002	0.119
Dowa	Msundwe	9.296	-0.290	-3.655	0.049	1.291	-0.008	-0.489
Dowa	Mtakataka	6.585	-0.259	-3.417	0.006	0.072	-0.019	-1.160
Dowa	Nanjiri	1.815	-0.117	-1.794	0.005	-0.036	-0.014	-0.795
Lilongwe	Mkhoma	9.063	-0.411	-4.271	0.308	1.041	-0.008	-0.456
Lilongwe	Mponela	7.634	-0.323	-3.531	-0.087	-0.575	-0.013	-0.723
Lilongwe	Msundwe	3.043	-0.095	-1.443	0.083	1.732	-0.021	-1.024
Lilongwe	Mtakataka	4.865	-0.246	-2.388	-0.066	-0.558	-0.044	-2.030
Lilongwe	Nanjiri	3.725	-0.056	-1.172	0.074	2.461	-0.022	-1.063
Lilongwe	Ntcheu	3.054	-0.118	-1.560	-0.133	-1.147	-0.026	-1.285
Kasungu	Msundwe	1.940	-0.039	-0.735	0.082	1.909	-0.003	-0.358
Kasungu	Mtakataka	0.317	-0.330	-0.654	0.032	0.654	-0.005	-0.513
Kasungu	Nanjiri	1.444	-0.019	-0.630	0.112	1.677	-0.005	-0.556
Kasungu	Ntcheu	1.081	-0.048	-1.303	-0.009	-0.200	0.006	-0.672
Kasungu	Ntchisi	1.370	-0.020	-0.608	-0.084	-1.346	-0.004	-0.445
Kasungu	Salima	1.137	-0.146	-1.753	0.027	0.299	-0.006	-0.696