SPATIAL PRICE TRANSMISSION IN MAJOR

EAST AFRICAN

HORTICULTURAL MARKETS

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Hermence Christopher Lulah

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Abstract

The objective of this study is to assess the integration of horticultural markets in East Africa. The analysis is conducted using monthly wholesale prices of fresh tomatoes and fresh onions. Four representative markets (two in Tanzania and two in Kenya) are selected for the analysis. These markets are analyzed in pairs using the bivariate Joe-Clayton copula (BB7). This copula involves two parameters, which control the degree of overall dependence of price shocks as well as the strength of dependence at the extremes of their joint distribution. The overall dependence is assessed by the Kendall's *tau*, which is calculated from a number of concordant and discordant pairs of observations. Information about dependence at the lower and the higher ranks is obtained by measuring the upper and the lower tail dependence coefficients. These coefficients give the probability that a price shock in one market will be above (below) a high (a low) quantile if a price shock in another market is also above (below) a high (a low) quantile. When considered together, the overall strength of co-movement and co-movement at the extremes provide information about the degree of market integration. Empirical results of this study suggest that the investigated markets are generally not very well integrated. The overall dependence of price shocks between different pairs of markets varies from low to medium. The pattern of dependence of these price shocks also appears to be predominantly asymmetric.

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List of Important Abbreviations

ACP	Africa, Caribbean and Pacific
AfDB	African Development Bank
ASHS	American Society for Horticultural Science
COMTRADE	Commodity Trade Statistics Database
EAC	East African Community
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FPEAK	Fresh Produce Exporters Association of Kenya
GDP	Gross Domestic Product
HODECT	Horticultural Development Council of Tanzania
HORTEXA	Horticultural Exporters Association of Uganda
ICT	Information and Communications Technology
ISHS	International Society for Horticultural Science
JICA	Japan International Cooperation Agency
KNBS	Kenya National Bureau of Statistics
MT	Metric Tons
NBS	National Bureau of Statistics
SADC	Southern African Development Community
TAHA	Tanzania Horticultural Association
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNdata	United Nations Statistical Database
USA	United States of America
USAID	United States Agency for International Development
WB	World Bank
WTO	World Trade Organization

CHAPTER 1: INTRODUCTION

1.1 Background

In recent decades, economists and policy makers have increasingly shown interest on how price shocks are transmitted between markets separated by space (distance) as well as how they are transmitted along different levels of the supply chains. Economists have particularly been interested on the speed and magnitude of transmission of these price shocks. Price transmission has become even a much more interesting research and policy area to agricultural economists and agricultural policy makers because of the inherent uncertainty and problems associated with agricultural production, processing and marketing (e.g. regulation of prices, perishability and commodity price volatility). Price transmission has proved to be a useful means of assessing the extent to which spatial agricultural markets are integrated and function efficiently. Market integration is important because it ensures that there is a distributional balance between food-surplus and food-deficit markets. Well integrated markets ensure that there is efficient movement of agricultural products between them. These markets also provide accurate price information or signals that assist market participants (e.g. producers, wholesalers, retailers and consumers) in making good marketing decisions. Assessment of the speed and extent of adjustment of price shocks along agricultural supply chains is also significant to economists and policy planners because it provides information on how these market participants make pricing decisions (hence react to price shocks) and how welfare benefits are distributed among them. This information is crucial for the formulation of intervention strategies. In view of the importance of price transmission, therefore, a significant number of empirical studies highlighting the extent to which agricultural markets are related vertically and horizontally have been conducted using various analytical approaches.

1.2 Objective and Importance of the Study

The objective of this study is to assess the integration of major horticultural markets in East Africa. Specifically, this study intends to assess (1) the degree of overall dependence of price shocks across horticultural markets in East Africa, as well as (2) the degree of dependence of these price shocks during extreme market conditions. Together, these provide information about the degree of integration of the markets under study. The analysis is pursued using monthly wholesale price data from two important horticultural commodities (fresh onions and tomatoes) and the statistical tool of copulas.

The East African horticultural markets have been chosen as a case study for three major reasons.

First is that, one of the central economic ideas behind the creation of the East African Community (EAC) was to establish common policies that would lead to the integration of various spatially separated product markets. Specifically, the ratification of the East African Community Common Market Protocol in 2010 (EAC, 2015) was designed to ensure free movement of goods (including agricultural goods) between these markets so that they would eventually become integrated and boost trade. The Common Market principles support free trade within the EAC, and specify common external tariffs. Even after ratification of the Common Market Protocol when formal barriers to trade were supposedly removed, some countries barriers to market integration remained especially in agricultural goods. For example, to ensure enough food surpluses in the country, Tanzania has restricted maize exports to Kenya and other neighboring countries in several occasions. Among factors that might further limit market integration in EAC agricultural markets are the absence mechanisms that exploit the price difference between markets within the region (arbitrage), along with residual barriers to efficient arbitrage and imperfect competition in these markets. However, the effectiveness of regional trade agreements such as the EAC Common Market is difficult to assess. Although it does not adequately explain the effectiveness of regional trade agreements, market integration is a necessary condition for the gains from trade expected from these regional trade agreements to be realized. The argument here is that if markets are not integrated, then prices cannot provide the appropriate signals on how resources should be allocated in order for gains from trade to be realized. Stylized facts about trade tell us that one of the measurable outcomes resulting from a regional trade agreement is increased market and price integration among member states. Hence, establishing whether markets are integrated or not becomes an important way of explaining the effectiveness of trade agreements. Integration helps to describe the movement of resources from the surplus into deficit (or from efficient to inefficient) countries engaged in trade. If market integration does not arise, trade liberalizing initiatives would not function as predicted (Moodley et al. 2000). The motivation of the researcher in this area has therefore, been driven by the concern that the East African horticultural markets are not well integrated in spite of the existence of the Common Market Protocol. In doing this, the study seeks to address major policy issues for the East African markets.

Second is that, horticultural production has been indicated as a subsector that offers real opportunities for improving farm earnings and reduce poverty in developing countries such as those in Africa (Weinberger and Lumpkin, 2005; Labaste, 2005). This is because horticultural crops are high value crops compared to many other traditional crops such as tea and coffee whose prices are determined at world market. Horticulture has one of the highest returns on labor, land and capital invested. Being in the tropics, East Africa is strategically positioned for horticultural production throughout the year as compared to many other regions of the world where weather conditions are unfavorable at certain periods. In spite of these opportunities, East African farmers of which the majority are poor and smallholders, have not been able to fully participate in the high value horticultural chains due to lack of good market systems (Shao, 2002 and Eskola, 2005). Earlier research on market access constraints has identified poor infrastructure as being of major importance (Minten and Kyle, 1999), which in turn tends to increase transportation costs (Alex and Temu, 2002) as well as transaction costs (Kherallah et al., 2000). Technological developments in infrastructure are important in order to allow exchange of goods and contribute to increased economic interdependence and spatial price convergence (Gordon, 2000; Sera and Goodwin, 2006). Since most horticultural products are highly perishable, they are amongst the most favored by technological developments in infrastructure. Infrastructures such as parking and cold storage systems play a vital role, not only to the emergence of food production and distribution systems, but also in the facilitation of trade between distant markets. Stimulated by increasing demand within and outside the region, the regional exchange of perishable agricultural goods in East Africa has been reported to increase in recent years. Although this claim has not been validated empirically, the argument would be that there have been some improvements in transportation and storage infrastructure. Market integration offers an interesting way of validating the role that infrastructure has played in the region's increasing trade in horticulture. Increased cross-border trade in fresh horticultural goods will imply increased investments in sophisticated infrastructure which in turn will play a significant role in linking farmers to high value markets as the integration becomes stronger (and vice versa). The analysis of price transmission indirectly provides an interesting contribution to the literature on the effectiveness of the existing marketing chains and market access constraints by smallholders. Hence, it is interesting to utilize price data to help us establish whether regional market integration is limited by the gap in infrastructure development, bearing in mind that most horticultural goods are perishable goods.

Third is availability of data. Among other factors that impede studies on price transmission in developing countries such as those in Africa is the unavailability and unreliability of data. Although there have been significant improvements in the use of ICT (e.g. use of mobile phones) which has facilitated the transmission of trade information between markets and between market participants, storage of information such as price data is a historical problem in these countries. The situation is worsened by the fact that most agricultural markets in Africa operate on daily or weekly basis, hence requiring high data collection frequency. Unlike staple food (e.g. grains) markets on which most previous agricultural market integration studies in the continent are based, price data for horticultural commodities is in most case completely unavailable. For East African horticultural markets, however, some useful data is available, which has made this study area of great interest. Since the data has not been used for price transmission analyses before, our interest is to use it in order to provide insights on how prices of horticultural products are transmitted in these markets, bearing in mind the high trade risks due to seasonality and perishability of most horticultural products (which might potentially interfere with price transmission and hence market integration and efficiency).

1.3 Overall Methodology of the Study

The statistical tool of copulas has recently become popular in the analysis of price linkages because it offers considerable flexibility in empirical research and it provides new insights about price interrelationships across space and along food supply chains (Nelsen, 2006; Durante and Sempi, 2010; and Patton, 2012). Although there are a number of past empirical studies on integration of agricultural and food markets in Africa (Abdulai, 2007; Rashid and Minot, 2010; and Zakari et al., 2014), none of them relied on copula models and/or in horticultural markets.

The analysis here utilizes the Joe-Clayton copula, which does not place any restrictions on the price linkages in different markets. The Joe-Clayton copula involves two parameters, which control the degree of overall dependence (co-movement) as well as the strength of co-movement at the extremes of the joint distribution of price shocks. The overall dependence is assessed by the Kendall's *tau* (a rank-based measure of functional dependence). Dependence at the extremes is measured by the upper and the lower tail dependence coefficients which give the probability that a price shock in one market will be above (below) a high (a low) quantile provided that a price shock in another market is above (below) a high (a low) quantile as well. Considered together, the overall strength of co-movement and the co-movement at the extremes provide information about the degree of market integration.

1.4 Structure of the Study

This work is organized into six chapters. Chapter 2 highlights how the East African horticultural sub-sector is organized and functions. Chapter 3 provides a review of earlier empirical studies on price transmission. Chapter 4 focuses on the analytical framework adopted in this work. Chapter 5 presents the empirical results. Finally, Chapter 6 concludes with a discussion on the implications of the results and highlights the research gap for future studies.

CHAPTER 2: HORTICULTURE IN EAST AFRICA: AN OVERVIEW

2.1 The East African Community (EAC)

The EAC is a regional economic bloc made of five countries namely Kenya, Uganda, Tanzania, Rwanda and Burundi. The Agreement for founding of the EAC was signed on 30 November 1999 and came into force on 7 July 2000 following its endorsement by the three founding partner states (Kenya, Tanzania and Uganda). Rwanda and Burundi signed the EAC treaty on 18 June 2007 and became full members of the Community on 1 July 2007. The headquarters of the EAC is in Arusha, Tanzania (EAC, 2015). Figure 1 presents the map of the EAC, with its five member states.

Figure 1: The EAC map

Source: UN, 2012

The EAC was established to provide a platform for widening and deepening economic, political, social and cultural integration of the people of East Africa. This was expected to eventually improve the quality of life through increased competitiveness, value added production, trade and investments. The EAC countries established a Customs Union in January 2005, a Common Market in July 2010, and ongoing negotiations for fast tracking a Monetary Union and eventually a Political Federation (EAC, 2015).

The EAC regional economic bloc has a total area of 1.82 million square kilometers (including water bodies), a combined population estimated at 145.5 million people and a combined GDP (current prices) of US$147.5 billion. The GDP per Capita in the region is estimated at US$1,014. Agriculture is the dominant sector in terms of its contribution to the GDP in all member states. In 2014, the sector contributed 27.7% of the total GDP, followed by trade (9.9%), manufacturing (8.2%) and construction (8.0%) (EAC, 2015). Table 1 provides an overview of macroeconomic statistics for each EAC member state.

Table 1: GDP statistics for EAC member countries (2013)

Country	Share of total GDP (%)	GDP growth rates (%)	GDP per capita (US$)
Kenya	39.54	4.7	1,055.2
Tanzania	25.90	7.0	742.6
Uganda	18.86	4.7	633.6
Rwanda	13.47	4.6	709.4
Burundi	2.23	4.8	294.2

Source: EAC, 2014

Although the EAC constitutes of five countries, for the sake of this study, our focus will be on Tanzania and Kenya. These two countries were chosen for three reasons. First, is the availability of data and information. Second, is because these two countries are the largest economies in the region and the third is due to them being the largest trading partner countries. Trade is possibly facilitated by their market size and by the fact that both countries use common languages (English and Swahili) as their main trade languages. Therefore, they potentially offer better insights on the level of integration and efficiency of the EAC markets in the selected agricultural subsector.

2.2 Tanzania: Country Profile

The United Republic of Tanzania was formed as a result of a union between Zanzibar (The Islands) and the former Tanganyika (Tanzania Mainland) in 1964. Zanzibar consists of two main islands of Unguja and Pemba and a number of small islands. The country covers a total area of 945,087 sq. km which includes 61,000 sq. km of inland water. Zanzibar has a total area of 2,654 sq. km. Unguja, which is the larger island, has a total area of 1,666 sq. km while Pemba, a smaller island has an area of 988 sq. km. According to the 2012 population and housing census, Tanzania has a population of 44,928,923 of which 43,625,354 are on Tanzania Mainland and 1,303,569 is in Zanzibar. The average annual population growth rate is estimated at 2.7% (NBS, 2015; EAC, 2014). Swahili and English are the official languages used in Tanzania. The country has the Tanzania Shilling (Tsh) as its currency.

The country has achieved a high overall economic growth rate in the last decade. The country's GDP growth rate has increased from 6.0% in 2001 to 7.0% in 2014, making it the fastest growing economy in the region. It is projected to continue growing by 7.0 % in 2015 driven by manufacturing, agriculture, trade, transport, communications, and financial intermediation. Growth is also supported by recent developments of public investment in infrastructure (AfDB, 2014). The country has managed to reduce inflation from 16 % in 2012 to 7.9% in 2013. Inflation is mostly caused by the energy (fuel prices) and food prices. Despite high economic growth being witnessed in the country, the recent household budget survey indicates that 28.2% of Tanzanians are poor, and poverty remains more prevalent in rural areas than in urban areas (NBS, 2015).

The country's economy depends largely on agriculture, which accounts for more than one-quarter of GDP, provides 85% of exports, and employs about 80% of the work force.

The value of horticulture in the total agricultural export has risen in recent years, highlighting its growing significance in the country's economy. For example, the contribution of horticulture to the total value of agricultural exports rose from 31% ($375 million) in 2013 to 38% ($477 million) in 2014, which is an annual increase of 7% valued at $102 million (Data from Tanzania Revenue Authority as reported by The Citizen, 2015). This growth has made horticulture one of Tanzania's major sources of foreign exchange. Other leading sectors of the economy are services, fishery, industry and construction. Table 2 presents the composition of Tanzania's GDP by broad economic categories.

Table 2: Tanzania's GDP contribution by economic activity

Activity	Sectors	Share in 2014 (%)
Primary	Involves agriculture and mining	35.0
Secondary	Involves manufacturing, electricity, gas and water	20.8
Tertiary	Includes services such as trade, information, communication and others	44.2

Source: NBS, 2015

Tanzania's international trade is dominated by export of traditional crops such as coffee beans, cotton, sisal, cashew nuts, cloves, tea, tobacco, peas as well as other commodities and products such as gold, copper, diamonds, and cement. Major imports are oil food and beverages, building and construction material, machinery and parts, and transport equipment. Other imported commodities are industrial raw materials, cotton fabrics, bulk wheat, fertilizers and chemicals (NBS, 2015). Table 3 present the composition of Tanzania's international trade.

Table 3: Tanzania's values of exports and imports (Tsh. billion)

Year	2011		2014	
Exports	**Value**	**Share of Total (%)**	**Value**	**Share of Total (%)**
Gold	3,463.8	76	2,705.7	57
Tobacco	437.9	9.6	319.3	6.7
Cashew Nuts	189.6	4.2	647.9	13.6
Cotton	103.9	2.3	558.4	11.8
Coffee	225.7	5	204.3	4.3
Imports				
Oil (Petroleum)	4,860.1	27.9	5,890.1	28.1
Transport Equipment	1,795.1	10.3	1,932.7	9.2
Machinery	2,068.4	11.9	2,163.5	10.3
Food & Beverages	1,059.0	6.1	1,773.3	8.5

Source: NBS, 2015

Tanzania has experienced robust export growth and diversification away from traditional markets and products. This rapid growth has been partly driven by higher prices for traditional agricultural export commodities, such as coffee, tea, tobacco and fish. In addition, light manufacturing and agro-processing exports grew from 7.0% of total merchandise exports to 20%. Between 2003 and 2012, exports to the EU decreased from approximately 50% to 30%. Total exports to Asia increased from 23% to almost 30%. Most importantly, exports to Tanzania’s neighboring countries in EAC and the Southern African Development Community (SADC) rose from less than 10% to over 30% (AfDB, 2014).

Tanzania’s overall trade patterns suggest significant trends, an important one being the diversification of agricultural commodities and markets. Tanzania’s export has for example, moved away from what can be considered as traditional markets in the EU to current increase in trade with Asia and regional neighbors in East Africa. These trends suggest that Tanzania has strengthened its linkages with regional markets in Africa in recent years. For example, value chain analysis of the cross-border trade of Tanzanian onions into the Kenyan market reveals that many farmers in Arusha have specialized in regional trade which is facilitated by the input cost advantages, superior quality of Tanzanian onions and reversed cropping seasons in both countries (USAID and Trade Hub, 2009).

2.3 Kenya: Country Profile

Kenya obtained its independence from Great Britain in 1963. The country, which lies across the equator, has a total surface area of 582,646 sq. km, which includes 11,230 sq. km of inland water. According to the 2012 estimates (UNData, 2015), Kenya has a population of 43,178,000. Annual population growth is estimated at 2.11% (CIA World Fact Book, 2014). The country also uses Swahili and English as official languages.

According to revised national statistics released by KNBS in 2014, Kenya achieved lower middle-income status in 2012. The country is now ranked as the ninth largest economy in Africa. The reviewed statistics revealed the GDP growth rate of 5.8% in 2010 which fell slightly to 5.3% in 2014 (KNBS, 2015). Inflation rose to 8.4% in August 2014, from 6.9% in May, due to higher food and energy costs (WB, 2014). The currency of Kenya is Kenya Shilling (Ksh).

Agriculture remains the most important economic activity in Kenya, although less than 8% of the land is used for production. Less than 20% of the land is suitable for cultivation, of which only 12% is classified as high potential (adequate rainfall) agricultural land and about 8% is medium potential land. The rest of the land is arid or semiarid. The sector contributes more than 25% of the GDP and about 75% of Kenyan population is engaged in agriculture, mainly subsistence agriculture. Manufacturing is the second largest subsector and accounts for about 10% of the GDP. Wholesale and retail trade, transport and communication, financial intermediation and education services are other important sectors of the economy. The mining and quarrying sub-sector has high potential to contribute to economic growth following the discovery of oil, coal and other minerals. Generally, growth has largely been driven by domestic demand, mainly private household consumption and investment (Odero et al., 2015). Figure 2 presents percentage contributions to Kenya’s GDP by activity.

Table 4: Kenya's GDP contribution by economic activity

Industry	**Share in 2014 (%)**
Agriculture, Forestry and Fishing	27.3
Manufacturing	10.0
Transport and Storage	8.3
Wholesale, Retail (Trade) and Repairs	8.2
Real Estate	7.8
Financial and Insurance Services	6.7

Source: KNBS, 2015

Agriculture is central to Kenya's export industry with horticultural and tea being the most important agricultural products. Black tea is Kenya's leading agricultural foreign exchange earner. The country is Africa's leading tea producer and third world producer. It accounts for about 60% of Kenyan and 6% of global tea production. Kenyan horticulture has become prominent in recent years and is now the second leading agricultural export. Horticulture accounts for about 21% of agricultural exports, and mainly consists of green beans, onions, cabbages, snow peas, avocados, mangoes and passion fruits (Ministry of Agriculture, 2015). Flowers exported include roses, carnations, statice, astromeria, and lilies. Kenya also is the world's largest producer and exporter of pyrethrum, a flower that contains a substance used in pesticides. Another important export crop is coffee, which accounts for about 4% of total export earnings. Tea, coffee and horticulture alone constitute about 25% of Kenya’s GDP. Agriculture, therefore, remains the single largest sector of the economy (Odero et al., 2015). Table 5 highlights the value of Kenya’s most important exports and imports.

Table 5: Kenya's values of exports and imports (Ksh. million)

Year	2011		2014	
Exports	**Value**	**Share of Total (%)**	**Value**	**Share of Total (%)**
Tea	102,236	21.1	93,996	20.4
Horticulture	83,331	17.2	97,105	21.1
Coffee	20,863	4.3	19,913	4.3
Imports				
Petroleum Products	199,120	15.4	292,643	18.1
Industrial Machinery	177,174	13.7	256,672	15.9
Motor Vehicles	62,870	4.9	101,792	6.3

Source: KNBS (2015)

Kenya's main export destinations are UK, Netherlands, Uganda, Tanzania, United States and Pakistan. Imports are principally machinery and transportation equipment, petroleum products and motor vehicles. Kenya imports mainly from India, China, UAE, South Africa, Saudi Arabia, United States, and Japan.

An important point to note is that the contribution of external trade to the GDP in both Kenya and Tanzania is rather muted as growth in volume of export of goods and services has been slower than that of import. While real import of goods and services grew significantly (Tables 3 and 4), exports have remained relatively the same or declined in some cases. This is because both countries rely on low value-added exports of primary commodities, and import mainly non-food industrial supplies, fuel and lubricants, and other capital equipment that are of high value. This has contributed to the persistent current account deficits due to the widening gap between the value of exports and that of imports.

2.4 The Concept of Horticulture

Horticulture is defined as the science and art of producing, improving, marketing, and using fruits, vegetables, flowers, and ornamental plants (ASHS, 2014). Horticultural products therefore, include all products, raw or processed, that arise from the horticultural industry. It is generally accepted by researchers and educators in horticultural science that horticultural crops include tree, bush and perennial vine fruits; perennial bush and tree nuts; vegetables (roots, tubers, shoots, stems, leaves, fruits and flowers of edible and mainly annual plants); aromatic and medicinal foliage, seeds and roots (from annual or perennial plants); cut flowers, potted ornamental plants, and bedding plants (involving both annual or perennial plants); and trees, shrubs, turf and ornamental grasses propagated and produced in nurseries for use in landscaping or for establishing fruit orchards or other crop production units (ISHS, 2014). Horticulture is practiced across cool to tropical latitudes and over a wide range of elevations and climatic conditions.

2.5 Global Perspective

Global fruit and vegetable production has received significant growth in recent years (annual production growth is estimated at 3%). Global annual fruit production is estimated at more than 600 million metric tons while that of vegetables is estimated at more than 1 billion metric tons (FAO, 2013). Major drivers for the growth in the global fruits and vegetables production have been expansion of production areas in Asia as well as the increasing significance of horticulture in food-insecure, low-income and land-scarce countries such as those in Sub-Saharan Africa and Southern Asia. Being labor intensive and capable of generating high returns per unit area of land, horticulture has become an important source of income for smallholders and the general rural majority in these regions. However, the realization of full economic benefits of horticulture in these countries is constrained by high postharvest losses, inefficient supply chains and poor infrastructure (FAO, 2013). On a global level, China is the largest producer of both fruits and vegetables with global fruit output share of 20% and 50% in vegetables. Other major producers of fruits and vegetables are India, USA, Vietnam and Brazil. Furthermore, growth in global spice production has been significant in the last few decades. For example, spice production increased from 1.15 million tons in 1993 to 2.10 million metric tons in 2012. Currently, spice production is estimated at 2 million metric tons (FAOSTAT, 2014). Asia produces about 94% of the total world production with India being the largest producer (about 50%). Other major producing countries include China, Bangladesh, Turkey, Thailand, Indonesia and Vietnam. The USA and Europe are the largest importers of spices. In 2011, land area under flower production worldwide was 400,000 hectares. Global trade volume of cut flowers is estimated to be more than US$100 billion per annum. Main players are divisible into producers (in developed and developing countries) and consumers (mainly in developed countries). The major consumer markets are Germany, the USA, France, the Netherlands, Japan, Switzerland and Italy. Together they consumed about 80% of the total flower production (Statista, 2013).

There exists substantial trade in horticulture across domestic, regional and global markets. On a global level, the value of all fruit and vegetables traded is more than double the value of all cereals traded (FAO, 2005). Horticulture has therefore, become the single largest category in agricultural trade, accounting for more than 20% of world agricultural exports (UNCTAD, 2012). Global demand for horticultural products grew from $69 billion in 2001 to $153 billion 2008, which is a growth of about 129%. All four categories of horticulture (fruits, vegetables, flowers and spices) grew by more than 10% per year since 2001 with spices and fruits growing at the fastest rate. Table 6 summarizes import volumes and growth in global horticulture for 2001 – 2008.

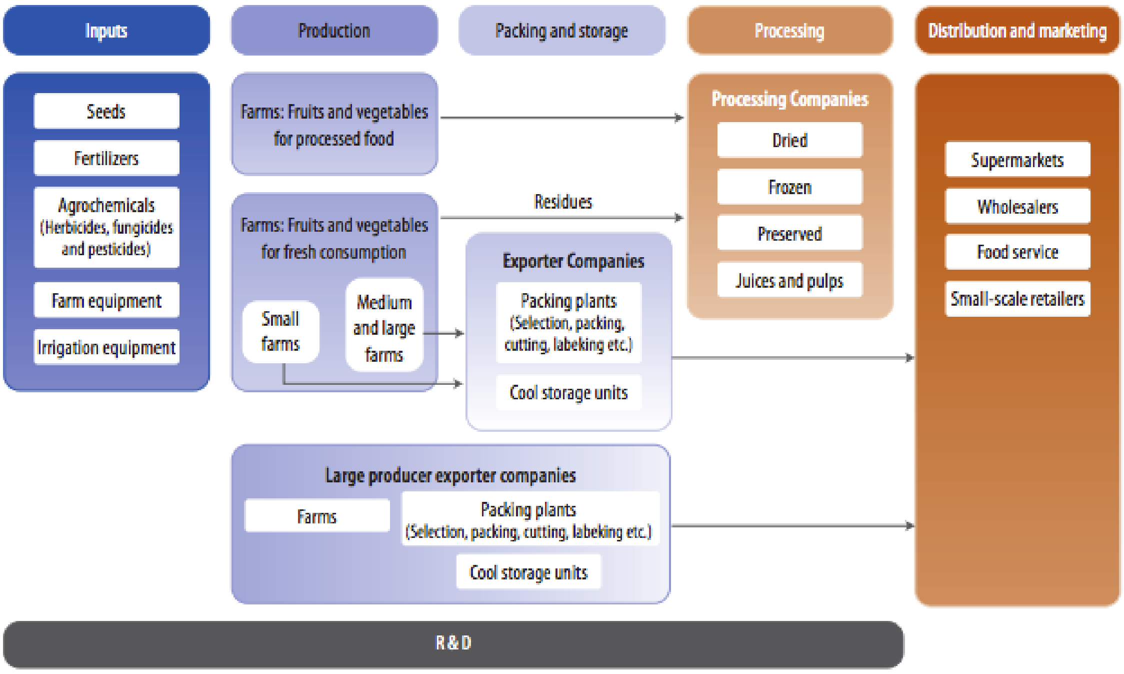
Table 6: World annual growth rates in horticulture

Category	**Global Imports in 2008 (US$ billion.)**	**Annual Growth 2001–2008 (%)**
Fruits	79,470,032	15.5
Vegetables	50,832,956	13.4
Cut Flowers	18,022,452	12.3
Spices	5,032,627	20.8

Source: HODECT, 2010

The global horticultural value chain includes several segments. It involves inputs, production, packing and storage, processing, and distribution and marketing. Key inputs are seeds, fertilizers, agrochemicals (herbicides, fungicides, and pesticides), farm equipment, and irrigation equipment. Logistics and transportation perform very important supporting functions. Due to the fragile and perishable nature of horticultural products, a high degree of coordination among different actors along the chain is required. This ensures that the perishable product reaches its destination in good condition. Cool storage (especially in tropical conditions such as those in East Africa) is required throughout the value chain to keep the produce fresh. Appropriate and reliable transportation means are needed to ensure good quality and timely delivery. Figure 2 presents the fruits and vegetable global value chain.

Figure 2: Global fruits and vegetables value chain



Source: WB, 2013

2.6 Horticulture in East Africa

The horticulture subsector represents a significant component of agriculture in East Africa. Beyond income generating opportunities for producers, vegetable production for domestic and export markets is an important driver for growth due to employment opportunities in production, processing and trade. Horticultural crops and products are high value commodities. Moreover, demand is income elastic, rising at an increasing rate with increased income. Within East Africa, increasing incomes and urbanization are translating into increased demand for horticultural products. Currently, the majority of horticultural produce is sold in kiosks and open-air markets (wet markets). There is however an increasing number of retail supermarkets and these are attracting market opportunities for producers who can meet the required quality standards. While there is a significant increase in large-scale production, the subsector is currently dominated by a majority of poor small holder farmers. Table 7 below is a list of major horticultural crops produced in East Africa.

Table 7: Major horticultural crops in East Africa

Fruits	Bananas, Citrus Fruits, Pineapples, Mangoes, Avocados, Passion fruits, Water Melons and Pawpaws
Vegetables	Cabbages, Kales, Tomatoes, Onions, Carrots, French Beans, Garden Peas, Okra, Egg Plants and Traditional Leafy Vegetables
Herbs and Spices	Vanilla, Pepper and Chillies, Cloves, Cumin, Coconuts, Curry, Tamarind, Ginger, Cinnamon, Nutmeg, and Cardamom
Flowers	Rose Flowers, Mixed bouquets, Alstromeria, Carnations, Alstro, Statice, and Veronica

Source: Mutuku, 2004

2.6.1 Market Channel Structure

Market channels in the region are often characterized by long chains. The main traders in the regional markets are the wholesalers. Wholesalers as a group are divided into Collecting wholesalers and Distributing wholesalers. The former specialize in collecting produce from farmers in the region. They travel long distances to purchase commodities in spot markets from the producing areas and towns. To facilitate operation, collecting wholesalers frequently employ purchasing agents who work in the production areas on their behalf. Purchasing agents reduce costs by identifying produce for sale, carrying out the negotiations, accumulating, assembling and moving the produce to a nearby earth road for ease of collection. Once enough produce is obtained, collecting wholesalers then transport the commodities to the main cities/towns usually using trucks or Lorries more than a 7-ton capacity. These professional collecting wholesalers sell primarily in urban wholesale markets to distributing wholesalers. For example, oranges are sourced from Tanga and Morogoro in Tanzania and sold in Moshi, Arusha, Mombasa, Nairobi and Kisumu; onions are obtained from Arusha/Mang'ola in Tanzania and sold in Mombasa, Dar es Salaam and Nairobi. Coconuts are obtained from Mombasa and sold in Dar es Salaam, Moshi, Arusha, Nairobi and Kisumu. Bananas are obtained from Mbale in Uganda and Kisii in Kenya and sold in Nairobi.

Wholesale markets often specialize in different produce. For instance, Temeke Stereo market in Dar es Salaam specializes in fruits such as oranges, watermelons, and mangoes, whereas the nearby Mabibo (Urafiki) market specializes mostly in Irish potatoes, bananas, and tomatoes. Market employees include security personnel, attendants and a market manager. Security personnel ensure that traders and wholesalers pay the stipulated taxes and also manage general order in daily trading. Market managers or superintendents, employed by the municipality, oversee all market operations. Relationships between the traders using the markets and these public sector authorities are often strained. Under the market manager is a team of attendants who are responsible for collecting taxes or fees from vehicles as they enter the market. Charges are generally collected per vehicle rather than by volume which perpetuates the practice of overloading trucks. No fees are applied to outgoing goods. Taxes are paid in cash and receipts are usually provided. At the end of each day, attendants submit cash intake to the market manager which is then remitted to the municipal council. The municipal council is responsible for budgeting resources toward operating expenses including salaries, electricity, maintenance and occasionally improvements in infrastructure. Local legislation on standards, packaging, and hygiene measures exists in these markets but is almost never reinforced by municipal councils because they lack incentives and the resources to do so. Market Trader Associations (MTAs) wield a great deal of influence in wholesale markets. At least one MTA operates in every major horticultural wholesale market in the region and their membership represents each of the major products traded in the market. They lobby to keep market fees reasonable and advocate for improved services and infrastructure from the market authorities. MTAs are run by a committee that appoints a chairman although meetings are often sporadic and convened only to resolve serious issues or conflicts. Table 8 shows the major horticultural markets in Tanzania, Kenya and Uganda.

Table 8: Major wholesale horticultural markets in East Africa

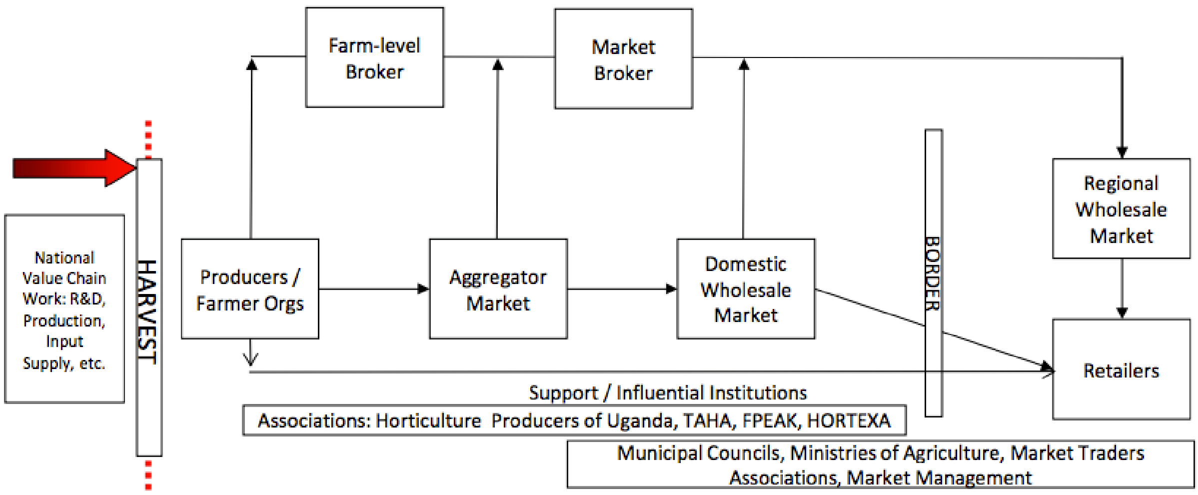
Country	Region/City	Market
Tanzania	Arusha	Kilombero
	Dar es Salaam	Kariakoo
Kenya	Nairobi	Wakulima
	Mombasa	Kongowea
Uganda	Kampala	Owino
		Nakasero

Source: USAID & Trade Hub - 2013

2.6.2 Aggregator Markets

Aggregation markets serve as collection points for farmers and brokers to bring produce for onward transport for sale in larger urban markets, as well as local retail trade. Wholesale markets are supplied by local production zones in addition to aggregation markets. Aggregation markets are rural produce collection points located near major highways, junctions and central road networks. They are generally located in uncovered, open areas with plenty of space for grading, sorting and re-packing. Some are close to major cross-border trading routes. For example, in Emali, Kenya, Tanzanian trucks bring onions to a central point on the Mombasa highway. From there, the produce is transported to the large Kongowea market in Mombasa, or to Wakulima market in Nairobi. According to Tschirley and Ayieko (2008), nearly 80% of all produce in Kenya moving off the farm is assembled by assemblers/intermediaries in rural areas who then transport the produce to urban wholesale markets. The regional horticultural value chain therefore consists of producers (mainly small-scale farmers), traders (intermediary, brokers and wholesalers), transporters, and retailers. Figure 3 and Table 9 present the horticultural value chain structure and value distribution among players in East African.

Figure 3: The East Africa horticultural value chain



Source: USAID and Trade Hub, 2013

Table 9: Value distribution in the East Africa's horticultural value chain

Value chain level	Average costs (%)	Share of retail price (%)
Farm gate price	15 – 44	25
Transport/Handling	3 – 13	13
Aggregator/Consolidator	3 – 7	5
Taxes	1 – 3	1
Wholesale/Distribution	32 – 50	39
Retailer	5 – 26	18

Source: USAID and Trade Hub, 2013

2.7 Important Developments, Challenges and Opportunities

2.7.1 Important Developments

Immediately after their independence, East African countries put more emphasis (in terms of policy, research and investments) into production of staple food crops (e.g. cereals) and traditional cash crops (e.g. tea, coffee and cotton) for export. Governments' involvement in cereals and export markets was very high, which led to formation of parastatals or government controlled agricultural cooperatives and boards. However, poor management, large overheads and losses made by these parastatals led to their failure. Much of the changes followed during the implementation of structural adjustments (African Studies Centre, 2015).

Nonetheless, agriculture has continued to be one of the most important economic sectors in East Africa. It employs about 80% of the population and contributes significantly to the economy. According to 2014 figures (EAC, 2015), the sector contributes about 34% of the GDP in Burundi, 29% in Kenya, 32% in Rwanda, 25% in Tanzania and 23% in Uganda. However, the trend shows that economic contribution of agriculture to total GDP has been declining in recent years due to current developments in the service sector. In Tanzania for example, economic contribution of agriculture to GDP dropped from 43% in 2007 to 33% in 2012. The sector however still contributes for a significant percentage of total exports.

Non-traditional, high value agricultural crops (horticultural) are gaining greater importance to the rural economy and to the growth of the economy in the EAC region. Increasing global, regional and local consumption of fruits, vegetables and spices have led to new market opportunities in and outside the region. Increased share of high value agricultural crops to total agricultural commodity export reflects the increasing importance of the sector to the economy. The contribution of fruits and vegetables to the total value of agricultural exports is increasing. Horticultural commodities have become highly tradable in both the domestic and international markets. An interesting observation is that Kenya has become a major exporter outside the region while Tanzania is playing a major role in regional trade.

Approximately more than half of horticultural production in East Africa is from smallholder farmers (JICA, 2009). At the farm level, increased farmers' engagement in horticultural farming can be attributed to some important shifts in the rural agricultural economy that are currently taking place. Land pressure in Kenya and some major production parts of Tanzania (Arusha and Kilimanjaro) is necessitating farmers to go for more intensive production and higher value crops. Changes in the income level and nutritional standards are increasing demand for horticultural food crops. The food processing sector (juices, syrups, pulps, pickles, value-added spices) is also growing fast, creating demand for raw materials. The status of horticultural crops in the rural and urban cash economy has increased, in most cases at the expense of traditional cash crops because they have higher value per unit of area, labour and capital invested (Labaste, 2005; Weinberger and Lumpkin, 2005). Increasing demand in emerging, existing and new markets outside the region have stimulated production and export of vegetables, fruits and flowers from East Africa.

2.7.2 Challenges[1]

In spite of the fast growth of the horticultural subsector being experienced in the region, there are a number of challenges that are limiting full realization of its potentials. These constraints vary from production, transport, processing, marketing and policy aspects.

Production is constrained by low productivity (low yields) as many farmers lack good crop management practises such as the use of recommended levels of fertilizers and agrochemicals (pesticides). Production is also characterised by small, scattered farms with mixed crops which in turn makes it difficult to manage. This also leads to difficulty in marketing and provision of extension services. There is also little availability and use of good quality seeds (resistant to pests and diseases and adaptable to different agro-ecological conditions). Hence there is heavy reliance on imported seeds which are expensive and unaffordable by most smallholder farmers. Functional producer organizations are also lacking in the region.

Lack of good marketing systems and infrastructure is potentially the single greatest obstacle to the development of the horticultural subsector in East Africa. The problem is

1 Golub and McManus, 2008; Sergeant, 2004; Salami et al., 2010.

closely linked with seasonality in production which fails to cope with demand during peak harvesting months. The problem is even greater for perishable crops like tomatoes because they cannot be stored or easily be transported to distant consumer markets in the region. Another factor closely linked with the marketing challenge is the limited number and capacity for processing horticultural crops especially during peak seasons as compared to excess supply. Lack of technologies and resources for storing perishable horticultural produce is leading to great postharvest losses. Other marketing constraints include limited availability of market information, inadequate market knowledge and agribusiness skills, lack of experience for export production and lack of functional market organizations.

The few existing processors of fruits and vegetables in the region have a very limited capacity to absorb the excess volumes supplied due to lack of storage, transportation and processing technologies, leading to great losses for farmers. Horticultural crops are therefore transported while unsorted (in many cases) and unprocessed, leading to excessive losses on handling as well as high transportation costs due to bulkiness. Primary causes of a poor processing sector include high capital requirements in terms of plants and parts (which in most cases have to be procured from abroad), lack of solid market channels for processed food products due to high competition from cheap food imports, seasonal availability of raw materials, high production costs due to lack of packaging materials, electricity, taxes, lack of good organization, small scale processing skills and promotion of locally processed food products.

2.7.3 Opportunities

There are many opportunities for high value horticultural products. Exporting of fresh and value-added horticultural products to developed consumer markets is amongst them. East African countries have preferential treatments and access to certain markets (e.g. USA) and regional economic blocs (e.g. EU) within the WTO framework or within bilateral and multilateral trade agreements. Most East African countries are among the founding members of WTO agreements and negotiations and have selected agriculture as their priority sectors. This offers preferential access to these high value markets and horticultural crops stand a great chance compared to traditional crops such as coffee. The existence of the EAC free trade agreement also opens opportunities for regional trade. Expectations are that regional trade will increase in the near future. Tanzania and Kenya are already taking the lead.

There are also various attractive investment opportunities ranging from production, processing to trading. Opportunities exist in production of high quality seeds and other planting materials that can suit production needs of various agro-ecological regions, small and large scale processing of fruits and vegetables and extraction of essential oils from spices that can be sold for a premium, supply of affordable inputs such as irrigation technologies, supply of quality packaging materials, large scale production of spices, fruits and vegetables, as well as capturing niche markets for organically grown spices, fruits and vegetable.

2.8 Regional Trade Flows

Regional trade in East Africa currently takes place under the framework of the Customs Union established by the East African Community (EAC). The Customs Union is one of significant steps taken by East African countries in the integration process. Trade is to a large extent stimulated by high demand of horticultural products in countries such as Kenya. Trade in the East African region is completely dominated by comparative advantage.

2.8.1 Fresh Tomatoes

Tomato *(Lycopersicon esculentum mill)* is one of the widely grown and consumed vegetable in East Africa. Kenya for example, is ranked as the sixth largest producer of tomato (FAO, 2012) among African, Caribbean, and Pacific (ACP) countries. According UNCTAD, thirty four ACP countries produced tomato among their top 20 agricultural commodities. Table 10 summarizes top ACP producers of tomatoes for 2008 – 2009.

Table 10: Tomato production in ACP countries

Country	Tomato production (MT)
Nigeria	1,000,000 – 2,000,000
Cuba, Cameroon, South Africa	500,000 – 1,000,000
Kenya, Sudan	250,000 – 500,000
Dominican Republic, Ghana	200,000 – 250,000
Tanzania, Benin, Mali	100,000 – 200,000
Rwanda, Niger, Senegal	30,000 – 100,000
Sierra Leone, Jamaica, Somalia, Mauritius	10,000 – 30,000
Namibia, Cape Verde, Fiji, The Bahamas, Swaziland	3,000 – 10,000

Source: UNCTAD, 2012

Tomato is widely grown in these countries because it is one of the high yielding horticultural crops per unit area of land. Tomato generates revenue in a short period of time since it takes only a maximum of three months from seedling to harvesting. It is also an important nutritional source of vitamin A, B and C and minerals such as Calcium, Potassium, and Iron.

Generally, there are two varieties of tomatoes grown: determinate (bush-like structure) and indeterminate (single stem) varieties. East African farmers prefer Italian varieties (Money Maker, Rio Grande, Eden, Onyx, and Roma). These varieties are preferred because they are high yielding, pest and disease resistant as well as their long shelf life. Tomato is grown either on open fields or under greenhouses. About 95% of tomato is grown on open fields with only 5% grown under greenhouse technology (Seminis, 2007).

On a global scale, tomato is the second most important vegetable crop next to potato. It presents about 33% of global vegetable production. The crop also accounts for 15% of all vegetable consumption globally (34% in America, 30% in Africa and South America and 25 % in Europe and Central America). In 2012 world production stood at about 163 million tons (FAOSTAT, 2014). It is a fast growing crop with maturity period ranging from 90 to 150 days. The crop is a day length neutral plant. Optimum mean daily temperature growth is 18 to 25ºC with night temperatures between 10 and 20ºC. Larger differences between day and night temperatures, however, adversely affect yield. The crop is very sensitive to frost. Temperatures above 25ºC, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20ºC accompanied by high humidity and low sunshine, lead to excessive vegetative growth and poor fruit formation. High humidity leads to a greater incidence of pests and diseases and fruit rotting. Dry climates are therefore preferred for tomato production (FAO, 2013).

Tomato can be grown on a wide range of soils but a well-drained, light loam soil with pH of 5 to 7 is preferred. Water logging increases the incidence of diseases such as bacterial wilt. The required soil pH for tomato growth ranges from 5.0 to 7.5. For high yielding varieties, the fertilizer requirements amount to 150 kg/ha of Nitrogen, 65 to 110 kg/ha of Phosphorus and 160 to 240 kg/ha of Potassium. Seeds are generally sown in a nursery and seeds emerge within 10 days. Seedlings are transplanted in the field after 25 to 35 days. The crop is moderately sensitive to soil salinity. The most sensitive period to salinity is during germination and early plant development. Therefore the necessary leaching of salts is frequently practised during pre-irrigation or by over-watering during the initial irrigation application. Total water requirements (ETm) of tomato after transplanting when the crop is grown in the field for 90 to 120 days are 400 to 600 mm, depending on the climate. All East African countries have slightly different tomato growing seasons. Table 11 below shows tomato production months in each country (Yara, 2014).

Table 11: Tomato production seasons in East Africa

Country	Months	Peak Months
Kenya	November - February	May
	April - June	
Tanzania	August - December	October
Uganda	April - September	-
	December – January (short season)	

Source: USAID and Trade Hub, 2013

There are three main tomato growing counties in Kenya: Kirinyaga (14%), Kajiado (9%) and Taita Taveta (7%) (Geoffrey et al., 2014). In Tanzania, tomato growing is concentrated on the Northern part, covering Kilimanjaro, Tanga and Arusha regions. These regions serve as tomato supply sources to Kenya and Tanzania. The leading tomato producing districts in Uganda are Mukono, Kayunga and Mubende.

Proximity to markets is a strong driver of intra-regional trade in tomato. This is because of perishability nature of the product. The Northern production areas of Tanzania are relatively closer to all major Kenyan and Tanzanian markets. Tanzanian tomato is also known for its quality and flavour. Although there are tomato-producing areas in Kenya, these advantages enable Tanzanian tomatoes to compete with those of neighbouring Taita and Taveta in Kenya. The difference in production seasons also facilitates the intra-regional tomato trade. The varying seasons causes price differentials that drive trade flow. An important point to note is that the reported intra-regional tomato trade is smaller than the actual trade due to poor data storage at border points. Although Tanzania exports tomato to Kenya, no evidence in terms of data was reported for exports from Kenya to Tanzania in 2010. The data available proves dominance of Tanzanian tomatoes over the Kenyan market. Figure 4 describes major tomato production areas, markets and trade flow in East Africa while Tables 12 and Table 13 show regional tomato production and trade volumes for 2010[2].

[2] Map and data were obtained from USAID and Trade Hub (2013)

Figure 4: Tomato production areas, markets and trade flow in East Africa

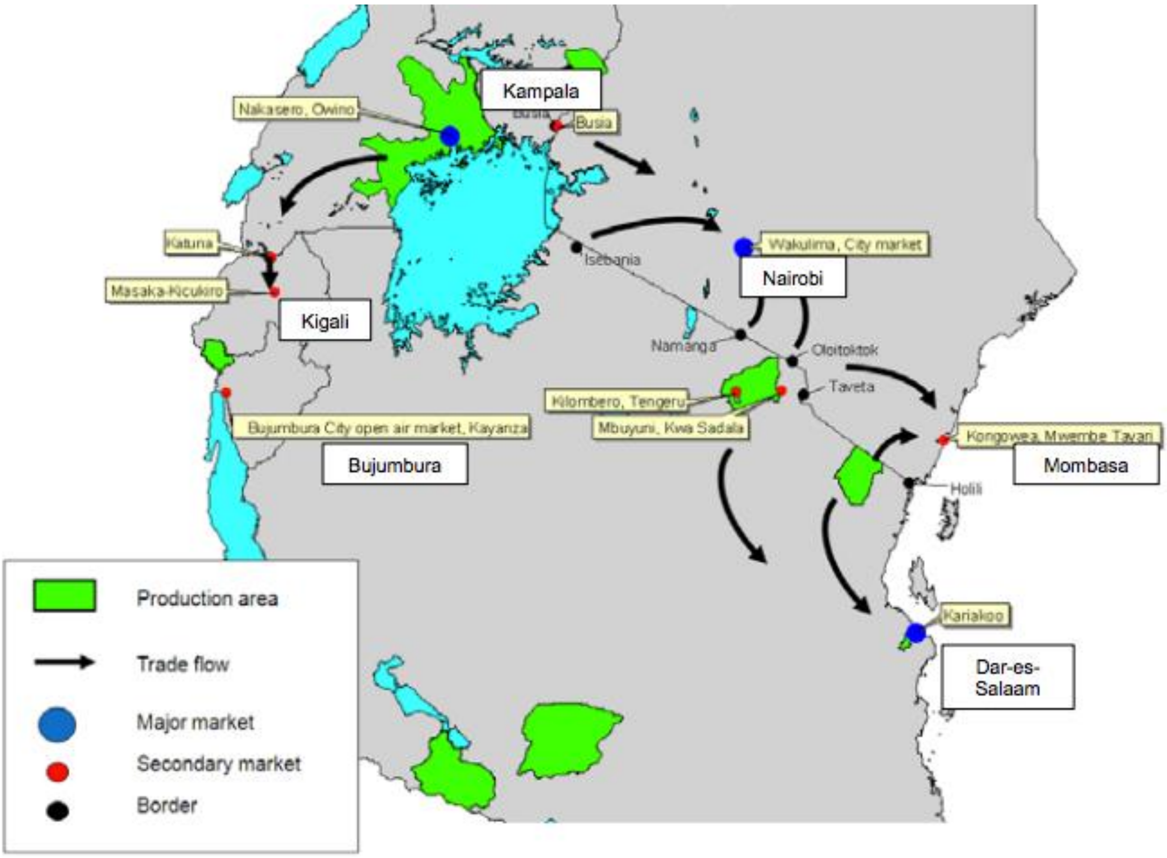


Table 12: Tomato production volumes (MT), 2010

Kenya	Tanzania	Uganda	Rwanda	TOTAL
539,151	235,000	31,000	42,800	847,951

Table 13: Tomato trade flow volumes (MT), 2010

		Destination				Total
		Kenya	Tanzania	Uganda	Rwanda	
Source	Kenya		-	267	-	267
	Tanzania	4,694		-	-	4,694
	Uganda	2,586	480		3,200	6,266
	Rwanda	-	-	-		0
Total		72,80	480	267	-	11,227
Imports/Production		1.35%	0.20%	0.86%	7.48%	1.32%

2.8.2 Fresh Onions

Comparative to other horticultural crops in East Africa, onions *(Allium Cepa)* are the most traded staple horticultural commodity. The high trade share of onions in the East African markets is partly attributed to the nature of the commodity itself. Compared to commodities such as tomatoes for example, onions can be transported over longer distances and have a longer shelf life. When onions are harvested at the right time and sufficiently cured (dried), they can last for up to three months. This makes the crop more attractive to traders due to a relatively lower spoilage risk associated with trade.

Apart from providing flavour, onions are an important source of nutrients and health promoting Phytochemicals. They are rich in vitamin C and B-6. They are also an important source of fibre, antioxidants and folic acid (Live Science, 2014).

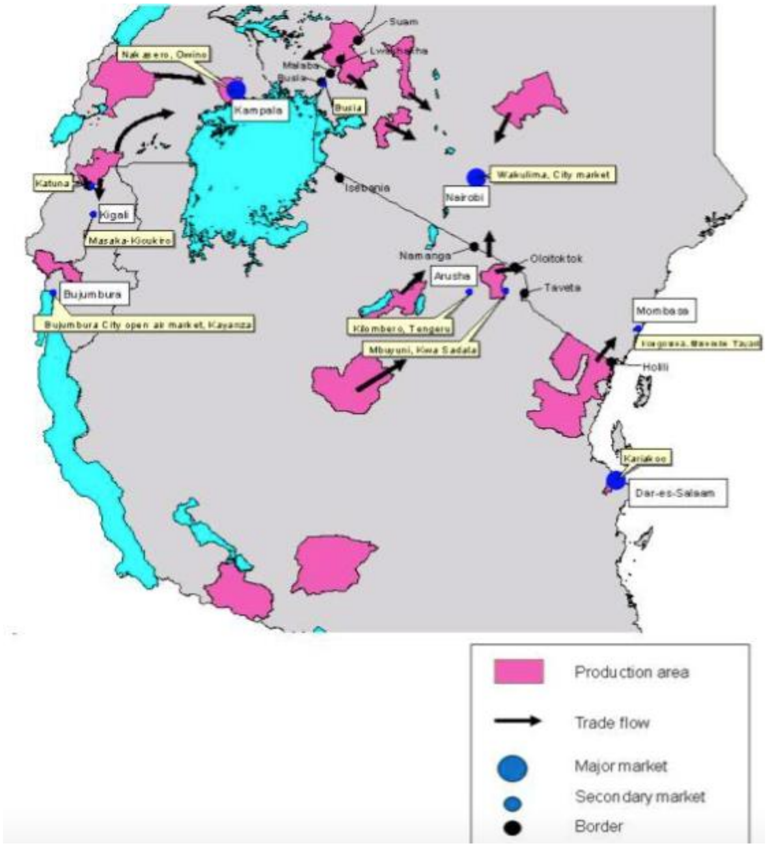
Onions are believed to originate from Near East. The crop can be grown under a wide range of climates from temperate to tropical. Present world production is about 83 million tons of bulbs. China, India and United States are the world's largest producers. Together, they account for about half of global onion production. The Netherlands is both the world's number one exporter and importer of fresh onions (Narain, 2015).

Under normal conditions onion forms a bulb in the first season of growth and flowers in the second season. The production of the bulb is controlled by day length and the critical day length varies from 11 to 16 hours depending on variety. The crop flourishes in mild climates without extremes in temperature and without excessive rainfall. For the initial growth period, cool weather and adequate water is advantageous for proper crop establishment, whereas during ripening, warm, dry weather is beneficial for high yield of good quality. The optimum mean daily temperature varies between 15 and 20°C. Proper crop variety selection is essential, particularly in relation to the day length requirements; for example, a long day temperate variety in tropical zones with short days will produce vegetative growth only without forming the bulb. The length of the growing period varies with climate but in general 130 to 175 days are required from sowing to harvest (FAO, 2013).The crop is usually sown in the nursery and transplanted after 30 to 35 days. Direct seeding in the field is also practised. The crop is usually planted in rows or on raised beds, with two or more rows in a bed. Optimum soil temperature for germination is 15 to 25°C. Onions can be grown on many soils but medium textured soils are preferred. Optimum pH is in the range of 6 to 7. Fertilizer requirements are normally 60 to 100 kg/ha of Nitrogen, 25 to 45 kg/ha of Phosphorus and 45 to 80 kg/ha of Potassium. The crop is sensitive to soil salinity and yield decrease at varying levels of ECe. For optimum yield, onion requires 350 to 550 mm water (FAO, 2013).

Generally, onions are grouped into brown, white and red onions (Onions Australia, 2010). East Africa mainly grows red onions. Red onion varieties such as Red Bombay, Red Creole, Red Pinoy and Red Snack are highly preferred by farmers. The crop is grown on flat beds of different dimensions with flood irrigation being a widely practised irrigation type.

Tanzania onion production constitutes a significant amount of total regional production. The country also plays a major role in regional onion trade. Kenya, a major onion market for example, imports onions from Tanzania despite favourable local production condition. Tanzanian onions are competitive in the region due to high quality, low production costs and higher yields. Proximity of Tanzania's production areas to markets such as Mombasa and Nairobi also gives Tanzania a competitive advantage. There are three major onion growing areas in Tanzania: The Northern regions (Arusha, Kilimanjaro and Tanga), the Central Region (Dodoma and Singida) and the Southern Region (Morogoro and Iringa). Onion traded between Kenya and Tanzania mainly comes from Mang'ola (Karatu District in Arusha). Onions produced in this area are considered the best in East Africa. Local supply of onion in Kenya comes from Bungoma District in the West and Meru District in the Central region. Uganda's eastern production area also supplies Kenya throughout the year, while its south-western production areas supply Rwanda. Figure 5 shows main regional onion production areas, markets and trade flow.

Figure 5: Onion production areas, markets and trade flow in East Africa



Source: USAID and Trade Hub, 2013

Despite increase in production in Kenya, the country still relies on onion imports from Tanzania to supplement demand. In 2010, the shortfall, only considering imports from then EAC, was about 16%. The country also imports onions from Non-EAC members especially Ethiopia. The table below shows onion production and trade volume data in 2010. Table 14 and Table 15 show reported regional onion production and trade volumes for 2010[3].

Table 14: Onion production volumes (MT), 2010

Kenya	Tanzania	Uganda	Rwanda	TOTAL
89,000	53,000	195,000	10,100	347,100

[3] Data obtained from USAID and Trade Hub (2013)

Table 15: Onion trade flow volumes (MT), 2010

Trade		Destination				Total
		Kenya	Tanzania	Uganda	Rwanda	
Source	Kenya		-	2,351	-	2,351
	Tanzania	14,274		395	-	14,669
	Uganda	2,234	-		3,366	5,600
	Rwanda	-	-	-		0
Total		16,509	0	2,746	3,366	22,621
Imports/Production		18.55%	0.00%	1.41%	33.33%	6.52%

Tanzania supplies onions to the Kenyan markets all year round. Although not to the same scale as Tanzania, Uganda's main production areas also supply the Kenyan markets with onion throughout the year. Table 16 shows the regional onion trade flow calendar.

Table 16: Onion trade flow calendar in East Africa

Market Pair	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UG - KE												
UG - TZ												
UG - RW												
TZ - KE												
KE - UG												

Source: USAID and Trade Hub, 2013

Overall, the intra-regional trade in horticulture appears to be small compared to total production. As shown above, tomato trade is only 1.32% of total production while for onion it is 6.5%. This means that domestic trade is higher than cross-border trade. This can be attributed to the nature of the commodities (short shelf-life) as well as much of the informal and unrecorded cross-border trade that has been taking place in the region for decades due to weak border controls. This creates a data and information gap that keeps the intra-regional trade artificially low. Low trade flow also signifies that there is substantially sufficient local production in most East African member states. Another important observation of the region's trade is that production clusters near the borders and consumers' preference of commodities produced in certain areas are the main drivers of regional trade in horticultural commodities.

CHAPTER 3: LITERATURE REVIEW

3.1 Asymmetric Price Transmission

In simple terms, price transmission occurs when a change in one price causes a change in another price. This can take place along a given food supply chain, also referred to as vertical price transmission (Vavra and Goodwin, 2005) or across spatially distinct markets of a homogeneous product, also referred to as horizontal/spatial price transmission (Emmanouilides et al., 2014). It can also take place across different agricultural commodities (Esposti and Listorti, 2011), from non-agricultural to agricultural commodities (Serra et al., 2008; Hassouneh et al., 2011) and from spot to futures markets (Baldi et al., 2011).

In economics, prices determine the input use and output decisions and integrate markets vertically and horizontally. Therefore, economists are very much interested in price transmission, especially in the so called asymmetric transmission where the transmission differs depending on whether prices are increasing or decreasing. The existence of asymmetric price transmission has two implications: First, it suggests that there might be problems in the distribution of benefits among the actors in spatial or vertical markets (e.g. final consumers feel the increases of prices at the farm level but they do not feel the decreases). Second, it signals market imperfections which are associated with welfare losses. In both cases, public intervention may be required to correct the problem.

3.1.1 Types of Asymmetric Price Transmission

Meyer and von Cramon-Taubadel (2004) classify price asymmetry on the basis of three criteria. The first criterion refers to whether the asymmetry is on speed or on magnitude of price transmission. The difference between these two types of asymmetric price transmission is described in the figures below[4]. Notice that the change in P_2 is said to depend

4 All figures were adopted from Meyer and von Cramon-Taubadel (2004)

on P_1 that changes at a specific point in time. In Figure 6, the magnitude of response in P_2 depends on the direction of change in P_1. Positive changes in P_1 are fully transmitted but negative changes are not. In Figure 7 it is the speed of response in P_2 that depends on the direction of response in P_1. Here, positive changes are transmitted more rapidly but negative changes are transmitted with a lag of *'n'* periods. Figure 8 presents asymmetry in both magnitude and speed. Notice that asymmetries in magnitude versus speed of price transmission have importantly different welfare consequences. While asymmetry in speed is associated with a temporary transfer of welfare, asymmetry in magnitude implies a permanent welfare transfer. Asymmetry with respect to magnitude and speed leads to both temporary and permanent welfare transfers.

Figure 6: Asymmetry in magnitude

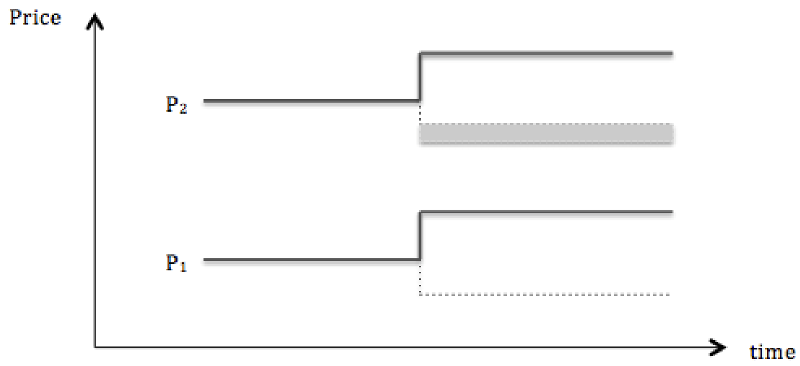


Figure 7: Asymmetry in speed

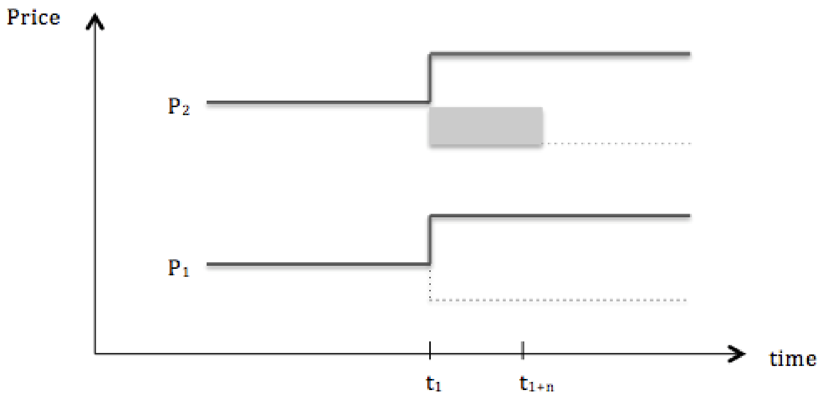
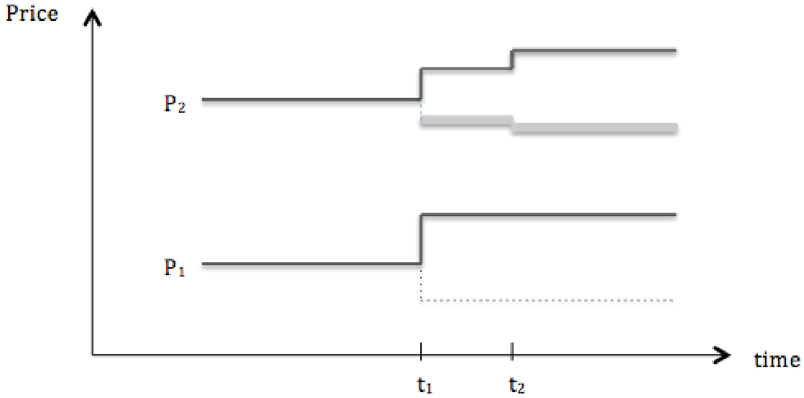


Figure 8: Asymmetry in magnitude and speed



The second criterion is whether the asymmetry is positive or negative. Positive asymmetry occurs when one price responds more fully or more quickly to an increase in another price than to a decrease, thus price movements that squeeze the margin are transmitted more rapidly and more completely than movements that stretch the margin. This is shown in Figure 9. One observes that P_2 tends to react more fully and rapidly to an increase in P_1 than to a decrease. Negative asymmetry occurs when one price responds more fully or more quickly to a decrease in another price than to an increase, thus rapid and/or complete transmission of price movements that stretch the margin. This is shown in Figure 10. One observes that P_2 tends to react more fully to a decrease in P_1 than to its increase. Positive and negative asymmetries have different welfare implications. For example, if we consider P_1 and P_2 to represent prices of a commodity at farm gate and retail levels, negative asymmetry will be good for the consumer while positive asymmetry will be bad for the consumer.

Figure 9: Positive asymmetric price transmission

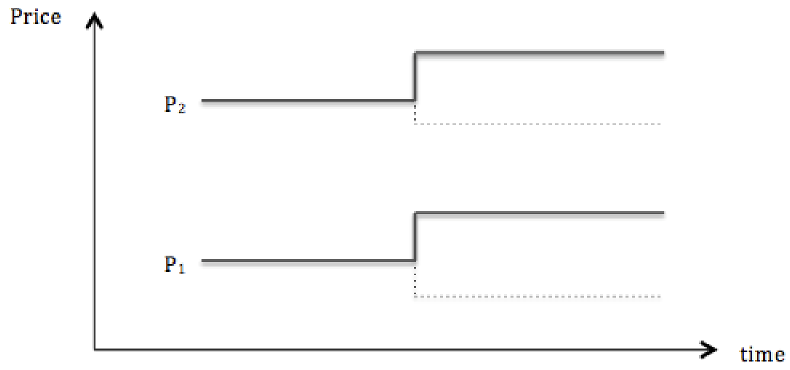
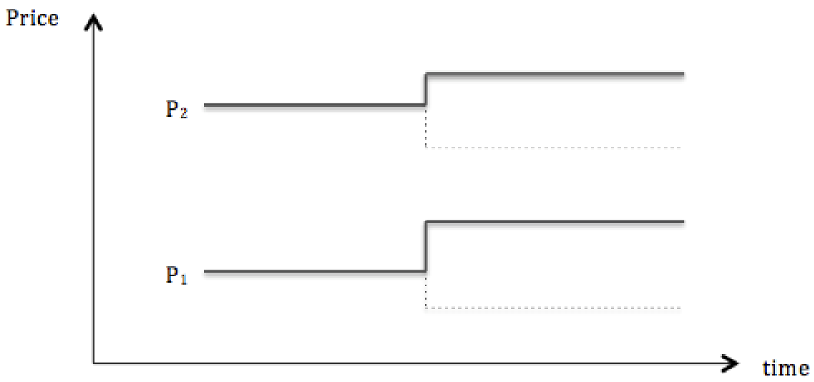


Figure 10: Negative asymmetric price transmission



Lastly, the authors classify asymmetry based on whether it affects vertical or spatial price transmission. Vertical price asymmetry occurs when increases (or decreases) in price at one level of the food supply chain are more fully and more rapidly transmitted to another level of the food supply chain than equivalent decreases (or increases) in price. An example of vertical asymmetry occurs when price increase at retail food markets does not translate into an equal increase in price to the farmers. Spatial asymmetry occurs when an increase (or decrease) in price in one spatial market does not result into a corresponding increase (or decrease) of the same magnitude of price in another spatial market. For example, this can occur when price increase in a food deficit market does not result into an equal increase (in magnitude) of price in a food surplus market. Both vertical and spatial asymmetries can be classified on the bases of speed and magnitude. They can also be classified as positive or negative.

3.1.2 Causes of Asymmetric Price Transmission

A number of possible reasons for asymmetric price transmission have been cited in the relevant literature **(**Abdulai, 2000; Meyer and von Cramon-Taubadel, 2004; Vavra and Goodwin, 2005; and Frey and Manera, 2005). The main causes for vertical asymmetric price transmission are market power due to uncompetitive structures in food supply chains, adjustment and menu costs which arise when firms change the quantities of input and output in response to price shocks, political interventions such as government support in terms of setting price floors, asymmetric flow of market information due to distorted price reporting processes by some strong players, and inventory management practices of some chain players. This work, however, will focus on how these factors can potentially lead to spatial asymmetric price transmission. Some factors specific to spatial asymmetric price transmission are also highlighted. In the spatial context, market power, asymmetric flow of market information between hub and spoke markets, transaction costs and the direction of trade flow have been proposed by Meyer and Von Cramon-Taubadel (2004) to be the major causes.

Market power in the spatial context is closely linked with imperfect competition between enterprises operating in the same industry. In simple terms, market power is the ability of an enterprise or a group of enterprises to raise (or lower) and maintain prices above (or below) a competitive level. This is particularly a case in non-competitive markets. For example, a firm will enjoy local market power as long as there are no competitors within a certain radius. Such a firm will use its market power to ensure that it reacts quickly and/or more completely to price shocks that squeeze its margin than those that stretch it. The result is positive asymmetric price transmission that is due to spatial market power. Furthermore, spatial asymmetric price transmission could result as firms with local market power compete for a share of the market in a region or market. To protect against loss of its market share, a firm might quickly respond to a price decrease by a competing firm than price increase. On the other hand, a price increase by the competitor might be viewed by the firm as an opportunity to grow its sales and gain more customers from the competitor. This leads to a slower response (or non-response at all) to the price increase as the firm tries to take advantage of the competitor's price increase, leading to spatial asymmetric price transmission. Spatial asymmetric price transmission can also be resulted from trading behaviors of major trading markets (e.g. John, 2014). Imperfect competition (and hence market power) is a common phenomenon in agricultural markets and many authors finding asymmetric price transmission point to it as a possible explanation (e.g. Weldegebriel et al., 2008; Bunte and Peelings, 2003; Saghaian and Tekgüç, 2012; Ozertan et al., 2014; Ben-Kaabia and Gil, 2007). However, whether price transmission and market structure are related or whether uncompetitive market structure leads to asymmetric price transmission is difficult to establish using conventional economic models since it is cross cutting and might involve some qualitative measurements.

In the spatial context, particular patterns of price behavior under competitive arbitrage depend on the costs associated with movement of goods between markets (transportation costs) as well as the direction of trade flow. More specifically, if trade flows between markets, these markets are said to be in competitive spatial equilibrium if and only if the price difference exactly equals the costs of moving goods between them, and that excess benefits from trade are completely realized. Spatial asymmetric price transmission occurs when these costs vary with the direction of trade flow. For example, due to historical reasons and/or natural conditions, speed of moving goods, transportation costs and infrastructure might predominantly favor trade (between two spatial markets) in one direction but less in the opposite. Asymmetric costs result into asymmetric price transmission between such markets. Some of the empirical works done on the effects of transaction/transportation costs in spatial agricultural markets include those of Meyer, (2004); Sera and Goodwin, (2004); Serra et al., (2006); Balcombe et al. (2007); Brosig et al., (2011); and Mengel and von Cramon-Taumbel, (2014).

Asymmetric flow of market information has also been cited as one of the causes for spatial price asymmetry (Cutts and Kirsten, 2006). This has, however, been indicated to be a cause that is more relevant to markets in developing countries (e.g. Abdulai, 2000). In these markets, there exist asymmetric flow of information between central (hub) and peripheral (spoke) markets. Because of their size and location, central markets may tend to be less responsive to price shocks in peripheral markets.

Other secondary factors such as domestic and border regulation policies, product heterogeneity, product perishability, exchange rate risks, and retailer price expectations have been cited to potentially interfere with spatial arbitrage, and consequently price transmission (Miljkovic, 1999; Graubner et al., 2011; Rezitis and Stavropoulos, 2010; Santeramo and Cioffi, 2010).

3.2 Previous Empirical Works on Asymmetric Price Transmission

Different methodological approaches have evolved and have been adopted in studying asymmetric price transmission. Generally, these approaches can be categorized into two groups. First are those relying on econometric models and second are those employing other statistical tools such as copulas. While econometric time series techniques are the most commonly used in price transmission analyses, copulas have been introduced and gained momentum in the relevant literature very recently.

3.2.1 Econometric-based Studies

The econometric-based studies focus mainly on the speed of price transmission using parametric and non-parametric regression models. The overwhelming majority of the parametric models have evolved out of the seminal work of Meyer and von Cramon-Taubadel (2004) who proposed the asymmetric Error Correction Model (ECM). In the ECM, the speed of price transmission depends on the sign of the deviation from the equilibrium. Variants of the ECM are the Threshold Autoregression (TAR) model, the Smooth Threshold Autoregression (STAR) and the Threshold Vector Error Correction (TVEC) model in which not only the sign but the magnitude of the deviation from the equilibrium impacts on the speed of price transmission. The non-parametric regression models also allow for both the sign and the magnitude of the deviation from the equilibrium to influence the speed of price transmission. However, they do so without using parametric functional forms.

Fackler and Goodwin (2001), Meyer and von Cramon-Taubadel (2004), Abdulai (2007) and Fackler and Tastan (2008) provide a comprehensive review of the econometric approaches. It is clear from these reviews that econometric techniques have evolved from simple bivariate correlation analyses to more diverse and sophisticated ones.

The econometric literature on price transmission is vast. Therefore, in the following only a few representative studies are discussed. von Cramon-Taubadel (1998) found that increases in pork prices at the farm level in Germany were transmitted to the retail level faster than decreases. Abdulai (2002) reported the same result for Switzerland. Goodwin and Piggott (2001) found price transmission asymmetries in speed for a number of North Carolina corn and soybean markets, and Sera et al. (2006) obtained the same result for the principal EU pork markets (Germany, Spain, France and Denmark). Ghoshray (2010) found price transmission asymmetry in speed for quality differentiated coffee beans. Gervais (2011) appears to be the only work that considered both asymmetry in speed and asymmetry in magnitude. He found evidence of asymmetry in magnitude but not in speed along the USA pork supply chain.

A number of works have focused on price transmission in the African agricultural markets using econometric models. For example, Abdulai (2000) applied Threshold Vector Error Correction (TVEC) model to analyse price linkages in three Ghanaian maize markets. In these markets, positive price shocks in surplus markets were found to be transmitted more quickly than negative price shocks. Isaac (2012) applied the Threshold Autoregressive model to analyse spatial price transmission in the Ghanaian regional maize markets. The study revealed that these markets were integrated both in the short and long run. Price adjustment was however found to be predominantly asymmetric, with traders responding more to price changes that squeeze their margins than those that stretch them (positive asymmetry). Van Campenhout (2007) studied market integration of seven maize markets in Tanzania using three different Autoregressive models. He found that price adjustments only occurred when prices exceed a certain threshold which is small for markets that are closer to each other and vice versa. Ihle et al. (2009) studied price transmission between Tanzania and Kenya maize markets. The study revealed two price relationship regimes; the "high" and the "low" ones which are associated with high and low price margins respectively.

3.2.2 Copula-based Studies

The copula-based studies focus on price co-movement. Copulas capture information contained in price time series such as the strength of the overall or global (across the entire joint distribution) co-movement as well as information about price co-movement under extreme market events (symmetry vs. asymmetry). The overall strength of the co-movement is measured by rank-based measures of dependence while symmetry or asymmetry is measured by comparing the tail dependence coefficients. High values of the overall co-movement and symmetric co-movement at the extremes are considered as evidence that the markets under study are well integrated. That is, prices in such markets move (boom and crash) together.

In agricultural markets, copulas have proven to be suitable for modelling the degree of market integration as well as the response to price shocks under extreme market conditions. They examine the joint probability distribution function of the variables and pay attention to the nature of the relationship between them. However, as mentioned earlier, copulas have been introduced into agricultural economics literature fairly recently. Hence, the number of works on price dependence in agricultural markets is still small.

Qiu & Goodwin (2013) applied copulas to assess price transmission in the USA farm and retail hog/pork supply chain levels. The empirical results of this work identified a time-varying asymmetric price relationship between these two supply chain levels. That is, price increases at farm level were found to be transmitted more to the retail level (positive upper tail dependence) while negative price shocks at farm were less likely to be passed on to the retail level (zero lower tail dependence).

Emmanouilides and Fousekis (2015a) analysed price co-movement along the beef supply chain in the USA. They found that prices at the farm and at the wholesale levels were closely related but those at the wholesale and the retail levels were not. Co-movement between wholesale and retail prices turned out to be asymmetric (zero for extreme negative price changes).

Emmanouilides and Fousekis (2015b) also analysed price co-movement along the pork supply chain in the USA. They considered linkages in two periods, prior and after 1990. According to their results, prior 1990 price relationships had been strong and generally asymmetric. After 1990, however, co-movement between wholesale and retail prices became very weak.

Sera and Gil (2012) studied price linkages between diesel, biodiesel and crude oil in Spain. According to their results, diesel prices equally reflect crude oil price decreases and increases. However, co-movement between biodiesel and crude oil prices was found to be asymmetric, something that protects biodiesel consumers in Spain from extreme crude oil price increases.

The relationship between world oil prices and agricultural commodity prices was also investigated by Roboredo (2012) who tested for price dependence between world oil and world food (corn, soybean and wheat) prices using a number of copula models. It was found that world oil and agricultural commodity prices did not have any significant dependence even during extreme market events. An important point to note in these findings is the seemingly neutrality of agricultural commodity markets to changes in world oil prices as well as non-contagion between these commodity markets. This means consumers of food commodities are protected from world oil price hikes.

Goodwin et al. (2011) investigated the joint distribution of four North American lumber prices (Eastern Canada, North Central, Southern and Southwest). According to their results, these markets were found to respond to generally larger price differences rather than smaller price differences. This implies presence of significant disequilibrium conditions and hence bigger arbitrage opportunities in these markets.

Emmanouilides et al. (2014) applied copulas to investigate price dependence in major EU olive oil markets. In their results, price co-movement between the most important players (Spain and Italy) was found to be asymmetric. That is, it was found that extreme price increases were likely to be transmitted from one market to the other but negative price decreases were not.

Panagiotou and Stavrakoudis (2015a) assessed price dependence between three different pork cuts (boneless, bone in and other chops) in the USA retail markets. According to their results, the overall price dependence existed for all pairs but no significant evidence that these prices were likely to boom and crash together was found; meaning that retailers did not adopt any identifiable pricing strategies even during extreme market conditions.

Panagiotou and Stavrakoudis (2015b) also applied a similar approach to assess price dependence between differentiated beef cuts and quality grades (Choice and Select categories) in the USA retail markets. Asymmetric price transmission was observed in the Choice cuts and quality grade but none was found on the Select cut and quality grade. For the pairs formed between the Choice and Select cuts and quality grades, only one pair (chuck roast cut) had statistically significant level of asymmetry. Hence, in this case, it was found that retailers adopted different pricing strategies during turbulent market events.

From all the empirical works presented here, an important observation to note is that econometric models and the statistical copula models analyze price linkages from quite different perspectives. As a result, their respective empirical findings are not directly comparable. Given, however, that the tail coefficients are calculated on the basis of the magnitude of price shocks (extreme high with extreme high and extreme low with extreme low), differences between them are likely to indicate asymmetry of price transmission in magnitude than in speed. In this study, the empirical analysis focuses on copula methods.

CHAPTER 4: ANALYTICAL FRAMEWORK

4.1 Copulas and Measures of Dependence

The study of dependence across agricultural markets has been gaining more attention in recent decades. Copulas models are among the most convenience approaches in studying dependence. They are derived from Sklar's theorem that postulates that a multivariate distribution of a vector of random variables is completely specified by the individual densities and a joining function known as *copula* (Sklar, 1959). Copula functions link univariate marginal distributions to their joint multivariate distribution. Therefore, in analysing dependence using copula functions, the joint distribution can be separated in two parts. These are marginal distribution functions of random variables and the dependence structures between random variables described by a copula function (Li, 2000).

Copulas can be used to express dependence for multivariate stochastic processes. In this study and for simplicity, we present the most important notions involved in bivariate processes only. For the bivariate case, let the joint cumulative density function (cdf) of a pair of random variables (X_1, X_2) be $F(x_1, x_2)$ and their marginal cdfs be $F_1(x_1)$ and $F_2(x_2)$ respectively. From Sklar's theorem, it follows that

$$F(x_1, x_2) = C\{F_1(x_1), F_2(x_2)\} \qquad (1)$$

where C is the copula function. Provided that the marginal distributions are continuous, C, F_1 and F_2 are uniquely determined by $F(x_1, x_2)$. Conversely, for any pair (F_1, F_2) and for any copula C, the function F given in equation (1) above defines a valid joint cdf for (X_1, X_2) with margins F_1 and F_2.

The copula is a bivariate cdf with uniform margins, $C: [0, 1]^2 \rightarrow [0, 1]$, and it can be obtained from equation (1) as

$$C(u_1, u_2) = F(F_1^{-1}(u_1), F_2^{-1}(u_2)) \qquad (2)$$

where F_i^{-1} (i = 1, 2) are marginal quantile functions and u_i are probabilities (quantiles) on U[0, 1]. The joint probability density function (pdf) associated with C is obtained by

$$c(u_1, u_2) = \frac{\partial^2 C}{\partial u_1 \partial u_2} = \frac{f(F_1^{-1}(u_1),\ F_2^{-1}(u_2))}{f_1(F_1^{-1}(u_1))\, f_1(F_2^{-1}(u_2))} = \frac{f(x_1, x_2)}{f_1(x_1) f_2(x_2)} \quad (3)$$

where f is the joint pdf associated with F, and f_1 and f_2 are marginal pdfs of X_1 and X_2 respectively. From equation (3), it follows that

$$f(x_1, x_2) = c(F_1(x_1), F_2(x_2))\, f_1(x_1) f_2(x_2) \quad (4)$$

where c is a joint pdf associated with C. This joint pdf contains information for both the marginal behavior of each variable and the dependence between them. Each random variable is fed into its own cdf in the term $c(F_1(x_1), F_2(x_2))$. In this fashion, it therefore sweeps away all the information contained in the marginal distributions, leaving the pure joint information between X_1 andX_2 . Thus, from observations drawn from equation (4), it can be concluded that this copula function fully characterizes dependence of the random variables by capturing the information missing from the marginal distributions to complete the joint distribution (Meucci, 2011).

Using copulas to analyze dependence (co-movement) between random variables offers several important advantages compared to other models. (1) Given that marginal distributions provide a complete description of the behavior of two random variables when measured independently, copula models exhaustively and uniquely characterize the dependence structure between them. (2) Due to converse of Sklar's theorem, copula models are capable of modelling dependence individually out of the marginal distributions. (3) While other standard measures of co-movement such as Pearson's correlation draw inference based on the correlation coefficient (provides information on whether two random processes are related in a linear way or not), there is an increasing number of studies suggesting that such measures are insufficient in the real world, both in domestic (Ang and Chen, 2002) and international markets (Longin and Solnik, 2001; Ang and Bekaert, 2002).

This is because they can hardly reveal sufficient evidence about the nature of dependence because even though random variables may have the same correlation coefficient, they might have different dependence structures. These different structures could increase or decrease their efficiency. Therefore, it is not only the degree of dependence that matters but also the structure (intensity) of dependence. In contract, copulas fully measure the general functional dependence (linear and/or nonlinear) between random variables as well as providing information about their degree of dependence. (4) Since copulas are based on ranks of stochastic processes, they are not affected by continuous and monotonically increasing transformations of the underlying marginal stochastic processes.

4.2 Common Copulas in Statistics

Different copulas imply different dependency structures even though the resulting bivariate distributions might have the same margins. This is because random processes may have different properties. It is therefore, important for the researcher to have a variety of copulas that adequately capture the relevant behaviors of the processes to be modelled. As Durante and Sepmi (2010) suggest, a *good* copulas family should be (1) interpretable: implying that its members should give useful probabilistic information that points to likely situations where this family could be useful; (2) flexible: meaning that its family should be capable of demonstrating a multiplicity of likely forms and levels of dependence; and (3) expressive: meaning that it should be possible to represent such members of the family in a unified form or, at least, it should be easy to manipulate them by the means of some known logarithm. In studying a multitude of possible dependence structures, the literature provides a large number of relevant bivariate parametric copula models. It is however, important to note that the parametric copula models discussed in this work are only those relevant and commonly applied in risk management, finance, and economics (e.g. Sera and Gil, 2012; Czado et al., 2012).

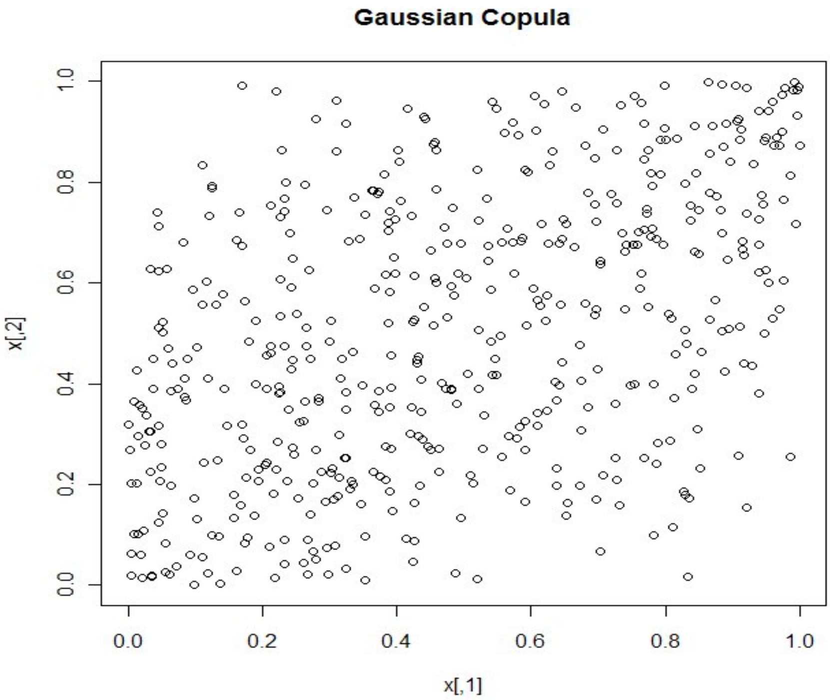
Generally, copulas can be grouped into two broad families. The first category consists of what is known as Elliptical Copulas. The most commonly used elliptical copulas are Student-*t* copula and Gaussian copula. The second family consists of a group of copulas collectively known as Archimedean Copulas. It includes copulas such as the Clayton, the Gumbel, and the Frank copulas. Other copulas under this family are those that are a joint of pdfs of Archimedean copulas such as the Gumbel-Clayton and the Joe-Clayton copulas.

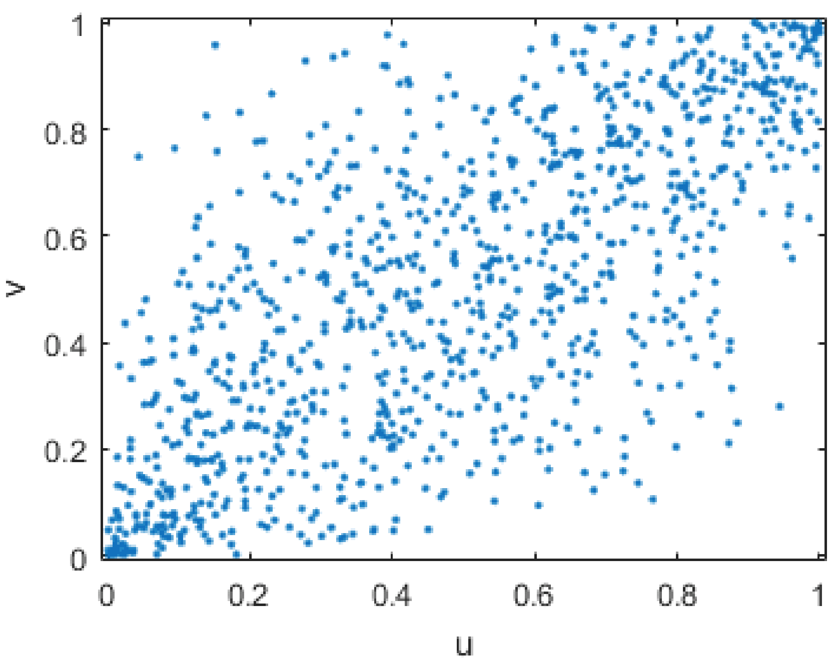
The Gaussian is among the simplest copulas to construct and estimate. It contains only a single dependence parameter – the linear correlation coefficient, ρ that corresponds to the bivariate normal distribution. To create a bivariate distribution that uses Gaussian copula, one needs a correlation coefficient, ρ. The Gaussian copula is a distribution over the unit square $[0, 1]^2$. It is constructed from a bivariate normal distribution over R^2 by using the probability integral transformation. The Gaussian is symmetric and displays zero dependence at the extreme values. If F(.) is a bivariate normal distribution $Np(\mu, \sum)$ and $\sum$ is the variance – covariance then C(.) is a Gaussian copula. If the location or scale of the distribution is changed, the copula does not change, so conventionally we replace μ by zero and $\sum$ by the correlation coefficient, ρ.

The Student-*t* copula can be thought of as a representation of the dependence structure implicit in a bivariate *t*-distribution (Demarta & McNeil, 2005). Relevant studies (Mashal & Zeevi, 2002 and Breymann et al., 2003) have shown Student-*t* copula to be superior to the Gaussian copula due to its ability to capture better the phenomenon of dependent extreme values. The Student-*t* copula has two parameters. These are the linear correlation coefficient, ρ and the degrees of freedom, v. The Student-*t* copula is symmetric and displays both positive and negative dependence at the extreme values. If F(.) is a bivariate *t*-distribution $t_v(\mu, \sum)$, then C(.) is a Student-*t* copula. Again, conventionally we replace μ by zero and $\sum$ by the correlation coefficient, ρ. But note that when $v \geq 30$, the Student-*t* copula becomes Gaussian.

Figure 11 provides scatter plots of the two important elliptical copula families.

Figure 11: Scatter plots of bivariate Gaussian and bivariate Student-*t* copulas





Source: Econometric Sense, 2012

The imposition of zero dependence at the extreme values (Gaussian) and/or the imposition of positive but symmetric dependence (Student-t) may turn to be too restrictive for empirical analysis. Certain members of the Archimedean family may provide a solution in this case. In particular, the Clayton copula is asymmetric and exhibits positive dependence at the low extremes and zero dependence at the high extremes. The Clayton family contains a single dependence parameter, θ. Its mathematical form is given by,

$$C_\theta(u, v) = max(u^{-\theta} + v^{-\theta} - 1)^{-1/\theta} \quad (5)$$

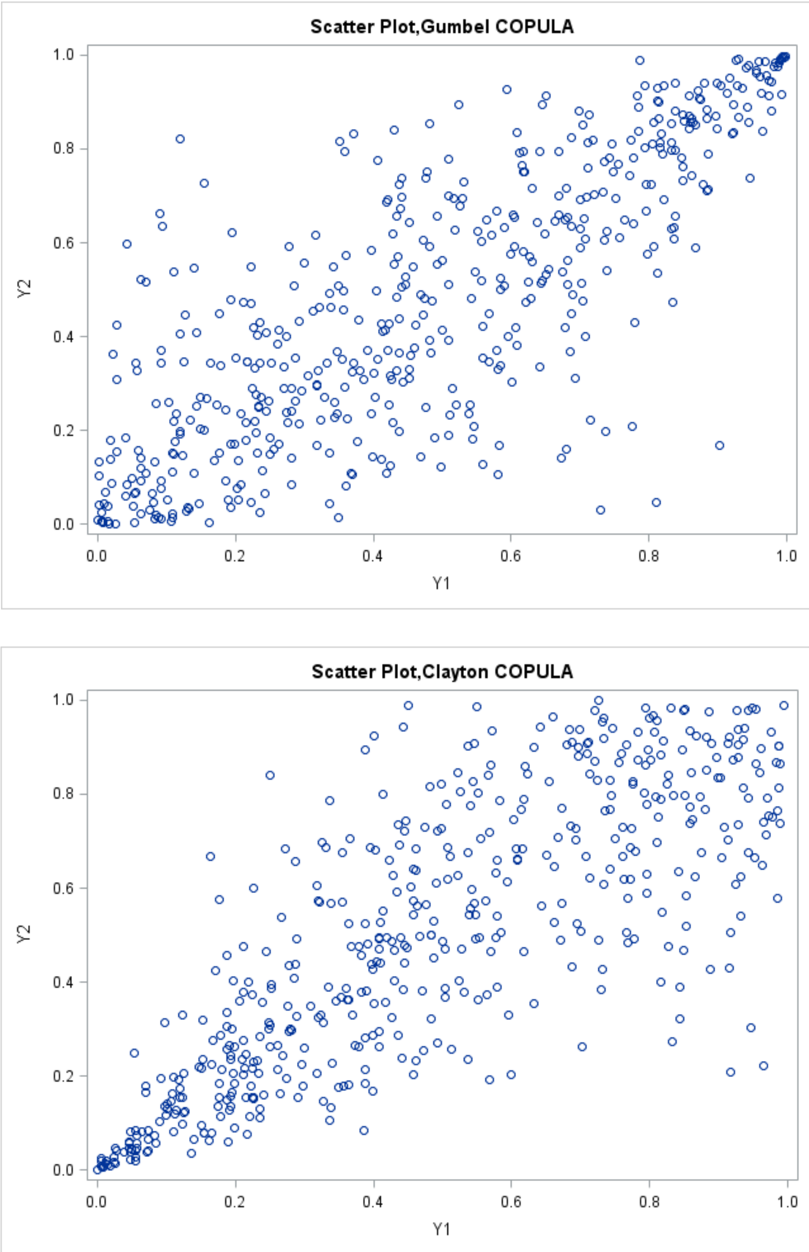
while $0 < \theta \leq 1$ is a parameter controlling the dependence. Perfect dependence is obtained when $\theta \to 1$, while $\theta = 0$ implies independence.

The Gumbel copula is asymmetric and exhibits positive dependence at the high extremes and zero dependence at the low extremes. The Gumbel copula also contains a single dependence parameter, θ. Its mathematical form is given by,

$$C_\theta(u, v) = \exp\left(-\left[(-\log u)^{\theta} + (-\log v)^{\theta}\right]^{1/\theta}\right) \quad (6)$$

while $0 < \theta \leq 1$ is a parameter controlling the dependence. Perfect dependence is obtained when $\theta \to 0$, while $\theta = 1$ implies independence. Figure 12 provides scatter plots of the two important Archimedean copula families.

Figure 12: Scatter plots of bivariate Gumbel and bivariate Clayton copulas



Source: Econometric Sense, 2012

The Gumbel-Clayton copula exhibits dependence at both the upper and the lower extremes. Its mathematical form is

$$C(u, v; \theta_1, \theta_2) = \{1 + [(u^{-\theta_1} - 1)^{\theta_2} + (v^{-\theta_1} - 1)^{\theta_2}]^{1/\theta_2}\}^{-1/\theta_1} \quad (7)$$

where $\theta_1 > 0$ and $\theta_2 \geq 1$. As it can be observed from the equation above, the Gumbel-Clayton has two dependence parameters θ_1 and θ_2. Likewise; the Joe-Clayton contains similar dependence parameters, θ_1 and θ_2. The Joe-Clayton copula can be expressed mathematically as

$$C(u, v; \theta_1, \theta_2) = 1 - \{1 - [(1 - u^{-\theta_1})^{\theta_2} + (1 - v^{-\theta_1})^{-\theta_2} - 1]^{-1/\theta_2}\}^{1/\theta_1} \quad (8)$$

where $\theta_1 \geq 1$ and $\theta_2 > 1$. The Gumbel-Clayton and Joe-Clayton copulas allow for both right and left co-movement (*i.e.* they are potentially asymmetric).

There are certain advantages in using Archimedean copulas over elliptical ones. This is because Archimedean copulas: (1) can be written in explicit form, and (2) they offer great flexibility in modelling different kinds of dependence because they are not restricted to radical asymmetry. Likewise, Elliptical models have their advantages compared to Archimedean models. Such advantages include that: (1) they are more suitable for modelling high-dimensional dependence structures and (2) they can specify different levels of correlation between marginal distributions (Hofert, 2010 and Han, 2012).

It is important to note that in most cases, direct comparisons of co-movement parameters across copula families are meaningless. The literature, therefore, proposes a number of alternative measures of co-movement. The most common measure of functional dependence is the Kendall's *tau* (τ). The Kendall's *tau* is calculated from a number of concordant and discordant pairs of observations. It provides information on dependence across the entire joint distribution function (at the center and its tails) (Genest and Favre, 2007). In terms of *C*, the population version of the Kendall's *tau* can be expressed as

$$\tau = 4\int\int_{I^2} C(u, v)\, dC(u, v) - 1 = 1 - 4\int\int_{I^2} \frac{\partial C}{\partial u}(u, v)\frac{\partial C}{\partial v}(u, v)\, du\, dv. \quad (9)$$

(Schweizer and Wolff, 1981; Nelsen, 2006)

If all the pairs are concordant then $\tau = 1$, i.e. the variables are in exactly the same order. If they are all discordant then $\tau = -1$ i.e. the variables are in exactly the opposite order. If the pairs are independent, then we would expect the coefficient to be approximately zero. The

Kendall's *tau* is a rank-based measure of dependence. That means, it does not change when there are strictly increasing transformations of the data. This is conversely not the case with the standard Pearson's ρ. However, ρ measures exactly linear dependence while Student-*t* measure exactly linear or non-linear dependence.

Information about tail dependence both at the lowest and the highest ranks of multivariate distributions is very useful to economists, managers and policy makers. Tail dependence at the extremes is measured by the upper and the lower tail dependence coefficients λ_U and λ_L respectively. These coefficients are defined as

$$\lambda_U = \lim_{u \to 1} prob\ (U_1 > u \mid U_2 > u) = \lim_{u \to 1} \frac{1-2u+C\ (u,u)}{1-u} \in [0, 1] \qquad (10)$$

and

$$\lambda_L = \lim_{u \to 0} prob\ (U_1 < u \mid U_2 < u) = \lim_{u \to 0} \frac{C\ (u,u)}{u} \in [0, 1] \qquad (11).$$

λ_U measures the probability that the random process X_1 is above a high quantile given that X_2 is also above that high quantile. λ_L measures the probability that X_1 is below a low quantile given that X_2 is also below that quantile. In other words, these two measures of tail dependence provide information about the likelihood for the two random variables to boom and to crash together correspondingly. Note that certain properties such as invariance to monotonically increasing transformations of the underlying processes apply to λ_U and λ_L. This is because they are both expressed via copula. Table 17 presents the Kendall's τ and the tail dependence coefficients for the Gaussian, the Student-*t*, the Clayton, the Gumbel, the Gumbel-Clayton and the Joe-Clayton copulas.

Table 17: A summary of common copulas in statistics

Copulas	**Parameters**	**Kendall's τ**	**Tail Dependence (Lower, Upper)**
Gaussian	$\rho \in (-1, 1)$	$\frac{2}{\pi}\arcsin(\rho)$	(0, 0)
Student-*t*	$\rho \in (-1, 1)$, $\nu > 2$	$\frac{2}{\pi}\arcsin(\rho)$	$(2t_{v+1}(-\sqrt{v+1}\sqrt{\frac{1-\rho}{1+\rho}})$ $2t_{v+1}(-\sqrt{v+1}\sqrt{\frac{1-\rho}{1+\rho}}))$
Clayton	$\Theta > 0$	$\frac{\theta}{\theta+2}$	$(2^{-\frac{1}{\theta}}, 0)$
Gumbel	$\Theta \geq 1$	$1 - \frac{1}{\theta}$	$(0, 2-2^{-\frac{1}{\theta}})$
Gumbel-Clayton	$\Theta_1 > 0$, $\Theta_2 \geq 1$	$1 - \frac{2}{\theta_2(\theta_1+2)}$	$(2^{-\frac{1}{\theta_1\theta_2}}, 2-2^{\frac{1}{\theta_2}})$
Joe-Clayton	$\Theta_1 \geq 1$, $\Theta_2 > 0$	$1 + \frac{4}{\theta_1\theta_2} + \int_0^1 (-1-(1-t)^{\theta_1})^{\theta_2+1}$ X $\frac{(1-(1-t)^{\theta_1})^{-\theta_2}-1}{(1-t)^{\theta_2-1}})dt$	$(2^{-\frac{1}{\theta_2}}, 2-2^{\frac{1}{\theta_1}})$

Note that: $\int_0^{\theta_1} \frac{c/\theta}{\exp(x)-1}\,dx$ is the Debye function

Source: Brechmann & Schepsmeier, (2013)

We observe that the tail dependence coefficients for the Gaussian are zero (there is no positive probability or joint boom and crashes). For the Student-*t*, the tail dependence coefficients are both positive and equal (meaning that the joint boon and crashes occur with exactly the same probability). In the case of the Clayton copula, only joint crushes occur with positive probability. Finally, the Gumbel-Clayton and Joe-Clayton exhibit positive and negative tail dependence (potentially asymmetric).

CHAPTER 5: EMPIRICAL RESULTS AND DISCUSSION

5.1 Data

Among many challenges facing researchers interested in the African agricultural markets is lack of sufficient and suitable data. For horticultural markets in East Africa, very limited data sources exist and often their reliability is questionable. However, the Tanzania Horticultural Association (TAHA) provided reasonably suitable data that was used in this study. These are monthly wholesale prices collected from four major urban food markets in Tanzania and Kenya; namely Arusha (Ars), Dar es Salaam (Dsm), Mombasa (Mbs) and Nairobi (Nrb). The data ranges from 2010:10 to 2014:07. In these markets, onions are sold in bags/sacks of 120Kg while tomatoes are sold in wooden crates of 40Kg. To make comparisons easier, all prices were converted into Tanzania Shillings per kilogram (Tsh/Kg).

Figure 13 presents the natural logarithms of prices in the four onion markets considered in this work. One observes that in certain periods (but not in all), prices increase or decrease together.

Figure 13: Time series of onion prices

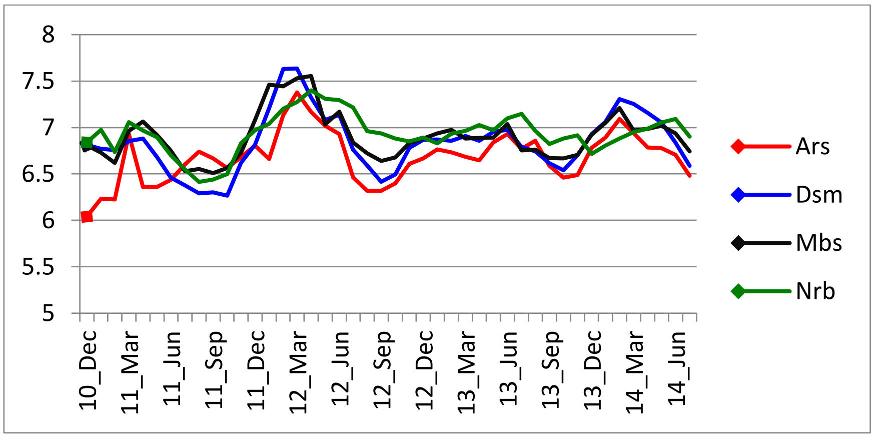


Table 18 presents descriptive statistics for onion prices. On average, prices are higher in Kenyan markets compared to those of Tanzania. There are three possible explanations for that. First, as it was mentioned earlier in section 2.3, only less than 20% of Kenya's total land is suitable for agriculture. Production is therefore, restricted to only few parts of the country. As a result, domestic supply fails to meet local demand. Second is that Tanzania is an exporter of onions to Kenya (the former has lower production costs or equivalently, a comparative advantage over the latter). Third is that Kenya is the largest exporter of horticultural products (including onions) outside the East African region. Part of the onions imported in Kenya from neighboring countries including Tanzania are re-packaged and re-exported to other international markets. The high level of Kenyan prices for onions, therefore, may be influenced by the level of prices outside the region.

Table 18: Onion price summary statistics

	Tanzania Markets		Kenya Markets	
	Ars	Dsm	Mbs	Nrb
Min.	420.0	526.5	671.0	610.4
Max.	1599.2	2069.4	1909.5	1635.0
Mean	826.8	980.9	1027.2	1048.9
Median	798.4	921.1	976.9	1036.0

Also, there is a sizable difference between the price levels in Ars and in Dsm. The difference reflects largely transportation and other transaction costs. While Ars is a producer of onions (hence low transportation cost from farms to the urban market), Dsm exclusively depends on supply from distant production regions (including Ars). Moreover, the higher onion prices in Dsm are potentially due to the fact that the market is also a major outlet of the commodity to water-locked markets in the Indian Ocean, such as those of Zanzibar and Comoros. Supply to these markets creates extra demand in the Dsm market which in turn rises its prices.

Figure 14 provides a plot of the natural logarithms of tomato prices in the four markets. Similar observations can be made on tomato price series when plotted against time period considered in this work. That is, one observes that tomato prices exhibit certain periods (but not all) of corresponding price increase and decrease.

Figure 14: Time series of tomato prices

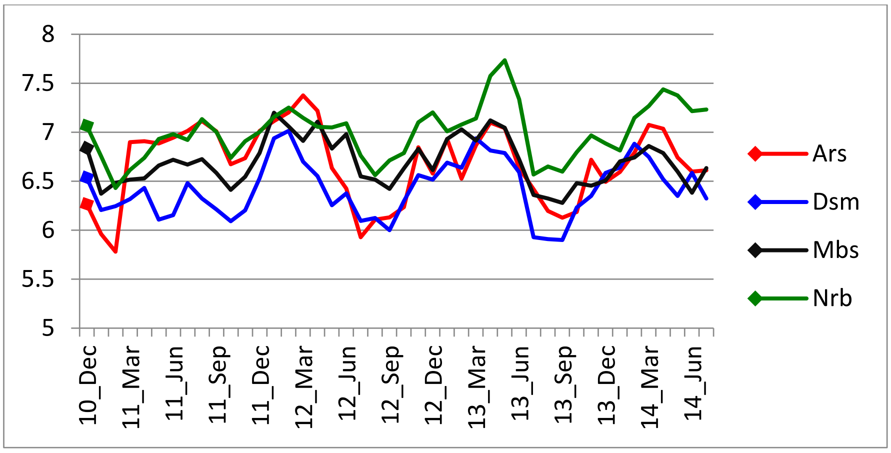


Table 19 provides descriptive statistics for tomato prices. One observes that on average, prices are higher in the Nrb market and are lower in the Dsm market. Prices in Ars and Mbs markets lie in between. Again, country-wise averages show that tomato prices in the Kenyan markets are at least 27 percent points higher than those of Tanzania. In this case, it is important to note that tomato is one of the most important horticultural crops in Kenya. Demand is high in the Nrb and Mbs markets. A likely explanation for the higher prices in these two markets is shortage of local supply. There are three major possible reasons for this. First (as it has been mentioned in the case of onions) is lack of suitable land and climate for tomato production in most parts of the country. Second is recent more extreme weather conditions that have affected tomato production. There have been reports of erratic weather with the few existing tomato production areas experiencing cold weather and heavy rainfall (which is unfavorable for tomato growth), causing a drop in tomato supply especially in the rainy seasons. Third is a prevalent pest that has appeared in most tomato production parts of Kenya. In recent years, a pest commonly known as tomato leaf miner (*Tuta absoluta*) has been reported by the Kenyan Ministry of Agriculture to ravage tomato open farms and greenhouses (The Guardian, 2015). The pest which is thought to be indigenous to Southern America is believed to have come to Kenya through Ethiopia.

Table 19: Tomato price summary statistics

	Tanzania Markets		Kenya Markets	
	Ars	Dsm	Mbs	Nrb
Min.	324.0	365.0	533.1	620.7
Max.	1596.7	1112.5	1338.2	2286.1
Mean	849.6	642.9	827.6	1138.2
Median	834.0	604.4	786.2	1104.5

All relevant earlier works on price dependence (e.g. Reboredo, 2011 and 2012; Sera and Gil, 2012; Emmanouilides et al., 2014; Emmanouilides and Fousekis, 2015) focus on the dependence between the price shocks calculated as $dlnP_{it}$ where P_{it} is the price of a commodity in market i at time t. This approach has been used here as well. The data for the empirical implementation of the copula model must be stationary and uniformly distributed on $[0, 1]$. To verify stationarity, the Augmented Dickey-Fuller (ADF) test has been applied to each individual series of the price shocks. The lag lengths have been selected using the Akaike's Information Criterion (AIC)[5]. Table 20 presents the stationarity test results for onion prices and Table 21 presents those for tomato prices. For all series, the null hypothesis (non-stationarity) is rejected by real world data. Note that the model has been estimated with a constant term.

The conversion of continuous variables (such as price shocks) into data that are uniformly distributed on $[0, 1]$ can be implemented in two steps. First one obtains the so called integral transforms (i.e. the ranks of individual observations) and second he/she multiplies (rescales) the ranks by the factor $^{\mathrm{T}}/_{\mathrm{T}+1}$, where T is the number of observations (e.g. Emmanouilides and Fousekis, 2015).

5 For technical details on the ADF and the AIC, see Appendix (Part A).

Table 20: Stationarity test results for onion price shocks

Market	*t*-statistic	*p*-value	Lag length
Ars	-6.756	0	0
Dsm	-3.498	0.015	0
Mbs	-5.538	0	0
Nrb	-5.019	0	0

Table 21: Stationarity test results for tomato price shocks

Market	*t*-statistic	*p*-value	Lag length
Ars	-6.551	0	0
Dsm	-5.683	0	0
Mbs	-6.943	0	0
Nrb	-5.174	0	0

5.2 The Empirical Model

The empirical analysis of dependence (co-movement) is carried here using the two-parameter Joe-Clayton copula also known as the BB7 copula. The BB7 has the desirable properties of interpretability, flexibility and expressiveness (Durante and Sempi, 2010). Its generator function is

$$(1-(1-t)^{\theta_1})^{\theta_2} \tag{1}$$

where $\theta_1 \geq 1$ and $\theta_2 > 0$ are parameters to be estimated. The Kendall's *tau* for the BB7 is computed as

$$\tau = 1 + 4\int_0^1 ((1-(1-t)^{\theta_1})^{-\theta_2} - 1) \,/ (-\theta_1\theta_2(1-t)^{\theta_1 - 1}(1-(1-t)^{\theta_1})^{-\theta_2 - 1})dt \tag{2}$$

while the lower and the upper tail dependence coefficients are computed as

$$\lambda_L = 2^{-\frac{1}{\theta_2}} \tag{3α}$$

and

$$\lambda_U = 2 - 2^{\frac{1}{\theta_1}} \tag{3β}$$

respectively (Brechmann and Schepsmeier, 2013). The BB7 allows for potentially asymmetric price dependence at the very extremes of the joint distribution function;

symmetry of dependence (co-movement) requires $2-2^{\frac{1}{\theta_1}} = 2^{-\frac{1}{\theta_2}}$. Moreover, when the parameter θ_1 approaches 1 from above, the BB7 collapses to the Clayton copula which is consistent with lower tail dependence (co-movement) only (i.e., $\lambda_U = 0$ and $\lambda_L > 0$); while when the parameter θ_2 approaches 0 from above, the BB7 collapses to the Joe copula which is consistent with upper tail dependence (co-movement) only (i.e., $\lambda_U > 0$ and $\lambda_L = 0$).

As mentioned in Section 4.2, the Kendall's *tau* gives the difference between the proportion of concordant and that of discordant pairs in a sample. However, since the two proportions (percentages) add up to one always, a simple mathematical manipulation shows that the proportion of concordant pairs in the sample is equal to $0.5(1+\tau)$.[6]

The upper tail dependence coefficient gives the probability of a joint boom; that is, the probability of an extreme positive price shock in one market, provided (conditional upon) there has been an extreme positive price shock in another market as well. The lower tail dependence coefficient gives the probability of a joint crash; that is, the probability of an extreme negative price shock in one market, provided (conditional upon) there has been an extreme negative price shock in another market as well. Taken together, the Kendall's *tau* and the tail coefficients provide information both about the overall strength of co-movement between two stochastic processes as well as the information about the structure of co-movement (symmetry vs asymmetry).

5.3 Empirical Results

5.3.1 Global and Local Dependence

Empirical analyses of price linkages in all earlier works (Reboredo, 2011 and 2012; Qiu & Goodwin, 2013; Emmanouilides et al., 2014; Panagiotou & Stavrakoudis, 2015;

[6] $\tau = x - y$ and $x + y = 1$, where *x* is the proportion of concordant pairs and *y* is the proportion of discordant pairs. From these two relations, it follows that $x = \frac{1+\tau}{2}$.

Emmanouilides, and Fousekis, 2015) have been conducted in pairs. Since there are four markets in this work, one has to consider six market pairs for each commodity. All estimations have been carried out in R using the CDvine package (Brechmann and Schepsmeier, 2013).

Table 22 presents the estimated copula parameters for the six onion market pairs. All θ_1 parameters are statistically significant[7]. However, four out of six θ_2 parameters are not statistically significant. These are for the market pairs (Ars-Mbs), (Ars-Nrb), (Dsm-Nrb), and (Mbs-Nrb). One concludes, therefore, that for onion markets, dependence (co-movement) is predominantly asymmetric where extreme positive price shocks are transmitted while extreme negative price shocks are not. For these pairs, the BB7 copula is reduced to the Joe one (consistent with upper tail dependence only).

Table 22: BB7 copula parameter estimates for onion price shocks

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
θ_2	0.961 *(0.426)*	0.570 *(0.371)*	0.003 *(0.286)*	1.219 *(0.503)*	0.184 *(0.368)*	0.360 *(0.355)*
θ_1	1.700 *(0.375)*	1.503 *(0.325)*	1.516 *(0.255)*	2.278 *(0.467)*	1.573 *(0.285)*	1.610 *(0.319)*

Standard errors in parentheses

Table 23 presents the values of Kendall's *tau* (global/overall dependence) and of the tail dependence coefficients (local dependence) for the onion market pairs. The Kendall's *tau* values are highly statistically significant for all pairs; they range from a low of 0.225 for the pair (Ars-Nrb) to a high of 0.551 for the pair (Dsm-Mbs). These figures suggest that the probability of concordance lies between 0.613 and 0.776. Therefore, there is a certain degree of dependence between prices over their entire (bivariate) joint distributions. Based on the estimated Kendall's *tau,* these results show that the market pair (Dsm-Mbs) is the most integrated one while the market pair (Ars-Nrb) is the least integrated one.

[7] The significance is verified for the coefficients the values of which are at least two times their respective standard errors.

Table 23: BB7 copula global and local dependence measures for onion price shocks

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
τ	0. 454 *(0.095)*	0.357 *(0.121)*	0.225 *(0.071)*	0.551 *(0.066)*	0.291 *(0.071)*	0.339 *(0.068)*
λ_L	0.486 *(0.207)*	0.297 *(0.221)*	0.017 *(0.046)*	0.566 *(0.145)*	0.023 *(0.149)*	0.146 *(0.167)*
λ_U	0.497 *(0.137)*	0.414 *(0.226)*	0.421 *(0.113)*	0.644 *(0.117)*	0.446 *(0.090)*	0.462 *(0.126)*

Standard errors in parentheses

Whether the markets considered in this work belong to the same country or not, it does not appear to be related with the intensity of global dependence. The two markets with the higher Kendall's *tau* belong to different countries; the same holds for the two markets with the lowest Kendall's *tau*.

Although Dsm and Mbs markets belong to different countries, they both share one major geographical characteristic. That is, they are both situated on the coast of the Indian Ocean (low altitude areas) where temperatures are extreme and humidity is high. These markets are therefore, located in marginal agricultural zones and so are deficit in terms of onion supply. Major sources of supply for both Dsm and Mbs markets are production regions in the Northern Tanzania (Arusha, Kilimanjaro and Tanga). Both being deficit markets with similar climatic conditions and sharing common major sources of onion supply exposes these markets to similar onion price shocks, making the pair the most integrated of all pairs considered here. Ars and Nrb markets belong to different countries but are the closest to each other compared to the rest of the market pairs. Although one would expect these markets to be more integrated due to their close proximity, these results suggest otherwise. Moreover, another market pair (Ars-Dsm) which consists of markets located far away from each other shows a high degree of dependence (co-movement). One can therefore, conclude that proximity does not appear to play a significant role in the integration of onion markets. This is possibly due to the long storability of onions which makes it possible to be transported to both close and distant markets with less spoilage risk.

The upper tail dependence coefficients are all highly statistically significant. They range from 0.414 for the pair (Ars-Mbs) to 0.644 for the pair (Dsm-Mbs). Only two out of six lower tail dependence coefficients are statistically significant. These are for the pairs (Ars-Dsm) and (Dsm-Mbs). Notice that the difference between the values of the upper and the lower tail dependence coefficients for these market pairs are small. This suggests that dependence between (Ars-Dsm) and between (Dsm-Mbs) is likely to be symmetric. For all the remaining pairs co-movement at the extremes is asymmetric. As it has been the case for the overall dependence, the symmetry or the asymmetry does not appear to be related with whether the markets in a pair belong to the same country or not. For example, there is symmetric dependence for the pair (Ars-Dsm) whose markets belong to the same country and asymmetric dependence for the pair (Mbs-Nrb) whose markets also belong to the same country. Asymmetric price co-movement also exists between Nrb (deficit) and the coastal markets Dsm and Mbs (also deficit).

Interestingly, price shocks in Ars (a surplus market in Tanzania) exhibit asymmetric dependence with price shocks in Nrb and Mbs (both deficit markets in Kenya). This suggests that (a) onion producers in Tanzania do pass even extreme increases in their production costs to consumers in the Kenyan markets but they do not pass extreme price decreases and/or (b) producers in Tanzania benefit from extreme positive price shocks in the Kenyan markets and are not harmed by negative price shocks in them while Kenyan onion consumers are harmed by extreme positive price shocks in Tanzania and do not benefit from extreme negative price shocks in them as well. These may be attributed to the elastic supply nature for Tanzania originated onions as well as the longer storability of onions (once well cured). When demand

and prices in Kenya are very low, producers in Ars simply withdraw from the market part of the onion supply chain and place the commodity into storage waiting until there is a recovery.

Taking into account all the evidence available from: (a) the values of Kendall's *tau* (b) the values of the tail dependence coefficients, and (c) the pattern of dependence one may conclude that the four onion markets considered in this study are not very well integrated. The Kendall's *tau* receives low to moderate values and the same holds for the tail dependence coefficients. Moreover, price dependence at the extremes is predominantly asymmetric. There appear to be two possible exceptions to the general pattern. Namely, the pairs (Ars-Dsm) and (Dsm-Mbs) where one observes relatively high values of overall dependence as well as symmetric co-movement at both the upper and the lower extremes of their respective joint price distributions.

Table 24 presents the estimated copula parameters for the 6 tomato market pairs. All are statistically significant. Notice however that in four pairs (Ars-Dsm, Ars-Mbs, Dsm-Nrb, and Mbs-Nrb), the values of θ_1 are very close to one, suggesting that for these pairs, the BB7 copula is reduced to a Clayton one (consistent with zero upper tail dependence only).

Table 24: BB7 copula parameter estimates for tomato price shocks

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
θ_2	0.737 *(0.333)*	1.253 *(0.385)*	0.815 *(0.363)*	0.982 *(0.384)*	0.733 *(0.306)*	1.096 *(0.325)*
θ_1	1.088 *(0.410)*	1.001 *(0.384)*	1.316 *(0.308)*	1.591 *(0.335)*	1.001 *(0.307)*	1.001 *(0.321)*

Standard errors in parentheses

Table 25 presents the values of Kendall's *tau* (global/overall dependence) and of the tail dependence coefficients (local dependence) for the tomato market pairs. Kendall's *tau* values are statistically significant for all pairs; they range from a low of 0.269 for the pair (Dsm-Nrb) to a high of 0.441 for the pair (Dsm-Mbs). These figures suggest that the probability of concordance lies between 0.635 and 0.721. Therefore, there is a certain degree of dependence (co-movement) between prices over their entire (bivariate) joint distributions. On the basis of the estimated Kendall's *tau*, the market pair (Dsm-Mbs) is the most integrated one while the pair (Dsm-Nrb) is the least integrated one. As it was in the case of onion market pairs, whether the markets are considered to belong to the same country or not, it does not appear to be related with the intensity of global dependence; markets with the highest (Dsm and Mbs) and those with the lowest (Dsm and Nrb) Kendall's *tau* belong to different countries.

Table 25: BB7 copula global and local dependence measures for tomato price shocks

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
τ	0.293 *(0.048)*	0.385 *(0.061)*	0.364 *(0.067)*	0.441 *(0.083)*	0.269 *(0.077)*	0.354 *(0.059)*
λ_L	0.390 *(0.114)*	0.575 *(0.082)*	0.427 *(0.169)*	0.494 *(0.112)*	0.388 *(0.139)*	0.531 *(0.088)*
λ_U	0.109 *(0.188)*	0.001 *(0.151)*	0.307 *(0.151)*	0.454 *(0.178)*	0.001 *(0.120)*	0.001 *(0.058)*

Standard errors in parentheses

With poor storage technologies (conditions) and transportation infrastructure, it is difficult to transport fresh tomatoes (highly perishable) from production regions to distant consumer markets without spoilage. Long transportation distance, poor road infrastructure, low prices in surplus markets during peak seasons and low storability of tomatoes limit trade between surplus and distant deficit markets in East Africa. Most of the commodity is instead sold in the surplus markets at low price or sold at extremely low prices to few existing processors for processing. In some major production regions (surplus markets) such as Ars, farmers use the unmarketable (reject) tomatoes for seed extraction which is then sold to seed companies but this is only at a marginal scale.

Proximity of markets to production regions or proximity between markets (surplus/deficit) therefore, plays a significant role in determining the volume of trade and hence price dependence in East African tomato markets. The more distant the markets are from production regions and from each other, the less they trade in the commodity and the lower is their price dependence (co-movement). Evidence on that comes from the pairs (Nrb-Dsm) and (Ars-Dsm) which involve markets located far away from each other relative to the other market pairs. Also notice that Ars and Nrb markets are very close to each other and hence appear to be more integrated.

Overall and with the exception of the (Dsm-Mbs) market pair, the Kendall's *tau* values for all market pairs don't vary significantly. As in the case of onions, a possible reason for the higher Kendall's *tau* for the (Dsm-Mbs) market pair is that these markets are deficit due to their less favorable climate for tomato production. In Mbs, tomato supply mainly comes from Taita Taveta (Kenya) and Tanga and some parts of Arusha and Kilimanjaro (Tanzania) which are relatively closer to it. For the Dsm market, supply mainly comes from Tanga, Morogoro and other relatively closer parts of Kilimanjaro and Iringa. The Northern production regions in Tanzania therefore, partly supply both Mbs and Dsm markets. Here again, both being deficit markets with similar climatic conditions and partly sharing common sources of supply of the commodity, potentially explains why the overall degree of price co-movement in these markets is relatively high.

While lower tail dependence coefficients for all market pairs are highly statistically significant, only two out of six upper tail dependence coefficients are statistically significant. These are for (Ars-Nrb) and (Dsm-Mbs) market pairs. For the former pair, the difference between the value of the lower and the upper tail dependence coefficients is 12 percentage points while it is only 4 percentage points in the latter pair.

As it was in the case of onion markets, the pattern of price dependence is predominantly asymmetric. While the probability of positive price shocks being transmitted is higher than that of negative price shocks for onion markets, with tomato markets, the probability of extreme negative price shocks being transmitted is higher than that of extreme positive price shocks (i.e. the vice versa is observed for tomato markets).

The pattern of dependence (co-movement) in tomato markets implies that (a) tomato producers in surplus markets do pass even extreme decreases in their production costs to consumers in distant deficit markets but they do not pass extreme price increases to them and/or (b) producers are negatively affected by extreme negative price shocks in distant deficit markets and do not benefit from extreme positive price shocks in them while consumers in distant deficit markets benefit from extreme negative price shocks in surplus markets but they are not harmed by extreme positive price shocks in them. These may be explained by the inelastic supply nature of tomatoes and its low storability (high perishability) nature of the commodity. Depending on the variety, tomatoes (on average) can be stored for only up to ten days. Even when faced with extreme negative price shocks, farmers cannot withdraw from the market part of the tomato supply chain from because it will only result to loss due to spoilage.

Again, taking into account all the evidence available from: (a) the values of Kendal's *tau* (b) the values of the tail dependence coefficients, and (c) the pattern of dependence one may conclude that the four tomato markets considered in this study are not very well integrated. The Kendall's *tau* receives low to moderate values and the same holds for the tail dependence coefficients. Moreover, the mode of dependence at the extremes is predominantly asymmetric. Possible exceptions to the general pattern are the pairs (Ars-Nrb) and (Dsm-Mbs). In these pairs, one observes relatively high levels for overall dependence as well as co-movement at both the upper and the lower extremes of their respective joint price distributions.

To check the robustness of the empirical results, the BB1 (Gumbel-Clayton) copula has also been estimated for the onion and the tomato prices. The BB1 copula, which is as flexible as the BB7 copula, collapses to the Gumbel copula when the lower tail dependence coefficient is zero and to the Clayton copula when the upper tail dependence coefficient is zero. The results are presented in the Appendix (Part C) and they as qualitatively similar to those obtained from the BB7 copula.

5.3.2 Identification of Causal Markets

Although tail dependence coefficients provide the probability of transmission of extreme price shocks from one market to another, they do not provide any information about the origin of these shocks. Testing the origin (causality) of the shocks is important because even if there might be a statistically strong correlation between the two markets, this correlation does not necessarily mean causality. Information about the source of price shocks in the East African onion and tomato markets has been obtained using the Granger causality tests. The results of these tests are presented in the Appendix (Part B).

Overall, the Dsm market was found to be the main source of price shocks for both onion and tomato markets in Kenya. This is because for the (Dsm-Mbs) and (Dsm-Nrb) market pairs (for both onions and tomatoes), the test results show that price shocks in the former market (Dsm) Granger-cause price shocks in the later markets but not vice versa; this means that shocks for both onion and tomato prices originate from Dsm and are transmitted to both Mbs and Nrb markets respectively.

The Ars market also appears to be the source of onion price shocks in Mbs market as well as the source of tomato price shocks in Nrb market. This is the case because for the (Ars-Mbs) onion market pair and for the (Ars-Nrb) tomato market pair, test results show that price shocks in the former (Ars) Granger-cause price shocks in the later and not vice versa; meaning that for these two pairs, onion price shocks originate from Ars and are transmitted to Mbs market, while tomato price shocks also originate from the same market and are transmitted to Nrb market. There is no causal relationship between Ars and Nrb onion markets and between Ars and Mbs tomato markets.

For comparisons between markets located within the same country, the source of both onion and tomato price shocks appears to be Dsm market for Tanzania and Mbs market for Kenya. This is the case because for the market pairs (Dsm-Ars) and (Mbs-Nrb), causality test results show that price shocks in the former market Granger-cause price shocks in the latter market (for both commodities) and not vice versa; meaning that within Tanzania, price shocks for both commodities originate from Dsm market and in Kenya, price shocks originate from Mbs market.

Overall, these results show strong evidence that regional price shocks for both commodities originate from Tanzania markets (especially the Dsm market). In contrast, there is no evidence of Kenya markets causing price shocks to Tanzania markets in either of the two commodities. In this case, it is important to note that Tanzania is a more surplus market for both commodities while Kenya is a deficit one. Hence regional-wise, these shocks appear to move from surplus markets to deficit markets.

However, an interesting observation is that for markets located within the same country, price shocks in surplus markets (Ars and Nrb which are in or near production regions) appear to be influenced by price shocks in the deficit markets (Dsm and Mbs which are deficit markets in the coast of both countries) but not vice versa.

CHAPTER 6: CONCLUSIONS

6.1 Summary

In recent years, price transmission between spatial agricultural markets and along food supply chains has received significant attention from economists and policy makers. Price transmission across space has proved to be useful in predicting the impacts of price changes in food surplus regions on food deficit regions. Likewise, the nature, speed and magnitude of transmission of price shocks along food supply chains have become an important indication of the actions of and welfare distribution among market participants.

As a result of this growing interest, several studies examining price transmission in agricultural markets using different techniques have been conducted. This study has provided a review of some of these empirical works. It is clear from the review that price transmission analysis techniques have evolved over time. Econometric approaches are known to be the oldest and the most common tools used in price transmission analysis. However, new approaches such as the use of copulas have emerged in recent years. These two approaches view price transmission from different perspectives. Although this work has reviewed some of the past empirical works that applied econometric approaches, more emphasis has been given to those that applied copulas.

The overwhelming majority of past empirical research on price transmission (integration) in African food markets has focused on staple food markets (e.g. grain markets) and the impacts of market reform policies (e.g. Goletti and Babu, 1994; Chirwa, 1999; Loy and Wichern, 2000; Rashid and Minot, 2010; Zakari, 2014). Most of the evidence suggests that African agricultural markets are generally integrated although the degree of integration has been found to differ between countries and between commodities (Abdulai, 2007). Grain markets especially, have been found to function reasonably efficiently (Rashid and Minot, 2010).

This study, however, aimed at investigating the integration of horticultural markets in East Africa. Contrary to past studies that have mainly focused on grain markets, the researcher's interest was in the functioning of horticultural markets which have received less attention in the past. This research also utilized a different approach. While the use of econometric tools has been the most common approach, the interest here has been on the use of a copulas tool (Joe-Clayton or the BB7). Apart from shedding light on the functioning of these markets and evaluating the open market policies adopted by the EAC, the study contributes to the growing efforts to address constraints in linking producers with the existing and emerging high-value agricultural chains and markets. Another important consideration made was availability of data.

Empirical results of this study provide two important findings about spatial price behavior of horticultural commodities in the investigated markets. First, results show that the East African horticultural markets are generally not very well integrated. For both fresh onions and fresh tomatoes used as study sample, the overall dependence of price shocks varies between pairs made of markets located in the same country, markets located in different countries, and combinations made between deficit and surplus markets. Hence, whether the markets considered belong to the same country or not, it does not appear to be related to the degree of global dependence. However, the interesting finding is the role that storability of the commodity and proximity of markets have on the degree of market integration. For fresh onions, proximity of markets does not appear to play a significant role in the integration of markets. This is potentially attributed to the longer storability of the commodity when postharvest handling is well executed. For traders, longer storability presents low risks. This encourages traders to trade with both closer and remote markets. Hence the differences in the levels of integration are not likely due to proximity differences but potentially transportation cost differences. It also does not appear to significantly depend on the difference in commodity supply between markets considered in a pair (deficit vs surplus markets). However, for fresh tomatoes which are highly perishable, proximity of markets appears to be a significant determinant of market integration. In this case, the closer the markets are to each other, the more integrated they become and vice versa. This implies that trade between surplus and distant deficit markets is limited by the high risk associated with the high perishability of this commodity. This also signifies that there have been little or no improvements in sophisticated storage and transportation infrastructure in the region due to the observed low integration between distant markets. As it was in the case of fresh onions, in this case also, the level of market integration does not appear to depend on whether the markets considered belong to the same country or not. An interesting finding is however, that for both commodities, deficit markets sharing a common source of supply are likely to be more integrated.

Second, these results show that the pattern of dependence of price shocks in the region for both commodities is predominantly asymmetric. This implies that for the two commodities studied, it is less likely that prices will boom and crash together. Perishability of the commodity which influences the actions of market participants is potentially the reason for the observed asymmetry in transmission of the price shocks. For fresh onions which have a relatively longer shelf-life, producers in surplus markets tend to pass even extremely high increases in production costs to consumers in some deficit markets. This is because for such commodities, supply appears to be elastic. At low prices producers withdraw from the supply chain until prices are reversed by low supply and are up again. Therefore, producers benefit from strong demand and hence high prices in deficit markets. The vice versa however happens for highly perishable fresh tomatoes. Due to the high spoilage risk coupled by poor storage and transportation infrastructure, producers rely on nearer markets which are in most cases saturated with the same commodity in peak seasons. To stimulate demand, producers pass decreases in production costs nearer markets rather than increases. Low prices benefit consumers but they harm producers. Hence, the asymmetry observed in both commodities implies unequal distribution of welfare benefits among supply chain participants. This distribution depends on the nature of the commodity.

The role of the Dsm market as the major source of price shocks in other markets in the region is observed in this work. A potential reason that explains this observation is high demand of food commodities in this market. Dsm is among the fastest growing cities in Africa (AfDB, 2014). Being a deficit market with a fast growing population, demand for food commodities is high in the market. Having a port, the market is also a major gateway for most food commodities destined for water-locked markets. Hence, it is likely that price shocks in water-locked markets have significant influence on other regional markets due to its size and importance. Generally, deficit markets appear to be the main source of price shocks in surplus markets. These markets provide an interesting area for policy interventions to ensure market integration.

6.2 Implications for Policy

As it has been indicated in past research, trade policy may facilitate or hinder trade depending on the regulatory and economic instruments that are put in place (Rashid and Minot, 2010). For instance, policies designed for less perishable commodities are bound to be different from those designed highly perishable commodities. While less perishable commodities might be significantly favored by improvements in physical transportation infrastructure alone, highly perishable commodities might need improvements in both physical transportation infrastructure as well as storage and packaging infrastructure (e.g. refrigerated storage). Hence, the results of this study have identified a number of key policy issues that need to be addressed by the EAC policy makers.

It is evident that to achieve an efficient integration of the EAC horticultural markets, improving transportation infrastructure which will in turn reduce transaction (transportation) costs and trade risks associated with perishability of the commodities is very important. The observed differences in the levels of integration and the performance of the studied horticultural markets might be attributed to differences in infrastructure development and hence transportation costs and trade risks. Therefore, addressing this issue becomes paramount. The EAC appears to have recognized this and have embarked on railway and road infrastructure improvement (EAC, 2009). Particular attention however, needs to be paid to the development of storage, packaging and transportation infrastructure that will eventually facilitate trade in fresh and highly perishable commodities between distant and close situated markets.

On the other hand, improving storage, packaging and transportation infrastructure alone is not enough where administrative and policy barriers are still existent but they become important when other barriers are reduced and eliminated eventually. The EAC, needs to reduce barriers to entry into the transportation sector by reducing administrative and regulatory barriers such as protection of local packaging material manufacturers and trucking companies. Attracting foreign businesses will promote competition in the handling and logistics sectors by attracting new investments in sophisticated transportation and storage infrastructure for highly perishable commodities.

Information is important for market participants to make correct marketing decisions. With the increasing use of mobile phones in the region, information such as those related to demand, supply and prices in different markets is important to harmonize the actions of marketing agents as well as providing data for future research and for commercial purposes. Mobile phones which have proved to be efficient and are now a common means of money transfer (e.g. the so called M-Pesa, Tigo Pesa and Airtel Money)[8] can also be used to collect and disseminate market information and improve market efficiency. Policies need to be put in place in order to improve availability and access to information. This will reduce asymmetries in market information which might potentially lead to incorrect pricing and unequal welfare distribution among market participants. It can be achieved for instance by subsidizing the collection, storage and provision of market information.

Other policy areas than need to be addressed include streamlining administrative border procedures so that perishable commodities can be transported faster to distant markets with less risk of spoilage due to delay. This will in turn stimulate cross-border trade in horticultural commodities and ensure availability of such commodities in deficit countries such as Kenya. Also governments need to reduce (or remove) within country (district-level) taxes and agricultural commodity check points which are currently very common in the region. They raise the cost of food in remote deficit markets as well as delaying transportation of perishable commodities. The EAC also should seek regional efforts that will facilitate access to high value export markets such as those in the EU. Kenya is already leading the way in this area.

6.3 Limitations and Future Research

A number of information gaps need to be addressed in future research. The present work focused on only two horticultural commodities in the vegetables category. Nonetheless, there exist other major horticultural crops in the fruits (e.g. bananas) and spices (e.g. chilies and peppers) categories that are produced and traded in the region. In addition, the length of the time series used for the empirical analysis was marginally adequate to obtain highly reliable results. The choice of the commodities and the span of the series were certainly

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[8] Money services that allow users to deposit, transfer and withdraw money or pay for goods or services using a pin-secured account created in their mobile devices. Registered airtime resellers and retail outlets act as agents for cash transfers.

constrained by data availability, which is a major problem for the agricultural sector in East Africa and the continent at large.

There are three possible avenues for future research. One is to extend the analysis to other important horticultural commodities and markets. Two is to employ alternative quantitative tools such as other copulas. Very recently, Racine (2015) proposed a method to estimate copula models with nonparametric kernel-based approach. Nonparametric modelling dispenses with the requirements to specific functional forms and is less prone to misspecification. Moreover, it is probably worth to estimate price dependence using nonparametric methods and/or to compare results from parametric and nonparametric methods.

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Appendices

Part A: ADF Tests for Non-Stationarity

ADF test is a unit root test used to identify stationarity in time series data. Given a time series x_t, the ADF test tests the null hypothesis that the given time series has a unit root against the alternative hypothesis that it does not have. The ADF test is based on estimating the test regression;

$$\Delta x_t = \beta x_{t-1} + \sum_{i=1}^{k} \Delta x_{t-i} + e_t$$

where β is the parameter to be estimated, k is the number of lagged difference terms and e_t is a pure white noise error term. A constant term or a linear trend is added to the model whenever necessary. In ADF test, we test whether $\beta = 0$ (null hypothesis). The alternetive hypothesis is that $\beta < 0$. The number of lagged difference terms to include is determined empirically, so that the error e_t is serially uncorrelated. Specification of the number of lags is an important step for effective implementation of an ADF test. In this work, the value of k was determined using the Akaike's Information Criteria (AIC). AIC is obtained as, $AIC = 2\varphi - 2\ln(L)$ where φ is the number of estimated parameters and L is the maximum likelihood value. The model with the lowest AIC value is preferred over the competing models.

Part B: Bivariate Granger Causality Tests

Granger (1969) defines causality as the situation where x_1 can improve the explanation of $x_2$by adding lagged values of x_1 in addition to lagged values of x_2. Given two time series x_{1t} and x_{2t}, the following Vector Autoregressive (VAR) models can be applied to capture causal interdependence of the variables;

$$x_{1t} = \alpha_0 + \alpha_1 x_{1,t-1} + \cdots + \alpha_p x_{1,t-p} + \beta_1 x_{2,t-1} + \beta_p x_{2,t-p} + u_t$$

$$x_{2t} = c_0 + c_1 x_{1,t-1} + \cdots + c_p x_{1,t-p} + d_1 x_{2,t-1} + d_p x_{2,t-p} + v_t$$

If the null hypothesis $\beta_1 = \beta_2 = \cdots = \beta_p = 0$ is rejected, we say that x_2 Granger-causes x_1. Likewise, if the null hypothesis $c_1 = c_2 = \cdots = c_p = 0$ is rejected, we say that x_1 Granger-causes x_2. In a Granger causality test, a series of *F*-tests on lagged values one of the variables (e.g. x_1) is used to determine if those values provide statistically significant information about future values of the other variable (e.g. x_2).

Table B1.1: Granger causality tests for onion markets

Causal pair of Regions (A-B)	*F*-statistic	*p*-value
(Ars-Dsm)	0.171	0.681
(Ars-Mbs)	5.286	0.024
(Ars-Nrb)	0.436	0.511
(Dsm-Mbs)	5.563	0.021
(Dsm-Nrb)	16.98	0.0001
(Mbs-Nrb)	5.819	0.018

Null Hypothesis: price shocks from region A do not Granger-cause price shocks in region B

Table B1.2: Granger causality tests for onion markets

Causal pair of Regions (B-A)	*F*-statistic	*p*-value
(Dsm-Ars)	4.034	0.048
(Mbs-Ars)	0.035	0.852
(Nrb-Ars)	1.142	0.289
(Mbs-Dsm)	0.004	0.952
(Nrb-Dsm)	0.0003	0.987
(Nrb-Mbs)	0.037	0.848

Null Hypothesis: price shocks from region B do not Granger-cause price shocks in region A

Table B2.1: Granger causality tests for tomato markets

Causal pair of Regions (A-B)	*F*-statistic	*p*-value
(Ars-Dsm)	0.037	0.848
(Ars-Mbs)	0.973	0.353
(Ars-Nrb)	4.115	0.046
(Dsm-Mbs)	5.216	0.025
(Dsm-Nrb)	5.164	0.026
(Mbs-Nrb)	9.978	0.002

Null Hypothesis: price shocks from region A do not Granger-cause price shocks in region B

Table B2.2: Granger causality tests for tomato markets

Causal pair of Regions (B-A)	*F*-statistic	*p*-value
(Dsm-Ars)	10.687	0.002
(Mbs-Ars)	1.043	0.310
(Nrb-Ars)	0.166	0.685
(Mbs-Dsm)	1.134	0.290
(Nrb-Dsm)	0.584	0.447
(Nrb-Mbs)	0.090	0.765

Null Hypothesis: price shocks from region B do not Granger-cause price shocks in region A

Part C: BB1 Copula Estimation Results for Onion and Tomato Markets

Table C1.1: BB1 Copula parameter estimates for onion marker pairs

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
q_2	1.497 *(0.298)*	1.372 *(0.265)*	1.308 *(0.155)*	1.956 *(0.382)*	1.426 *(0.173)*	1.506 *(0.292)*
q_1	0.483 *(0.422)*	0.282 *(0.390)*	0.001 *(0.001)*	0.404 *(0.381)*	0.001 *(0.001)*	0.033 *(0.383)*

Standard errors in parentheses

Table C1.2: BB1 copula global and local dependence measures for onion market pairs

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
τ	0. 462 *(0.095)*	0.361 *(0.122)*	0.236 *(0.077)*	0.575 *(0.064)*	0.299 *(0.073)*	0.347 *(0.069)*
λ_L	0.383 *(0.228)*	0.167 *(0.217)*	0.714 *(0.029)*	0.416 *(0.230)*	0.898 *(0.122)*	0.924 *(0.144)*
λ_U	0.411 *(0.130)*	0.343 *(0.197)*	0.301 *(0.098)*	0.575 *(0.108)*	0.374 *(0.089)*	0.416 *(0.101)*

Standard errors in parentheses

Table C2.1: BB1 Copula parameter estimates for tomato marker pairs

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
θ_2	1.147 *(0.260)*	1.001 *(0.251)*	1.234 *(0.236)*	1.337 *(0.249)*	1.001 *(0.208)*	1.001 *(0.230)*
θ_1	0.543 *(0.445)*	1.251 *(0.636)*	0.570 *(0.427)*	0.626 *(0.406)*	0.732 *(0.460)*	1.094 *(0.553)*

Standard errors in parentheses

Table C2.2: BB1 copula global and local dependence measures for tomato market pairs

	Market Pair					
	Ars-Dsm	Ars-Mbs	Ars-Nrb	Dsm-Mbs	Dsm-Nrb	Mbs-Nrb
τ	0.354 *(0.051)*	0.385 *(0.062)*	0.370 *(0.068)*	0.430 *(0.087)*	0.269 *(0.076)*	0.354 *(0.059)*
λ_L	0.329 *(0.148)*	0.575 *(0.087)*	0.373 *(0.200)*	0.437 *(0.156)*	0.388 *(0.141)*	0.531 *(0.088)*
λ_U	0.170 *(0.153)*	0.001 *(0.112)*	0.247 *(0.128)*	0.321 *(0.174)*	0.001 *(0.077)*	0.001 *(0.033)*

Standard errors in parentheses