Evaluation of the prospects of hedging Botswana's maize prices against the Johannesburg Stock Exchange Commodity Market Derivatives

by

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ABSTRACT

Maize is an important source of food consumed in Botswana and it helps the country to achieve food security status. Food security refers to everyone always having access to healthy, dependable, and adequate food to meet their dietary requirements and live a healthy life. Botswana imports maize primarily from South Africa and is a net importer. The study evaluated how maize prices in Botswana are linked with maize prices in South Africa. To explain hedging opportunities in minimising price risk in Botswana, cointegration and vector error correction models were used in this study. Secondary data on monthly white and yellow maize prices from 2008 to 2019 were used in this study. The empirical data show that maize prices in South Africa and Botswana have a long-run equilibrium relationship. In the short run, results indicate that the previous years' maize prices in the Botswana market positively impact all Botswana maize prices at a 1% significance level on average *ceteris paribus*. South Africa's maize market does not respond to any market changes in Botswana for white maize prices lagged for one and two periods. The Botswana maize market, on the other hand, reacts to price fluctuations in the South African market for both white and yellow maize.

The adjustment speed in the Botswana maize market ranged from 17% to 29% while the adjustment speed in the South African market ranged from 13% to 17%. Overall, the empirical data show that the two markets have a positive long-run equilibrium relationship and a short-run asymmetric relationship. The empirical findings prompted the Botswana maize value chain assessment to understand how it operates as well as the existence of relationships among the actors. The study ascertained that Botswana's maize value chain faces an array of challenges that limit the country's food sufficient.

The assessment of the Botswana maize value chain was vital to promote policy formations that will promote the development of the Botswana maize sector. The study focused on the interaction between smallholder farmers and the intermediaries focusing on the challenges and opportunities therein. The Agency and Social Network theories were used to assess the economic behaviour of the two farmers and middlemen. The investigative methods used included a thorough assessment of the literature and key informant interview. The challenges identified from the investigation included poor coordination, lack of trust, information asymmetry, lack of cooperatives, and inadequate access to finance. The study thus recommended contract farming, prioritisation of training programmes for farmers and extension workers, third-party enforcement of regulations, and revival of cooperatives to

improve the quality of the relationship between the middlemen and the smallholder farmers, and thus improve the overall performance of the chain.

DECLARATION

I, Goetswamang Phankie Ofentse, declare that the dissertation is my work and I am submitting it for the University of Pretoria’s Master of Science in Agricultural Economics degree. I have never submitted this work for a degree at this or any other educational institution.

Signature: Date: 21-07-2022

DEDICATION

I dedicate this work to my lovely daughter Sethunya Skylar Ofentse.

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Profound gratitude to God for guiding my steps and lifting me during the dark times and giving me the strength to complete this degree. I am thankful for his presence, love, and grace in my life. I am thankful for the strength He gave me throughout the compilation of this document. May He continue to be the source of my strength, enlighten my path, and enlarge my territory.

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LIST OF ACRONYMS

AERC	African Economic Research Consortium
BAMB	Botswana Agricultural Marketing Board
BIDPA	Botswana Institute for Development Policy Analysis
BOBS	Botswana Bureau of Standards
BURS	Botswana Unified Revenue Service
CEO	Chief Executive Officer
CMAAE	Collaborative Master of Science in Agricultural and Applied Economics
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
ICG	International Grains Council
ISO	International Organization for Standardization
ISPAAD	Integrated Support Program for Arable Agriculture Development
JSE CDM	Commodities Derivates Market Johannesburg Stock Exchange
JSE	Johannesburg Stock Exchange
SA	South Africa
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAFEX	South African Futures Exchange
SGR	Strategic Grain Reserve
US$	United States Dollar
VAT	Value-Added Tax

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is one of Botswana's most crucial economic sectors; it accounts for approximately 2 per cent of the country's gross domestic product (GDP) (Statistics Botswana, 2018). The agriculture sector employed about 23 per cent of Botswana's total workforce in 2018 (World Bank, 2019).

In Botswana and the rest of the Southern African region, maize is a highly crucial cereal crop, and it is the primary source of food. White maize is consumed by humans, while yellow maize is mainly used to manufacture animal feeds. Due to the weather and other natural constraints, such as unreliable rainfall and hot temperatures, Botswana's agricultural industry is faced with various challenges. The challenges include poor management of agricultural land, poor infrastructure, and overdependence on rain-fed agriculture. Moreover, poor linkages within the value chain, weak agro-industries, and poor agribusiness skills result in the country's lack of self-sufficiency in food production. As a result, most of the country's maize imports are imported from South Africa (Gases, 2012; Dana et al., 2006). These factors have hindered the development of the supply chain required to propel Botswana's maize sub-sector forward.

The government of Botswana has been promoting an increase in maize production over the years through the Integrated Support Program for Arable Agriculture Development (ISPAAD). Furthermore, the Botswana Agricultural Marketing Board (BAMB) has been designated as a vital stakeholder in ensuring the country's food security by the Botswana government. The Board manages and maintains the Strategic Grain Reserve (SGR). It holds 70 000 metric tonnes (Mt) of the grain reserve consisting of 30 000 Mt sorghum, 30 000 Mt maize, and 10 000 Mt pulses. However, the SGR in 2018/2019 recorded a total of 32 000 Mt (BAMB, 2019).

Despite Botswana's government efforts, maize production is still insufficient to meet local demand (Marumo et al., 2014). As a result, Botswana is dependent on South Africa for both whole grain maize and maize flour imports. From early as 1969, Botswana has entered into trade agreements with the Southern African Customs Union (SACU) member states. The agreement aids Botswana to purchase maize from maize net exporters within the region by applying the same tariffs and trade regulations on imported goods (Mutambatsere, 2008).

Even though the government provides subsidies to maize farmers, maize production in Botswana is significantly volatile. Botswana has a small commercial maize sector, a large smallholder maize sector, large human consumption of maize, a large animal feed sector, and no maize industrial users. In the South African Development Community (SADC), South Africa has the most developed commercial farming sector with about 98 per cent of maize production (Grant et al., 2012). Botswana produces 10% of its demand for maize (BAMB, 2021). Although maize is sometimes imported into Botswana from Zambia, South Africa dominates the maize export market to Botswana. South Africa exported about one-third of its total export of maize in the 2015/16 marketing season (see. Fig 1.1). Botswana's maize prices are therefore heavily dependent on events in South Africa.

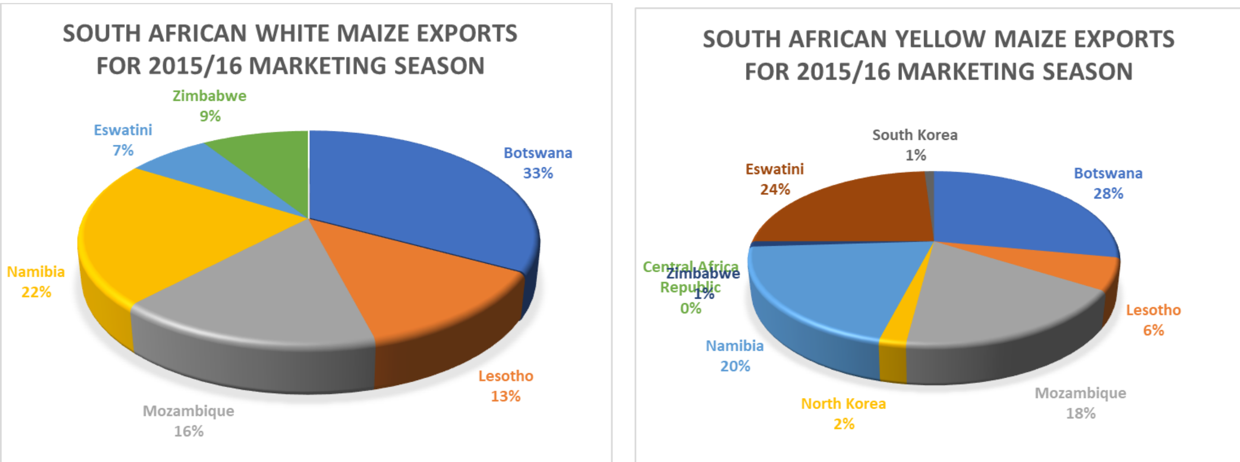

Figure 1.1: The size of Botswana maize import from South Africa for the 2015/16 marketing season

Source: Grain SA (2018)

Figure 1.1 shows that Botswana is the main destination for South Africa's maize exports during the 2015/16 marketing season. Based on this figure, Botswana is the leading importer of both white and yellow maize from South Africa according to Grain South Africa (GrainSA, 2018).

Statistics Botswana (2018) states that maize imports are a result of the agricultural sector's decreased contribution toward the gross domestic product (GDP). The sector contributed a mere 2 per cent to GDP in 2018 (Statistics Botswana, 2018). The GDP decreased from 2.4 per cent and was registered the previous year in 2017. The decrease in the agricultural sector's production performance caused the country to import more maize and other commodities from South Africa as the maize industry is critical in Botswana to maintain food security.

Figure 1.2 below shows the percentage of each cereal crop contributed to the total grain reserve in the year 2018/2019. The Board did not have any maize reserve in the year 2018/2019, as shown in Figure 1.2, and the figure confirms that Botswana's maize industry is struggling to meet the nation's desire to be maize secure. Sorghum cereal crop is performing well, unlike maize in Botswana as the crop met the quantity of 30 000 Mt required by SGR.

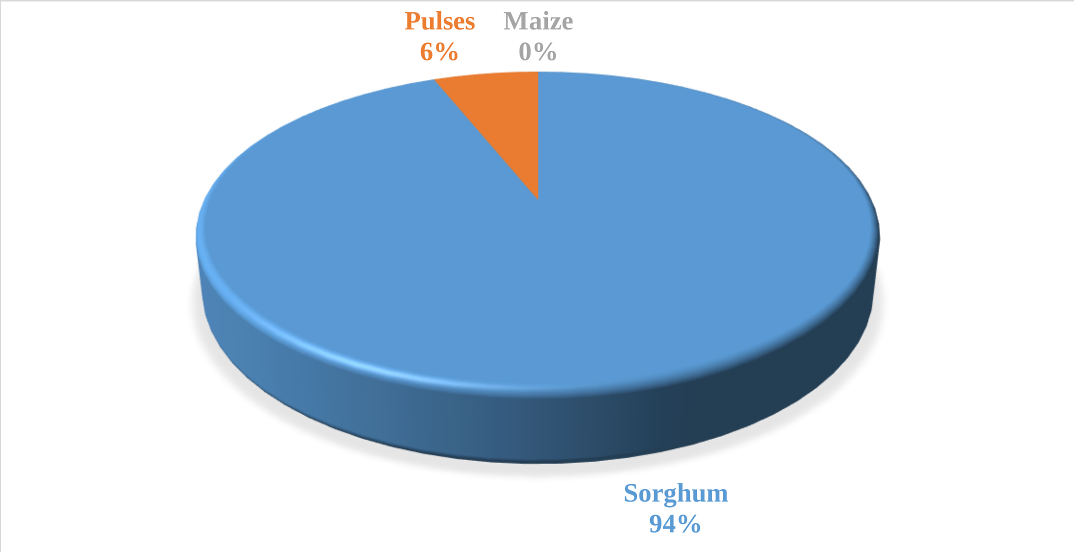

Figure 1.2: National grain reserve in 2018/19 for Botswana

Source: BAMB (2019)

South Africa is the main maize exporter within the SACU region and has the upper hand in controlling maize prices despite BAMB's involvement in the maize industry. BAMB was established with a mandate to promote crops grown locally, provide a stable grain market, and be a price setter. The board is a major player in the effort to ensure sustainable arable farming in Botswana through marketing the access, selling, and storing of farm produce. BAMB purchases maize from farmers between June and September across Botswana with monthly fixed prices that fluctuate over the year.

Food price unpredictability in the poorest continent like Africa has become more erratic than in the past (Gerard et al., 2011; G20, 2011). Minot (2011) states that deprived families dedicate a larger portion of their revenue to foodstuffs and fluctuations in food prices influence their purchasing power. Therefore, food price volatility has a direct impact on them as they rely on agriculture. The price of agricultural goods dramatically increased in Botswana between 2005 and 2008 and between 2010 and 2012 as a result of international energy and food commodities prices (Tlhalefang & Galebotswe, 2013).

According to Reliefweb.int (2019), a drop of 92 per cent in cereal production was estimated (production moved from 66 093 tonnes in 2017/18 to 5 356 in the 2018/2019 season). Consequently, about 38 300 people are either permanently or temporarily food insecure in Botswana. The percentage of people who are food insecure increased to 9.3 per cent from the previous year. The minor increase resulted from the blow of drought conditions on agricultural livelihoods that impacted households' food supplies and income levels. These conditions on domestic and regional supplies have burdened domestic food prices. As a result, a slight increment in the annual food inflation rate was recorded at 2 per cent year on year in August 2019, unlike a stagnant rate in August 2018 (Reliefweb.int, 2019). The rise in bread and cereal prices contributed to this rise because they hold the largest weight in the food inflation index.

In developing countries, the price instability of traditional dishes is a major source of concern stated (Minot, 2011). The impact of the global recession in 2008 brought the food price surge which revealed that most nations experienced an increase in poverty levels when there was a rise in domestic food prices (Dessus et al., 2008). Maize farmers experience significant price risk due to seasonal production which relies on yearly precipitation and leads to huge alterations in maize availability, price inelastic nature of maize demand, and maize prices (Wiseman, 1999; Cohen, 1999). The South African Futures Exchange (SAFEX) was established to aid in dealing with price fluctuations to acquire price stability (Scheepers, 2005). The author states that hedging a commodity at the right time and price could improve international competitiveness and sustainability.

Hedging is a management tool that helps producers to manage price fluctuations. According to Botha (2005), it is a procedure in which short or long positions are established to mitigate the risks associated with price fluctuations. The long position deals with the purchase of a commodity (asset) whilst the short position involves the sale of an asset. The actors in this transaction are producers and/or processors of the commodities who are called hedgers with the main focus of being participants and reducing price risk (Botha, 2005). When more buyers and sellers participate in dealing on SAFEX, Scheepers (2005) states that the accuracy of the price will be reflected in the spot market price.

The futures market provides a projection of a commodity's spot price, allowing hedgers to minimise exposure by setting the price ahead of time for transactions involving physical commodities Therefore, futures markets on SAFEX can be a useful mechanism for hedgers in Botswana as a market intervention to price stabilisation technique since currently, BAMB has the power to set maize prices. The futures contract reduces transaction costs due to its highly standardised nature, with the information being publicly displayed and having a lot of participants in the market (Wisemen, 1999). According to Elliot (1986), futures trading benefits hedgers with the shifting risks through hedging, improved coordination, and planning, ensuring contract obligations and a decrease in procurement costs.

1.2 Problem statement

During the 2002 to 2008 period, the International Grains Council (IGC) recorded a dramatic increase in cereal prices (Mensi et al., 2014). The dramatic increase in foodstuff prices has been a problem in developing countries. Energy prices in the United States and European Union have caused international wheat and maize prices to increase. Mitchel (2008) suggested that without the global increase in energy prices, global wheat and maize price increases would have been moderate and oilseed prices would not have tripled. Martin (2008) reported an increase in world maize prices by 80 per cent between 2005 and 2007.

According to Ackello-Ogutu (2011), it is uncertain how farmers will react to price increases despite positive supply response prediction by economic theory. The author states that farmers in Africa are behind because of agricultural and institutional capacity weaknesses. In addition, the exchange rate between the United States Dollar (US$) and the local currency has a major effect on commodity prices and food market exposure. Ackello-Ogutu (2011) alluded that escalating food prices present a chance for African farmers to boost their agricultural revenues if they are net buyers or sellers.

The decrease in global production of fossil fuels has caused countries to shift to using biofuels as a source of renewable energy. The shift is a result of climate change and the rise in oil prices. Feedstock such as corn, wheat, sunflower, and soybean, among others, are used for biofuels production. Conversely, biofuels production has significantly increased food prices over the years (Ajanovic, 2011). Currently, there is a debate and/or discussion on the extent to which biofuels affect feedstock prices on the international level (Elbehri et al., 2013).

Consequently, international cereal prices have been transferred into domestic markets affecting the welfare of consumers and farmers (Keats et al., 2010). Botswana's consumer price index increased by 0.3% in February from 104.9 (Statistics Botswana, 2021). The increase raised concern for Botswana as the nation relies more on food commodities and energy imports (Tlhalefang & Galebotswe, 2013). The authors stated that higher prices are negative blows to the country's trade which results in higher import bills. Dana et al. (2006) reported that futures contracts or financial call options may be used to hedge imports. Hedging is a risk management tool against price movements.

Botswana is a net importer of maize and the country is facing a food insufficiency challenge. Conversely, poverty results in the high cost of food importation and low quantities of domestic maize production. Food accounts for a substantial portion of poor households, therefore, large price changes have a significant impact on their income. During the periods of price increase, productive assets such as livestock can be sold at cheap prices potentially leading households into poverty traps as farmers derive their income from producing food, as a result being vulnerable to drops in agricultural output (WFP et al., 2011). In addition, SACU agricultural tariffs duties increase the cost of food in many homes in Botswana. As a result of Botswana's involvement in the customs union, cereal import prices have risen (Cathie & Herrmann, 1988).

Farmers and users are therefore exposed to these price risks fluctuations. However, if farmers and millers could use SAFEX, formerly known as the Johannesburg Stock Exchange Commodities Derivatives Market (JSE CDM), as a price risk management tool, they could benefit by generating lower average costs (Dana et al., 2006). SAFEX will provide its users with constant maize (white and yellow maize) prices over the period without any disruptions of the price increase.

The benefits will be the limitation of price movements, transparency, and management of production risks. For hedging to happen, Botswana's local prices need to correlate with SAFEX prices. Thus, there must be a mutual relationship between Botswana's yellow and white maize prices and SAFEX ones. Hedging against price risk on SAFEX can be a management tool for Botswana farmers as price variability is crucial for for-profit variability. Dana et al.'s (2006) study on hedging grain price risk focused on Malawi and Zambia representing the SADC region. Unfortunately, no study has been conducted on hedging between Botswana and the Johannesburg Stock Exchange (JSE). The lack of evidence on hedging between Botswana and the JSE is because researchers have not paid attention or have lack of knowledge or understanding to this issue. In addition, no studies have been done to assess the maize value chain in Botswana and there is a scarcity of scholarly articles on the Botswana maize value chain. It is, therefore, crucial to evaluate the connection that exists between Botswana and

South Africa's maize prices and to assess the correlation between yellow and white maize prices in these countries.

Most of the studies on maize value chains are in sub-national regions such as Southern Africa and Eastern Africa. Therefore, there is limited evidence of detailed analysis of the Botswana maize value chain. Consequently, there is a lack of statistical data on the chain. Lastly, poor linkages within the maize value chains are a major challenge in achieving positive outcomes in the maize industry. Lack of coordination between actors within the chain leads to food insufficiency (Odongo et al., 2016). In addition, there are unreliable supply systems that affect the functionality of the maize value chain and the flow of information within the chain is minimal, leading to an imbalance of information which makes other actors act opportunistically. Moreover, mistrust issues arise within the chain as parties do not fully disclose quality information, market opportunities, and pricing strategies (Odongo et al., 2016). Hedging through futures or options, according to Dana et al. (2006), can stretch out import expenses over time and cut average costs.

1.3 Research questions

This study seeks to address the overall question "How can the Botswana maize value chain be improved?" To answer this question, the following supporting questions need to be answered:

(1) What have the market price trends for maize in Botswana been?
(2) How are prices transmitted both in the long and/or short run across the maize markets between Botswana and South Africa?
(3) How do maize prices respond to shocks?
(4) What are the challenges and opportunities that exist within the chain between farmers and intermediaries?

1.4 Research objectives

The overall objective of this study is to identify and evaluate the correlation, if any, between Botswanan maize prices and maize prices quoted on SAFEX. The econometric analysis will be carried out to assess the correlation. The study seeks to address the following objectives:

(1) To describe the price trends of the Botswana maize market.

(2) To analyse short-run and/or long-run transmission of maize prices across the Botswana and South African markets.
(3) To determine how Botswana maize prices adjust to shocks.
(4) To determine the challenges and opportunities that exist within the chain between farmers and intermediaries.

1.5 Research hypotheses

Since 2006, food prices have been rising over the world (Donmez & Magrini, 2013). The upsurge in global food prices has had implications on Botswana's economy. These implications include a rise in income poverty, a rise in government expenditure, and an increase in import bills as the country is a net food importer (BIDPA, 2008). Price transmission aids producers and consumers in finding adjustments to stabilise the world price changes (Keats et al., 2010). Furthermore, the futures contracts help producers to minimise risks associated with price changes and function as a mechanism that shifts price risk onto others (Carter, 1985). Users can lessen the volatility of import costs by using futures and options to hedge (Sarris et al., 2011). This study aims to test the following hypotheses:

1. Botswana's white maize prices are positively and significantly affected by South African white maize prices in the short run.
2. Botswana's yellow maize prices are positively and significantly affected by South African yellow maize prices in the short run.
3. Botswana's white maize prices are positively and significantly affected by South African white maize prices in the long run.
4. Botswana's yellow maize prices are positively and significantly affected by South African yellow maize prices in the long run.

1. 6 Academic value and contribution

Policymakers will benefit from the findings of this study as they design and improve trading policies that will benefit Botswana's maize industry and fill the knowledge gap in understanding how the chain works. Like most countries, Botswana maize producers and processors are exposed to price risk. If there is a significant correlation between local Botswanan maize prices and maize prices as quoted on SAFEX it will enable the local industry to manage price risk through SAFEX, hence, helping farmers and millers to minimise losses due to price fluctuations. In addition, information on the supply chain assessment will contribute to an improved understanding of the maize value chain in Botswana. This study, therefore, conducts an econometric analysis of maize prices and evaluation of the maize value chain. In this way, the study provides evidence of the correlation between maize prices that will enable farmers and intermediaries to hedge against price increases.

1.7 Outline of the study

The overarching purpose of Chapter 2 is to provide the reader with an overview of the maize industry in Botswana. This review entails the maize production outline, the net imports, local maize consumption, and maize value chain structure and reviews of previous studies relating to this study. Chapter 3 will present the methodological approaches required to assess the maize value chain and determine the correlation between maize prices between Botswana and SAFEX, respectively. Chapter 4 will address the findings of the study and the relationship that exists between SAFEX and the Botswana maize industry. Lastly, Chapter 5 will be a summary of conclusions and recommendations reflected in the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter's goal is to give a comprehensive review of pertinent material on the maize industry in Botswana. It provides the overview structure of the maize value chain indicating various actors participating within the chain. It outlines the net imports, local maize consumption, and regulatory and institutional issues governing the Botswana maize industry. Previous research on the maize value chain is reviewed in this chapter, with a concentration on relationships among the actors within the chain and following reviews on price volatility, price transmission, and hedging on agricultural commodities.

2.2. Maize production areas in Botswana

Maize cereal crop is grown across the nation of Botswana. The country is divided into ten administrative districts, namely Southern, South-East, Kweneng, Kgatleng, Central, North-East, Ngamiland, Ghanzi, Chobe, and Kgalagadi, which are shown in Figure 2.1 below.

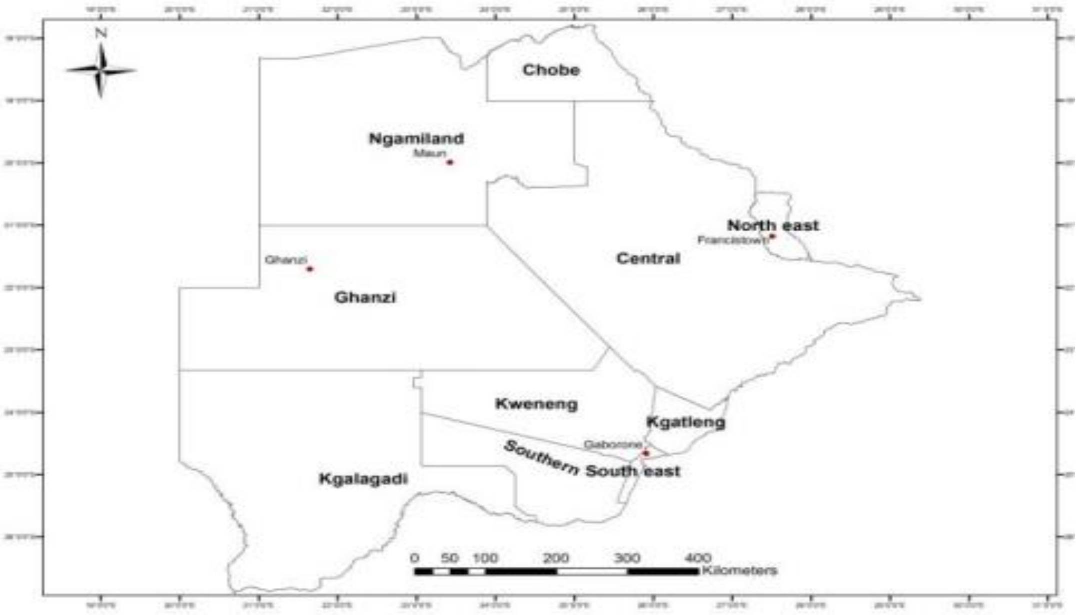

Figure 2.1: A map of districts with potential maize production in Botswana

Source: Kent (2011)

Areas such as Pandamatenga, which is in the Chobe district, Barolong Farms, Southern Ngwaketse areas, and Chobe Enclave are the leading areas where maize farming activity occurs – Chobe and the Southern districts are the main maize production areas. These areas favour maize farming due to soil fertility and suitable weather conditions for maize farming. During 2016/17, BAMB signed contracts with up to 400 farmers and more than 50 per cent were from the Pandamatenga area (BAMB, 2017). However, for the year 2018/2019, the Board signed contracts with 221 farmers (BAMB, 2019). Most of these farmers across the nation are small-scale farmers who practise subsistence maize farming characterised using family labour, rudimentary tools like hoes, and their fragmented land of an average of 0.8 hectares. There has been an increase in maize farmers in the Pandamatenga area after farmers understood the benefits of contract farming. However, Pandamatenga does not produce enough output for the maize crops. Therefore, BAMB intends to increase its base to farming areas around Dukwi as well as the Thuli block due to the emergence of farmers around these areas. Ghanzi area is identified as one of the potential areas to expand maize farming because of the availability of underground water (BAMB, 2019).

Table 2.1: Botswana grain crop calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize	Sowing	Growing			Harvesting						Sowing	
Millet	Growing				Harvesting						Sowing	
Sorghum	Sowing	Growing			Harvesting							Sowing

Source: FAO (2021)

According to the Food and Agriculture Organisation (FAO), for the United Nations, the planting season for maize crops starts from mid-November to January every year, while harvesting months are from mid-April to June, as depicted in Table 2.1. The maize crop is planted during these months because of the availability of adequate rainfall which is used to irrigate crops as most of the crops planted in Botswana are rainfed. During post-harvest season, higher yield results in lower prices, and lower yield causes higher prices (Beurs & Brown, 2013). The fluctuation in price seasonality is a result of households' and traders' unwillingness and inability to reserve grain (Beurs & Brown, 2013). Thus, abundant supply turns to low grain prices and prices turn to rise when there is the uncertainty of supply, leading to a price seasonality pattern.

2.3 Botswana maize import

Botswana is a net importer of cereals as the country cannot produce enough to meet its local demand (FAO, 2019). Table 2.2 shows a minor increase in maize imports from 2010 to 2012 with quantities of 41 722, 64 123, and 81 243 tonnes, respectively. However, from 2013 to 2015, the maize imports increase immensely to 190 061, 196 993, and 209 998 tonnes. Between the years 2016 and 2017, the maize imports decreased slightly with a quantity of 205 087 and 181 174 tonnes respectively. Maize imports increase because of weather conditions such as unreliable rainfall, recurrent droughts, extremely high summer temperatures, and/or heat waves which cause low maize production levels (Statistics Botswana, 2015).

Table 2.2: Botswana maize import quantity over time

Year	Import quantity (tonnes)
2010	41 722
2011	64 123
2012	81 243
2013	190 061
2014	196 993
2015	209 998
2016	205 087
2017	181 174

Source: FAOSTAT (2018)

Table 2.3: Botswana cereal imports

Period	Import quantity (tonnes)
Average 2015/16 to 2019/20	372 000
2019/20	422 000
2020/21 forecast	Above 465 000

Source: FAO (2021)

As can be seen in Table 2.3, Botswana cereal imports have been on the rise over the years. Botswana is relying on neighbouring countries like South Africa to import maize to be food secure. According to FAO (2019), imports satisfy more than 90 per cent of domestic cereal requirements.

In addition, maize is the biggest part of the cereal imports in Botswana at 290 000 tonnes, with white maize imports at 230 000 tonnes and yellow maize imports at 60 000 tonnes (FAO, 2021). The year 2020 recorded an increase in imports from 170 000 tonnes, which was recorded annually, to 290 000 tonnes. The huge amounts of maize imports were due to the country's aim to get more stock to combat the threat of severe food insecurity brought by the COVID-19 pandemic (FAO, 2021).

2.4 Supply and demand of Botswana maize industry

Botswana is still far from being food secure due to the unfavourable weather conditions and the recent occurrence of heat waves which result in late rains. These challenges discourage farmers from ploughing in numbers and stimulate maize grain import from South Africa and neighbouring countries by millers. The import for the year 2016/2017 was about 170 000 metric tonnes, which are also imported on an annual basis to meet the local demand. The production for 2016/2017 was 20 000 tonnes, which was regarded as a good year with a demand that ranged from 180 000 to 190 000 tonnes of maize per annum reported (BAMB, 2017). The Storage Grain Reserve for 2016/2017 indicated that maize had run down. However, the maize expectation for the 2017/2018 season was 12 000 tonnes, which was still underperforming. Based on this information, the maize demand and supply for the 2016/2017 season are as follows:

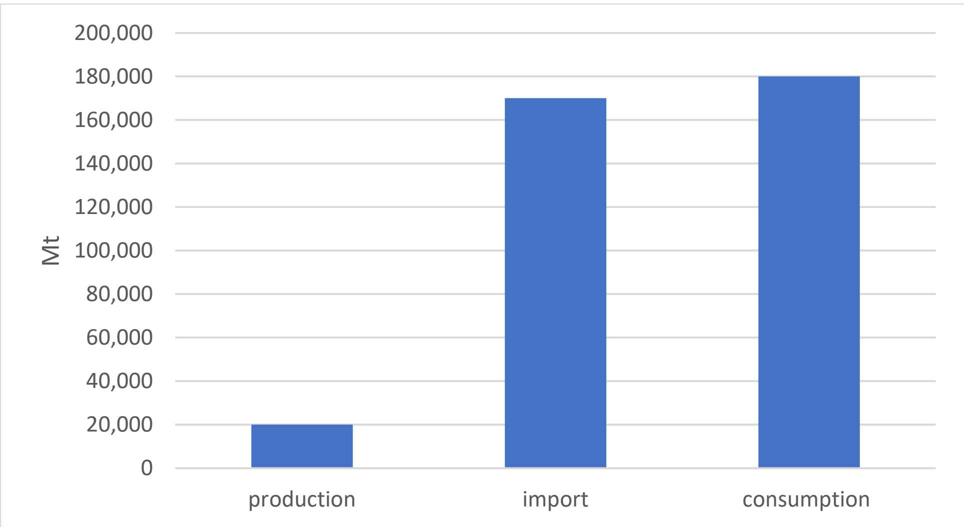

Figure 2.2: Botswana's demand and supply for maize for the 2016/17 season

Source: BAMB (2017)

Figure 2.2 depicts the maize balance sheet for the year 2016/17. During that time, the country had an extreme shortfall in output level indicating higher maize imports. The imports were slightly close to the local demand.

Table 2.4: Botswana's maize supply in 2020

	Tonnes
Production	15 000
Imports	290 000
Exports	0
National supply; Production- exports+ imports	305 000

Source: FAO (2021)

Table 2.5: Botswana cereal balance sheet as of 2020

	2016-2020 average (000 tonnes)	2020 (000 tonnes)	2021forecast (000 tonnes)	2021/2020 (Percentage change)
Maize	12	15	20	33.3
Sorghum	29	30	40	33.3
Millet	3	4	5	25.0
Others	1	1	1	0.0
Total	46	50	66	32.0

*Note percentage change was calculated from unrounded data.

Source: FAO (2021)

Table 2.4 shows the average maize production for Botswana during the last few seasons. The maize industry is facing a decrease in production because most of the land consists of desert terrain which results in harsh weather conditions not suitable for maize farming. The average maize production was 12 000 tonnes during the following years 2016 to 2020, while in the harvesting year of 2020 the production increased to 15 000 tonnes above average. Based on the figure, sorghum is the leading grain crop in Botswana followed by sorghum. FAO (2019) implies that dry conditions like a severe decrease in seasonal rainfall are the reason for this shortfall. The unevenly distributed rains, dry spells and heat waves experienced throughout the season caused lower hectarage planted and crop failure (FAO, 2019).

2.5 The structure of the maize value chain in Botswana

According to Grant et al. (2012), the SADC countries have different maize value chain structures but similar overall components and actors. Botswana's maize value chain comprises smallholder farmers, emerging commercial farmers, commercial farmers, and middlemen (aggregators) (Grant et al., 2012). The maize value chain like other agricultural value chains commences with input supply followed by production, aggregation, processing, distribution and marketing, and consumption. The transaction within the value chain forms relationships and/or links as the actors interact.

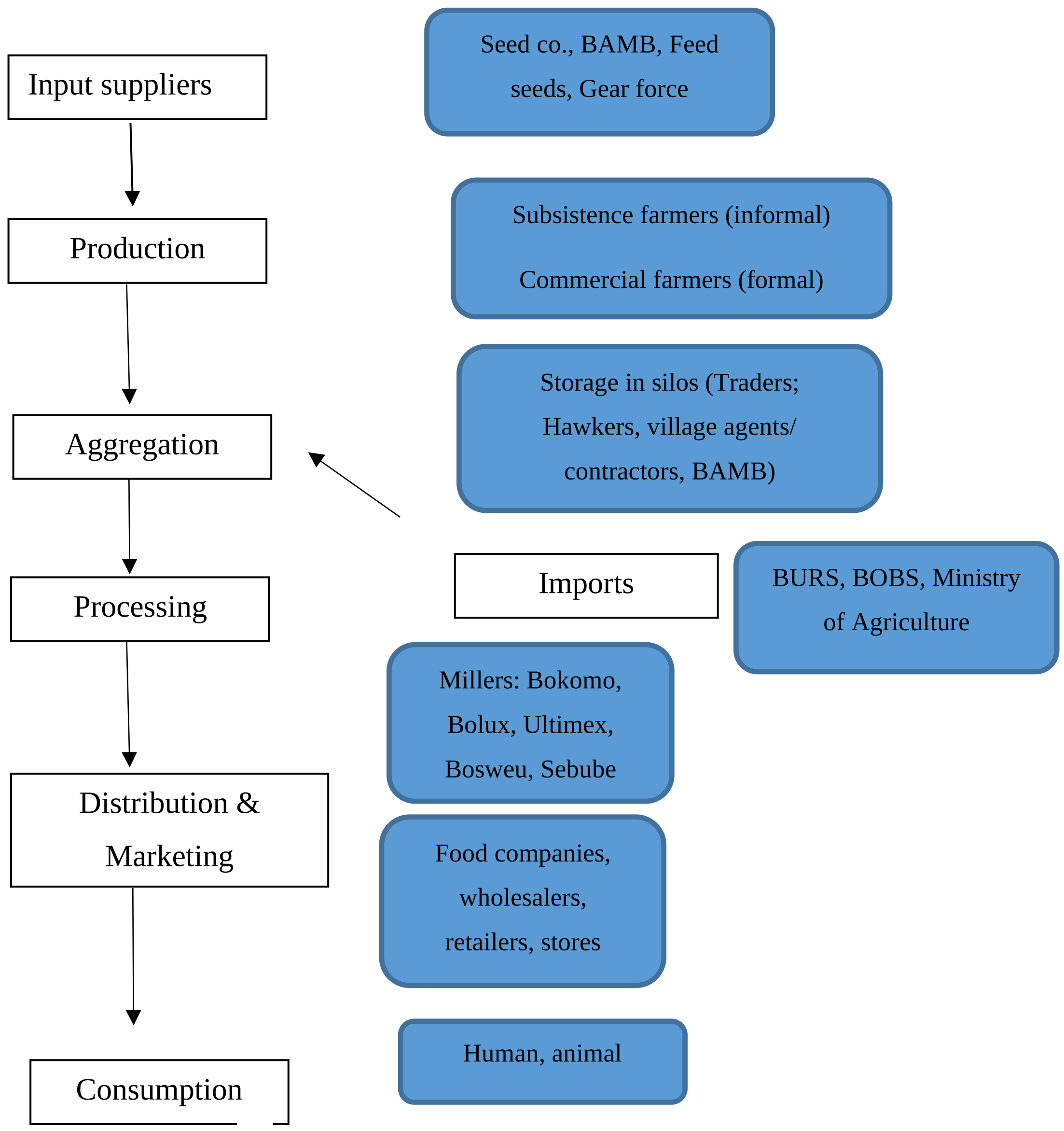

Figure 2.3: Botswana maize value chain structure

The key actors in the Botswana maize chain and their functions are as follows:

2.5.1 Input suppliers

These are companies that manufacture seeds, pesticides, and fertilisers, and they have distribution networks where their end-user are farmers. These companies include Cross Corn, Seed Co., BAMB, Gear Force, and Feed Seeds. In addition, fertilisers, protection products, and water are inputs resulting from separate value chains.

2.5.2 Producers

At the production level, actors comprise subsistence farmers and commercial farmers (emerging commercial farmers, surplus farmers, and full commercial farmers). The average farm size in Botswana is 5 hectares according to (Statistics Botswana, 2012). Most of the commercial farmers use machinery such as large tractors and combine harvesters whilst small-sized farms use manual labour.

2.5.3 Aggregators

At this level, individuals who have silos or warehouses to store maize are found here. This includes contractors, hawkers, BAMB, and aggregators who have accessibility to market and market information-like prices. The storage can be publicly owned or privately owned.

2.5.4 Processors

This stage involves direct maize meal consumption and animal feed. Processors buy maize from BAMB or their contracted companies and turn maize into a finished product ready for consumption. Bokomo Botswana, Bolux Milling Pty Ltd, Bosweu Milling Pty Ltd, Sebube Milling Pty Ltd, and Ultimex Pty Ltd are the leading milling companies in Botswana.

Both the middlemen and processors can buy their maize grain from exporters when maize supply is scarce in the nation. The imports are being monitored by BOBS, BURS, and the

Ministry of Agriculture. Millers can either import maize grains or finished maize meal products.

2.5.5 Distributors and marketers

After maize is processed, food companies, wholesalers such as CA Sales & Distribution Pty Ltd, retailers, and stores can buy their finished product from processors and market it to consumers so that it is readily accessible to end-users.

2.5.6 Consumers

The end products consist of maize flour or finished manufactured products. Conversely, the Botswana maize industry has not yet developed to an extent that it can manufacture biofuel products.

2.6 Regulatory and institutional issues governing the Botswana maize industry

The government of Botswana has trading systems with the mandate to protect domestic industries and the trading of specific goods. This includes the operation of borders and ports by government parastatals to monitor the local content requirements of products entering and in the country. Consequently, the local content requirement for grain production which includes maize and sorghum is at 40:60. The procurement rule is that before issuing import permits thus, grain processors must have at least 40 per cent of maize and 60 per cent of sorghum domestically produced before the import permit is issued (Grant et al., 2012). The regulatory institutions include the Ministry of Agriculture, Botswana Bureau of Standards (BOBS), and Botswana Unified Revenue Service (BURS).

2.6.1 The Ministry of Agriculture

The Ministry of Agriculture through the Division of Plant Protection monitor and manage the outbreak of pests and disease across the country. The division was established in 1986/87 after the nation suffered an outbreak of locusts. One of its tasks is to promote the protection of plant health by controlling plant and plant product importation and exportation through the granting of phytosanitary certificates and import licences.

2.6.2 Botswana Bureau of Standards

BOBS was founded by the Botswana Act No. 16 of 1995 with a mandate to develop and implement Botswana Standards. The International Organization for Standardization (ISO) has acknowledged that BOBS has the authority to set national standards. The standards in Botswana are divided into mandatory and voluntary categories. Compulsory standards affect human health, the environment, and or export, while voluntary standards are not legally binding or required. However, complying with voluntary standards may increase product competitiveness. Maize falls under compulsory standards to promote commodity quality and safety for human consumption and it is monitored by BOBS to ensure compliance.

Seven products BOBS monitors under compulsory standards are poultry feed, cattle feeds, drinking water, cereals/sorghum grains for consumption, garments, pre-packaged goods for consumers, and petroleum gas (Export.gov, 2019). BOBS as the sole organisation of national standards annually sends its plan to the ISO. Consequently, the National Food Control Board is the only supporting organisation in Botswana to develop an annual plan. BOBS has certified Grade 1 and 2 as quality specifications acceptable for grain for human consumption. Factors that determine grain classification in Botswana are moisture content, defective grains, foreign matter, grains of another colour, poisonous weed seeds, and live insects (BAMB, 2019).

Table 2.6: The specifications/standards for acceptable grades of white and yellow maize

Factor	**White maize tolerance (%)**		**Yellow maize tolerance (%)**	
	Grade 1	**Grade 2**	**Grade 1**	**Grade 2**
Moisture content	13	13	13	13

Factor	White maize tolerance (%)		Yellow maize tolerance (%)	
	Grade 1	Grade 2	Grade 1	Grade 2
Defective grains	7	10	6	12
Foreign matter	0.3	0.5	0.3	0.5
Maize kernels of another colour	2	3	2	3
Pinked maize	12	12	7	7

Source: BAMB (2019).

Table 2.5 shows the specifications or standards for acceptable grades of white and yellow maize respectively. Moisture content, foreign matter, and maize kernels of another colour are all the same in both white and yellow maize for Grade 1 and 2. White maize has acceptable defective grains at 7 per cent for Grade 1 and 10 per cent for Grade 2, while yellow maize has 6 and 20 per cent for Grade 1 and 2 respectively. However, pinked maize for white maize is 12 per cent for both grades and yellow maize has 7 per cent for both Grade 1 and Grade 2.

2.6.3 Botswana Unified Revenue Service

BURS was founded in 2004 with the mission of assessing and collecting taxes on behalf of the Botswana government. Customs and excise tariffs, import value-added tax, and other levies are among the taxes collected. As a result, lawful imports and exports are made easier, Botswana's society is protected from cross-border crimes, and discriminatory and destructive economic practices are prevented. Import or export permits, certificates of origin, etc. are required when clearing goods at the ports. Accordingly, the importers must make payments to BURS where there are no prohibitions or restrictions on imported goods. However, there are cases where imported goods may be excused in harmony with trade agreements between countries. Botswana benefits from such an agreement as it has entered into exchange arrangements with other countries and economic communities. The benefits are granted quota-free and/or duty-free access in the markets of those parties. Conversely, Botswana has trade agreements with member nations such as Lesotho, Namibia, South Africa, and Swaziland which are Southern African Customs Union (SACU) members. Goods imported from these member states attract only 12 per cent of value-added tax (VAT) while imported goods outside the region are responsible for 12 per cent VAT and tariff rates.

2.7 Informal supply chain

Informal channel involves buying maize grains from farmers' gate for social functions, investment or reselling, and consumption. The key players here are the smallholder farmers and the middlemen. The advantage of buying at farmers' gate is that there is no transport cost. Sometimes farmers dry the maize themselves and sell it to fellow villagers at a larger stage after the process is complete. However, the informal market is not reliable as it presents disorderly and unpredictable availability of buyers. Furthermore, the informal channel influences producers to trade their maize to individuals with little purchasing power, at cheap rates relative to their yield. The channel presents farmers with critical difficulties. Therefore, a farmer needs to make an informed decision based on reliable maize grain prices, the right selling time, maize grain type, and available channels. These will make the farmer anticipate higher returns for his or her produce. The small-scale hammer millers process maize at a low cost without defined traceability of their low-quality maize flour being the final product, which presents a challenge to information, standards, and quality assurance in the value chain. Therefore, there is a need to address this uncertainty within the maize sub-sector to encourage investment by farmers and large-scale commercial investors. To date, the government is the key player in leading the intervention in the sub-sector.

2.8 Formal supply chain

The formal supply chain or channel is when the farmers sell their maize grains directly to millers and middlemen like BAMB. BAMB buys and grades the maize grains from farmers and then sells them to millers. The millers then process the maize grains into various products such as samp, maize meal, etc., package them and distribute them to supermarkets and wholesalers. BAMB has signed a contract with some farmers across the country to supply them with maize grains. However, during low yield periods, BAMB imports maize from South

Africa to ensure a steady supply in the country and it is the main key player in Botswana's maize formal supply chain. The organisation is set to monitor the grain standards and is fully involved in the grain trade. Major players are large-scale processors like Bokomo Botswana, Bolux Milling Pty Ltd, Bosweu Milling Pty Ltd, Sebube Milling Pty Ltd, and Ultimex Pty Ltd. These processors buy maize from BAMB and farmers then turn it into a desired finished product. They have their own processing facilities, pack, and distribute their products themselves. The quality standards of maize grains are communicated across the chain from traders to farmers.

2.9 Relationship of actors within the maize value chain

The main distinction between a value chain and a supply chain is that in the supply chain, there are no authoritative connections where commodities, services, or financial agreements are executed (Kit et al., 2006). The value chain is described as the set of actions required to take a product or service from conception to final disposal after usage, including several phases of production, distribution to end customers, and final disposal (Kaplinsky & Morris, 2000). The product cannot go through various stages of creation and conveyance to definite buyers without the occurrence of physical, monetary, and social exchanges (Kaplinsky & Morris, 2000).

The social network theory explains the quality of relationships (trust and commitment) between farmers and middlemen. In addition, factors such as information asymmetry and opportunism which constitute the Agency theory are essential to provide further insight into this relationship. The Agency theory is concerned with the relationship between the principal and the agent, whose transaction is characterised by conflicting interests (Palmer, 2013). For example, the smallholder farmers want to sell their maize grain for the highest price possible regardless of the quality, while the middlemen want to purchase the best quality maize grains for the lowest price possible.

In some situations, agents may have an incentive to engage in opportunistic behaviours that maximise their utility function, at the expense of the principal. According to new institutional economics, the agent-principal problem is a result of asymmetric information, bounded rationality, and conflict of interest, which is characteristic of the general behaviour of economic actors (Williamson, 1973; Dorward et al., 2009). Challenges often arise when bounded rational individuals who have conflicting interests transact with each other in environments with asymmetric information, leading to opportunistic behaviour by both actors. Therefore, the agency theory is useful in explaining the bounded rationality of individuals.

Asymmetric information is when one side of a transaction has more information than the other, or when one party has no information at all (Do, 2003; Hobbs, 2004; Dorward et al., 2009). This is typical of the environments in which smallholder farmers and the middlemen in the maize chain transact. Opportunistic behaviour often results when information is not equally distributed among actors (Dalipagic & Elepu, 2014). For example, the middleman might have information on price, quality, and market demand, but might choose to withhold it from the farmer. Similarly, the farmer may intentionally withhold information about the poor quality of their grains from the middleman. In either case, opportunistic behaviour leads to higher transaction costs (Hobbs 1996; Do 2003; Groenewegen et al., 2010).

The Social Capital theory concerns itself with the relationship or interaction between actors in a chain (Borgatti & Ofem, 2010). It asserts that supply chain actors make great efforts to build closer and stronger relationships with each other (Odongo et al., 2016). Stronger relationships, characterised by trust and commitment contribute to improved performance of the entire supply chain by providing mutual benefits to the actors involved. Such benefits accrue from complementarities or interdependencies in terms of knowledge and resource sharing, markets, and technology (Trienekens, 2011; Odongo et al., 2016). Where high levels of trust exist between actors, social capital has been proven to boost action efficiency and reduce opportunistic and transaction monitoring costs (Odongo et al., 2016).

To address the challenges created by poor coordination such as the mismatch between quantity and quality demanded and delivery delays, studies suggest contract farming as a potential solution (Kherallah & Kirsten, 2002). The increasing need for actors to vertically integrate and improve the supply chain performance has made contract farming necessary to connect smallholder farmers to high-value markets. The terms and conditions for transactions are defined in contract farming. For example, the middlemen who have contracted with the smallholder farmers are to buy an exact amount and grade of the maize grains at a predetermined value. Middlemen might provide farmers with support services such as extension services, inputs including seeds and fertilizers on credit, and technological information. The benefits of contracting include a reduction in marketing and production risk ensuring a steady and reliable supply of the desired quantity and quality of the grains; it further provides farmers with a ready market (Sykuta & Cook 2001; Kherallah & Kirsten 2002; Federgruen et al., 2019).

According to Wilson and Lewis (2015), the Tanzanian maize value chain faces lots of challenges such as access to finance, the uncertainty of land tenure, limited access to improved seeds, and corruption that hinder its performance. The most affected link is between producers and processors which is characterised by mistrust. The study suggested that the improvement of commercial links with farmers' cooperatives promotes maize value efficiency in Tanzania.

The Kenyan maize value chain comprises weak and informal vertical linkages without contractual business relationships among millers and traders (USAID, 2010). However, efforts to establish business relationships by millers with farmers have been unsuccessful as farmers tend to sell their products on a first-come, first-served basis to the highest bidder. Some traders have established informal agreements with farmers by selling inputs to farmers on credit and in exchange, farmers offer their produce at agreed prices after crop harvest (USAID, 2010). The report states that vertical linkages among producers and regional traders, and producers and millers are promoted in case the other actor does not meet the supply contract requirements.

2.10 Price volatility in agricultural commodities

Minot (2014) defines food price instability as a change in food price over time. Agricultural commodities have had this change in prices over three decades. Between 2007 and 2008, there was an increasing and decreasing trend in food prices (Minot, 2014). The variation is due to changes in output because of weather, pests, demand, and supply elasticities (FAO et al., 2011). In African agricultural commodities markets, there has been a lot of price volatility (Minot, 2014). The instability of prices poses a greater risk in sub-Saharan Africa due to poor households and food price volatility having a strong relationship with the risk for poor households (Minot, 2014).

Food price volatility mostly affects households in developing countries where grains are the main source of food (Gilbert & Morgan, 2010). The developing economies face a greater influence of high and unstable commodity prices than the developed economies. Moreover, as people get richer, they gradually shift from grain consumption (Gilbert & Morgan, 2010). According to Hernandez et al. (2014), agricultural commodity markets are mostly connected to own and cross-volatility transmissions.

2.11 Price transmission in agricultural commodities

Listorti (2008) defines price transmission as the co-movement shown by prices of the identical item in marketplaces at various sites. Acosta (2012) employed the asymmetric error correction model to investigate the geographical spread of white maize prices in Mozambique and South Africa. The model was used to estimate the degree to which prices are conveyed from the global marketplace to the local marketplace. The Mozambique white maize prices did not cointegrate with South African maize prices in the short run but only in the long run (Acosta, 2012).

Ankamah-Yeboash (2012) carried out a similar study in Ghana assessing the maize price transmission. Unlike the findings from Acosta, the study found interdependency in the bidirectional market for both short- and long-run market pairs. Consequently, the long-run causalities demonstrated a heterogeneous relationship given the positive and negative shocks.

Davids et al. (2016) examined cointegration between maize prices covering Malawi, Mozambique, South Africa, Zambia, and Zimbabwe in the Southern African region. The study used the Engle-Granger two-step procedure which found the existence of cointegration of maize prices within the Southern African region.

Chimaliro (2018) carried out a study to evaluate soybean price volatility with South African and US soybean prices. Monthly secondary data of soybeans prices for these countries was used from April 2002 to November 2016. The Engle and Granger strategy was adopted to estimate cointegration between soybean prices in Malawi, South Africa, and the US. The results showed that five out of six pairs exhibited long-run cointegration relationships.

2.12 Hedging in agricultural commodities

Due to the agreement in 1994 when South Africa became a SADC member, Botswana benefits from the trade agreements that were made among members to have a free trade area. Therefore, Botswana can hedge price risks on SAFEX. Botswana can have more information about South African weather conditions, market information, demand and supply, and issues relating to the political stability of the South African country unlike when hedging on the Chicago Board of Trade (CBOT) because of the distance factor. However, CBOT hedging mechanisms are like that of SAFEX as South African farmers will not be considering factors such as currency fluctuations and maize ports when hedging. Therefore, SAFEX will be a price insurer for Botswana millers against maize price risks.

According to Dana et al. (2006), countries can import grains during bad years when there was a decrease in harvest; the government can choose whether to import the grain by establishing grain import requirements and import the grains directly or pass it on to private companies to tender and/or give the private companies the full responsibility to implement import regulations. However, Dana et al. (2006), pointed out that grain markets within the southern region are heavily regulated by the government which is challenging for the private sector to be more involved hence limiting their potential to expand the grain markets.

The government is the key player in maize trade limiting the private sector's involvement and because of the lack of productivity of the public sector, the private sector should have control of most of the grain trading while the public sector deals with food security reserves (Coulter, 2005). In addition, Dana et al. (2006) continue to argue that even if the private sector was to have authority over grain import requirements, the government public sector will keep getting involved, in the long run making the process difficult. Hence, Dana et al. (2006) suggest that grain import requirements must be clear and transparent indicating conditions where the government must get involved. In the case of Botswana, the government is the one that is regulating the grain imports through the Ministry of Agriculture and the private sector has no or little involvement in regulating the grain market.

Hedging means protection against any price movements (Dana et al., 2006). The risk associated with grain trading can be minimised by either buying the futures contracts or call options. A trader who has purchased the call option will be protected against a price increase which will be closed when the trader exercises the option or when the expiry date approaches (Dana et al., 2006). Consequently, his study showed that futures contracts and call options hedges give similar results expected during times when there are shortages, and holding these hedges has some advantages for the trader who purchased them. Moreover, for the private sector to be efficient, the public sector must design and implement policies that are transparent and enable the private sector to meet the required standards for grains.

Forward contracts deal with setting prices of a certain commodity before planting season. The prices can be either fixed on agreed terms among players or a minimum price can be put in the contract as a guarantee, with the possibility of a price increase when delivering the commodity, and/or a farmer can sign a contract to receive funds for his or her production operations and later pay-out at the end of the season with his/her crop harvest (Bown et al., 1999).

SADC countries import grain at the time there are deficits during harvest season to meet their local demand. A hedging mechanism tool is used to reduce the average costs of imports during shortfalls (Dana et al., 2006). In their study, they found that the correlation between Zambian and Malawian prices was stronger than that of South African prices. Consequently, the shortfalls in both markets led to an increase in import parity.

The study by Taušer and Čajka (2016) analysed these four hedging strategies: commodity futures, forward contracts, options, and options strategies for wheat farmers. The farmers benefit from locking prices at the beginning of futures and forward contracts despite what might happen to the future spot price. In addition, the study pointed out that wheat farmers have the advantage of not paying option premiums as futures are standardised and traded easily daily (Taušer & Čajka, 2016).

Pennings and Meulenberg (1997) carried out a study on offsetting risks in Amsterdam for the potato futures market. The study suggests that more usage of futures to hedge risk reduces risks in the potato futures market. Thus, potato farmers who trade in the futures market experience lesser exposure than those producers who deal individually. Moreover, the price that the farmers use to participate in the market has no impact on their ability to hedge risk (Pennings & Meulenberg, 1997).

2.13 Summary

The conclusions on regional and international markets depict that the maize value chain faces an array of challenges with opportunities to improve the relationships within the chain. There have been studies on hedging risk using different hedging strategies such as hedging with the futures market. There have not been any studies that particularly assess hedging options in the Botswana maize market that the researcher is aware of.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The data, theoretical framework, and econometric analysis utilised to determine the cointegration relationship between Botswana maize prices and South African maize prices quoted on the JSE from 2008 to 2019 are described in this chapter.

3.2 Data description

The study used both quantitative and qualitative data. The key informant interview technique was employed to gain general insights as well as an expert opinion into the existing structure of the maize value chain in Botswana. In this regard, an interview guide was developed comprising a list of questions on topical issues. The interview was done physically (face-to-face), and the expert revealed some of the opportunities and challenges the maize value chain presents. In determining the opportunities and challenges within the maize value chain, a qualitative study of institutional and policy perspectives was used.

Secondary data was also used in this study which consists of white and yellow maize prices series in Botswana and South Africa. Monthly maize prices data was used in this study running from January 2008 to December 2019. Data has been retrieved from the BAMB and JSE websites. The product studied in maize grains' price per tonne. The maize grain monthly prices from both countries were converted into USD currency to have the same currency and/or value (USD/ton). However, the daily maize prices quoted on the JSE were converted into monthly prices by calculating the average for each month. Table 3.1 presents a description of variables from the time series obtained.

Table 3.1: Data definitions

Title	Series ID	Expected sign
Botswana White Maize Price Grade1	$BWPWMG1_t$	+/-
Botswana White Maize Price Grade 2	$BWPWMG2_t$	+/-
Botswana Yellow Maize Price Grade 1	$BWPYMG1_t$	+/-
Botswana Yellow Maize Price Grade 2	$BWPYMG2_t$	+/-
South Africa White Maize Price	$RSAWM_t$	+
South Africa Yellow Maize Price	$RSAYM_t$	+

The expected signs for all Botswana maize prices are ambiguous. It is unclear whether Botswana maize prices can significantly impact the South African maize prices. However, the expected signs for South African maize prices are positive implying that both South African maize prices will have a substantial impact on Botswana maize prices because South Africa is a net exporter of maize.

Table 3.2: Socio-economic status of Botswana

Total population	2.2M (2017)
Life expectancy	68 yrs. (2011)
Population growth rate	1.69% (2017)
Human development index	0.717 (2017)
Adult literacy	88.7% (2015/16)
Rural population	0.78M (36% total population
Unemployment rate	17.6% (2017)
Average GDP growth	4.5% (2018)
Under 5 mortality rate	37.6 per 1 000 live births
Inflation rate	3.2% (2018)
HIV/AIDS	20.3% (2018)

Source: Reliefweb.int. (2019)

Table 3.2 shows the country's socio-economic context indicating that 88.7 per cent of people in Botswana can read and write. The life expectancy in Botswana is estimated at around 68 years with a population growth rate recorded at 1.69 per cent. The Human Development Index is estimated at 0.717 indicating that about 72 per cent of people in Botswana are well-fed, healthy, sheltered, have education, work, vote, and participate in community life. The inflation rate depicts an increase of 3.2 per cent in 2018. The HIV/AIDS prevalence is estimated at 20.3% which can worsen poverty if it increases as many people will not turn up to work hence adversely affecting production. Consequently, access to employment can help households to be food secure as they will have money to buy food. There are limited job opportunities in Botswana currently due to regional and global competition. However, the good performance or improvement of the maize industry can present the nation with the opportunity to fight against poverty by creating more employment.

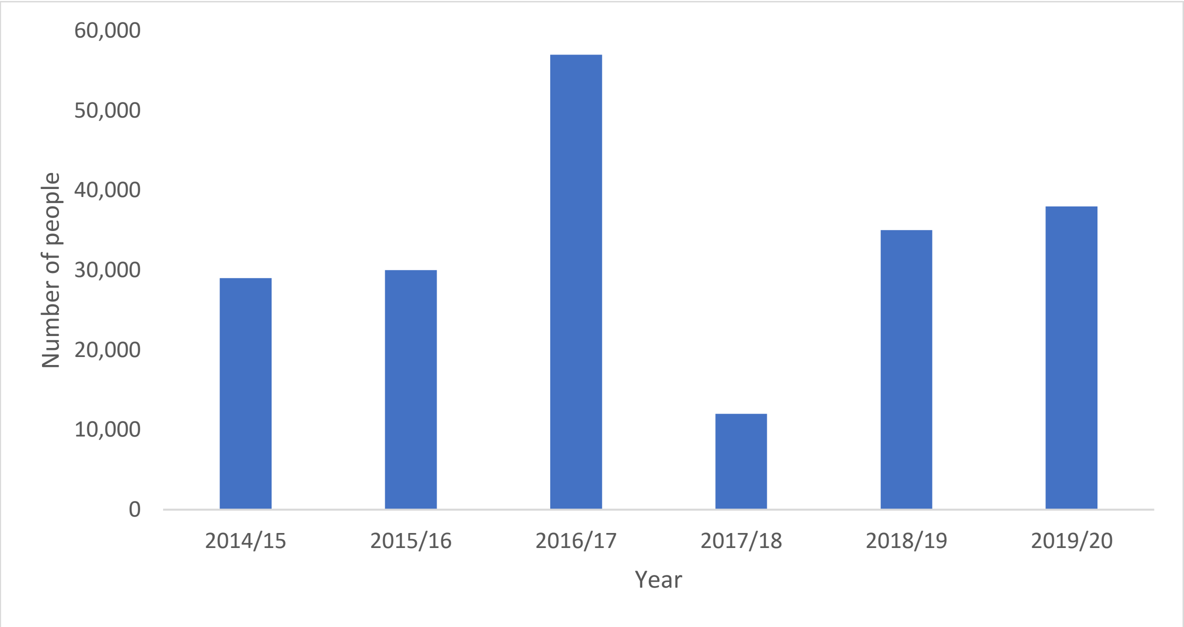

Figure 3.1: Botswana food insecure populations trends

Source: Reliefweb.int. (2019)

Figure 3.1 illustrates the number of people who are food insecure over years. The year 2016/17 has the largest number of people affected, recorded at 57 000. The number decreased in 2017/18 to 12 000 people but increased to 35 000 people in 2018/19. There is an upward trend between 2017/18 to 2019/20. Thus, the number of people who are food insecure continued to increase significantly.

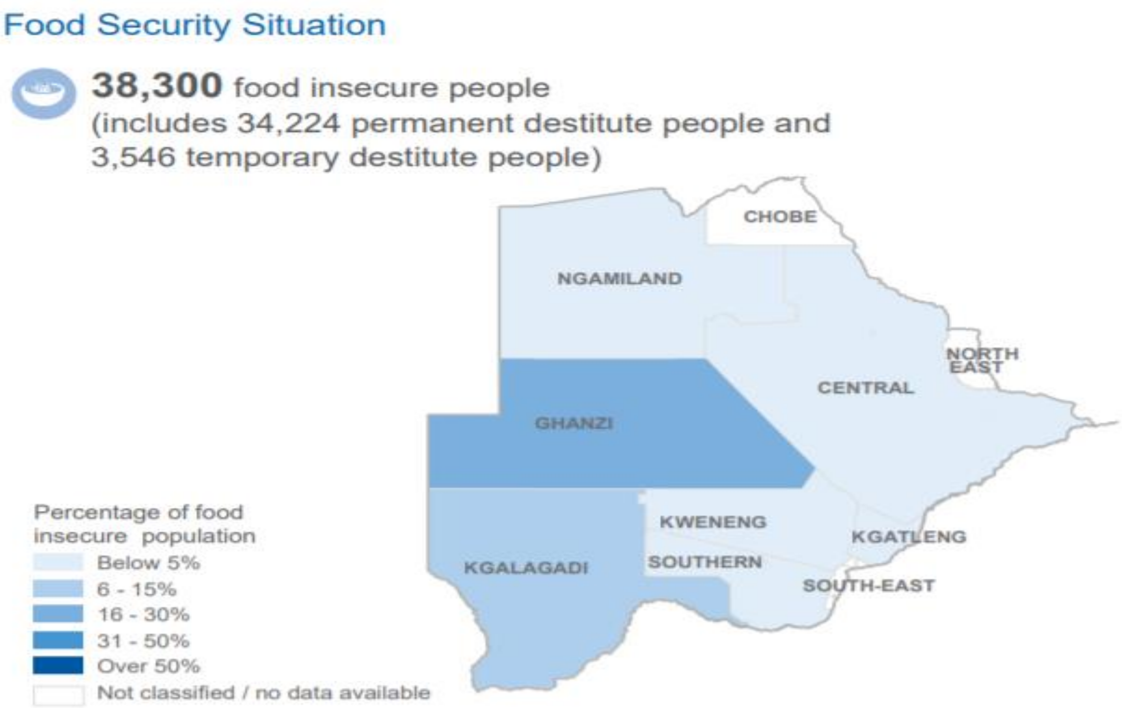

Figure 3.2: Food security status across Botswana districts

Source: Reliefweb.int. (2019)

Figure 3.2 demonstrates how people in Botswana are affected by food security. Ghanzi is the leading district where 31 to 50 per cent of people inhabiting are food insecure, while the Central district is one of the least regions where people are food insecure. Thus, between 11873 and 1915 people are food insecure in Ghanzi district. However, the total number of people residing in Ghazi district was estimated at 43355 in 2011 (Statistics, 2011). In the Chobe and North-East regions, the status of people regarding food security is not classified or no data was captured. According to Grant et al. (2012), Botswana has high human consumption of maize, and the country imports more of its maize from South Africa. Botswana's primary source of carbohydrates is maize (BAMB, 2021). This shows that maize is important to maintain food security in Botswana. In addition, some of the maize is used to feed livestock, which is the source of food for Botswana, hence maize is critical to the country's food security. Subsequently, the FAO (2021) reported that around 38 000 people in Botswana were food insecure between April 2020 and March 2021. The country faced a sharp recession in 2020 due to the COVID-19 pandemic that left many households with no access to food and income reductions (FAO, 2021).

3.3. Theoretical framework

The general concepts of market integration and hedging are discussed in this section**.**

3.3.1 Market integration

A positive correlation exists over a period between prices at various market locations in an efficiently integrated market system. The correlation measures the relationship of commodity prices in different marketplaces (Ravallion, 1986). Fackler and Goodwin (2001) describe market integration as the degree to which demand and supply disruptions in one marketplace are transferred into another market. The concept of market integration is seen as a degree rather than a specific connection, ranging from zero to one for fragmented and seamlessly blended markets. Market integration is linked with price transmission results in three types of market integration. Spatial integration deals with prices of the same good in two separate markets whilst vertical integration deals with prices of raw materials and final product. Lastly, cross-commodity deals with the integration of different goods (Ayalew, 2018). In this study, the Botswana maize prices are linked with maize prices in South Africa to justify hedging opportunities.

However, spatial arbitrage and the Law of One Price (LOP) influence the fundamentals of trade relations. The spatial arbitrage concept involves the movement of a good to a higher price location from a lower price location given that the price variation is greater than the minimal shipping and handling costs. The shipping will cause the charge to increase in lower-cost locations and decrease in higher-cost locations (Fackler & Goodwin, 2001). LOP states that regional markets are linked via trades, disregarding variances in transaction costs, and arbitrage will have a similar and unique pricing (Rapsomanikis et al., 2003).

On the same note, the cointegration relationship between Botswana and South African maize prices is presented in this study. Conversely, the market integration concept adheres to cointegration and rebuilding an equilibrium in the long run. Some factors affect price discovery among markets other than transportation costs (Ayalew, 2018). According to Zant (2013), linked markets extend the opportunity to minimise impacts due to climatic conditions, shifting foodstuff from excess to discrepancy places. In this regard, the hedging of price risk associated with weather shocks in the Botswana maize market is evaluated as is the case in this study. A lot of households in developing areas strive to have unlimited access to manpower, food, and investment to minimise exposure to severe high transaction costs and changes in prices (Lutz et al., 1995).

3.3.2 Hedging

Hedging is the management tool used to minimise or avoid risk for farmers. Traditional hedging theory suggests that for risk to be avoided in the futures market, an equal but opposite position is used to hedge cash positions (Working, 1962). The speculation hedging theory involves hedgers who function like speculators. The speculators focus on relative prices rather than absolute prices and only hedge if prices are likely to drop but not when prices are expected to rise. In portfolio theory, the exposure to price movements is incorporated through a hedging model via variance function to indicate the link connecting divergence and expected returns (Working, 1962).

The portfolio approach which is the most common theory ponders both the exposure and expected returns in hedging. Quantity and price risk are the primary causes of exposure faced by producers. Quantity exposure includes things like weather conditions and disease whilst price risk is caused by sudden movements in the collective number of demanded items or sold goods (Pennings & Meulenberg, 1997). The futures contracts are created due to the rapid changes in agricultural prices. The risks are introduced in the futures contracts which affect the returns as well as the success of the option. However, the costs associated with futures trading are required to be evaluated against the benefits of the futures contracts (Pennings & Meulenberg, 1997).

A futures contract's expiry date is predetermined and is in the future. The producer takes a short position futures contract on SAFEX to sell a commodity and hedge against price changes in the upcoming season; whilst a long position futures contract deals with the miller buying a commodity to hedge against any price increase within the market. Moreover, there is an options hedging technique which is an agreement for a primary item that allows the proprietor the privilege but not the duty to perform the option (Hull, 2002).

3.4. Analytical or empirical approach

Cointegration is a time series forecasting technique used in a variety of financial markets. Long-term hedging techniques based on cointegrated financial assets are more effective

(Alexander, 1999) and there are different methods used to find cointegration – one of these is the Engle-Granger method. In this method, the regression between integrated series and residual tests for stationary are performed (Alexander, 1999). Relevant stationary tests include those by Philips and Perron (1988), Dickey and Fuller (1979), Choi (1992), and Schmidt and Philips (1992), but the Augmented Dickey-Fuller (ADF) test is the most popular. Ordinary least of squares (OLS) can be performed when dealing with two log prices x and y using the Engle-Granger method pointed out by Alexander (1999). However, the regression results will be valid only if log prices are cointegrated.

Conversely, cointegration can be investigated using Johansen's methodology which is considered significantly better than the Engle-Granger method when more than two variables are involved (Alexander, 1999). The OLS estimation effectively minimises the variance of the residuals, but they may appear stationary even when they are nonstationary. The null hypothesis of no cointegration would be over-rejected if the Standard Dickey-Fuller distribution was used. The distribution of the Engle-Granger test varies on the number of variables that involve the error term (dependent and independent variables), the deterministic structure of the model, and sample size (Bilgili, 1998). MacKinnon's tables are used to obtain the desired level of significance and consider the deterministic structure. When considering more than two variables, it is no longer possible to demonstrate the uniqueness of the cointegrating vector. If, for example, a vector on N variables means each will be integrated of the same order, that is there can be up to N-1 cointegrating vectors. The method lacks a systematic procedure for estimating several cointegrating vectors separately (Bilgili,1998).

Given these limitations, the Johansen (1988) test can predict and then assess the presence of several cointegrating vectors. In addition, the procedure can examine constrained iterations of the cointegrating vectors as well as the speed with which the correction constraints are adjusted. It is important to evaluate whether economic theories can be verified by imposing limits on the intensities of the regression analysis. The Johansen test helps in the identification of several cointegrating vectors among various variables. For many equation scenarios such as in this study, Johansen's method is superior since it permits for the empirical evaluation of the maximum number of cointegration vectors and relationships. Therefore, the study adopted Johansen's method for the cointegration test.

3.4.1 Time series data properties

Nonstationarity is a process where mean and variance change over time, while in the stationarity process, variance remains constant over time. Correlograms and data plots informally test the stationarity of time series data (Gujarati & Porter, 2009). Moreover, unit root tests formally detect the stationary of time series data. Correlograms are the graphical image of serial correlation data that changes over time. Based on the correlogram, one can get a feeling if the time series is not stationary, which can be verified by formal testing to prove the existence of white noise or a unit root. In the case of nonstationary data, all distributions are non-standard.

The empirical analysis of time series data must display a stationary process assumption. That is, it is recommended to verify the stationary of the time series data before running the model or performing any econometric analysis (Gujarati & Porter, 2009). Spurious regression occurs when variables are nonstationary (Granger & Newbold, 1974). Therefore, further investigation is required to change nonstationary time series data to stationary time series data, i.e. the mean and variance must be steady with time. The significance of the correlation between two points in time relies on the length of lag between two time periods, but not on the time at which correlation is calculated (Gujarati & Porter, 2009). However, relationships among nonstationary variables might be significant but not make economic sense (Wooldridge, 2013). The results obtained will be invalid and misleading.

3.4.2 Testing for unit roots

Nonstationarity occurs when a parameter encompasses a unit root or is I(1) which will lead to an error in statistical inference. Therefore, unit root tests are necessary to ensure that the time series data is steady (Gujarati & Porter, 2009). This will make results valid after achieving stationary. Augmented Dickey-Fuller (ADF) is a commonly applied procedure for screening unit root and it is based on an autoregressive model (AR). The null hypothesis implies nonstationary while the alternative hypothesis implies stationary of the data. Features such as deterministic constant and trend are found in this test.

3.4.3 Stationary testing

The stationary of the transformed series was verified using the Augmented Dickey-Fuller (ADF) test. Both procedures test the null hypothesis of nonstationary as opposed to an alternative of stationary. It can be demonstrated that the traditional assumptions for asymptotic analysis are invalid if the variables are not stationary, meaning the traditional "t-ratios" do not follow a t-distribution; hence, meaningful hypothesis tests cannot be conducted on regression parameters. Moreover, even if two parameters are not connected, a regression of one on the other can have a high R^2 if they are changing over time. The nature of a series, whether stationary or nonstationary, can have a significant impact on its behaviour and features such as the unlimited stress endurance of nonstationary series (Brooks, 2007). As mentioned earlier, stationary can be defined as constant mean, constant variance, and constant covariance. There is no unit root in a stationary series, i.e. *I*(0). The equation, $y_t = \rho y_{t-1} + \varepsilon_t$ is the first order autoregressive process where variable y_t (the value of the time series at time "t") is generated by its own past together with a disturbance term (ε_t).

$y_t = \rho y_{t-1} + \varepsilon_t$ with $|\rho| < 1$…………………………………………… Equation 1

Whilst nonstationary series contains one-unit root that is integrated of order 1 i.e. *I*(1). The series will become stationary after differencing once.

$y_t = \rho y_{t-1} + \varepsilon t$ with $|\rho| = 1$……………………………………………Equation 2

The nonstationary explosive series contains two-unit roots meaning it is integrated of order 2 i.e. *I*(2). The series becomes stationary after differencing twice.

$y_t = \rho y_{t-1} + \varepsilon_t$ with $|\rho| > 1$…………………………………………… Equation 3

The Augmented Dickey-Fuller (ADF) test

The ADF test adds deterministic terms such as trend and intercept, intercept, and no trend and intercept. The hypothesis is as follows:

H_0: $(\rho-1) = 0 \equiv |\rho| = 1 \equiv y_t$ is nonstationary…………………... Equation 4
H_A: $(\rho-1) < 0 \equiv |\rho| < 1 \equiv y_t$ is stationary………………………. Equation 5

Reject H_0 if $\tau < \tau_{crit}$ or $\rho \leq \alpha$ with $\alpha = 0.10$, 0.05 or 0.01 (the significance level). The τ represents the test statistic. If we reject H_0, we will conclude that the series is stationary (and stop testing). We conclude that the series is nonstationary if we fail to reject the null hypothesis. The next step will be to verify if the series is nonstationary $I(1)$, or nonstationary I(2); then difference the series ($\Delta y_t = y_t - y_{t-1}$) and retest; if we reject H_0, we conclude it is nonstationary $I(1)$. If we fail to reject, the series is likely nonstationary $I(2)$, however, we have to difference again and test to confirm (MacKinnon, 1996). After performing the ADF test, and the variables show that they are integrated in the same order, the next step will be a cointegration test.

3.4.4. Testing for cointegration

Engle and Granger (1987) describe cointegration as an econometric concept that is used to discover any possible relationship between economic time series in the long run. Furthermore, cointegration analysis enables the determination of short-run disequilibrium relationships using estimated long-run parameters (Rao, 2016). If variables are cointegrated, it means that they move closer together and the absence of cointegration implies that such variables drift apart from each other; they roam arbitrarily. Cointegration analysis aims to test for a long-run relationship among any two nonstationary time series. In this study, the Johansen cointegration approach is adopted to examine the connection between Botswana and South African maize prices. The procedure will be used to test for cointegration in maize price series for Botswana and South Africa.

The ADF test is used for nonstationary on the residuals of a suspected cointegration equation. Price transmission analysis assesses the influence of prices in one location on prices in another location. The null hypothesis is rejected if the variables are cointegrated, whereas the alternative hypothesis is true if there is a unit root. The following cointegration equation is employed for estimating the long-run relationship between maize price series:

$$\mathbf{Inp_t^{BWPM} = \alpha_0 + \beta_i Inp_t^{RSAM} + \varepsilon_t} \text{..} \textbf{Equation 6}$$

Where:

p_t^{BWPM} is Botswana maize prices (white and yellow maize prices)

p_t^{RSAM} is the South African maize price

β_i is the long run elasticity

ε_t is the error term

A study by Lee (1993) applied the two-step technique like that utilised by Engle-Granger in examining the cointegration relationship between total consumption and disposable income in Japan. The Japanese data used was from January 1961 to April 1987 and investigated whether seasonality in financial gain cointegrates' therewith in consumption. In both the long and short run, the results indicated that total consumption and disposable income are integrated in the same order. Moreover, total consumption and disposable income series are nonstationary with significant variation in the seasonal pattern over time.

Kanioura and Turner (2003) used the same procedure to assess the presence of a cointegration relationship between the United Kingdom (UK) nominal interest rates and the United States of America (USA) nominal interest rates. The study used time series data from February 1977 to December 2002 – the International Monetary Fund (IMF) International Financial Statistics database being the source of their data. The null hypothesis was rejected implying that there was no cointegration between both nominal interest rates of the UK and USA at the 5% level of significance.

Maslyuk and Smyth (2009) examined the cointegration relationship between crude oil spot and futures prices of the same and various categories. The study used daily spot and futures prices from January 1991 to November 2008 – spot prices data was sourced from the Energy Information Administration (EIA). In addition, the futures prices were from Intercontinental Exchange (ICE) and New York Mercantile Exchange (NYMEX). The results indicated the presence of a cointegration relationship between both prices of crude oil of the same and different grades for spot and futures prices.

After estimation of the long-run connection across the sets of log prices, the next step is to employ the evaluation of the residuals (ε_t) for stationary. The Error Correction Model (ECM) can be used to analyse the short-run dynamics of two nonstationary series of the same order that have a long-run connection. Dhungel (2014) used data from 1974 to 2011 to look at the short- and long-run equilibrium between factors like GDP, foreign aid and electricity consumption. The results from ECM indicated the existence of both short- and long-run equilibrium in the system.

Moreover, the study by Davids et al. (2016) used weekly secondary data on white maize prices for the Southern African region. The data period was from November 2011 to December 2015, presented in US dollars. The ECM results showed variability of rates of adjustment on market shocks with error correction terms indicating shocks to be bi-directional. The following vector error correction model will be used in this study:

$$\Delta \boldsymbol{Inp_t^{BWPM}} = \boldsymbol{\alpha_0} + \sum_i^n \boldsymbol{\beta_i} \Delta \boldsymbol{lnp_{t-1}^{RSAM}} + \sum_j^n \boldsymbol{\Theta_j} \Delta \boldsymbol{Inp_{t-j}^{BWPM}} + \boldsymbol{\alpha_1} \overline{\mathcal{E}}_{t-1} + \boldsymbol{\mu_t} \text{......}\textbf{Equation 7}$$

Where:

p_t^{BWPM} is Botswana maize price (white and yellow maize prices respectively)

p_t^{RSAM} is the South African maize price

Δ is the difference operator

$\overline{\mathcal{E}}_{t-1}$ is the error correction term

μ_t is the error term

According to Conforti (2004), the vector error correction model shows the short run adjustment of prices to the long run equilibrium. Thus, it shows the long run relationship which is indicated by a negative and significant error correction term coefficient. In addition, it denotes the speed at which a dependent variable returns to equilibrium after the change in other variables.

3.5 Summary

The empirical findings on commodity markets show that commodity prices can be cointegrated and have long-run relationships. The cointegration and vector error correction models are also applied in this study to provide an analytical tool that analyses the connection between Botswana and South African maize prices and justifies the hedging opportunity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, empirical findings of the cointegration relationship of maize prices in Botswana and South Africa are outlined according to the methods explained in Chapter 3. The data examined are the monthly maize prices from 2008 to 2019. The long-run equilibrium and short-run dynamics findings are discussed here to examine the impact of maize prices. The study discusses the responsiveness of maize prices to shocks. Section 4.2 presents discussions on the summary statistics of maize price series data. Section 4.3 presents results for the unit roots test. Section 4.4 presents the results of the cointegration analysis. The results of the vector error correction model and diagnostic tests are shown in Section 4.5. Finally, sections 4.6 and 4.7 represent the main findings of the value chain and a summary of results and discussions.

4.2. Summary statistics of maize price series data

Table 4.1 presents a summary of descriptive statistics of all the variables for a time series period commencing from 2008 to 2019. There are 144 observations for each variable in this analysis. Table 4.1 depicts that the average monthly price of $BWPWMG1_t$ is 211.75 USD per tonne and $RSAWM_t$ was 210.39 USD per tonne having a small difference of 1.36 USD per tonne. Unlike with $BWPWMG1_t$, the difference between $RSAWM_t$ and $BWPWMG2_t$ was 65.53 USD per tonne. Thus, on average Botswana white maize prices for Grade 1 were slightly higher than South African white maize prices whereas the Botswana white maize prices for Grade 2 are lower than that of South Africa. Furthermore, the yellow maize prices for Botswana, $BWPYMG1_{t,}$ and $BWPYMG2_t$ were less than $RSAYM_t$ on average. The difference between $BWPYMG1_t$ and $RSAYM_t$ was 10.22 USD per tonne whilst for $BWPYMG2_t$ was 72.72 USD per tonne. Botswana had the same maximum monthly price for white and yellow maize Grade 1 for 309.00 USD per tonne and Grade 2 for 216.30 USD per tonne.

Table 4.1: Descriptive statistics for maize prices (USD/tonne) from 2008 to 2019

	$BWPWMG1_t$	**$BWPWMG2_t$**	**$BWPYMG1_t$**	**$BWPYMG2_t$**	**$RSAWM_t$**	**$RSAYM_t$**
Mean	211.75	144.86	208.88	146.38	210.39	219.10
Median	210.99	147.10	201.72	141.21	202.86	218.90
Maximum	309.00	216.30	309.00	216.30	345.31	362.40
Minimum	138.59	14.15	146.91	102.84	143.64	133.82
Std. Dev.	40.32	35.79	38.28	26.60	46.79	55.15
Skewness	0.42	-0.97	0.66	0.68	0.63	0.40
Kurtosis	2.32	5.97	2.71	2.73	2.66	2.19
Jarque-Bera	7.01**	75.30***	11.10***	11.55***	10.23***	7.74***
Observations	144	144	144	144	144	144

***, **and *denote statistical significance at 1%, 5% and 10% levels respectively

Notes: $BWPWMG1_t$: Botswana White Maize Price Grade1, $RSAWM_t$: South Africa White Maize Price
$BWPWMG2_t$: Botswana White Maize Price Grade 2 $RSAYM_t$: South Africa Yellow Maize Price
$BWPYMG1_t$: Botswana Yellow Maize Price Grade 1 $BWPYMG2_t$: Botswana Yellow Maize Price Grade 2

From the time series data, the results depict that none of the series $BWPWMG1_{t,}$ $BWPWMG2_{t,}$ $BWPYMG1_t$, $BWPYMG2_t$, $RSAWM_{t\backslash}$, and $RSAYM_t$ were normally distributed. This is indicated by the positive skewness which is greater than zero for each series except for the $BWPWMG2_t$ series. This could mean that there is an existence of outliers in the variables which makes the model prediction difficult. The $BWPWMG2_t$ series show a negative skewness with a value less than zero. According to Wooldridge (2013), to be symmetric or normally distributed a series must be zero. Positive skewness suggests a long right tail in the distribution, while negative skewness shows a long left tail in the distribution (Wooldridge, 2013). Conversely, the kurtosis of the normal distribution is 3 but the results show that only the $BWPWMG2_t$ series has a peaked distribution and other series have flat distribution relative to the normal.

The Jarque-Bera normality test results indicate that series $BWPWMG1_t$ and $RSAWMG_t$ are significant at 5% whilst $BWPWMG2_t$, $BWPYMG1_t$, $BWPYMG2_{t,}$ and $RSAYM_t$ are significant at 1%. The Jarque-Bera (1980) test's null hypothesis is that the price series is normally distributed. This implies that all the series are not normally distributed, as such the null hypothesis of normal distribution for each series was rejected. The series were transformed into logarithms to stabilise the variance of the series. It helps to establish the extent of maize price swings from 2008 to 2019. Therefore, $BWPWMG1_t$, $BWPWMG2_t$, $BWPYMG1_t$, $BWPYMG2_t$, $RSAWMG_t$, and $RSAYM_t$ series were transformed into $LBWPWMG1_t$, $LBWPWMG2_t$, $LBWPYMG1_t$, $LBWPYMG2_t$, $LRSAWMG_t$, and $LRSAYM_t$, respectively. The descriptive statistics of the transformed variables are presented in Table 4.2.

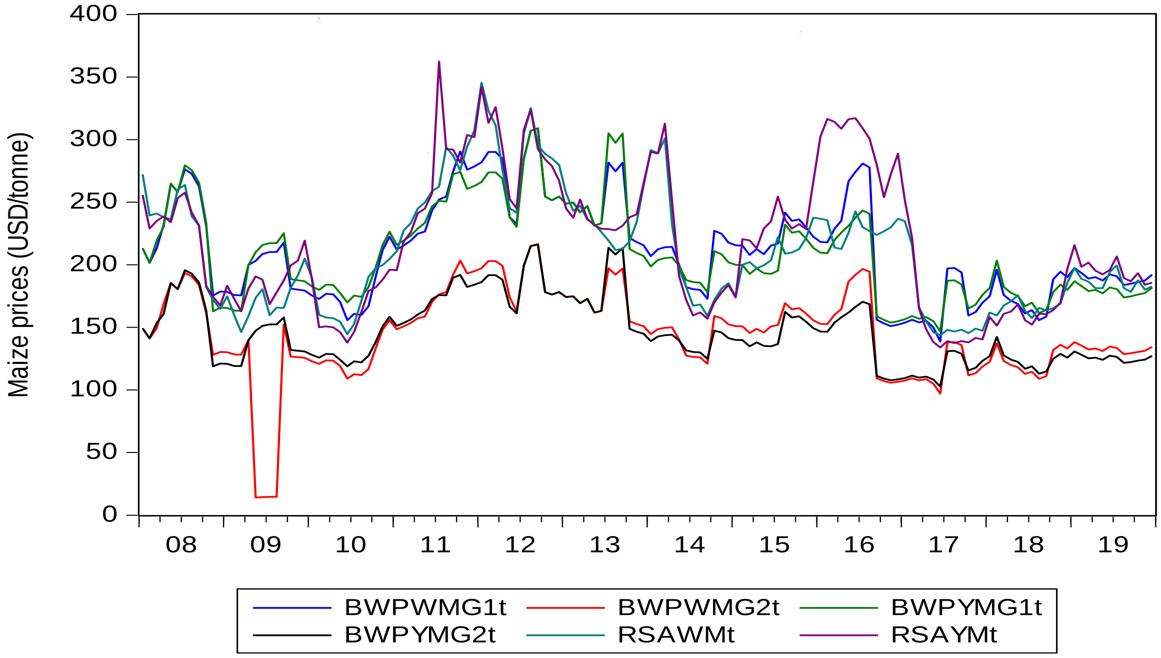

Figure 4.1: Maize monthly prices from 2008 to 2019

Based on Figure 4.1, it is inadequate to conclude stationarity as the figure provides the visual inspection of all the variables. With the expectations drawn from the figure, formal testing can be done to confirm the stationary of the variables.

The price of Grade 2 white and yellow maize in Botswana recorded the lowest prices across the time series with both having the same price from 2012 to 2013. South African white maize prices recorded an increase in prices during 2011 and from 2015 to 2016. Grade 1 white and yellow maize prices started increasing from 2010 until 2012 when prices started declining. The maize prices kept showing an upward and downward trend throughout the time series. According to Manthe-Tsuaneng (2014), Botswana faces a challenge of recurring drought which affects all sectors including agriculture. The impacts of drought were experienced between 2011 and 2013 which adversely affected the already fragile sector and led to poor crop yields (Statistics Botswana, 2015). According to Statistics Botswana (2015), the year 2011 recorded the top fiscal deficits because of natural disasters. In 2011, Botswana recorded the largest total area affected by fire estimated at 15 439 034 hectares, followed by 12 685 235 hectares in 2010 and 11 846 790 hectares in 2008 (Statistics Botswana, 2015).

The Grade 2 white maize price for Botswana experienced decreasing prices during the 2009 period. Botswana like any country was negatively impacted by the recession known as The Great Recession which took place in the late 2000s. Food commodity prices raised sharply across the globe due to an increase in oil prices (BIDPA, 2010). However, BIDPA (2010) states that even though global maize prices rose sharply, maize prices in Southern Africa did not increase. Rather Botswana maize prices remained low as Botswana's main supplier South Africa had an abundant harvest in 2008. Moreover, the dramatic price increase in 2008 due to the global recession led to new development policies to subsidise oil prices which caused a decline in food prices including maize prices in Botswana. BIDPA (2010) continues to state that in 2008, Botswana had a maize surplus harvest which contributed to a sharp decline in maize prices.

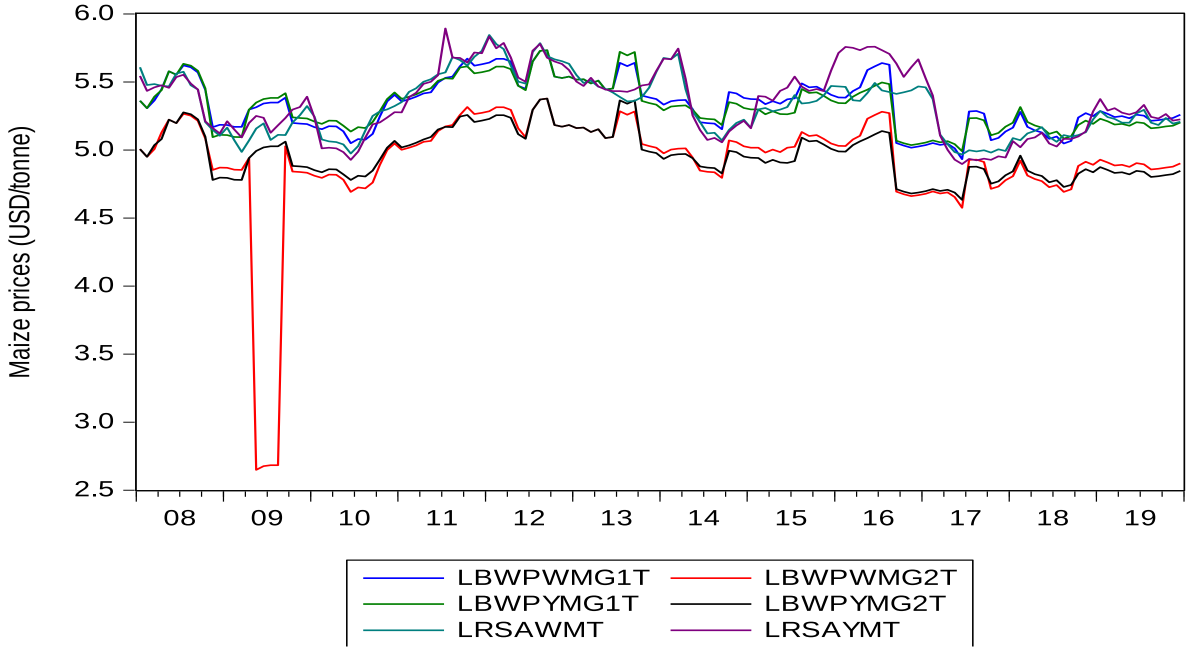

Figure 4.2: Maize monthly prices from 2008 to 2019 transformed into logarithms

The price series shown in Figure 4.2 shows the process of white noise, which suggest the series is stationary. However, formal unit root tests are conducted below to validate the visual inspection of the results.

4.3. Results for unit roots test

Table 4.2 displays the results of the ADF test for unit roots. The results indicate that all the test statistics are statistically insignificant. Furthermore, the null hypothesis stating the variables are nonstationary is not rejected and hence concludes that the variables have a unit root. According to the ADF test results, maize price data in Botswana and South Africa are nonstationary.

Table 4.2: ADF test results

Variable	Lags	Test statistics
$\mathbf{LBWPWMG1_t}$	4	-2.46
$\mathbf{LBWPWMG2_t}$	4	-2.39
$\mathbf{LBWPYMG1_t}$	4	-2.52
$\mathbf{LBWPYMG2_t}$	4	-2.44
$\mathbf{LRSAWM_t}$	4	-2.26
$\mathbf{LRSAYM_t}$	4	-2.53

Notes: ***, **and *denote statistical significance at 1%, 5% and 10% levels respectively

Since the results in Table 4.2 indicate that the maize price series are not stationary, differencing them is vital to determine stationary. Therefore, the ADF test is conducted further in the first difference form and the results are presented in Table 4.3.

Table 4.3: ADF test results in first difference

Variable	Lags	Test statistics
$\mathbf{\Delta LBWPWMG1_t}$	4	-6.36***
$\mathbf{\Delta LBWPWMG2_t}$	4	-7.03***
$\mathbf{\Delta LBWPYMG1_t}$	4	-6.34***
$\mathbf{\Delta LBWPYMG2_t}$	4	-6.32***
$\mathbf{\Delta LRSAWM_t}$	4	-5.68***
$\mathbf{\Delta LRSAYM_t}$	4	-5.53***

Notes: ***, **and *denote statistical significance at 1%, 5% and 10% levels respectively
Δ denotes the first differenced operator.

After differencing the variables in the first difference form, all the variables became stationary implying integration in the order $I(1)$, as presented in Table 4.3. The ADF test shows that all the variables are statistically significant at a 1% level. This means that the null hypothesis of nonstationary is rejected after differencing the variables once. If the unit root test on price series reveals that all variables have been differenced with the same order or are integrated of the same order, then the next step will be to test cointegration. In this study, Johansen's (1988) cointegration approach with full information maximum likelihood was used because it performs better than other estimators (e.g. Engle-Granger's (1987) ordinary least square procedure) (Gonzalo, 1994).

4.4. Results for cointegration analysis

The diagnostic test on the unrestricted Vector Auto-Regressive (VAR) model was used to determine the number of lags for the analysis. The criteria used are AIC, HQIC, and SBIC, respectively. The number of lags identified was 3, 2, 3, and 3 for the $BWPWMG1_t$ - $RSAWM_t$ pair, $BWPWMG2_t$ - $RSAWM_t$ pair, $BWPYMG1_t$ - $RSAYM_t$ pair, and $BWPYMG2_t$ - $RSAYM_t$ pair respectively demonstrated by the selection criteria.

4.4.1 Cointegration test

The cointegration analysis will test the following hypotheses:

H_0: No long-term cointegration exists between variables

H_1: Long-term cointegration exists between variables

Table 4.4 depicts the results of the Johansen test for cointegration between Botswana and South Africa for both yellow and white maize prices and their grades respectively. The null hypothesis of the cointegration test states that there is no cointegration (Wooldridge, 2013). Thus, rejection of the null hypothesis means stationary for the residuals of the cointegrating function, and there is a long-run equilibrium relationship for the spatial prices. The results from the Johansen test for cointegration show that all four pairs of series are cointegrated. Thus, there is a long-run equilibrium relationship between the markets. These findings are consistent with the *priori* expectation. The null hypothesis of no cointegration is rejected, suggesting that Botswana maize prices follow South African maize prices, and they have a long-run equilibrium relationship. This is supported by the findings which state that maize markets in the SADC region and South Africa are highly transmitted (Myers & Jayne, 2012; Rapsomanikis, 2009).

Table 4.4: Results of Johansen tests for cointegration (maize prices)

Variables	Lag	Lag order selection criteria			Johansen test		Conclusion
		AIC	HQIC	SBIC	Trace statistic	5% critical value	
$BWPWMG1_t$ - $RSAWM_t$	3	16.89*	17.01*	17.19*	34.55	15.41	Cointegrated
$BWPWMG2_t$ - $RSAWM_t$	2	17.11*	17.20*	17.33*	23.59	14.07	Cointegrated
$BWPYMG1_t$ - $RSAYM_t$	3	17.52*	17.64*	17.82*	24.05	15.41	Cointegrated
$BWPYMG2_t$ - $RSAYM_t$	3	16.78*	16.90*	17.08*	23.59	15.41	Cointegrated

*Notes: * denotes the lag order selected by the criterion*
AIC: Akaike information criterion SBIC: Schwarz information criterion HQIC: Hannan-Quinn information criterion
$BWPWMG1_t$: Botswana White Maize Price Grade1 $RSAWM_t$: South Africa White Maize Price
$BWPWMG2_t$: Botswana White Maize Price Grade 2 $RSAYM_t$: South Africa Yellow Maize Price
$BWPYMG1_t$: Botswana Yellow Maize Price Grade 1 $BWPYMG2_t$: Botswana Yellow Maize Price Grade 2

Table 4.5: Short-run effects of SA white maize prices on Botswana white maize (Grade1) price

Variable	Coefficient	Std error	Z-statistic	P-value
BWPWMG1t				
BWPWMG1t (L1)	0.89***	0.08	10.75	0.00
BWPWMG1t (L2)	-0.16*	0.08	-1.91	0.06
RSAWMt (L1)	0.37 ***	0.10	3.84	0.00
RSAWMt (L2)	-0.22**	0.09	-2.37	0.02
Constant	25.58***	8.18	3.13	0.00
RSAWMt				
BWPWMG1t (L1)	0.05	0.07	0.77	0.44
BWPWMG1t (L2)	0.05	0.07	0.73	0.47
RSAWMt (L1)	1.19***	0.08	14.55	0.00
RSAWMt (L2)	-0.33***	0.08	-4.15	0.00
Constant	8.46	6.95	1.22	0.22
Number of obs	142			
Log-likelihood	-1191.18			
AIC	16.92			
HQIC	17.00			
SBIC	17.13			

Table 4.5 shows that in the short run, the first lag of $BWPWMG1_t$ has a positive impact on $BWPWMG1_t$ at a significant level of 1% on average ceteris paribus. The second lag of $BWPWMG1_t$ has a negative impact on $BWPWMG1_t$ at a 10% significant level on average *ceteris paribus*. Thus the first and second lags of $BWPWMG1_t$ have asymmetric effects on $BWPWMG1_t$. The first lag of $RSAWM_t$ has a positive impact on $BWPWMG1_t$ at a significant level of 1% on average *ceteris paribus*; whilst the second lag of $RSAWM_t$ has a negative impact on $BWPWMG1_t$ at a significant level of 5% on average *ceteris paribus*. In addition, the first and second lag of $RSAWM_t$ have asymmetric effects on $RSAWM_t$ at a 1% significant level *ceteris paribus*.

However, the first and second lags of $BWPWMG1_t$ do not have any significant impact on $RSAWM_t$. South Africa influences Grade 1 maize prices in Botswana. This is expected as South Africa is a net exporter of maize to Botswana. Botswana does not influence maize prices in South Africa as it is not the main player in larger maize production output in SADC. This is supported by findings Chimaliro (2018) where the author stated that South African soyabean prices have an impact on the changes in Malawian soyabean prices in the short run. This is because South Africa has an oversupply of both maize and soyabean commodities than Botswana and Malawi. Oversupply of maize in South Africa presents the country with the opportunity to export maize to other countries which hold their prices stable (Grain SA, 2018).

Even though there are several international regulations, such as import tariffs, Botswana maize farmers and middlemen can benefit from this by hedging against price changes on the JSE SAFEX platform as maize prices in South Africa can be stable.

Table 4.6 shows that in the short run, the first lag of $RSAWM_t$ has a positive impact on $BWPWMG2_t$ at a significant level of 1% on average *ceteris paribus*; whilst the second lag of $RSAWM_t$ does not have a significant impact on $BWPWMG2_t$ on average *ceteris paribus*. In the short run, the first lag of $BWPWMG2_t$ has a positive impact on $BWPWMG2_t$ at a 1% significant level *ceteris paribus*.

Table 4.6: Short-run effects of SA white maize prices on Botswana white maize (Grade2) price

Variable	Coefficient	Std error	Z-statistic	P- value
BWPWMG2t				
BWPWMG2t (L1)	0.78***	0.08	9.27	0.00
BWPWMG2t (L2)	-0.09	0.08	-1.11	0.27
RSAWMt (L1)	0.27***	0.10	2.66	0.00
RSAWMt (L2)	-0.11	0.99	-1.14	0.26
Constant	13.54*	7.72	1.75	0.08
RSAWMt				
BWPWMG2t (L1)	0.07	0.07	1.10	0.27
BWPWMG2t (L2)	0.03	0.07	0.49	0.62
RSAWMt (L1)	1.19	0.07	1.10	0.27
RSAWMt (L2)	-0.32***	0.07	-4.15	0.00
Constant	12.72**	6.13	2.08	0.04
Number of obs	142			
Log-likelihood	-1203.08			
AIC	17.09			
HQIC	17.17			
SBIC	17.29			

In addition, $BWPWMG2_t$ does not have any significance on $RSAWM_t$ for both lags. Thus South African white maize prices have a significant impact on Botswana whilst Botswana does not influence South African white maize prices for Grade 2.

Table 4.7: Short-run effects of SA yellow maize prices on Botswana yellow maize (G1) price

Variable	Coefficient	Std error	Z-statistic	P value
BWPYMG1t				
BWPYMG1t (L1)	0.94***	0.09	10.97	0.00
BWPYMG1t (L2)	-0.09	0.12	-0.75	0.45
BWPYMG1t (L3)	-0.05	0.09	-0.57	0.57
RSAYMt (L1)	0.18**	0.07	2.50	0.01
RSAYMt (L2)	-0.12	0.10	-1.15	0.25
RSAYMt (L3)	-0.01	0.07	-0.08	0.93
Constant	28.02***	8.67	3.23	0.00
RSAYMt				
BWPYMG1t (L1)	0.16*	0.10	1.66	0.09
BWPYMG1t (L2)	-0.30**	0.13	-2.24	0.03
BWPYMG1t (L3)	0.30***	0.10	3.06	0.00
RSAYMt (L1)	1.00***	0.08	11.99	0.00
RSAYMt (L2)	-0.05	0.12	-0.47	0.64
RSAYMt (L3)	-0.11	0.08	-1.28	0.20
Constant	0.75	9.96	0.07	0.94
Number of obs	141			
Log-likelihood	-1220.85			
AIC	17.52			
HQIC	17.63			
SBIC	17.81			

Table 4.7 shows that in the short run, the first lag of $BWPYMG1_t$ has a positive impact on $BWPYMG1_t$ at a 1% significant level on average *ceteris paribus*. The first lag of $RSAYM_t$ has a positive impact on $BWPYMG1_t$ at a significant level of 5% on average *ceteris paribus* in the short run; whilst the second and third lag of $RSAYM_t$ do not have a significant impact negative impact on $BWPYMG1_t$ on average *ceteris paribus*. $BWPYMG1_t$ has a significant impact on $RSAYM_t$ for both the first and third lags at significant levels of 10% and 1% respectively on average *ceteris paribus*; while the second lag of $BWPYMG1_t$ has a negative impact on $RSAYM_t$ on average *ceteris paribus* at a 5% significant level. The first lag of $RSAYM_t$ has a positive impact on $RSAYM_t$ at a 1% significant level on average *ceteris paribus*. The results indicate that both yellow maize prices from these two countries influence each other.

Table 4.8: Short-run effects of SA yellow maize prices on Botswana yellow maize (G2) price

Variable	Coefficient	Std error	Z-statistic	P value
BWPYWMG2t				
BWPYMG2t (L1)	0.94***	0.09	10.97	0.00
BWPYMG2t (L2)	-0.08	0.12	-0.74	0.46
BWPYMG2t (L3)	-0.04	0.09	-0.52	0.61
RSAYMt (L1)	0.13**	0.05	2.50	0.01
RSAYMt (L2)	-0.08	0.07	-1.20	0.23
RSAYMt (L3)	-0.00	0.05	-0.04	0.97
Constant	19.20***	6.03	3.18	0.00
RSAYMt				
BWPYMG2t (L1)	0.23	0.14	1.64	0.10
BWPYMG2t (L2)	-0.43**	0.20	-2.24	0.03
BWPYMG2t (L3)	0.43***	0.14	3.06	0.00
RSAYMt (L1)	0.99***	0.08	12.00	0.00
RSAYMt (L2)	-0.06	0.12	-0.48	0.63
RSAYMt (L3)	-0.11	0.08	-1.28	0.20
Constant	0.53	10.04	0.05	0.96
Number of obs	141			
Log-likelihood	-1168.78			
AIC	16.78			
HQIC	16.90			
SBIC	17.07			

Table 4.8 shows that in the short run, the first lag of $BWPYMG2_t$ has a positive impact on $BWPYMG2_t$ at a 1% significant level on average *ceteris paribus*. The first lag of $RSAYM_t$ has a positive impact on $BWPYMG2_t$ at a significant level of 5% on average *ceteris paribus* in the short run. The impact on the second and third lags of $RSAYM_t$ do not have any significant impact on $BWPYMG2_t$. The first lag of $BWPYMG2_t$ does not have any significant impact on $RSAYM_t$ on average *ceteris paribus*; whilst the second lag of $BWPYMG2_t$ has a negative impact and the third lag has a positive impact on $RSAYM_t$ at a significant level of 5% and 1% respectively on average *ceteris paribus*. The first lag of $RSAYM_t$ has a positive impact on $RSAYM_t$ at a 1% significant level on average *ceteris paribus*. The results point out that when it comes to white maize, South Africa positively influences prices of white maize prices for grades 1 and 2 in Botswana but Botswana does not influence white maize prices in South Africa. However, yellow maize prices are the opposite. Botswana influences maize prices in South Africa and South Africa influences yellow maize prices in Botswana.

4.5 Error correction model for price transmission

Since the long-run relationship between the pairs is established, the next step will be analysing the long-run effects and speed of adjustment to examine how maize prices respond to shocks in the long run. The results of the ECM models for the different pairs of series are presented and discussed below. It is important to mention that the long-run coefficients are the equilibrium relationship between the series. The ECM coefficients from the results suggest that short run changes between the variables in the short run result into stable long run relationship of the variables.

Table 4.9: Long-run effects of SA white maize prices on Botswana white maize (Grade1) price

Variable	Coefficient	Std error	Z-statistic	P value
DBWPWMG1t				
Adjust_coeff.	-0.24***	0.06	-4.05	0.00
BWPWMG1t (LD)	0.15*	0.08	1.73	0.08
RSAWMt (LD)	0.21**	0.10	2.12	0.03
Constant	-0.07	1.52	-0.04	0.97
DRSAWMt				
Adjust_coeff.	0.13**	0.05	2.54	0.01
BWPWMG1t (LD)	-0.06	0.07	-0.88	0.38
RSAWMt (LD)	0.31***	0.08	3.77	0.00
Constant	-0.12	1.30	-0.09	0.93
Johansen normalisation restriction imposed				
DBWPWMG1t				
RSAWMt	0.77***	0.10	7.55	0.00
Number of obs	142			
Log-likelihood	-1194.78			
AIC	16.95			
HQIC	17.03			
SBIC	17.14			
LM-test	7.56 (P= 0.11)			
Jarque-Bera test	673.51 (P=0.00)			
Eigenvalue	1			
Modulus	1			

The results in Table 4.9 show that $RSAWM_t$ has a positive impact on $BWPWMG1_{t,}$ and the coefficient is statistically significant at the 1% level. The adjustment term is -0.24 and is statistically significant at a 1% level, suggesting that the previous year's errors or deviation from the run long-run equilibrium are corrected for within the current year at a convergence speed of 24% within a month in the Botswana market. From the Johansen normalisation restriction-imposed results, it is evident that South African white maize prices ($RSAWM_t$) have a positive impact on $BWPWMG1_t$ in the long run. This is shown by the significant coefficient of 0.77 and significant at 1%. The adjustment term is 0.13 and is statistically significant at a 5% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 13% within a month in the South African market. After running the diagnostic tests, the results show that there is no serial correlation, there are no disturbances as the results indicate that the series is normally distributed, and the model is stable.

Table 4.10: Long-run effects of SA white maize prices on Botswana white maize (Grade2) price

Variable	Coefficient	Std error	Z-statistic	P value
DBWPWMG2t				
Adjust_coeff.	-0.29***	0.07	-4.49	0.00
BWPWMG2t (LD)	0.08	0.09	0.95	0.34
RSAWMt (LD)	0.10	0.10	0.95	0.34
Constant	-0.07	1.62	-0.05	0.96
DRSAWMt				
Adjust_coeff.	0.13**	0.05	2.55	0.01
BWPWMG2t (LD)	-0.05	0.07	-0.69	0.49
RSAWMt (LD)	0.31***	0.08	3.78	0.00
Constant	-0.16	1.30	-0.12	0.90
Johansen normalisation restriction imposed				
DBWPWMG2t				
RSAWMt	0.66***	0.10	6.71	0.00
Number of obs	142			
Log-likelihood	-1206.46			
AIC	17.12			
HQIC	17.20			
SBIC	17.31			
LM-test	2.82(P= 0.59)			
Jarque-Bera test	1948.55 (P=0.00)			
Eigenvalue	1			
Modulus	1			

In the long run, $RSAWM_t$ has a positive impact on $BWPWMG2_t$, and the coefficient is statistically significant at the 1% level. The adjustment term is -0.29 and is statistically significant at a 1% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 29% within a month in Botswana. From the Johansen normalisation restriction-imposed results, it is evident that South African white maize prices (RSAWMt) have a positive impact on $BWPWMG2_t$ in the long run. This is shown by the significant coefficient of 0.66 and significant at 1%. The adjustment term is 0.13 is statistically significant at a 5% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 13% within a month in the South African market. There is no autocorrelation, the errors are normally distributed, and the model is showing stability.

Table 4.11: Long-run effects of SA yellow maize prices on Botswana yellow maize (Grade1) price

Variable	Coefficient	Std error	Z-statistic	P value
DBWPYMG1t				
Adjust_coeff.	-0.17***	0.05	-3.28	0.00
BWPYMG1t (LD)	0.13	0.09	1.45	0.15
RSAYMt (LD)	0.09	0.07	1.37	0.17
Constant	-0.14	1.50	-0.09	0.93
DRSAYMt				
Adjust_coeff.	0.12*	0.06	1.90	0.06
BWPYMG1t (LD)	0.03	0.10	0.26	0.80
RSAYMt (LD)	0.09	0.09	1.08	0.28
Constant	-0.20	1.78	-0.11	0.91
Johansen normalisation restriction imposed				
DBWPYMG1t				
RSAYMt	0.54***	0.12	4.43	0.00
Number of obs	142			
Log-likelihood	-1238.10			
AIC	17.57			
HQIC	17.64			
SBIC	17.75			
LM-test	9.30 (P=0.05)			
Jarque-Bera test	518.93(P=0.00)			
Eigenvalue	1			
Modulus	1			

In the long run, $RSAYM_t$ has a positive impact on $BWPYMG1_t$, and the coefficient is statistically significant at the 1% level. The adjustment term is -0.17 and is statistically significant at the 1% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 17%. From the Johansen normalisation restriction-imposed results, it is evident that South African yellow maize prices (RSAYMt) have a positive impact on $BWPWYG1_t$ in the long run. This is shown by the significant coefficient of 0.54 and significant at 1%. The adjustment term is 0.12 is statistically significant at a 5% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 12% within a month in the South African market. After running the diagnostic tests, the results show that there is no serial correlation, there are no disturbances as the results indicate that the series is normally distributed, and the model is stable.

Table 4.12: Long-run effects of SA yellow maize prices on Botswana yellow maize (Grade2) price

Variable	Coefficient	Std error	Z-statistic	P value
DBWPYMG2t				
Adjust_coeff.	-0.17***	0.05	-3.21	0.00
BWPYMG2t (LD)	0.12	0.09	1.37	0.17
RSAYMt (LD)	0.07	0.05	1.39	0.16
Constant	-0.15	1.03	-0.14	0.89
DRSAYMt				
Adjust_coeff.	0.17*	0.09	1.92	0.06
BWPYMG2t (LD)	0.04	0.15	0.26	0.80
RSAYMt (LD)	0.09	0.09	1.08	0.28
Constant	-0.14	1.78	-0.08	0.94
Johansen normalisation restriction imposed				
Adjust_coeff.				
RSAYMt	0.38***	0.09	4.40	0.00
Number of obs	142			
Log-likelihood	-1185.60			
AIC	16.83			
HQIC	16.90			
SBIC	17.01			
LM-test	9.37 (P=0.05)			
Jarque-Bera test	550.60 (P=0.00)			
Eigenvalue	1			

Modulus	1

In the long run, $RSAYM_t$ has a positive impact on $BWPYMG2_{t,}$ and the coefficient is statistically significant at the 1% level. The adjustment term is -0.17 and is statistically significant at the 1% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 17%. From the Johansen normalisation restriction-imposed results, it is evident that South African yellow maize prices (RSAYMt) have a positive impact on $BWPYMG2_t$ in the long run. This is shown by the significant coefficient of 0.38 and significant at 1%. The adjustment term is 0.17 is statistically significant at a 5% level, suggesting that the previous year's errors or deviation from the long-run equilibrium are corrected for within the current year at a convergence speed of 17% within a month in the South African market. After running the diagnostic tests, the results show that there is no serial correlation, and there are no disturbances as the results indicate that the series is normally distributed and the model is stable.

4.6 Value chain analysis

Cointegration relationship between maize in Botswana and South Africa has been established together with the long-run equilibrium relationship and short-run dynamics. This prompted the assessment of Botswana's maize value chain. The study assesses the Botswana maize value chain to understand the relationship among actors within the chain. The study discusses the findings on the opportunities and challenges that the Botswana maize value chain faces. This will help in understanding how Botswana's maize sector operates as well as give insights about its performance and how it can be improved so that Botswana can be food sufficient. For this section, the relationship between middlemen and smallholder farmers was explored using the Agency and Social Network theories. It was found that it is the most affected link in the Botswana maize value chain. The main findings of the relationship discuss the opportunities and challenges within the chain.

4.6.1. Opportunities within Botswana maize value chain

There is high demand for yellow maize in Botswana where it can be successfully grown in Chobe Enclave, Pandamatenga, Southern Ngwaketse areas, and Barolong farms (BAMB, 2017). These places offer a lower cost relative to other parts of Botswana which can promote investment and monitoring in linkages involving the maize supply chain. Yellow maize demand opens a market for animal feed usage which can be profitable for maize farmers as Botswana is known for its high-quality beef produce.

Moreover, the formation of cooperatives can benefit maize farmers in Botswana. The reform will catalyse marketing and financial cooperatives which will enable maize farmers to have better bargaining power, and access to credit, training, and information, hence promoting the performance of Botswana's maize sector and its linkages within it. Moreover, there will be a reduction of transaction costs bared by all stakeholders within the chain. It will be cheaper to access market information and buying of inputs as a group than individually.

There is an opportunity to formalise the maize sector in Botswana which will stimulate agro-processing activities that will improve the chain. The industrial use of maize in Botswana can stimulate production as more farmers will venture into growing this crop and increase yield. Botswana imports most of its processed maize products from South Africa which creates a gap that can be filled and create market opportunities for commercial maize production. There is a demand for maize processed and packaged convenience foods.

The informal maize sector in Botswana should be strengthened as it plays a major role. The formation of associations, maize unions, or clustering that can advocate for stakeholders in this sector can assist in improving the chain. This will aid the inflow of product and market information amongst the players, being farmers and hawkers. Moreover, this can promote a link or relationship between formal and informal sectors enabling farmers and middlemen to have trust in each other. As a result, access to information, coordination, and monitoring of maize grades and standards will be easy.

Maize-specific programmes and policies should be implemented in Botswana to stimulate the production and development of the maize value chain. These policies can encourage the flow and trade of maize across the country.

4.6.2 Challenges within Botswana maize value chain

The Botswana maize supply chain faces numerous challenges that limit the performance of the chain and its competitiveness. The qualitative results are presented here using the data obtained through the key informant interview technique. The local experts were interviewed for data collection to gain general insights as well as an expert opinion into the structure of the Botswana maize value chain. The challenges are related to poor coordination, a mismatch between demand and supply due to variation in production levels, poor maize quality, inadequate access to financing facilities, and lack of physical infrastructure.

Poor coordination: Information asymmetry within the maize supply chain causes coordination problems faced in this chain. As maize is grown across the nation it is difficult to manage and monitor the chain without the proper establishment of cooperatives or associations. There is a lack of communication or inadequate information related to price, quality and safety standards, and market information. Moreover, information asymmetry results in opportunistic behaviours among farmers, hawkers, and processors. This is exacerbated by the absence of farmer cooperatives and the seasonal nature of the middlemen. The lack of or withholding of information among the actors creates suspicion and mistrust. This makes it hard for the middlemen and the smallholder farmers to cooperate and coordinate business transactions, affecting the overall performance of the supply chain.

A case in point is that the middlemen do not trust the quality of grains that the farmers offer, and thus they set a lower price for the grains to cater to the costs of processing and improving quality. On the other hand, the farmer believes he or she will be paid lower prices for the grains and therefore adulterates the product by not drying properly, harvesting prematurely, and poorly storing the grains. This translates into higher transaction costs and a decline in the performance of the supply chain.

The chain is also clouded by casual or informal maize exchanges which shadow its scope. This can be ascribed to poor government regulation of the supply chain, which makes it difficult to register all transactions, especially within the informal sector. Consequently, it is difficult to project with accuracy the actual production and demands. For example, more farmers may be drawn into maize enterprise in the new season if farmers benefited from the high grain prices from the previous year, which might drive the prices down for the upcoming season.

Lack of commercial scale: Most of the farmers produce maize on a small scale and are unable to meet the demands of processing firms, and national and export markets; consequently, justifying the role of the middlemen who come as aggregators to collect bulk and do preliminary value addition. Through this, economies of scale necessary to meet the demands of the domestic and export markets are realised. Associated with the production scale is also the maize price dilemma at the farm gate. The prices at the farm-gate are too low to incentivise farmers to produce maize on large scale. Similarly, maize price fluctuations discourage smallholder farmers from venturing into commercial maize production.

Poor grain quality: The poor quality of maize is due to poor post-harvest handling, inadequate storage facilities, and inadequate or no processing facilities. Even though BOBS has established national maize standards, there is still a challenge in monitoring the maize quality. Thus, birthing opportunistic behaviour within the chain by actors. This is due to insufficient information sharing and/or poor information flow across the chain.

Lack of physical infrastructure: Transportation networks such as road and rail are essential for transporting maize within and outside the country. Therefore, poor and lack of physical infrastructure can lead to high transaction costs. Similarly, transporting maize across the country can be challenging, delaying the product, and not being cost-effective.

4.7 Summary of results and discussions

In conclusion, the Vector Correction Model results indicate that maize prices for both yellow and white in South Africa positively influence maize prices in the long run in Botswana. It was found that the speed of adjustment was very low ranging from 17% being the lowest to 29% being the highest. Botswana maize prices do not respond quickly to maize price changes in South Africa. This is because the government subsidises prices to reduce the impact on the local market and regulate import permits. Through BAMB, the government sets maize prices which does not reflect immediately on Botswana markets when changes happen in South African market as decisions has to be made by the board. Thus, this process takes sometime hence delay in responses. An individual is to be only allowed to acquire a certain amount of grain outside and top up with the local produce to meet his or her target.

The procurement rule is that one must have 30% of locally produced maize grain before an import permit is issued (Issuance of Permits for Dried Grains | Government of Botswana, 2022). The coefficients of South African maize prices for both yellow and white were all positive and statistically significant at 1% in the long run. However, in the short run, maize prices in Botswana are not affected by the changes in South African maize prices. Diagnostic tests were done to validate the accuracy of the models used in this study. The study proved that there is no serial correlation – residuals are normally distributed and the models are stable. Thus, the estimators are efficient and there is unbiasedness of standard errors and no misleading results.

Moreover, the informal maize sector plays a crucial role in the maize market in Botswana which can help eliminate issues of mistrust and opportunistic behaviour if it is strengthened. This can help regulate the chain and improve the relationships within the chain.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

This chapter summarizes the outcomes of the objectives and hypotheses. Subsequently, it describes the methods used, discusses the main findings of the study, and derives conclusions. Recommendations and limitations of the study are also presented in this chapter.

It is noted that maize is one of the most consumed cereal crops in Botswana and its supply chain is still mostly informal and not well regulated. The study analysed the maize value chain and found that it is characterised by an array of challenges including agency problems such as opportunism, inadequate financing options, poor coordination, lack of commercial scale, and poor-quality grains. The relationship between middlemen and the small farmers is characterised by high levels of mistrust and inadequate information sharing. The lack of farmer cooperatives in the maize supply chain makes these challenges worse. Considering the crucial roles that the middlemen perform, eliminating them from the chain completely is not feasible and could potentially affect overall supply chain performance. Therefore, the solution is to seek ways or opportunities for improving the relationship between these two actors in the supply chain and revive cooperatives specifically targeting the maize supply chain, and reform policy to enact, communicate and effectively enforce the policies to enhance compliance and improve quality, as potential solutions.

The study revealed that Botswana imports most of its maize from South Africa as about 90% of Botswana's maize demand comes from South Africa. It was revealed by some studies that agricultural maize markets are impacted by the world agricultural commodity prices. BAMB is the main player in setting maize prices in Botswana. The Johansen test for cointegration technique was used to estimate the long-run relationship between maize prices in Botswana and South Africa. The maize prices were divided into four pairs which noted the existence of a long-run equilibrium relationship among the pairs. Secondary data was used from 2008 to 2019 to examine the relationship between maize prices in Botswana and South Africa. The study conducted a unit roots test on maize price series using the ADF test. The study found that prices became stationary in first difference $I(1)$ and statistically significant at 1%. The empirical results from the Johansen Cointegration approach indicate the presence of cointegration in maize markets. The existence of a long-run equilibrium relationship was established between maize markets in Botswana and South Africa. In the short run, the first lags of Botswana maize prices and South African maize prices have a positive impact and are statistically significant at 1% on average *ceteris paribus* on each other. Moreover, in the long run, South African white and yellow maize prices have a positive impact on white and yellow maize prices in Botswana.

The speed of convergence ranged from 17% to 29% in Botswana whilst in South Africa from 12% to 17% and the Vector Error Correction Model (VECM) was carried out to evaluate the long-run and short-run relationships between the cointegrated pairs. The error correction term had a negative sign ranging from -0.54 to -0.77 and was highly significant. The presence of cointegration affirms that Botswana and South African maize prices have a long-run equilibrium relationship. Therefore, hedging opportunities exist for Botswana maize farmers as an effective price risk management strategy. Thus, farmers can adopt the SAFEX hedging mechanism to manage price risk and have the opportunity to increase their profits. The findings from Dana et al. (2006) in the SADC region state that hedging reduces average import costs and cost variability.

5.2. Conclusion

The purpose of this study is to explore the essence of integration between Botswana and South African maize prices. Botswana maize prices have been more volatile over the years. The study concludes that changes in South African maize prices significantly impact maize prices in Botswana. It is observed that South African white maize prices have a significant asymmetric effect on Botswana white maize prices in the short run. This proves that Botswana maize prices are not positively and significantly affected by South African maize prices in the short run. Moreover, Botswana's yellow maize prices are positively and significantly affected by South African yellow maize prices in the short run. However, in the long run, changes in the South African maize market positively affect the Botswana maize market. Thus, both Botswana's yellow and white maize prices are positively and statistically affected by South African maize prices in the long run. Therefore, SAFEX can be used as a risk management tool to guard against maize price fluctuations. The study also concludes that the Botswana maize market does not respond quickly to price changes in the South African maize market.

5.3. Recommendations

The study concluded that Botswana maize markets are significantly influenced by maize prices in the South African maize market. Therefore, the study recommends that the involvement of the Botswana Agricultural Marketing Board in setting maize prices and the import procurement level be minimised to allow a free flow of price transmission in Botswana. Thus, reducing the maize import procurement level will help enhance the maize price transmission relationship between Botswana and South Africa. Actors within the maize value chain must be allowed to import maize directly from South Africa without a struggle to aid in food security.

There is a need to revive the cooperatives to improve the farmers' negotiation power. Cooperatives further invest in the training and education of their members on issues related to established quality standards, market information, and providing access to quality inputs. This helps farmers to achieve better quality maize required by premium markets. The coordination challenges are also addressed as farmers are centrally organised and only operate through cooperatives. For example, if they all market their grains through cooperatives and opportunistic behaviour attracts punishment while good behaviour earns rewards, coordination challenges can be minimised or eliminated. Therefore, farmers are encouraged to join and/or form cooperatives.

Contract farming is encouraged amongst farmers and middlemen in the maize supply chain to build trust and discourage opportunistic behaviour. For this to be effective there must be mechanisms to enforce stringent adherence to the terms and conditions of a contract and properly defined property rights. To this end, parties that violate contracts must be prosecuted in the courts of law.

5.3 Future research

The study suggests further research on price relationships inclusive of transaction costs to account for various places in Botswana. Furthermore, this will be a starting point in understanding the hedging effectiveness across all the relevant actors within the Botswana maize value chain. Furthermore, it is recommended that detailed full qualitative research on the maize value chain be conducted to gather all the information needed to strengthen the maize sector in Botswana which will prompt the conduct of quantitative studies.

5.4. Limitation of the study

During this study, some challenges were encountered such as difficulty in accessing up-to-date information on most of the organisation's websites. Undated reports are the only ones that can be accessed on the website. This may be due to the absence of updated data and/or restricted data. As a result, the author decided to adopt related studies conducted in neighbouring countries and other supply chains with similar characteristics. In addition, annual and project reports from national and international development partners were used to collate information.

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APPENDICES

Appendix 1: Results for unit root test ($BWPWMG1_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   139

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-2.458	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1260

Appendix 2: Results for unit root test ($BWPWMG2_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   139

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-2.389	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1449

Appendix 3: Results for unit root test ($BWPYMG1_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   139

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-2.516	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1116

Appendix 4: Results for unit root test ($BWPYMG2_t$)

Augmented Dickey-Fuller test for unit root Number of obs = 139

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.442	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1302

Appendix 5: Results for unit root test ($RSAWM_t$)

Augmented Dickey-Fuller test for unit root Number of obs = 139

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.258	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1859

Appendix 6: Results for unit root test ($RSAYM_t$)

Augmented Dickey-Fuller test for unit root Number of obs = 139

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.526	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.1092

Appendix 7: Results for unit root test in first difference ($BWPWMG1_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-6.363	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 8: Results for unit root test in first difference ($BWPWMG2_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-7.029	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 9: Results for unit root test in first difference ($BWPYMG1_t$)

Augmented Dickey-Fuller test for unit root   Number of obs   =   138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-6.338	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 10: Results for unit root test in first difference ($BWPYMG2_t$)

Augmented Dickey-Fuller test for unit root   Number of obs = 138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-6.319	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 11: Results for unit root test in first difference ($RSAWM_t$)

Augmented Dickey-Fuller test for unit root   Number of obs = 138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.677	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 12: Results for unit root test in first difference ($RSAYM_t$)

Augmented Dickey-Fuller test for unit root   Number of obs = 138

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.526	-3.497	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

Appendix 13: Lag selection criteria ($BWPWMG1_t$ $RSAWM_t$)

Selection-order criteria
Sample: 2008m9 - 2019m12 Number of obs = 136

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1355.38				1.6e+06	19.9614	19.9789	20.0043
1	-1153.23	404.3	4	0.000	86832.9	17.0475	17.0997	17.176
2	-1140.45	25.562	4	0.000	76317.9	16.9184	17.0054*	17.1325*
3	-1134.4	12.099*	4	0.017	74060.3*	16.8882*	17.0101	17.188
4	-1132.51	3.7773	4	0.437	76411.6	16.9193	17.0759	17.3048
5	-1130.17	4.6826	4	0.321	78323.6	16.9436	17.1351	17.4148
6	-1126.45	7.4272	4	0.115	78690.5	16.9479	17.1741	17.5047
7	-1122.02	8.8621	4	0.065	78242.7	16.9415	17.2026	17.584
8	-1119.75	4.5407	4	0.338	80324.8	16.967	17.2629	17.6951

Endogenous: BWPWMG1t RSAWMt
Exogenous: _cons

Note: The Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwartz information criterion (SBIC) are used as the lag selection criteria for the model.

Appendix 14: Lag selection criteria ($BWPWMG2_t$ $RSAWM_t$)

Selection-order criteria
Sample: 2008m9 - 2019m12 Number of obs = 136

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1355.58				1.6e+06	19.9645	19.9819	20.0073
1	-1163.31	384.56	4	0.000	100704	17.1957	17.2479	17.3242*
2	-1153.78	19.058	4	0.001	92844.8*	17.1144*	17.2014*	17.3285
3	-1151.66	4.2355	4	0.375	95461.7	17.1421	17.2639	17.4419
4	-1149.69	3.9424	4	0.414	98372.9	17.1719	17.3285	17.5574
5	-1144.14	11.094*	4	0.026	96190.7	17.1491	17.3406	17.6203
6	-1140.72	6.8332	4	0.145	97064.4	17.1577	17.384	17.7145
7	-1138.02	5.412	4	0.248	98991.7	17.1767	17.4378	17.8192
8	-1133.52	8.9993	4	0.061	98348.2	17.1694	17.4653	17.8976

Endogenous: BWPWMG2t RSAWMt
Exogenous: _cons

Note: The Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwartz information criterion (SBIC) are used as the lag selection criteria for the model.

Appendix 15: Lag selection criteria ($BWPYMG1_t$ $RSAYM_t$)

Selection-order criteria
Sample: 2008m9 - 2019m12 Number of obs = 136

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1390.64				2.7e+06	20.48	20.4974	20.5228
1	-1187.06	407.15	4	0.000	142810	17.545	17.5972*	17.6735*
2	-1183.15	7.8279	4	0.098	142999	17.5463	17.6333	17.7604
3	-1177.51	11.279	4	0.024	139608*	17.5222*	17.644	17.822
4	-1175.95	3.1122	4	0.539	144746	17.5581	17.7148	17.9436
5	-1174.02	3.8584	4	0.426	149270	17.5886	17.78	18.0597
6	-1172.22	3.612	4	0.461	154236	17.6208	17.8471	18.1777
7	-1165.9	12.628*	4	0.013	149170	17.5868	17.8479	18.2293
8	-1164.23	3.347	4	0.502	154490	17.621	17.9169	18.3492

Endogenous: BWPYMG1t RSAYMt
Exogenous: _cons

Note: The Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwartz information criterion (SBIC) are used as the lag selection criteria for the model.

Appendix 16: Lag selection criteria ($BWPYMG2_t$ $RSAYM_t$)

Selection-order criteria
Sample: 2008m9 - 2019m12 Number of obs = 136

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1341.27				1.3e+06	19.754	19.7714	19.7968
1	-1136.55	409.44	4	0.000	67950.1	16.8023	16.8545*	16.9308*
2	-1132.73	7.6525	4	0.105	68127.5	16.8048	16.8919	17.019
3	-1127.15	11.151	4	0.025	66574.8*	16.7817*	16.9035	17.0815
4	-1125.43	3.4385	4	0.487	68859.8	16.8152	16.9719	17.2007
5	-1123.48	3.9146	4	0.418	70982.5	16.8452	17.0367	17.3164
6	-1121.72	3.5195	4	0.475	73393.9	16.8782	17.1045	17.435
7	-1115.42	12.595*	4	0.013	71000.3	16.8444	17.1055	17.4869
8	-1113.63	3.583	4	0.465	73404.8	16.8769	17.1728	17.605

Endogenous: BWPYMG2t RSAYMt
Exogenous: _cons

Note: The Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwartz information criterion (SBIC) are used as the lag selection criteria for the model.

Appendix 17: Short-run effects results ($BWPWMG1_t$ $RSAWM_t$)

```
Vector autoregression

Sample:  2008m3 - 2019m12                       Number of obs     =        142
Log likelihood =  -1191.177                     AIC               =   16.91798
FPE            =   76289.25                     HQIC              =   17.00257
Det(Sigma_ml)  =    66262.8                     SBIC              =   17.12614
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
BWPWMG1t	5	17.9268	0.8105	607.2952	0.0000
RSAWMt	5	15.2346	0.8969	1235.025	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
BWPWMG1t						
BWPWMG1t						
L1.	.8949511	.0832637	10.75	0.000	.7317572	1.058145
L2.	-.15798	.0829244	-1.91	0.057	-.3205089	.0045488
RSAWMt						
L1.	.3684895	.0959544	3.84	0.000	.1804223	.5565567
L2.	-.2245193	.0948773	-2.37	0.018	-.4104754	-.0385633
_cons	25.58214	8.177113	3.13	0.002	9.55529	41.60899
RSAWMt						
BWPWMG1t						
L1.	.0547854	.0707594	0.77	0.439	-.0839005	.1934712
L2.	.0511114	.070471	0.73	0.468	-.0870093	.189232
RSAWMt						
L1.	1.18676	.0815442	14.55	0.000	1.026936	1.346583
L2.	-.3347119	.0806288	-4.15	0.000	-.4927415	-.1766823
_cons	8.46384	6.949094	1.22	0.223	-5.156135	22.08382

Appendix 18: Short-run effects results ($BWPWMG2_t$ $RSAWM_t$)

```
Vector autoregression

Sample:  2008m3 - 2019m12                        Number of obs     =        142
Log likelihood =  -1203.083                      AIC               =   17.08568
FPE            =   90217.94                      HQIC              =   17.17027
Det(Sigma_ml)  =   78360.89                      SBIC              =   17.29384
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
BWPWMG2t	5	19.1822	0.7247	373.861	0.0000
RSAWMt	5	15.2416	0.8968	1233.76	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
BWPWMG2t						
BWPWMG2t						
L1.	.7776508	.0838782	9.27	0.000	.6132526	.942049
L2.	-.0924461	.0836297	-1.11	0.269	-.2563572	.071465
RSAWMt						
L1.	.265974	.0999796	2.66	0.008	.0700176	.4619304
L2.	-.1131656	.0993358	-1.14	0.255	-.3078601	.0815289
_cons	13.54164	7.716842	1.75	0.079	-1.583089	28.66638
RSAWMt						
BWPWMG2t						
L1.	.0730747	.0666469	1.10	0.273	-.0575508	.2037002
L2.	.0328701	.0664494	0.49	0.621	-.0973684	.1631086
RSAWMt						
L1.	1.193247	.0794406	15.02	0.000	1.037546	1.348948
L2.	-.3277531	.078929	-4.15	0.000	-.4824511	-.1730551
_cons	12.72371	6.131554	2.08	0.038	.706086	24.74134

Appendix 19: Short-run effects results ($BWPYMG1_t$ $RSAYM_t$)

```
Vector autoregression

Sample:  2008m4 - 2019m12                        Number of obs     =       141
Log likelihood =  -1220.846                      AIC               =  17.51555
FPE            =   138684.4                      HQIC              =  17.63452
Det(Sigma_ml)  =   113687.8                      SBIC              =  17.80833
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
BWPYMG1t	7	17.797	0.7973	554.4728	0.0000
RSAYMt	7	20.4559	0.8706	948.4861	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
BWPYMG1t						
BWPYMG1t						
L1.	.9388193	.085573	10.97	0.000	.7710993	1.106539
L2.	-.0868452	.1154633	-0.75	0.452	-.3131492	.1394588
L3.	-.0483297	.0853627	-0.57	0.571	-.2156376	.1189782
RSAYMt						
L1.	.1806102	.0723577	2.50	0.013	.0387917	.3224286
L2.	-.1159736	.1007371	-1.15	0.250	-.3134148	.0814676
L3.	-.0059836	.0721349	-0.08	0.934	-.1473655	.1353982
_cons	28.01997	8.672066	3.23	0.001	11.02303	45.01691
RSAYMt						
BWPYMG1t						
L1.	.1630024	.098358	1.66	0.097	-.0297757	.3557804
L2.	-.2967108	.132714	-2.24	0.025	-.5568255	-.036596
L3.	.3002561	.0981163	3.06	0.002	.1079517	.4925605
RSAYMt						
L1.	.996903	.0831682	11.99	0.000	.8338963	1.15991
L2.	-.0547745	.1157877	-0.47	0.636	-.2817142	.1721652
L3.	-.1060548	.0829122	-1.28	0.201	-.2685597	.0564501
_cons	.7469324	9.967709	0.07	0.940	-18.78942	20.28328

Appendix 20: Short-run effects results ($BWPYMG2_t$ $RSAYM_t$)

```
Vector autoregression

Sample:  2008m4 - 2019m12                        Number of obs     =       141
Log likelihood =  -1168.775                      AIC               =  16.77695
FPE            =   66260.94                      HQIC              =  16.89592
Det(Sigma_ml)  =   54317.99                      SBIC              =  17.06973

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
BWPYMG2t              7     12.294   0.7996   562.6713   0.0000
RSAYMt                7     20.453   0.8706   948.7959   0.0000
----------------------------------------------------------------
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
BWPYMG2t						
BWPYMG2t						
L1.	.938508	.0855431	10.97	0.000	.7708465	1.106169
L2.	-.0849787	.1153671	-0.74	0.461	-.3110941	.1411367
L3.	-.0441417	.0853274	-0.52	0.605	-.2113803	.1230969
RSAYMt						
L1.	.1250213	.0499629	2.50	0.012	.0270957	.2229469
L2.	-.083697	.0695778	-1.20	0.229	-.220067	.052673
L3.	-.0020574	.0498264	-0.04	0.967	-.0997153	.0956005
_cons	19.19626	6.032492	3.18	0.001	7.37279	31.01972
RSAYMt						
BWPYMG2t						
L1.	.2337219	.1423146	1.64	0.101	-.0452095	.5126533
L2.	-.4303542	.1919315	-2.24	0.025	-.806533	-.0541754
L3.	.4348527	.1419556	3.06	0.002	.1566248	.7130805
RSAYMt						
L1.	.9976322	.0831213	12.00	0.000	.8347175	1.160547
L2.	-.0551447	.1157537	-0.48	0.634	-.2820177	.1717284
L3.	-.1058091	.0828941	-1.28	0.202	-.2682785	.0566602
_cons	.5288327	10.03601	0.05	0.958	-19.14138	20.19904

Appendix 21: Cointegration results (BWPWMG1$_t$ RSAWM$_t$)

Johansen tests for cointegration

Trend: constant — Number of obs = 142

Sample: 2008m3 - 2019m12 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-1208.4535	.	34.5534	15.41
1	9	-1194.7757	0.17523	7.1978	3.76
2	10	-1191.1768	0.04943		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-1208.4535	.	27.3557	14.07
1	9	-1194.7757	0.17523	7.1978	3.76
2	10	-1191.1768	0.04943		

Appendix 22: Cointegration results (BWPWMG2$_t$ RSAWM$_t$)

Johansen tests for cointegration

Trend: constant — Number of obs = 142

Sample: 2008m3 - 2019m12 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-1220.6775	.	35.1886	15.41
1	9	-1206.4565	0.18151	6.7464	3.76
2	10	-1203.0832	0.04640		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-1220.6775	.	28.4422	14.07
1	9	-1206.4565	0.18151	6.7464	3.76
2	10	-1203.0832	0.04640		

Appendix 23: Cointegration results ($BWPYMG1_t$ $RSAYM_t$)

Johansen tests for cointegration

Trend: constant Number of obs = 142

Sample: 2008m3 - 2019m12 Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-1246.873	.	24.0520	15.41
1	9	-1238.0981	0.11626	6.5022	3.76
2	10	-1234.847	0.04476		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-1246.873	.	17.5498	14.07
1	9	-1238.0981	0.11626	6.5022	3.76
2	10	-1234.847	0.04476		

Appendix 24: Cointegration results ($BWPYMG2_t$ $RSAYM_t$)

Johansen tests for cointegration

Trend: constant — Number of obs = 142

Sample: 2008m3 - 2019m12 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-1194.1533	.	23.5893	15.41
1	9	-1185.5968	0.11353	6.4764	3.76
2	10	-1182.3586	0.04458		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-1194.1533	.	17.1129	14.07
1	9	-1185.5968	0.11353	6.4764	3.76
2	10	-1182.3586	0.04458		

Appendix 25: Long-run effects results ($BWPWMG1_t$ $RSAWM_t$)

```
Vector error-correction model

Sample:  2008m3 - 2019m12                          Number of obs     =        142
                                                   AIC               =   16.95459
Log likelihood = -1194.776                         HQIC              =   17.03071
Det(Sigma_ml)  =  69708.14                         SBIC              =   17.14193

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_BWPWMG1t           4     18.0593   0.1636   26.99845   0.0000
D_RSAWMt             4     15.4809   0.1148   17.90328   0.0013
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_BWPWMG1t   |
        _ce1 |
         L1. |   -.242036   .0597497    -4.05   0.000    -.3591432   -.1249288
             |
    BWPWMG1t |
         LD. |   .1464542   .0847877     1.73   0.084    -.0197267     .312635
             |
      RSAWMt |
         LD. |   .2053283   .0966749     2.12   0.034     .0158489    .3948077
             |
       _cons |  -.0657247   1.517431    -0.04   0.965    -3.039835    2.908386
-------------+----------------------------------------------------------------
D_RSAWMt     |
        _ce1 |
         L1. |   .1298599    .051219     2.54   0.011     .0294724    .2302473
             |
    BWPWMG1t |
         LD. |   -.064268   .0726823    -0.88   0.377    -.2067227    .0781866
             |
      RSAWMt |
         LD. |   .3128056   .0828723     3.77   0.000     .1503788    .4752324
             |
       _cons |  -.1224994   1.300783    -0.09   0.925    -2.671986    2.426988
------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 1   56.96772   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
        beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_ce1         |
    BWPWMG1t |          1          .        .       .            .           .
      RSAWMt |  -.7689263   .1018756    -7.55   0.000    -.9685989   -.5692538
       _cons |  -50.94384          .        .       .            .           .
------------------------------------------------------------------------------
```

Appendix 26: Long-run effects results ($BWPWMG2_t$ $RSAWM_t$)

Vector error-correction model

Sample: 2008m3 - 2019m12		Number of obs	= 142
		AIC	= 17.11911
Log likelihood = -1206.456		HQIC	= 17.19523
Det(Sigma_ml) = 82173.69		SBIC	= 17.30645

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_BWPWMG2t	4	19.2659	0.1490	24.15945	0.0001
D_RSAWMt	4	15.4713	0.1159	18.09659	0.0012

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_BWPWMG2t						
_ce1						
L1.	-.2921961	.0650922	-4.49	0.000	-.4197745	-.1646177
BWPWMG2t						
LD.	.0805654	.0851351	0.95	0.344	-.0862964	.2474273
RSAWMt						
LD.	.0956687	.1008818	0.95	0.343	-.1020559	.2933934
_cons	-.073516	1.618322	-0.05	0.964	-3.245369	3.098337
D_RSAWMt						
_ce1						
L1.	.1334908	.0522718	2.55	0.011	.0310399	.2359417
BWPWMG2t						
LD.	-.0473513	.0683672	-0.69	0.489	-.1813485	.0866459
RSAWMt						
LD.	.3064263	.0810124	3.78	0.000	.1476449	.4652077
_cons	-.1609182	1.299582	-0.12	0.901	-2.708052	2.386216

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	1	45.01148	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
BWPWMG2t	1	.	.	.	.	.
RSAWMt	-.6550914	.0976428	-6.71	0.000	-.8464678	-.463715
_cons	-7.578473	.	.	.	.	.

Appendix 27: Long-run effects results ($BWPYMG1_t$ $RSAYM_t$)

Vector error-correction model

Sample: 2008m3 - 2019m12		Number of obs =	142
		AIC =	17.56476
Log likelihood = -1238.098		HQIC =	17.64089
Det(Sigma_ml) = 128315.6		SBIC =	17.7521

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_BWPYMG1t	4	17.8127	0.0993	15.22255	0.0043
D_RSAYMt	4	21.2582	0.0375	5.378387	0.2506

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_BWPYMG1t						
_ce1 L1.	-.1744562	.05318	-3.28	0.001	-.2786871	-.0702253
BWPYMG1t LD.	.1262338	.0868127	1.45	0.146	-.0439161	.2963836
RSAYMt LD.	.0986895	.0719423	1.37	0.170	-.0423148	.2396937
_cons	-.1364757	1.495459	-0.09	0.927	-3.067521	2.79457
D_RSAYMt						
_ce1 L1.	.1202756	.0634667	1.90	0.058	-.0041168	.2446681
BWPYMG1t LD.	.0264493	.1036051	0.26	0.798	-.176613	.2295115
RSAYMt LD.	.0923992	.0858582	1.08	0.282	-.0758798	.2606782
_cons	-.1979539	1.784728	-0.11	0.912	-3.695957	3.300049

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	1	19.63958	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
BWPYMG1t	1	.	.	.	.	.
RSAYMt	-.5400881	.1218705	-4.43	0.000	-.7789498	-.3012264
_cons	-91.16515	.	.	.	.	.

Appendix 28: Long-run effects results ($BWPYMG2_t$ $RSAYM_t$)

Vector error-correction model

Sample: 2008m3 - 2019m12		Number of obs	= 142
		AIC	= 16.82531
Log likelihood = -1185.597		HQIC	= 16.90143
Det(Sigma_ml) = 61254.48		SBIC	= 17.01265

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_BWPYMG2t	4	12.3058	0.0963	14.71266	0.0053
D_RSAYMt	4	21.2497	0.0383	5.492617	0.2404

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_BWPYMG2t						
_ce1						
L1.	-.1688284	.052669	-3.21	0.001	-.2720577	-.0655991
BWPYMG2t						
LD.	.1191327	.0868421	1.37	0.170	-.0510746	.28934
RSAYMt						
LD.	.0693092	.0496982	1.39	0.163	-.0280975	.1667159
_cons	-.1472885	1.033519	-0.14	0.887	-2.172948	1.878371
D_RSAYMt						
_ce1						
L1.	.1747687	.0909489	1.92	0.055	-.0034878	.3530253
BWPYMG2t						
LD.	.0388912	.1499591	0.26	0.795	-.2550232	.3328056
RSAYMt						
LD.	.0930213	.085819	1.08	0.278	-.0751809	.2612234
_cons	-.1422823	1.784683	-0.08	0.936	-3.640196	3.355631

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	1	19.32386	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
BWPYMG2t	1	.	.	.	.	.
RSAYMt	-.3787343	.0861564	-4.40	0.000	-.5475978	-.2098708
_cons	-64.15105	.	.	.	.	.

Appendix 29: Diagnostic results ($BWPWMG1_t$ $RSAWM_t$)

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	12.2205	4	0.01578
2	7.5572	4	0.10921

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_BWPWMG1t	627.093	2	0.00000
D_RSAWMt	46.419	2	0.00000
ALL	673.512	4	0.00000

Eigenvalue stability condition

Eigenvalue	Modulus
1	1
.5808342	.580834
.2682684 + .1721145*i*	.318734
.2682684 - .1721145*i*	.318734

The VECM specification imposes a unit modulus.

Appendix 30: Diagnostic results ($BWPWMG2_t$ $RSAWM_t$)

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	5.7330	4	0.21999
2	2.8218	4	0.58808

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_BWPWMG2t	1875.235	2	0.00000
D_RSAWMt	73.310	2	0.00000
ALL	1948.545	4	0.00000

Eigenvalue stability condition

Eigenvalue	Modulus
1	1
.4443755	.444376
.39761	.39761
.1653615	.165361

Appendix 31: Diagnostic results ($BWPYMG1_t$ $RSAYM_t$)

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	8.3037	4	0.08107
2	9.2968	4	0.05409

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_BWPYMG1t	396.945	2	0.00000
D_RSAYMt	121.988	2	0.00000
ALL	518.933	4	0.00000

Eigenvalue stability condition

Eigenvalue	Modulus
1	1
.7404839	.740484
.1643307	.164331
.0744027	.074403

The VECM specification imposes a unit modulus.

Appendix 32: Diagnostic results ($BWPWYG2_t$ $RSAYM_t$)

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	7.9902	4	0.09194
2	9.3707	4	0.05247

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_BWPYMG2t	428.730	2	0.00000
D_RSAYMt	121.866	2	0.00000
ALL	550.596	4	0.00000

Eigenvalue stability condition

Eigenvalue	Modulus
1	1
.7484755	.748475
.1575345	.157534
.07112467	.071125

The VECM specification imposes a unit modulus.