Determinants of maize exports from South Africa

by

Masego Moabi

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DECLARATION

I, Masego Moabi, hereby declare that the dissertation which I am hereby submitting to the University of Pretoria for the MSc (Agric) Agricultural Economics degree, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

Signature: 

Date: July 2025

DEDICATION

The ability to pursue and fulfil the requirements of this master's degree is by the grace of God. He gave me the wisdom, the perseverance and courage to start and finish this course as a result, I dedicate this degree to the Lord Almighty, Jesus Christ.

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- To my friend and mentor, Mancoba Mndzebele, I am extremely thankful for all the insight and guidance you provided in this journey! Without you present in this journey with me, the quality of this dissertation would not be up to par since you are man of excellence, and I thank you for imparting that standard of work in me.

ABSTRACT Maize is one of the major grain crops globally, as approximately 1.2 billion individuals in Latin America and Sub-Saharan Africa is dependent on it as a nutritious and accessible food source. South Africa is the ninth major producer and the eighth major exporter of both white and yellow maize globally. Since this grain crop plays such a vital part in the economy of South Africa and in food security, having a better understanding of the specific factors that influence South Africa's maize exports is necessary. Therefore, the objective of this study is to determine the key factors that affect South African maize exports. Furthermore, this research aims to add to the body of existing literature to prove that the Coronavirus pandemic (COVID-19) and the strict restrictions imposed during the period barely impact on South African maize exports.

The study uses annual secondary data from 1980 to 2023. The Autoregressive Distributed Lag (ARDL) technique for long-run association and the Error Correction Model (ECM) for the short-run were employed for the analysis of this study. The ECM analysis reveals that, in the short-run, both average rainfall and maize production were found to have a direct and statistically significant impact on export volumes in the short term with the coefficients of 0.24% and 1.11% respectively. The elasticity of maize production was particularly high, with a 1% increase in production translating into a 1.11% increase in exports. This high level of responsiveness might be a result of South Africa's export infrastructure and effective maize value chain. The ECM term indicated that approximately 67% of the previous year's disequilibrium in export volumes is corrected annually. Long-term findings showed that producer price, average rainfall and maize production were all significant at -0.84%, 0.31% and 1.21% respectively. Producer price was inversely correlated with exports, indicating that higher domestic prices diminish export volumes, which in turn encourages producers to sell in the domestic market. Furthermore, average rainfall and maize production showed positive and significant relationships with exports, which implies that better rain and production increases maize exports. These findings emphasize the climate-sensitive nature of maize production in South Africa, where 90% of maize is rainfed, and highlight the need for investments in irrigation systems, agricultural productivity, and price stabilization mechanisms to enhance long-term export. Trade openness and COVID-19 had positive, but insignificant relationship with maize exports, while world maize price had a negative and insignificant association with maize exports. With regards to Covid-19, the insignificant results confirm previous findings, which showed that theCOVID-19 pandemic did not have any significant effect on South

African maize exports. This is partly due to the fact that the agricultural sector was exempted from lockdown restrictions and its production was not affected.

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Keywords: Maize; South Africa; export determinants; ECM; ARDL; cointegration.

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LIST OF ABBREVIATIONS

AfCFTA	African Continental Free Trade Area
ADF	Augmented Dickey Fuller
ARDL	Autoregressive Distributed Lag
DAFF	Department of Agriculture Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform, Rural Development
ECM	Error Correction Model
ECT	Error Correction Term
EPA	Economic Partnership Agreement
FAO	Food and Agriculture Organisation
GCIS	Government Communication and Information System
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LDARD	Limpopo Department of Agriculture and Rural Development
NAMC	National Agricultural Marketing Council
OEC	Observatory of Economic Complexity
PP	Phillips Peron
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAGIS	South African Grain Information Service
VAR	Vector Autoregression
VECM	Vector Error Correction Model
VIF	Variance Inflation Factor
WTO	World Trade Organisation

CHAPTER 1: INTRODUCTION

1.1 Introduction and Background

Maize is considered to be a crucial crop and has just over one billion individuals in Sub-Saharan Africa and South America dependent on it (International Institute of Tropical Agriculture, 2018). Given its fast-growing ability, its reduced labour needs and high nutrient composition, maize has become a key grain in Africa. In Africa, over three hundred million people are dependent on maize a key source of food and approximately twenty-four % of land designated for farming is covered by maize (International Institute of Tropical Agriculture, 2018). Maize in South Africa is a significant and staple grain crop and is farmed all over the country (Du Plessis, 2003). When it comes to maize, there are two main varieties of maize, white and yellow maize of which both are grown in South Africa. For human consumption, white maize is often preferred whilst, yellow maize predominantly for the purpose of animal grain feed and industrial use (DALRRD, 2022)). According to the Department of Agriculture Land Reform and Rural Development (DALRRD), the average yearly production of yellow maize ranges between 4 370,000 to 7,700 000 tons and 7,700,000 to 16,800,000 tons for white maize (DALRRD, 2020). In South Africa, there are approximately 9,000 commercial maize farmers producing most of the maize for commercial and export purposes, while the emerging small-scale farmers produce for subsistence farming (Du Plessis, 2003).

In 2023/2024, South Africa was the ninth largest producer of maize globally, producing 17 million metric tons of maize (USDA, 2024). With South Africa's maize consumption averaging around 12 million metric tons (SAGIS, 2024), that leaves a surplus for the country to export and subsequently receive export earnings, which in turn contributes to the agricultural GDP. In Africa, South Africa is considered as a major maize producer and the largest maize exporter in Southern Africa, accounting for 88% of total exports in the region and mainly exports white maize to its African markets and yellow maize to its Asian markets (Glauber & Anderson, 2024). Maize generated over R9 billion in export value and contributed about R168 million in 2020 to the agricultural sector, making South Africa one of the major producers in the global maize industry (DALRRD, 2023). Figure 1.1 below, shows South Africa's total production of maize in metric tons from 1980 to 2023.

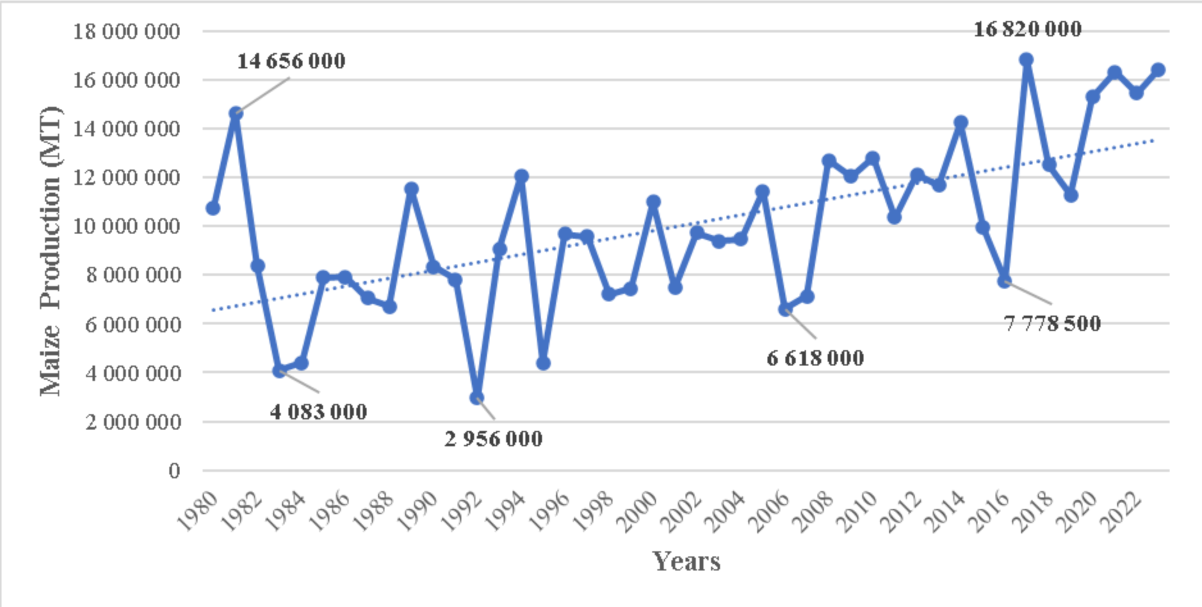

Figure 1.1 Total maize production in metric tons (MT)
Source: South African Grain Information Service, SAGIS (2024)

The trend line depicts a slightly increasing trend over the fifty-four-year period, with low and peak production years recorded over the years. The years 1981/82 and 2017/16 were the highest recorded maize production seasons. According to (Kirsten, et al., 1994), the maize production in South Africa in 1981/82 was the result of a bumper harvest[1]. 2017 was the largest recorded maize production year and the high yield was due to plentiful rainfall during the crucial maize growing stages as well as enhanced seed varieties (USDA, 2018).

On the other hand, in the year 1983/84 maize production decreased sharply due to a severe drought as well as changes in agricultural policy, moving from regulations and state subsidization to a deregulated and liberal maize industry (Bernstein, 1993) and (Sandrey & Vink, 2008) . In 1992/93, South Africa suffered through a severe drought that led to the lowest recorded production of maize in South Africa, forcing South Africa to import about 4.3 million tons of maize to meet local demand (Theron, 2016). The decrease in maize production in 2007/08 was a result of a drought in significant provinces where maize is produced, such as the North-West, Free State and Mpumalanga provinces in South Africa (Galal, 2022). In 2015/16 a severe El Nino led to drought conditions in the beginning stages of the maize growing season resulting in lower maize production that year (USDA, 2015).

Figure 1.2 shows South African maize export volumes from the year 190 to 2023 in metric tons. The extremely low export quantities in 1984/85 were due to severe droughts as well as

[1] An unusually large or abundant harvest from a specific crop.

reduced government support for maize producers due to changes in agricultural policy by moving towards a more deregulated maize sector (Bernstein, 1993) and (Sandrey & Vink, 2008). Between 1991/92 and 1992/93 South Africa experienced a devastating drought which grossly affected maize crops. This in turn resulted in the lowest recorded maize production which subsequently resulted in record low maize export volumes between 1980 and 2023 (Bernstein, 1993). In the 2007/2008 the significant decline in maize exports was a result of a drought, which got worse during the 2009 global recession. Furthermore, a 60 % decrease in export volumes was recorded in the year 2015/2016 in comparison to 2014/2015. This significant drop in exports was also attributed to severe drought, in turn causing South Africa to resort to maize imports (FAO, 2020).

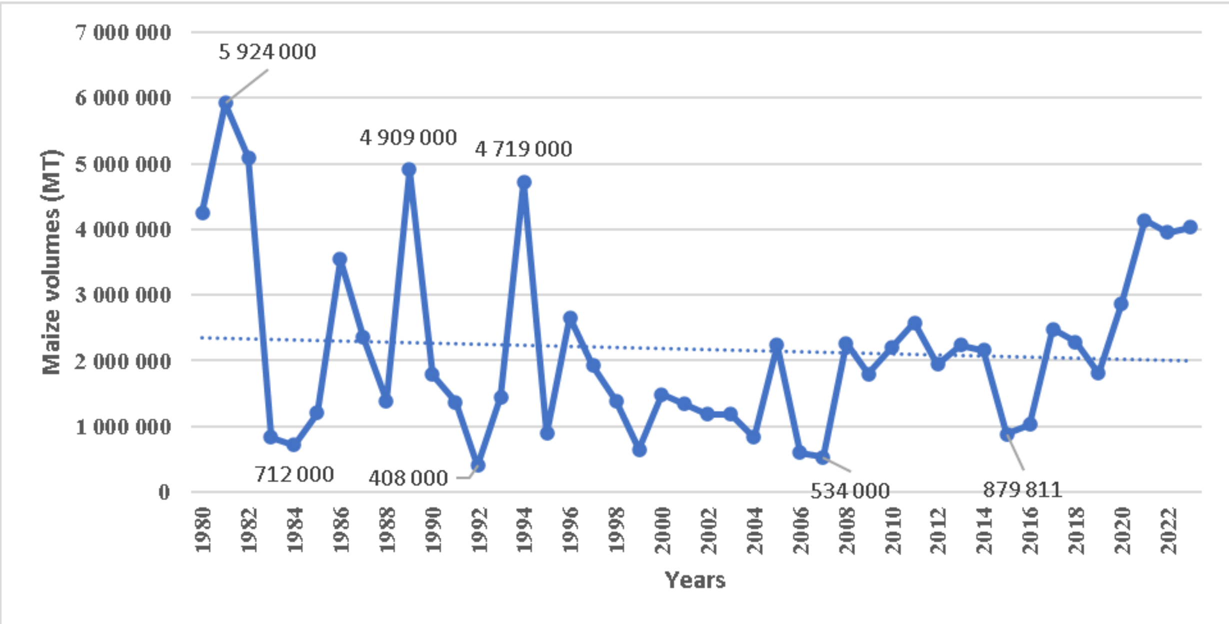

Figure 1.2: South Africa's maize exports in metric tons (MT)

Source: South African Grain Information Service (Galal, 2022)

In contrast, 1981/82 was a bumper crop period, due to weather, which led to record volumes of maize being exported from South Africa. A bumper harvest was also recorded in 1990/91 and 1994/95 leading to higher maize exports (Bernstein, 1993) and (South African History Online, 1994).

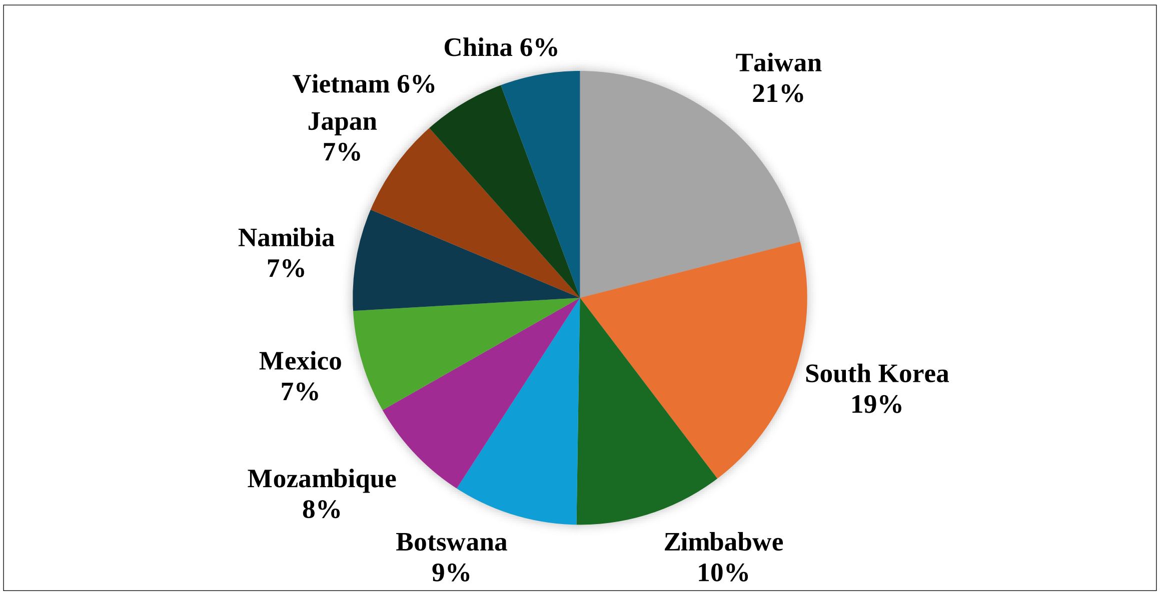

Figure 1.3 Maize importing countries from South Africa

Source: Trade map 2023

With South Africa being a net maize exporter globally, this has enabled the nation to diversify its export market over the years. Previously, South Africa's exports were heavily concentrated in neighbouring African markets and a few Asian countries. However, over the years, the trading partners of South Africa's have expanded as presented in Figure 1.3, which illustrates South Africa's maize export markets in 2023. The figure shows that South Africa's main export markets are in Asia, with Taiwan and South Korea as the largest maize importers in 2023. In Africa, South Africa's neighbouring countries, such as Zimbabwe, Botswana, Namibia, and Mozambique, were the largest importers in 2023. According to (NAMC, 2023), Asia accounted for 71% of total maize exports estimated at about R4.7 billion, exports directed to Africa generated about R1.4 billion, while Mexico, generated up to R197 million in export revenue for South Africa (NAMC, 2023).

The background information presented above shows that the maize sector is important in South Africa and it makes up a vital component in export earnings. Therefore, understanding the myriad of factors affecting South Africa's maize exports is necessary.

1.2 Problem statement

Several studies looked at maize exports from South Africa and other countries using various analytical approaches based on their objective. For example, (Kapuya & Sihlobo, 2014) found that South Africa's maize export market was concentrated in Africa with room to diversify into other larger markets like Asia and the Middle East. As a result, they used a Strategic Export Market Analysis (SEMA) analysis to determine which maize export markets South Africa had a greater trade potential in. Over time, South Africa's export market has broadened and became more diversified trading with different countries beyond the African continent. Another study by (Hussien, 2015) used the error correction model (ECM) to analyse the factors of export supply for Ethiopian coffee, and found that the short-run was affected by terms of trade (ToT), real income, exchange rate and foreign capital flow. Whereas, in the long-run export supply was determined by exchange rate, real income, term of trade and domestic price. A study was proposed by (Dube, et al., 2018) to analyse the determinants that affected the horticultural export response in Ethiopia. The ARDL bound test co-integration method was utilized and the research reported that the real GDP of Ethiopia, the real effective exchange rate, FDI, prices, and the structural break all had a major effect on the horticultural export response in the short-run and long-run. Whereas foreign GDP and interest rates were shown to have a key impact in the long-run only. In 2021 (Abodi, et al., 2021) investigated the major factors of Kenyan maize import volumes from 1963 to 2016 using the ARDL method. The study discovered that trade openness, local price of maize, and GDP were all significant to Kenyan maize imports in the long-run. In the short-run however, maize imports were determined by the lag of maize import volume, production, exchange rate and the lag of exchange rate. Furthermore, (Geyser, et al., 2024) investigated the trends and determinants of maize exports in South Africa post-deregulation, focusing their study on how the cost of transport and logistical weaknesses impacted South Africa's maize exports and competitiveness. The results reflected that price had a negative and significant influence on South African maize exports whilst, lagged maize production had a major direct effect on maize exports.

Another study by (Edwards & Alves, 2006) investigated the factors that affected South Africa's export supply volumes and found that tariff rates, real effective exchange rate, infrastructure costs and skilled labour were important factors.

However, little is known regarding the factors that specifically influence South Africa's maize exports and this study aims to take a deeper dive into the specific determinants that influence South Africa's maize exports. The review of previous studies sheds light on the type of factors that affect maize exports in general as well as types of analyses used. However, the previous studies did not explore how weather affect maize exports, especially in the short run, given the heavy depends of maize production on rainfall as shown in fig. 1.2, where maize exports declined during drought periods. The current study builds on previous studies by looking at macroeconomic and climatic factors that influence South Africa's maize exports, including a dummy variable to capture if the COVID-19 pandemic played any role, in addition to weather. With this background in mind, there is a need to better comprehend the specific determinants that impact South Africa's maize exports, using the ARDL model.

The review of previous studies sheds light on the type of literature that is currently available for the stakeholders and policymakers in South Africa's maize export industry. However, there seems to a gap in this literature that focuses on identifying the key determinants that affect South Africa's white and yellow maize exports. The maize exports studies for this research covers both yellow and white maize for consumption or industrial use (not for planting) under the *Harmonised System (HS) code: 1005.90 – Maize (corn), other than seed*. The current study builds on previous studies, particularly that of (Geyser, et al., 2024), by looking at macroeconomic and climatic factors that influence South Africa's maize exports using the ARDL model. The aim of this study therefore, is to investigate which factors have a notable relationship with South Africa's maize exports considering the Coronavirus pandemic as a dummy variable.

1.3 Research question of the study

1. Which factors affect South Africa's maize export volumes in the short-run?

2. Which factors affect South Africa's maize export volumes in the long-run?

3. Is there a Granger Causal connection between the potential factors above and maize export volumes?

1.3.1 Objectives of the study

The key aim of this study is to investigate the key determinants that affect maize export volumes from South Africa. To accomplish the main objective, the specific objectives are to:

1. Investigate which factors influence South African maize exports quantities over the short-run.
2. Investigate which factors influence South African maize exports quantities over the long-run.

3. Determine whether the significant determinants obtained in the first and second objective have a Granger causal effect with maize exports, or whether maize exports have a Granger causal effect on those significant determinants.

1.4 Hypotheses

This study will conduct tests on the following null hypothesis:

- H_0 = There is no significant short-run relationship between the selected determinants and maize export volumes.
- H_0 = There is no significant long-run relationship between the selected determinants and maize export volumes.
- H_0 = There is no Granger causal relationship between maize exports quantities and the significant determinants identified.

1.5 Significance of study

In South Africa, maize is the largest produced, consumed and exported grain in South Africa. The maize industry in South Africa feeds most of the population and is the largest contributor of maize exports in Southern Africa. Maize plays such a key role in serving as a nutritious and accessible source of food for South Africa and its trading partners. Maize is also an essential sector in creating revenue, generating around R9 billion of export value in 2020 (DALRRD, 2022). Therefore, this sector should be given precedence regarding support and policy. As a result, the key of this research is to better comprehend the factors that affect South Africa's maize exports. Moreover, this study will include the Coronavirus pandemic as a dummy variable to further prove and add on to the work by (Meyer, et al., 2021) that COVID-19 had minimal impact on South Africa's maize market. Furthermore, empirical research identifying the key determinants of maize export volumes is not well documented thus opening an avenue to fill this gap. The results of this study may be used to assist South African maize producers and policymakers by providing them with a modest guideline of which macroeconomic and climatic factors mostly affect maize exports in South Africa.

1.6 Structure of the dissertation

The dissertation is made up of chapters one to five. Chapter one starts with the introduction and introducing the problem statement and the main study objectives. Chapter two continues with the review of literature, and this is followed by chapter three that extensively explains the study area and the methodology applied in the study. Chapter four focuses on discussing the findings determined, followed by chapter five which discusses the conclusion and the recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

Chapter two starts with the review of trade theories, encompassing both classical and neo classical theories of international trade. This is followed by an overview of the current global trade of maize and thereafter the trade of maize in Africa is presented. The chapter then takes a deeper dive into the maize trade environment in South Africa, discoursing the various maize sectors, the trade regulations, and agreements governing them. The relationship between the chosen explanatory variables and South African maize exports is covered and this is preceded by the review of empirical literature. The chapter then closes off with concluding remarks of this section.

2.2 Review of Trade theories

When countries exchange goods and services, this notion is called international trade (Heakal, 2024). Furthermore, the analysis of international trade is directed by a number of different theories under classical and nonclassical theories. The efficient allotment of resources as well as the specialisation explains up part of classical theory of international trade (Anand, 2008). On the other hand, neoclassical theory of international trade focuses on expanding classical theory through better comprehension regarding the varying relative cost amongst nations (Gandolfo, 1986).

2.2.1 The Classical Theory of International Trade – Comparative advantage theory

When nations trade with goods or services, they have a relative advantage in explains one of the key pillars of international trade, comparative advantage. This concept of comparative advantage was established in the 19th century by David Ricardo (Montevirgen, 2024).

The basis of comparative advantage explains that a specialized economy is achieved by allowing a nation to specialize in an area with the least transaction costs to (Samuelson, 1969). In his famous book, ‘The Principles of Political Economy and Taxation’ of 1817, David Ricardo explained the principle of comparative advantage, using wine and cloth as examples for trade between England and Portugal. His classical example demonstrated that Portugal could import cloth from England in exchange for wine exports based on their comparative advantage (Faccarello, 2015). Whereas England could import wine from Portugal whilst trading it for cloth (Faccarello, 2015). The concept of comparative advantage is based on the notion of labour hours, measuring the cost of production and the opportunity cost. The varying labour needs are a direct result of the country's different conditions due to a nation's climate, geography as well as other natural or man-made advantages (Ricardo, 1817). From this example, Portugal has the total advantage in making both wine and cloth due to the country's smaller transaction costs. However, Ricardo states that trade between the England and Portugal would still be beneficial for both nations since Portugal can produce wine at a relatively cheaper cost than cloth, it should specialise in wine production. Whilst cloth production should be England's specialisation because it manufactures it at a relatively less expensive cost. This is a demonstration of how the theory of comparative advantage, where Ricardo showed that the gains from trade are achieved for both nations when they specialise with respect to their comparative advantage (Schumacher, 2013). This consequently means that a country's welfare could increase from international trade due more affordable goods that are available in large quantities for consumers. By differentiating a country's opportunity cost to produce certain goods, one can determine their comparative advantages.

The favourable yields of maize in South Africa are due to advantageous weather conditions and advanced farming techniques. South Africa produces sufficient maize to meet its local demand with the surplus maize being exported to in neighbouring African countries a few nations in Asia such as, Taiwan, Japan, Vietnam, and South Korea. On the other hand, South Africa imports approximately 90% of its rice from Thailand, India, Pakistan, and Vietnam. One of South Africa's larger maize importers, Vietnam, exported over 4 million USD worth of rice to South Africa in 2022 (OEC, 2021). The main reason why South Africa relies heavily on Vietnamese rice imports is because it lacks the conducive environment to commercially produce rice. Rice is known for being a highly water-intensive crop and due to South Africa's water scarcity, it makes it challenging to grow the crop commercially (Kogut, 2023). Moreover, the temperature required to successfully grow rice is between 21 to 37 degrees Celsius (Kogut, 2023), which is a stark difference from the temperatures needed for maize production, which is relatively cooler at about 19 to 25 degrees Celsius for the flowering season (DALRRD, 2022). These weather characteristics naturally occur in Vietnam, making rice production favourable and allowing the nation to be the third largest rice exporter globally (Ha, 2024). The different endowments that naturally occur in South Africa and Vietnam make Ricardo's principle of comparative advantage plausible. When a nation, South Africa in this instance, specialises in the production of maize in accordance with its comparative advantage, whist Vietnam focuses its efforts on the production of rice with respect to its comparative advantage, the net production in both nations rises and it is beneficial for the two countries to trade with each other.

2.2.2 Neo-Classical Theory of International Trade – The Heckscher-Ohlin Theory

Following the classical theory of trade, Ohlin and Heckscher, introduced the Factor Endowment Trade theory, which led to the Heckscher-Ohlin model (Meini, 2013) and (Mulder, 2023). Their theory of Factor Endowment is part of the Neo-classical international trade theories (Meini, 2013). According to (Leamer, 1995) the Heckscher-Ohlin model shows that traded goods represent bundles of factors like capital, labour, and land. Therefore, the model explains that nations should preferably trade goods that they have in abundance and import goods they lack to enhance the advantages of global trade. Furthermore, (Duignan, 2024) explains that nations that are well-endowed with capital, as opposed to labour, normally have advanced machinery and equipment assisting their workers, thus decreasing the need for a large quantity of labour. Furthermore, these nation's wage rates have a tendency to be higher resulting in a higher cost of producing labour-intensive goods. In contrast, nation labour and reduced wage costs tend to have less advanced machinery and equipment assisting their workers. Therefore, these nations should rely more on the large and affordable labour to produce labour-intensive goods and trade these goods for capital-intensive goods thus enabling both nations to benefit from trade with each other (Duignan, 2024).

2.3 Overview of Maize trade

2.3.1 Overview of global maize trade

The world's leading staple cereal crops, of which are cultivated on approximately 200 million hectares(rounded), are wheat, rice and then maize (Erenstein, et al., 2022). Domesticated over 9,000 years ago in Mexico (Awika, 2011), since then the global area of maize (dry grain) planted is 197 million hectares with noticeable planted areas in Asia, Latin America and sub-Saharan Africa (SSA) (FAOStat, 2021). The role of maize can be seen as more versatile than other cereal crops. Apart from being a nutritious and accessible staple food source, especially in Latin America and SAA, it also plays a major role as feed for livestock, and has some industrial and energy uses too (Erenstein, et al., 2022). The cultivation of maize covers most of the continents in the world encompassing 165 countries spread throughout these continents (FAOStat, 2021). Over 50% of the worlds maize production is supplied by the Americas. Asia contributes 32% with Europe and Africa supplying 11% and 7.4% respectively (FAOStat, 2021). The major players in the global maize production are illustrated in figure 2.1 below. As of 2022, The chart shows that the United States of America (USA) produced 32%, followed by China at 23% both dominating maize production with more than half of global production. Brazil contributes 10% of global maize production and the European Union supplies 5%. This is followed by Argentina at 4% and India at 3% of the world maize production. Ukraine, Mexico, and South Africa come in at 2%, 2% and 1% respectively (USDA, 2025).

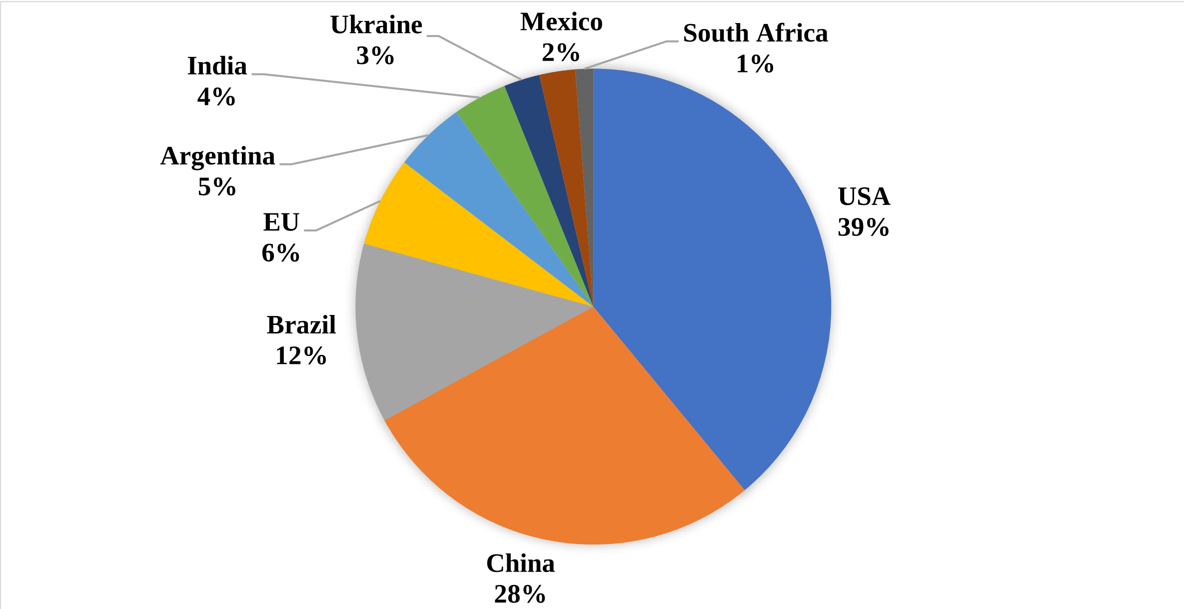

Figure 2.1 Largest maize producing countries globally

Source: (USDA, 2025).

The top net exporting nations worldwide for maize are the USA, Brazil, Argentina, Ukraine, and Romania exporting about 5 to 54 million tons annually. On the contrary, the top net importing countries for maize include Mexico, Korea, Vietnam, Japan, and Spain importing roughly 9 to 15 million tons annually (FAOStat, 2021). The variability of maize allows for this grain crop to have multiple uses. 56% of maize (dry grain) is utilized mainly for feed globally, followed by 20% for industrial (or non-food) uses and lastly about 13% for food (FAOStat, 2021). Maize production for feed is significantly higher than for human consumption since it is utilized to obtain animal-sourced foods thus supplying an indirect route to consumption. For example, according to (Mottet, et al., 2017), in theory, a kilogram (kg) of boneless meat is formed from about 3 kg of maize grain or soy. This in turn provides high protein and higher value foods derived from the maize grain. Maize consumption as a food source amounts to 18.5 kg/capita/year (FAOStat, 2021).

2.3.2 Regional trade of maize: sub-Saharan Africa (SSA)

In the context of sub-Saharan Africa (SSA), according to (Cairns, 2021), maize is the predominant grain produced in more 50% of the nations in SSA. According to (Erenstein, et al., 2022), 22 of the 161 countries that consume maize, account for over the 50 kg/capita/year and are located in southern and eastern Africa as well as Latin America (FAOStat, 2021). In southern Africa, maize consumption is predominantly high in Lesotho, Malawi, Zambia, and South Africa. In addition, as opposed to developed nations, in which more than 70% of the maize produced is mainly used for livestock feed, in the case of sub-Saharan Africa, the maize designated for human consumption makes up more than two thirds of the maize produced in the region (Smale, et al., 2011) and (Shiferaw, et al., 2011).

According to (FAOStat, 2021) and (Alliance for Green Revolution in Africa, 2021), there is substantial opportunity to expand maize production in sub-Saharan Africa because of its vast arable land, enhanced technology and most importantly an ever-increasing demand for affordable and nutritious food. However currently, apart from South Africa's dominance as the top supplier in sub-Saharan Africa (USDA, 2025), maize production is controlled predominantly by small holder farmers (Asfaw, et al., 2024). The challenges faced by both smallholder and large scale maize producers in SSA are inconsistent policies like export bans and import tariffs (Jayne, et al., 2010) and (Sitko & Jayne, 2014) as well as lacking market infrastructure. Nevertheless, between 2007 to 2017, the area of maize planted in sub-Saharan Africa rose by approximately 60% (excluding South Africa) (FAOStat, 2019). Furthermore, with the increasing implementation of regional trade agreements like the African Continental Free Trade Area (AfCFTA) as well as enhancing market infrastructure, this may lead to improved trade within the region (United Nations Economic Commission for Africa, 2019).

2.4 Review of South Africa's Maize Segments

Getting a clearer picture of the market composition of the white and yellow maize industry in South Africa is important to better understand the role players and their responsibilities within the supply chain. This section presents the function of the key role players from the primary, secondary and the tertiary segments of the maize sector in South Africa illustrated in figure 2.1 above. To give a better presentation of the sector, figure presents the different segments of the maize sector supply chain starting with the primary, secondary and tertiary sectors.

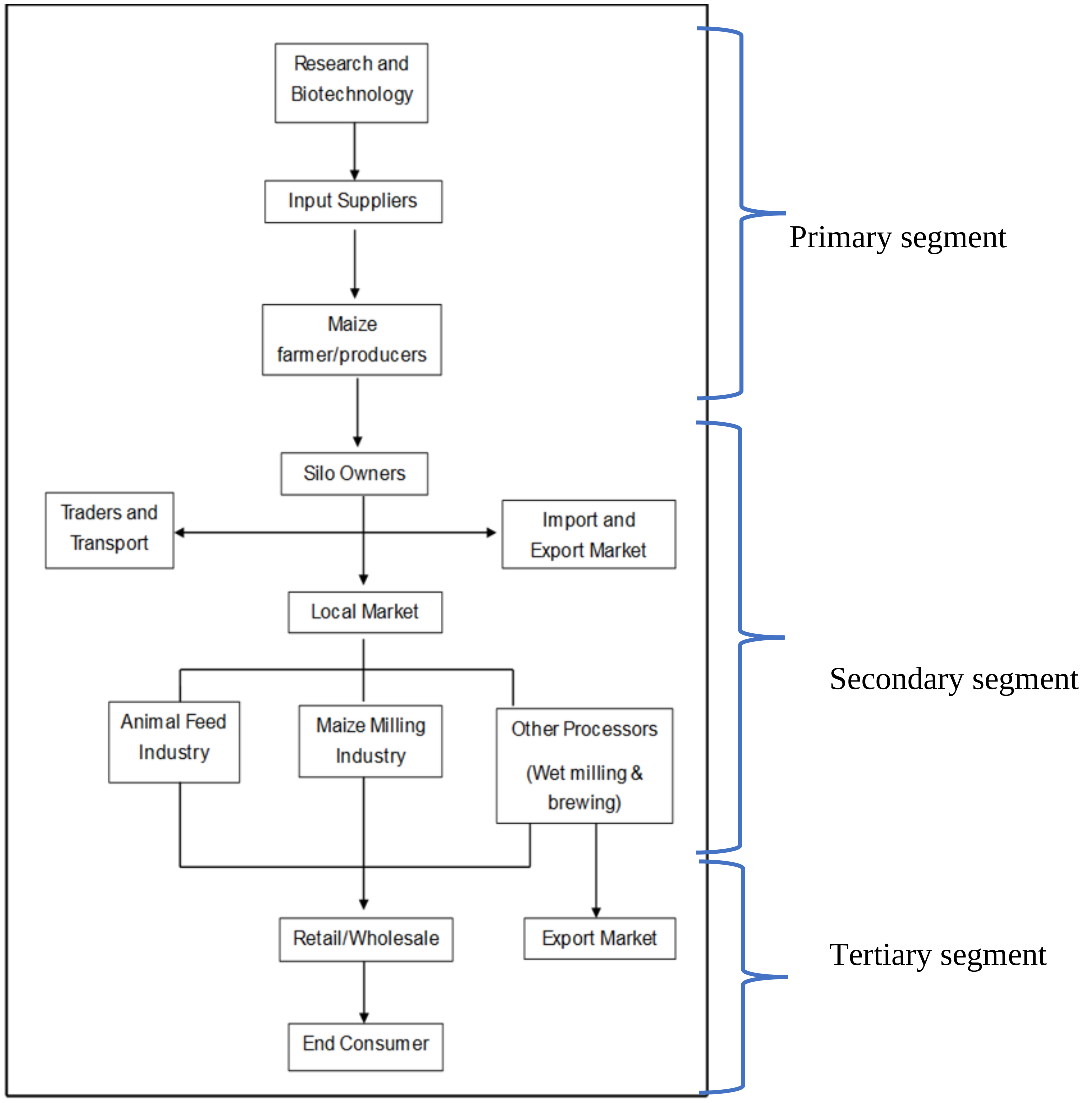

Figure 2.2 presents the supply chain along the three sub-sectors of the maize sector in South Africa

Source: Department of Agriculture, Forestry's and Fisheries, 2021

2.4.1 The primary segment of the maize value chain in South Africa

The primary segment of the maize sector comprises of input suppliers, producers (farmers) and silo owners (storage). Firstly, input suppliers are made up of numerous different role players that greatly contribute to all the essential physical components and financial support that farmers require to successfully produce quality maize. These input suppliers include financial services (loans), seed and fertilizer companies, farming machinery as well as labour. Secondly, there are approximately between 9,000 to 10,000 small-scale and commercial farmers producing maize in South Africa, with majority being settled in regions where maize production is conducive such as the eastern and central parts of South Africa (ADAMA, 2023) and (Du Plessis, 2003) . Once the maize has been produced and harvested, the next step is for it to be adequately stored in which farmers have four main storage options. Firstly, and most commonly, they can make use of commercial silos. Secondly, farmers can deliver the grain crop to a miller for immediate processing. Farmers can also construct their own silos which would be the third option and lastly, they can utilize the latest method of crop storage in the form of silo bags (DAFF, 2021). The key roles of silo owners are to provide storage facilities for the handling of maize, to safely store the maize and to continuously make it available to maize buyers throughout the year (DAFF, 2021). In South Africa, about 85% of the maize silos are owned by private companies formerly known as agricultural co-operatives prior to the deregulation of the maize industry which are mainly located in the northern region of South Africa (DAFF, 2021) and (NAMC, 2017).

2.4.2 The secondary segment of the maize value chain in South Africa

The secondary segment of the maize sector consists of the processing of maize using three main processes such as, wet milling, dry milling and feed milling. These three processes each result in different products designated for diverse markets (DAFF, 2021) and (Louw, et al., 2010). When maize kernels are refined to become maize meal, this process is called dry milling, which produces staple food like, samp, maize rice, maize grits and various grades of maize meal (DAFF, 2021) and (Gwirtz & Garcia-Casal, 2014). The resulting products from the dry milling process are designated for human consumption and most of the maize products remains in the country to meet local consumption (NAMC, 2023). On the other hand, wet milling requires a 36-hour procedure facilitated in water. In this processing method, raw maize is produced which contains several elements such as the starch, gluten, germ and the husk. The products produced from this process are designated towards the South African animal feed sector whereas some is exported to a few neighbouring countries like Botswana, Lesotho, Namibia and Eswatini. According to the Department of Agriculture Forestry and Fisheries, the animal feed sector is comprised of approximately 100 to 150 animal feed millers of varying magnitudes (DAFF, 2021). The last processing method, feed milling, consist of crushing entire maize kernels in which nutrients like vitamins and minerals are added in order to create healthy and nutritious feed for livestock (Louw, et al., 2010).

2.4.3 The Tertiary segment of the maize value chain in South Africa

The third and last section of the value chain of maize mainly encompasses the sale or the transaction of the final maize products at varying degrees. The processed white maize designated for the local market is sold to formal wholesalers and retail stores. Thereafter, consumers can purchase maize products, such as samp, grits, maize rice and or different varieties of maize meal from the local retailers. The remainder of the white maize is exported to the African market. The processed yellow maize is sold to the animal feed industry, mainly the poultry and pig sectors and the rest of the yellow maize is exported to Asia and other countries (DAFF, 2021).

2.5 Maize trade **regulations in** South Africa

2.5.1 Overview of Maize Regulation

Before the 1990s, South Africa's maize industry was highly regulated under the *Marketing Act of 1937*, which established the Maize Board. The responsibilities of the Maize Moard was to control the pricing of maize by setting fixed producer prices, controlling local distribution, monitoring the flow of imports and exports, as well as strategic reserves (Theron, 2016). The deregulation procedure was initiated in the early 1990s due to a desire to move towards trade liberalisation, which would increase competition and reduce some of the inefficiencies of the control boards. The *Marketing of Agricultural Products Act (No. 47 of 1996)* replaced the *1937 Marketing Act* and by 1997, the maize industry was fully deregulated and the Maize Board was dissolved (Traub & Jayne, 2006). The deregulation of the maize industry meant that prices were and currently are controlled by supply-demand market forces furthermore, the formation of the South African Futures Exchange (SAFEX) focuses on enabling the trading of futures contracts in the current market (Geyser, et al., 2024).

The key trade regulations that govern the production, handling, and export of maize in South Africa encompass the safety, quality, health, trade control and documentation requirements. These regulations and the various institutions involved, facilitates the trade of maize in South Africa and are briefly discussed below.

a) **The Agricultural Product Standards Act (No. 119 of 1990)** – the purpose of this Act is to ascertain the safety and quality of agricultural goods designated for domestic and international markets. This Act sets the minimum standards for grading, packaging, labelling as well as quality and all maize exported from South Africa must adhere with the standards. The Department of Agriculture, Land Reform and Rural Development (DALRRD) is responsible for administering this Act by issuing certificates of compliance necessary for exports (DALRRD, 2016).

b) **The Genetically Modified Organism Act (No. 15 of 1997)** – Genetically Modified (GM) maize was introduced in 1999 in South Africa in an effort to improve food security and enhance agricultural efficiency (Ala-Kokko, et al., 2021). By 2022 the adaptation of GM maize was at 87.7% of the total area of maize planted. Currently, approximately 85 to 90% of South African maize is GM, with only about 12.3% of maize non-GM (Phillips, 2023). The Department of Agriculture, Land Reform, Rural Development (DARRLD) regulates the establishment, use and export of genetically modified organisms (GMOs) in South Africa. Due to the restrictions of exporting GM maize in certain markets, GM maize exporters are issued permits by the (DALRRD, 2004).

c) **Sanitary and phytosanitary (SPS) regulations** – the purpose of this regulation is to outline the major guidelines required for food safety, plant, and animal health (WTO, 1998). According to, maize exporters in South Africa must adhere to the phytosanitary requirements of the importing nation by presenting a phytosanitary certificate confirming their maize is pest and disease free. Thes certificates are issued out by the National Plant Protection Organisation (NPPZOA) within the Department of Agriculture, Forestry and Fisheries (DAFF) thus ensuring maize exporters comply with the International Plant Protection Convention (IPPC) guidelines (DAFF, 2012).

d) **Customs and excise regulations** – this is aimed at controlling border processes and trade statistics and is facilitated by the South African Revenue Service (SARS). SARS ensures that all maize exports are declared through SARS' Custom system, it checks export documentation and furthermore, they also ascertain that all maize exports are classified appropriately using the Harmonized System (HS) code. Lastly, South Africa does not impose export tariffs or duties on maize, only under special cases – extreme maize shortages yet maize imports, in times of drought in South Africa, are tariffed (South African Revenue Service, 2025).

e) **Food Safety Regulations (Foodstuffs, Cosmetics and Disinfectants Act (No. 54 of 1972))** – aims to regulate the "manufacturing, selling and importing of foodstuffs, cosmetics and disinfectants; and to provide or incidental matters (National Department of Health, 1972)." The Act ensures that all white maize, reserved for human consumption, adheres to the mycotoxin, pesticide residue, and heavy metal limits (National Department of Health, 1972)

f) **National Agricultural Marketing Council (NAMC) Regulations (under the Marketing of Agricultural Products Act (Act No. 47 of 1996))** – this is facilitated by the National

Agricultural Marketing Council (NAMC) and encourages orderly marketing and collection of export data. This helps to ensure market transparency and food security (DAFF, 1996).

2.5.2 *Trade agreements supporting South African maize exports*

a) **Southern African Development Community (SADC) Trade Protocol** – This agreement was signed in 1996 and comprises of 16 countries in the Southern African region. It was established to promote economic union via duty-free or decreased tariffs amongst its members. As a result, South Africa's maize can be exported to SADC nations without tariffs given it meets the SADC Rules of Origin (SADC, 1996).

b) **African Continental Free Trade Area (AfCFTA)** – this agreement was launched in 2021 with 54 African Union member countries, with a goal to phase out tariffs on 90% of goods. Although the implementation of this trade agreement is still in progress, it has the potential to enhance market access for South Africa's maize as well as to reduce the non-tariff barriers (NTB) (Mahlangu, 2024).

c) **South African Customs Union (SACU)** – this was formed in 1910 and revised in the early 2000s. Its members include: Botswana, Eswatini, Lesotho, Namibia and South Africa and its aim is to establish a common external tariff and free trade (no tariff duties) of goods amongst its members. This means that South Africa can export its maize without customs duties or border controls within the SADU region (Mathis, et al., 2005).

d) **EU-SADC Economic Partnership Agreement (EPA) and the UK-SADC Economic Partnership Agreement (EPA)** – these agreements were established in 2016 and 2019 respectively (after Brixit was established). The parties involved include: the European Union (EU) and SADC EPA Group (Botswana, Eswatini, Lesotho, Mozambique, Namibia, and South Africa) whilst the latter agreement includes the United Kingdom (UK) and the SADC EPA Group too. Its focus is to abolish tariffs and quotas on majority of goods traded between the EU and SADC EPA Group as well as the UK and the SADC EPA Group respectively. This results in increased market access to higher value EU markets and UK markets for South Africa's maize exports (South African Revenue Service, 2016).

2.6 Review of potential impact of the Coronavirus pandemic

COVID-19 was proclaimed to be an international pandemic by the World Health Organisation in early 2020, which led to a mandatory global lockdown across the world to reduce the span of the virus. There were mainly two forms of lockdown that were implemented namely, domestically, and internationally. On the international level, countries shutdown their national borders thus limiting the movement of citizens and goods. This in turn hindered the once flourishing human and economic relations amongst nations (Onyeaka, et al., 2021). Conversely, domestic lockdown limited the movement of people thus completely stopping their daily physical interactions with others (Onyeaka, et al., 2021). These mandatory restrictions imposed due to lockdown, caused a plethora of effects in many countries.

As a result of the lockdown limitations placed to reduce the spread of COVID-19, this led to a rapid decrease in worldwide economic activity. For instance, because of the economic inactivity during this period, world GDP declined by 4.9% in the second quarter of 2020. This in turn led to a 3.5% decline in global trade in the second quarter as a result of the frail demand and supply (IMF, 2020). Moreover, according to, (Vidya & Prabheesh, 2020) the lockdown throughout most economies interrupted worldwide supply chains thus decreasing the aggregate supply for most commodities. The restrictive lockdown measures led to changes and instabilities, not only on the global level, but also at a national level for both developing and developed countries.

Due to a sudden halt in economic activity, the agricultural and pharmaceutical sectors were impacted, and this became a concern over the price of goods and food security. The fear of food insecurity during COVID-19 was mainly associated to the restriction of movement, the interruption of food supply chains and export limitations (Onyeaka, et al., 2021). This in turn led to reduced worldwide demand for certain cash crops and a massive hike up in the price of certain foods, due to increased demand in Sub-Saharan Africa. In addition to that, the lock down restrictions lessened labour and interrupted the inflow and outflow of food and goods because of closed borders, which in turn led to adverse effects on health and cost of living (Ogbolosingha & Singh, 2020). As mentioned above, the International Monetary Fund (IMF) recorded that global trade decreased by 3.5% during COVID-19 (IMF, 2020). The ripple effect of this decrease in global trade resulted in a negative impact on international trade of both importing and exporting countries (Hayakawa & Mukunoki, 2021).

A study by (Zhao, et al., 2021), who investigated the consequences of COVID-19 on China's exports. Their study found that there was a major adverse impact of China's export trade due to COVID-19. Another study investigated the effect of COVID-19 on exports from selected countries from the European Union and Turkey. This study found that the COVID-19 pandemic had an adverse effect on export trade in Turkey and the European Union. The findings suggest that exports declined by 0.102% due to a 1% increase in COVID-19 stringency, and exports reduced by 1.620% due to a 1% increase in COVID-19 cases (Cengiz & Manga, 2022). On the contrary, a study by (Barichello, 2021) re-examined the impact of COVID-19 on Canada's agricultural trade. Surprisingly, the study found that agricultural trade in Canada actually increased by 11% during COVID-19. The export boom of oilseeds, lentils and cereals from Canada, was a result of commodity-specific conditions causing large exports of cereals to China to restore their short hog herd and large exports of lentils to India to make up for their short crop.

In South Africa's case, the economy shrunk, with the GDP declining by 16% in the first and second quarter of 2020 (Statistics South Africa, 2020). Furthermore, numerous sectors in the country were grossly affected by the pandemic. For instance, there was a 74% decline in the country's metal and machinery manufacturing sector due to the decreased demand for steel (Statistics South Africa, 2020). Moreover, due to the stringent lockdown restrictions imposed during this time, (Ndhlovu & Dube, 2023) discovered that numerous tourism related businesses were liquidated whereas some had to close temporarily or permanently. However, according to (Statistics South Africa, 2020), the agricultural sector remained unaffected amid the COVID-19 pandemic. In addition to that, maize exports increased and there was also an increase in the international demand for pecan nuts and citrus fruits (Meyer, et al., 2021) and (Statistics South Africa, 2020). It is clear to see that COVID-19 has had toll on international trade and has grossly affected the export trade and numerous countries whilst other industries remained unaffected like South Africa's maize market. This study intends to add to the body of literature that the pandemic had little to no effect on the maize sector in South Africa.

2.7 Potential factors of South African maize exports

About 90% of maize planted in South Africa is dryland, meaning that it is highly dependent on rainfall, whilst the remaining 10% is under flood, drip, or sprinkler irrigation. This means that seasons of drought highly impact the country's maize output. Over the years South Africa has experienced numerous devastating droughts furthermore, Southern Africa was impacted by the

El Nino Southern Oscillation, in late 2023 early 2024, which caused intensified drought throughout the region with Zimbabwe, southern Mozambique, southern Malawi, southern Zambia and South Africa being the most affected. The Crop Estimate Committee estimated that the country's white maize production may decrease by 17% while yellow maize production was expected to decrease by 8%, therefore reducing the entire maize production (Glauber & Anderson, 2024). Moreover, this decrease in maize production may be fully experienced in the end of the 2024 maize season potentially causing a decline in maize production to a projected 13.3 million tons in the following 2024/2025 maize marketing season (Glauber & Anderson, 2024) . With the El Nino Southern Oscillation drastically impacting maize yields, earlier in the season South Africa's white maize prices surged by 21% and yellow maize increased by 11% because of the decreased yields. When maize yields drop it means that the maize available to the market is scarce, thus leading to higher maize prices. Thus, the above shows the potential impact that rainfall as well as maize price may have on South Africa's maize exports.

The Coronavirus pandemic grossly affected the world in 2020-2021, causing concern regarding the unpredictability of possible prolonged impacts of the agricultural value chains. The pandemic led to a mandatory national shutdown causing massive panic buying amongst citizens particularly for staple food items like maize meal. At the start of the pandemic, South Africa's white maize prices soared by 24% due to the panic buying by locals, increased demand for maize from Zimbabwe and the weakening South African Rand against the US dollar (Meyer, et al., 2021). The price spike corrected itself soon after and it was later realised that the price volatility was due to a coinciding increased demand from Zimbabwe and South Africa during the lockdown. The feed market in South Africa was adversely affected due to the decreased demand for meat products during the pandemic and the reduction in feedlot placements. This caused a decline of 150,000 tonnes of yellow maize in 2020. Nevertheless, apart from this decrease in yellow maize, the maize market in South Africa had minimal impact from COVID-19. Furthermore, the local maize market was steady lacking any prominent disturbances during the pandemic according to (Meyer, et al., 2021). This research purposes to add to the body of literature to by including COVID-19 as a dummy variable to determine its impact particularly on South Africa's maize export sector.

2.8 Empirical Literature Review

The review of empirical literature will discuss various studies that identify the determinants of exports. The empirical literature review presents previous studies that looked at the factors that affect agricultural exports. This section will conclude with a summary of the studies reviewed.

2.8.1 Review of empirical literature

A study by (Khan., et al., 2020) analysed the short-run and long-run determinants influencing agricultural exports of Pakistan. They used an Autoregressive Distributive Lag Model (ARDL) with a Vector Error Correction Model (VECM), using annual time series data for the duration 1976-2016. The ARDL model proved a short-run link between the land cultivated and the producing of crops for the export of agricultural goods. However, there was no long-run link between the other chosen variables in their model. Additionally, the VECM confirmed a two-way relationship between work in agriculture and the export of agricultural products. Hence, the study confirms that it is vital to grow agricultural production using the accessible resources to grow exports in agricultural goods of Pakistan to grow international sources of income. (Khan., et al., 2020).

Using the ECM to research the factors of coffee export in Ethiopia. The results confirmed by (Hussien, 2015)'s study concluded that in the short run, the Ethiopian export of coffee was in affected by terms of trade, real income, exchange rate and foreign capital flow. Whereas, in the long-run export supply was influenced by exchange rate, real income, term of trade and domestic price (Hussien, 2015).

Moreover, (Dube, et al., 2018) proposed a study to analyse the determinants that impacted the horticultural export response in Ethiopia utilizing annual time series data for the duration 1985-2016. The ARDL bound test co-integration was applied to examine the short-run and long-run associations. The study found that, Ethiopian horticultural exports were influenced by the real GDP of Ethiopia, the real effective exchange rate, FDI, prices, and the structural break in the short and long-run. Whereas foreign GDP and interest rates were shown to influence the measured variable in the long-term only (Dube, et al., 2018).

The cointegration approach and an ECM was utilized by (Abdul, et al., 2013) in their study to determine the key factors affecting the export of Pakistani mangoes during 1970-2005. The technique employed regresses mango exports against the index of relative prices of mango exports, real agricultural GDP, quantity of domestic mango production, and the effect of the

World Trade Organisation (WTO) agreement. The co-integration test indicates that mango production followed by GDP had the highest elasticity coefficients in the short-run and long-run (Abdul, et al., 2013).

Utilizing time series data over 30 years, (Yusuf & Yusuf, 2008) examined the factors that determined exports performance of rubber, cocoa and palm-kernel employing the ECM. The study discovered that GDP had a direct association with cocoa exports whereas the year before cocoa exports and value of world trade have a negative impact on cocoa exports. For rubber, the lagged price ratio was negatively related to rubber whereas the real exchanged rate had a major direct influence on rubber export performance. For palm kernel, the year before exports, and the real GDP had a positive impact on palm kernel exports whilst lagged premium and palm kernel output adversely contribute to palm kernel exports.

The determinants of Tanzanian cotton lint were investigated by (Kingu, 2014) using secondary data from 1970 to 2010. The cointegration and ECM was used. The results reflected that real exchange rate and agricultural productivity were the driving force for cotton lint export earnings as their estimated coefficients were positive and statistically significant. Furthermore, non-parametric test showed that trade liberalization was a significant factor for cotton lint in Tanzania.

Furthermore, (Gebreyesus, 2015) investigated the key determinants of Ethiopian coffee export supply fusing the Vector Auto Regressive and Error Correction techniques. The research uses secondary time series for the duration 1981 to 2015 and aims to analyse total export supply of coffee against export price, real exchange rate, domestic production, road network, trade openness and world production. Local production, export coffee price, road infrastructure and world coffee production had a significant influence on Ethiopian coffee supply in the long-run and short-run. In contrast, real exchange rate was insignificant to Ethiopian coffee exports in both the long run and short-run. Also, openness for trade had an influence of coffee exports only in the long- run. Finally, the output suggests a rise in local Ethiopian coffee production and improving the road infrastructure as well as enhancing the quality of coffee exports may provide substantial influence on Ethiopian export supply of coffee.

The Ordinary Least Squares regression was employed by (Amoro & Shen, 2012) to investigate the determinants that affect the exports for cocoa and rubber in Cote d'Ivoire, using secondary data for the duration 1970 to 2005. The findings reported that rubber export in Cote d'Ivoire is significant as well as positively affected by local rubber production, producer price and interest rate. Whereas rubber exports had a negative significant influence with exchange rate and domestic consumption. For cocoa exports, the findings showed a positive significant relationship with cocoa output, local production, and rainfall. Finally, the study recommended a focus in the adding of value in the case of the cocoa being exported.

This study chose the ARDL model over Johansen's cointegration since the Autoregressive Distributed Lag (ARDL) bound test is more advantageous over Johansen's co-integration technique (Mosayeb Pahlavani, 2005). According to (Subrata Ghatak, 2001), as cited by (Mosayeb Pahlavani, 2005), analysing the cointegration relationship of a small sample is more statistically significant using the ARDL technique, whereas the Johansen co-integration technique needs a larger sample for reliability, which fits for this study given the small sample size of time series data from 1980 to 2023. Another advantage of the ADRL technique is that it can be employed irrespective of the regressors being integrated on the same order (I (1) and/or I (0)) (Mosayeb Pahlavani, 2005). Therefore, given these advantages, this study will employ the ARDL together with the ECM

2.8.2 Summary of literature review

The review of trade theories laid a foundation for understanding why South Africa is doing well in maize production and hence, a comparative advantage in maize exports. The number of factors that determine a country's comparative advantage also need to be taken into account, to achieve a trade balance between trading nations. The global and regional maize trade discussed set the stage for comprehending the current maize industry South Africa is a part of. The review of South Africa's maize segments highlighted the 'farm to fork' process of maize in South Africa whilst also detailing all the stakeholders involved in the industry. Assessing the regulations as well as the trade agreements that the South Africa's maize industry is shaped by and is a part of respectively, clearly explained the landscape at which South African maize is controlled and its current market access.

The final section of this chapter focused on the empirical review, in which various models such as the ECM, VECM, the ARDL model and Johansen's cointegration are reviewed to show evidence from previous studies. Both the theoretical and empirical review laid the groundwork for this study, which employs the ARDL model together with the ECM to analyse the factors that influence South Africa's maize exports and to investigate the long-run relationship between South Arica's maize exports and maize production, maize price, maize consumption, rainfall, trade openness and COVID-19.

CHAPTER 3: METHODS AND PROCEDURES

3.1 Overview

The area of study is discussed in this section followed by the description of the variables used and the respective sources of data utilised as also explained. The chapter goes into detail on the type of models used and how the data is analysed.

3.2 Study area

South Africa is in the southwestern end of Africa, and its neighbouring countries are Zimbabwe, Namibia, Mozambique, and Botswana. Since South Africa is enclosed by the sea and given the elevation of the interior plateau, this results in a subtropical climate and warm weather conditions (GCIS, 2015). These conditions make it conducive for agricultural production like maize, grapes, citrus, some deciduous fruit, wool, and sugar, just to name a few, to thrive thus producing more than enough for the population and a surplus to export. According to (NAMC, 2023), maize was one of the agricultural products that generated the most value in the 1st quarter of 2023 in South Africa. The production of maize in South Africa is intensified in four provinces, namely: the North-West, the Free State, Mpumalanga, and KwaZulu-Natal. Rainfall in the west of this key maize production region is unpredictable, and ranges between 550 and 650 mm (NAMC, 2023). In addition to that, the high heat in the Free State, North-West and KwaZulu-Natal lead to a conductive environment for maize production, specifically white maize. Moreover, the average yearly rainfall in the middle and eastern areas i.e. Gauteng and Mpumalanga, ranges between 650 and 850 mm. The lower heat and higher rainfall make it favourable for yellow maize (NAMC, 2023).

3.3 Data sources and definition of variables

This study employed time series data of fifty-four years from 1980 to 2023. Explanatory variables, such as the price, trade openness, rainfall, maize production, maize consumption, GDP, and Covid-19 are used in this study. Identifying these factors using quantitative analysis would help to guide policymakers and maize stakeholders through robust evidence-based findings.

Data was collected from different secondary data sources as presented in the table below:

Table 3.1: Data types and sources

Data sources	Data type	Description	Expected signs
World Development Indicators (World Bank)	Trade Openness (% GDP)	Percentage of GDP	+
South African Grain Information Service (SAGIS)	Maize export quantities	Metric tons	N/A
	Domestic maize consumption	Metric tons	-
	Domestic maize production	Metric tons	+
International Monetary Fund (IMF) and USDA	International Maize price	Dollars/ton	+
FAO	Real Exchange rate	Rands/USD	-
South African Weather Service	Average rainfall (key maize producing areas in South Africa)	Millimetres (mm)	+
South African Grain Information Service (SAGIS)	Maize producer price	Rands/ton	-
N/A	Coronavirus (COVID-19) (Dummy Variable)	N/A	-

Source: Constructed by author, 2023

3.3.1 Relationship between explanatory variables and maize export volumes

a. **Trade openness** – according to (Fuji, 2019) the measure of trade openness can be explained as a ratio of South Africa's imports plus its exports to the Gross Domestic Product (GDP) and is a widely used determinant in international macroeconomic studies. In the case of South Africa, due to the numerous trade agreements briefly mentioned above, this highlights the 'openness' of the nations' borders in terms of trade which in turn may enhance the maize exports. The connection between a country's trade openness and its exports tends to be positive and this is supported by (Ajmi, 2015)

b. **Domestic maize consumption** – maize is a staple food source is South Africa; hence majority of the maize produced in South Africa remains to meet its local demand whilst the surplus is exported. A previous study supports an inverse association between local maize consumption and maize exports, explaining that in years of low maize surplus or high local consumption, exports tend to be lower (Sihlobo, 2016).

c. **Local maize production** – There tends to be a positive and direct relationship between South Africa's maize (white and yellow) production and maize exports. This means that, generally, higher production creates a larger surplus thus allowing greater export volumes. A study by (Kargbo, 2006) highlighted that maize is mainly exported in years when production surplus exits.

d. **International maize price** – international maize price mirrors the world supply-demand dynamics and adds value as a potential determinant as it has a direct effect on the competitiveness and profitability of exports. There tends to be a direct relationship between international commodity prices and export volumes, meaning that, when international maize prices are high, it becomes more attractive for South African exporters to access those global markets and this is supported by (Bond, 1987). Furthermore, the study expected this association too.

f. **Real exchange rate** – the real exchange rate can be defined as determining the prices of a nations goods comparative to that of another nation (Ellis, 2001). The relationship between real exchange rate and a country's exports affect the macroeconomic landscape of the nation. The real exchange rate can either depreciate or appreciate. When the real exchange rate appreciates, meaning the Rand becomes 'stronger', South Africa's maize becomes more expensive in the world market, thus becoming less attractive to buyers and subsequently decreasing exports. Conversely, a depreciating exchange rate means that the local currency becomes cheaper, resulting in cheaper South African maize thus potentially boosting export demand. Furthermore, a study by (Edwards & Golub, 2004) found that a depreciated real exchange rate improves non-mineral export performance in South Africa. With this in mind, a negative relationship between maize exports and real exchange rate is expected.

g. **Rainfall** – According to the Limpopo Department of Agriculture and Rural Development (LDARD, 2022), 90% of the maize grown in South Africa is rainfed whilst the remaining 10% is under irrigation. Due to this, including the average rainfall (in millimetres), covering the key maize producing provinces (Free State, North West, and Mpumalanga) in South Africa, as a variable against maize exports seemed necessary. The relationship between South Africa's maize exports and rainfall is expected to be direct and significant given its high dependency on rainfall and this is supported by (Nhemachena, et al., 2019).

h. **Producer price** – the producer price of maize reflects the local price obtained by producers and is regarded as a crucial factor of export support decisions. The relationship producer price has with maize exports can vary. A higher producer price may decrease maize export volumes through incentivizing domestic sales. On the other hand, if producer price is low, farmers may resort to export markets for higher profits.

Coronavirus dummy variable – this is a dummy variable reflecting the period during the pandemic as 1 and 0 otherwise. COVID-19 was proclaimed to be an international pandemic by the World Health Organisation in early 2020, which led to a mandatory global lockdown across the world to reduce the span of the virus (WTO, 2022). This in turn hindered the once flourishing human and economic relations amongst nations as compulsory lockdown restrictions were imposed (Onyeaka, et al., 2021).

3.4 Methodology: Analytical Framework3.4.1 The Error Correction Model (ECM)

To determine whether variables are cointegrated in the short-run, the ECM is employed. The ECM starts by testing whether time series variables are stationary or not, in order to ensure robust findings when using such variables in the regression models. The cointegration tests are used to determine whether at least two non-stationary time series are combined or integrated collectively in a manner that the likelihood of a long-run equilibrium divergence is not plausible. The tests include testing for a long-run correlation between two or more variables that are in times series (Corporate Finance Institute, 2023).

Several studies (Dube, et al., 2018), (Hussien, 2015) and (Kingu, 2014) used the ECM by to analyse the short-run association amongst variables. The theory of representation says: “two or more integrated time series that are cointegrated have an error correction representation, and two or more time series that are error correcting are cointegrated” (Engle & Granger, 1987). As a result, there exists a strong correlation between error correction models and cointegration. The built-in features in the ECM controls the long-run characteristic of the endogenic variable to merge to their cointegrating association though permitting for short-run adjustment dynamics (Mndzebele, 2021). The cointegration of non-stationary methods correlates with a data generating error correction method according to work by (Engle & Granger, 1987). A change in a parameter (variable) that is related to a change in another parameter including the space in the middle of the variables in the prior time can be defined as the “error correction” cointegration characteristic.

3.4.2 The Autoregressive Distributed Lag (ARDL) Model

The ADRL bounds test is employed to resolve the long-run connection between the independent variable and the factors that may influence it. According to (Kripfganz & Schneider, 2018) using time series data in a one equation structure, the ARDL model is employed to establish the dynamic associations. Furthermore, the ARDL models can be used to investigate the occurrence of a long-run association between variables (Kripfganz & Schneider, 2018). According to (Mosayeb Pahlavani, 2005), using the ARDL model has some advantages since the variables need not be of the same order of integration, whereas other models, like Johansen's Cointegration, variables need to be of the same order of integration. Thus, making the ARDL slightly more advantageous over other models. This model was also used by (Dube, et al., 2018) and (Khan., et al., 2020).

The ARDL model helps to discover the immediate and long-term association between maize exports as the measured parameter, and other variables identified from the literature review (Bhattacharjee, et al., 2023). ARDL was reparametrized into an ECM, this was done to determine whether maize exports from South Africa (the measured variable) was cointegrated with the explanatory variables.

3.5 Unit Root Tests

In time series econometric testing, unit root testing is crucial to confirm that there is stationarity in all the variables utilized when the analysis is performed. A stationary variables' statistical properties (the variance, mean or autocorrelation) are sustained throughout time, whilst the statistical properties of non-stationary variables vary over time. As a result, omitting this step in the methodology and analyzing time series data that may be non-stationary may lead to a spurious regression (Wallstreetmojo, 2024). According to (Giles, 2007), a spurious regression leads to the misinterpretation of results and thus formulating artificial conclusions about the data patterns. There are numerous ways to conduct unit root tests, such as the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) tests and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS). Furthermore, various studies used these unit root tests like (Dube, et al., 2018) and (Hussien, 2015) in their respective studies.

In 1981, Dickey and Fuller developed ADF test. To capture the higher order autocorrelation, Dickey and Fuller expanded or 'augmented' the Dickey-Fuller test with higher order lags as noted by (Jalil & Roa, 2019). Another diagnostic test done after the ADF test is the Phillips-Perron (PP), which was established by Philips and Perron in 1988. It uses a nonparametric methodology to rectify the problem of autocorrelation when testing for unit roots. A nonparametric correction is made to the t-statistic when using the Philips Perron test and it offers a more robust output with regards to indefinite heteroscedasticity (Jalil & Roa, 2019). Therefore, this study employed ADF test and the PP tests to ensure non-stationarity in all the variables.

3.6 Optimal Lag Selection

In time series data analysis, it is fundamental to find out the optimal lag length to analyse if there is a time lag effect on the variables, testing if the previous value impacts the current value of the variable in question (Wooldridge, 2012). There are numerous ways to verify the optimal lag length, such as the information criteria utilizing the AIC (Akaike, 1974), the Schwarz-Bayesian Criteria (SIC), the Final Prediction Error (FPE), and the Hannan-Quinn Information Criteria (HIQ).

3.7 Granger Causality Test

The Granger causality test is used to verify whether a series can foresee another. Parameter X_i is perceived to be "Granger-causal" of parameter X_k on the condition that it assists in forecasting the other variable. In contrast, variable X_i fails to Granger-cause the other variable, if it does not assist in predicting variable X_k (Shojaie & Fox, 2023).

3.8 Model Specification

After reviewing and presenting the theoretical econometric techniques and the associated tests for time series data, the study adopts the ARDL-ECM model in which E-views 12 was the statistical software chosen to conduct these analyses. The ECM was applied to investigate whether South African maize exports have a short-run association with its explanatory variables. To test for cointegration and a long-run association amongst the, the ARDL analysis was used. The ARDL model was selected as variables need not have the same integration order and be used together whether they are stationary at level I (0) or after first differencing I (1) making it advantageous over other models.

The ECM is presented in equation one, which shows the modification of y_t by means of a_i (1) to equilibrium deviations in the prior time (Engle & Granger, 1987) $y_{t-1} - \beta^1 X_{t-1}$:

$$\Delta y_t = \gamma y_{t} + \theta` X_{t-1} + \sum_{i=1}^{p-1} a\Delta y_{t-1} + \sum_{i=0}^{n-1} \emptyset i \Delta X_{t-1} + \varepsilon_t \qquad (1)$$

Where: $y = -a(1), \theta = a(1), \beta = -y\beta.$

The ARDL was reparametrized into an ECM, this was done to determine whether maize exports from South Africa (the measured parameter) was cointegrated with the predictor parameters. The following equation below shows the ARDL reparametrized model of order *p* and *n* for a scalar variable *yt:*

$$y_t = \sum_{i=1}^{p} \alpha y_{t-1} + \sum_{i=0}^{n} c\prime X_{t-1} + \varepsilon_t \tag{2}$$

Where:

P Represents the number of lags

ε_t Indicates a scalar zero mean

N Represents the number of leads

X_t Represents the k-dimensional column vector process

α_i Represents the coefficients

C'_i Denotes a vector

y_t Represents the dependent variable (South Africa's maize exports)

X_{t-1} Indicates the independent variables (Exchange rate, maize production, maize consumption, world maize prices, producer price, trade openness, rainfall and COVID-19).

To better understand the association brought about by the causal association between South African maize export volumes and its determinants, the Granger Causality test was conducted using the Pairwise Granger Causality approach. The causality between South African maize exports and its regressors was determined using the following augmented VAR model (Sims, 1980) and (Granger, 1969):

$$y_i = a_0 + \Sigma_{i=1}^{k+m} a_i y_{t-i} + \Sigma_{j=i}^{k+m} b_i X_{t-j} \ldots + u_{it} \tag{3}$$

$$x_i = C_0 + \Sigma_{i=1}^{k+m} c_i x_{t-i} + \Sigma_{j=i}^{k+m} d_i y_{t-j} \ldots + u_{it} \tag{4}$$

Where Y is the dependent variable, South African maize exports, X represents the independent variables (world maize price, maize consumption, producer price, rainfall, GDP, trade openness, exchange rate and maize production), m shows the maximum order of integration of the parameters. The model results from the approximation of an augmented VAR model ($k+d_{max}$) in which k is the time lag that is optimal of the initial VAR.

3.9 Diagnostic tests

Diagnostic tests were performed assess the validity of the findings as well as observe the statistical properties of the models utilized. Firstly, the Jarque-Bera test for normality was performed after the unit root tests. The Jarque-Bera test is applied to determine whether the model was accurately specified and whether there is a normal distribution in the residuals. Secondly, cumulative sum of squares and cumulative sum test for model stability was done to ensure that the model was dynamically stable. The third test was for autocorrelation applying the Breucsh-Godfrey Serial Correlation LM Test. The fourth test performed was for multicollinearity and was to ensure that variables that are highly correlated are removed from the model to avoid any misleading results. Lastly, was the test for the presence of heteroscedasticity employing the Breusch-Pagan test.

3.10 Summary

This chapter started out by briefly discussing the study area and was followed by explaining the parameters used in the study and the sources they were obtained from. Thereafter, the statistical software that was used to analyse the data was specified. Afterwards, detailed review of the analytical framework models relevant for the current study and several post-estimation diagnostic tests were presented in this chapter.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of the various analysis, using the econometric models and tests presented in chapter three. Firstly, the descriptive statistics are presented thereafter, the findings of the unit root test to test for stationarity of the selected parameters. Thereafter, the findings from the lag selection criterion were discussed and this was followed by the model diagnostic tests. Thereafter, the cointegration amongst the variables is determined. The ECM was applied to reflect the immediate association of the parameters, and this was followed by obtaining the long-run association from the ARDL analysis. Lastly, the Granger Causal relationship was determined to close off the chapter.

4.2 Descriptive statistics

Table 4.1 presents the descriptive statistics by tabulating the mean, median, maximum, minimum and the standard deviation. The average amount of maize exports in South Africa was 2,170,000 tons though the average maize production was 10,049,729 tons from 1980 to 2024. The average exchange rate over the study period is estimated to be R7.07/USD. The world maize price was $149.2/ton an average of, while the maize producer price was R1,147.6/ton on average over the same study period. The average rainfall for the maize growing areas in South Africa was 51.4 mm in the period 1980 to 2023 (South African Weather Service, 2023). Some of the variables (exchange rate and local maize consumption) were not included in the final model for this study, based on the selection of the best fit model. The data used in the study contained some variables with fluctuations experienced over the duration of the study which could affect the maize production and exports. Therefore, the transformation to natural logs was done to decrease their influence (Metcalf & Casey, 2016).

Table 4.1: Descriptive statistics

	Exports (Metric tons)	Exchange rate (Rands/ USD)	World maize Price (Dollars/ ton)	Maize Consumption (Metric tons)	Maize Producer Price (Rands/ ton)	Production (Metric tons)	Rainfall (millimetres)	Trade openness (%)	COVID-19 (Dummy variable)
Mean	2170000	7.06549	149.2359	7839791	1147.59	10049729	51.41092	48.90483	0.090909
Median	1865287	6.615621	124.5835	7086500	761.54	9712915	52.46067	48.55961	0.0000
Maximum	59240000	18.45024	318.3610	11353240	4037.34	16820000	73.12196	65.97452	1.0000
Minimum	408000	0.842023	75.52100	5236000	102.08	2956000	30.19941	34.32135	0.0000
Std. Dev.	1382922	4.902740	62.26506	1820209	1005.46	3420141	9.436946	7.754218	0.290803

Source: Computation by author

4.2.1 Jarque-Bera probability

The skewness and Jarque-Bera probability were determined thereafter. To determine the data's symmetrical distribution, skewness was used. All the variables in the study had a skewness of between -1 and +1 which indicates that the data was moderately skewed. The Jarque-Bera probability must be greater than 0.05 to indicate that the data is normally distributed. Four out of the nine variables had a probability greater than 0.05 thus implying that the data leans more towards a normal distribution.

4.2.2 Correlation matrix

The correlation matrix explains the measure and association in which the variables are associated with each other but more importantly to the dependent variable, maize export volumes. According to (Disha, 2016), the rule of thumb with regards to correlation is that any value greater than (negative or positive) 0.70 indicates that the variables are highly associated. When two independent variables are highly correlated, this may increase the likelihood of multicollinearity in the results. When there is a presence of multicollinearity in the study, it decreases the accuracy of the coefficients thus reducing the statistical power of the study's regression model (Frost, 2024). The initial correlation matrix table that was done, which comprised of the same variables as table 4.1 above, this table however had a few variables that were very highly correlated. The strong association amongst these variables meant that they are likely to cause multicollinearity which, in turn may cause inaccurate results. Therefore, the following variables were removed from the study to reduce the presence of multicollinearity: local maize consumption and exchange rate. Table A, in the appendix, presents the correlation matrix without the variables exchange rate, and local maize consumption.

4.3 Optimal Lag Selection

This study utilizes the Vector Autoregression (VAR) function in E-views to find out the number of lags for each variable and the entire model. Furthermore, the Final Prediction Error (FPE), the Akaike Information Criterion (AIC), the Schwarz Bayesian Information Criterion (SC) and the Hannan-Quinn Information Criterion (HQ) were applied to investigate the optimal lag selection (Shrestha & Bhatta, 2018). All the outputs of the lag selection are tabulated in Table B in the appendix. The number of lags to add in the study were different for all the six variables. Table B in the appendix presents, the number of lags selection for the variables used in the model. The number of lags included for maize exports, rainfall, trade openness and for the entire model was one whilst, the lag to includes for maize production, producer price, world maize price was three.

4.4 Unit root tests

4.4.1 The Augmented Dickey Fuller (ADF) test for stationarity

The Augmented Dickey Fuller (ADF) test for stationarity was conducted in the study. The null hypothesis of the ADF test states that: the variable has the presence of a unit root, which means that the variable is non-stationary (Ng & Perron, 2001). The rule of thumb for the ADF test is to reject the null hypothesis if the p-value is smaller than 5% level of significance. Conversely, if the p-value is greater than 5% level of significance, then we fail to reject the null hypothesis and can conclude that the "Time series is non-stationary" and needs to be differenced (Nkoro & Uko, 2016).

The ADF test results are as follows: variables that had a p-value smaller than 5% level of significance and were stationary at level (I (0)) were maize export volumes and rainfall, s. In contrast, the ADF test concluded that world maize price, producer price and openness to trade all had a p-value greater than 5% level of significance and thus, required differencing in order to be stationary (Nkoro & Uko, 2016). The non-stationary variables were differenced once to ensure stationarity. Thereafter, the ADF test was conducted again on the differenced variables. The ADF test concluded that after first differencing, the non-stationary variables, world maize price, producer price, maize production and trade openness, had a p-value smaller than 5% level of significance and were stationary at fist difference (I (1)) as presented in table 4.2.

Table 4.2: Augmented Dickey-Fuller (ADF) test for stationarity

Variable	Critical values (5%)	Probability	Critical values (5%)	Probability	Stationarity
LnExports	-2.931404	0.0009	-	-	I (0)
LnWorld Maize Price	2.931404	0.5023	-2.935001	0.0000	I (1)
LnRainfall	-2.931404	0.0000	-	-	I (0)
LnTrade openness	-2.931404	0.2256	-2.933158	0.0000	I (1)
LnProduction	-2.938987	0.9824	-2.935001	0.0000	I (1)
LnProducer price	-2.941145	0.9999	-2.935001	0.0000	I (1)

Source: Authors own computation

4.4.2 The Philips-Perron (PP) test for stationarity

The Philips-Perron (PP) test was the second test for stationarity conducted in the research. Comparable to the ADF test, the rule of thumb for the PP test states that if the p-value is greater than 5% level of significance, then we fail to reject null hypothesis thus, concluding that the time series is non-stationary. In contrast, if the p-value is smaller than 5% level of significance, then we reject the null hypothesis and can confirm that the "time series is stationary" at first order and does not need to be differenced (Nkoro & Uko, 2016). The PP test was conducted, and maize export volumes, rainfall and maize production volumes were all stationary at level (I (0)). On the other hand, world maize price, openness to trade and producer price were stationary at first difference I (1) as depicted in table 4.3 below. The findings of the unit root tests also concluded that the ARDL model was indeed appropriate for this study as all the variables were stationary at level and at 1st order only (Mosayeb Pahlavani, 2005).

Table 4.3: Phillips Peron test results for stationarity

Variable	Critical values (5%)	Probability	Critical values (5%)	Probability	Stationarity
LnExports	–2.931404	0.0015	-	-	I (0)
LnWord Maize Price	-2.931404	0.4868	-2.933158	0.0000	I (1)
LnRainfall	-2.931404	0.0000	-	-	I (0)
LnTrade openness	-2.931404	0.2293	-2.933158	0.0000	I (1)
LnProducer Price	-2.931404	0.9573	-2.933158	0.0000	I (1)
LnProduction	-2.938987	0.0090	-	-	I (0)

4.5 Model diagnostic tests

Six model diagnostic tests were conducted in this study to ensure that the model was stable before any analyses could be performed (Nasrullah, et al., 2021). Firstly, the Jargue-Bera test for normality was conducted, followed by the stability Cusum test and the Cusum square test. Other tests conducted are the serial correlation test, a test for multicollinearity and the heteroscedasticity test.

4.5.1 Jarque-Bera test for normality

The Jarque-Bera technique was applied to examine whether the model was accurately specified and whether there is a normal distribution in the residuals. The null hypothesis of this test states that the data follows a normal distribution. The findings obtained, which are depicted in table 4.4 show that the Jarque-Bera probability is 0.171913 at 5% level of significance, thus we fail to reject the null hypothesis of normality at 5% level of significance. This confirms that the model was accurately specified, and that there is a normal distribution of the residuals. A similar study was conducted by (Gebreyesus, 2015) and they obtained the same results for their study.

Table 4.4: Jarque-Bera test for normality

Jarque-Bera. H_0: Residuals are normally distributed	
Jarque-Bera	3.521539
Jarque-Bera Probability (5%)	0.171913

Source: Authors own computation

4.5.2 Testing for model stability

4.5.2.1 CUSUM Test

To measure parameter constancy is essential for South African maize exports. This was achieved using the stability diagnostic test, the cumulative sum test or the CUSUM test. For the model to be considered stable, the parameter should be positioned within the 5% critical bound. For the short-run and long-run parameters of the maize export function stability, it is critical that the blue line (trend) be positioned within the bounds of the red lines in figure 4.1. Based on the results presented in figure 4.1, the trend line position between the 5% critical bounds or the red lines, then we can conclude that the model is dynamically stable.

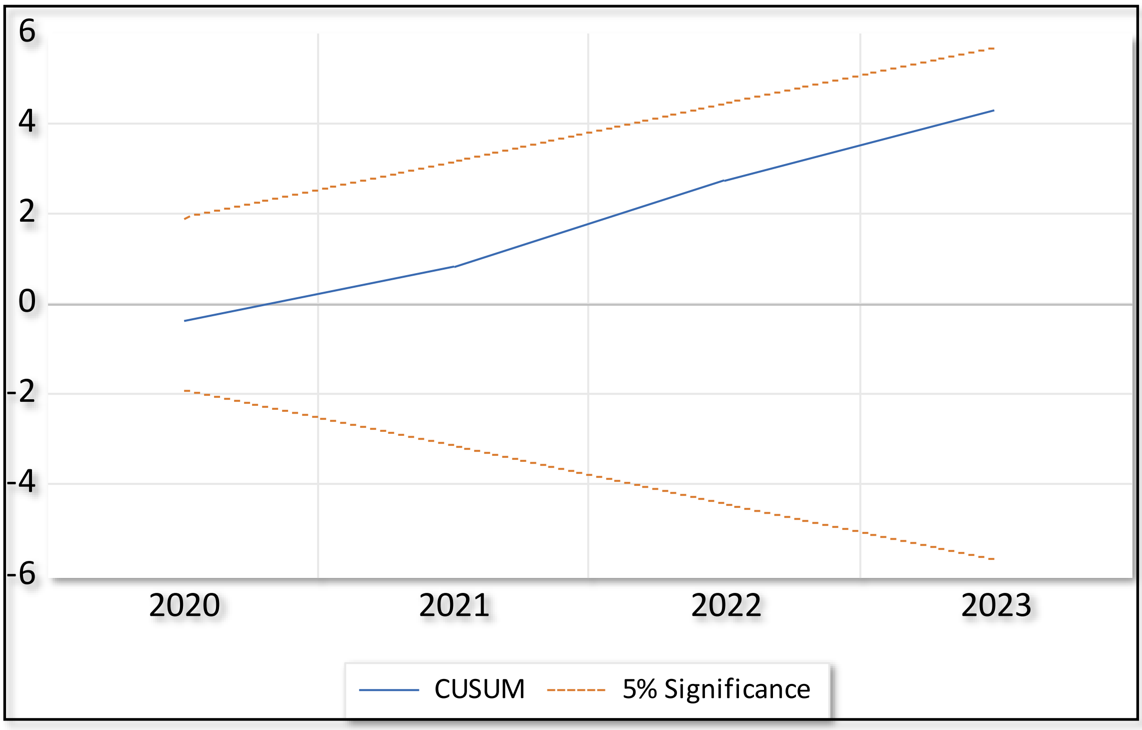

Figure 4.1 CUMSUM test
Source: Authors own computation

4.5.2.2 CUSUM Square Test

Estimating the stability of the coefficients of any model is important and by utilizing the CUSUM squares test we can do so. The graph of the CUSUM statistics shows that the bounds of the critical region (blue line) does not go beyond the critical region at the 5 % level of significance (the red boundary lines). Figure 4.2 illustrates a graphical representation of the test results for the CUSUM Square test indicating that there is stability in this model. According to the results, we therefore fail to reject the null hypothesis of model stability at 5% level of significance confirming that the CUSUM square test output shows that there is stability in this model.

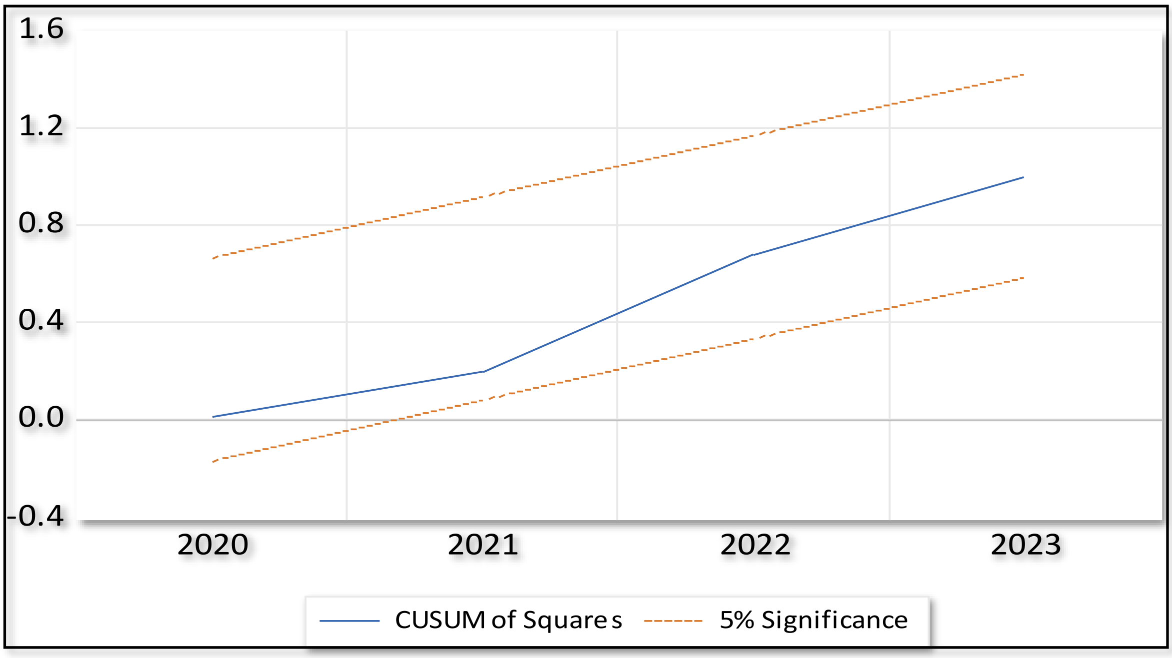

Figure 4.2: CUSUM square test
Source: Authors own computation

4.5.3 Testing for autocorrelation

In time series statistical analysis, autocorrelation amongst the variables may be a problem that arises. Autocorrelation represents the level of likeness between a given time series as well as a lagged variety of the time series itself over continuous time intervals. Thus, autocorrelation is supposed to determine the association between a variable's current value and past values that are accessible (Georgiou-Dotis, 2019). There are a couple of reasons as to why autocorrelation may occur in a study, and according to (Durbin & Watson, 1950) lags, non-stationarity and data manipulation may be some of the causes for autocorrelation. To test for autocorrelation, this study the Breusch Godfrey LM test for serial correlation by (Breusch & Pagan, 1979). The null hypothesis of the test states that: "there is no serial correlation at up to two lags." The output in table 4.5, the Chi-square test is greater than the 5% level of significance, therefore, we fail to reject the null hypothesis and ascertain that the model has no serial correlation in it.

Table 4.5: Breucsh-Godfrey Serial Correlation LM Test

Breucsh-Godfrey Serial Correlation LM Test H_0: No serial correlation at up to two lags			
F-statistics	1.308389	Prob. F (2,6)	0.2839
Observed R-squared	3.159226	Prob.Chi-Square (2)	0.2061

Source: Authors own computation**4.5.4 Multicollinearity**

Another diagnostic test to determine whether independent variables have a close association over time is multicollinearity. If multicollinearity is present amongst the variables, this will lead to a high correlation thus resulting in inflated coefficients and reporting misleading results. The Centred Variance Inflation Factor (VIF) was used in this study to test whether multicollinearity is present. The rule of thumb is that if the Centred VIF value of a variable is greater than 10, it implies that multicollinearity is present amongst the variables and those variables should be dropped from the study (Kim, 2019). Table 4.6 presents the findings obtained from the test and all the variables had a Centred VIF value less than 10, indicating that there is no existence of multicollinearity within the study.

Table 4.6 Multicollinearity test

Variable	Coefficient Variance	Uncentered VIF	Centred VIF
LnExports	0.010583	3.823807	1.101585
LnWorld Maize Price	0.026400	3.008248	2.947639
LnProduction	0.015507	16.97161	1.765188
LnRainfall	0.013828	43.16651	1.396676
LnTrade Openness	0.025601	119.0651	2.875000
LnProducer price	0.038141	4.122531	3.916589
COVID-19 (Dummy variable)	0.194595	1.897574	1.721056

Source: Authors own computation

4.5.5 Heteroscedasticity Test

Heteroscedasticity means that the variance of the residual is unstable in a regression model. When heteroscedasticity is detected in the model, it may result in the standard errors of the estimates to be inaccurate therefore affecting the accuracy and reliability of the entire model. On the other hand, if the variance of the residual remains constant from one observation to another then this is referred to as homoscedasticity and leads to a more accurate and trustworthy model (Murphy, 2015). To conduct the heteroscedasticity test, the Breusch-Pagan test was used and table 4.7 presents the results. If the value of probability of the f-statistic is greater than the 5% level of significance, it is confirmed that there is no presence of heteroscedasticity. Table 4.7 shows that this value is greater than 0.05 at 0.0939. Thus, we can confirm that the model has no presence of heteroscedasticity, and these results are also in line with (Gebreyesus, 2015).

Table 4.7 Heteroscedasticity test

F-statistic	1.931247	Prob. F (7, 35)	0.0939
Obs*R-squared	11.98105	Prob. Chi-Square (7)	0.1012
Scaled explained SS	7.336625	Prob. Chi-Square (7)	0.3947

Source: Authors own computation

4.6 Auto-regressive Distributed Lag (ARDL) Bound Test for Cointegration

Table 4.8 presents the cointegration relationship amongst the variables. The test was conducted using the ARDL long-run form and bounds test function in E-views 12. Cointegration occurs when the F-statistic is greater than the 95% upper bound at a 5% level of significance (Nkoro & Uko, 2016). Since the F-statistic (12.19) is greater than the 95% upper bound (3.28) in table 4.8, we reject the null hypothesis of no co-integration at 5% level of significance and conclude that there is cointegration present amongst the parameters.

Table 4.8: ARDL Bound Test for Cointegration

Null Hypothesis H0	F-statistic	95% lower bound	95% upper bound	Remark
No cointegration	12.1980	2.27	3.28	Reject H0, cointegration present in model

Source: authors own construction

4.6.1 Error Correction Model

The short-run dynamics was re-estimated by manually including one lag and a short run effect for each variable as guided by EViews using the Least Squares analysis. The results of the re-estimated short-run dynamics are presented in table 4.9. After re-estimation, maize production was found to have a highly significant and direct relationship at 1% level of significance. This means that a 1% increase in the production of maize is associated with a 1.11% increase in maize exports in the short run, holding other factors constant. A highly strong positive elasticity is illustrated in these results, showing that enhanced maize production instantaneously translates into greater export volumes. This may occur during periods of a bumper harvest, in which excess supply is immediately directed to the export market. These results align with (Geyser, et al., 2024) who reported that maize production was positively associated with maize exports in the short run. The findings also presented a direct and significant relationship between rainfall and maize exports holding other factors constant at 5% level of significance. This means that a 1% increase in the average rainfall in major maize producing areas, suggests a 0.24% increase in maize exports. These results are in line with (Mqadi, 2005) , whose findings highlighted how rainfall impacts maize production and the exportable surplus over a short period of time.

According to Table 4.9, the Error Correction Term (ECT) is negative (-0.673598) and statistically significant at the 1% level, as economic theory suggests. The ECT validates the cointegration of the variables in this study, which indicates a long-run equilibrium relationship. In addition, it measures back to equilibrium after a shock speed of adjustment, according to (Gebreyesus, 2015). The ECT value indicates about 67% of any disequilibrium in maize exports is rectified after one year. In other words, relatively 67% immediate adjustment of South Africa's maize export volumes takes place for external shocks including trade openness, world maize price, rainfall, maize production, trade openness, and COVID-19 dummy. Also, the imbalance in the maize export supply if any will be corrected at the rate of 67%per annum. Hence, the system has a strong tendency to move towards equilibrium.

Table 4.9: Error Correction Model

Variable	Coefficient	Standard Error	Probability
D(World maize price)	-0.054423	0.226359	0.8116
D(Production)	1.107930	0.177727	0.0000***
D(Rainfall)	0.243075	0.113819	0.0410**
D(Producer price)	0.271735	0.359608	0.4558
D(Trade openness)	-0.129067	0.226389	0.5728
COVID-19	-0.309676	0.506021	0.5452
Correction Error Term (ECT)	0.673598	0.062247	0.0000***

*Note: *** = 1% (0.01), ** = 5% (0.05) and * = 10% (0.1) significance level*

Source: Authors own computation

4.6.2 ARDL Bound Test for Long-Run Relationship

The analysis in Table 4.10 highlights the factors of maize export volumes over the long-run. The analysis revealed that maize producer price has an inverse effect on maize export quantities, with statistical significance at the 1% level. When all conditions remain constant, a 1% rise in maize producer prices causes a 0.84% reduction in maize export volumes. A plausible explanation for this inverse relationship is because when producer prices are high, farmers will opt to sell their maize to the local market since the domestic price is more attractive thus causing the amount of maize exported to reduce. Furthermore, production shocks such as droughts lead to a surge in maize prices due to the total reduction of the overall maize production and subsequently a reduction in the maize exported. Nevertheless, these findings are in line with (Kannan, 2013) whose results found that the domestic price of rubber had an inverse and significant effect on Indian rubber exports. The findings also revealed that maize exports increase by 1.21% for every 1% rise in maize production which shows a significant positive relationship. This significant and direct relationship between maize production and maize exports was expected indicating that the South Africa's maize exporting capacity is greatly influenced by the overall maize production. In periods of high maize output, South Africa has the surplus to export more maize as opposed to periods of drought resulting in major maize imports. Similar results were recounted by (Jalata, 2021) who discovered that local coffee production growing by 1% resulted in a 1.2% increase in coffee exports. The results shows that an increase of 1% in rainfall results in a 0.31% growth in maize export volumes when all other variables remain unchanged. Previous studies from (Khan & Gbetnkom, 2008), demonstrated similar results which showed that cocoa and coffee growth rates rose by 0.18% and 0.24% respectively with every 1% increase in average annual rainfall. Our findings are supported by the fact that the majority of South Africa's maize production relies on rain where 90% of it is rain-fed, while only 10% gets irrigation support (LDARD, 2022). Openness to trade and COVID-19 both had a positive but insignificant relationship with maize export volume. Finally, world maize price also had an insignificant and negative relationship with maize exports.

4.10: ARDL Bounds test and cointegration

Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
LnWorld maize price	-0.012506	0.241678	-0.051745	0.9590
LnProduction	1.205396	0.268303	4.492668	0.0001 ***
LnRainfall	0.313861	0.179642	1.747148	0.0894 *
LnProducer price	-0.839751	0.302107	-2.779646	0.0087**

LnTrade openness	0.086282	0.239012	0.360996	0.7203
COVID-19	0.295077	0.649608	0.454238	0.6525

*Note: *** = 1% (0.01), ** = 5% (0.05) and * = 10% (0.1) significance level*

Source: Authors own computation

4.7 Discussion of Results

The results show that a direct and significant relationship between rainfall and maize exports holding other factors constant at 5% level of significance. This means that a 1% increase in the average rainfall, in major maize producing areas (Mpumalanga, Free State, and North West), reported a 0.24% increase in maize exports. These results are in line with (Mqadi, 2005) , whose findings highlighted how rainfall impacts maize production and the exportable surplus over a short period of time. Maize production was found to have a highly significant and direct relationship at 1% level of significance. This means that a 1% increase in the production of maize is associated with a 1.11% increase in maize exports in the short run, holding other factors constant. These results align with (Geyser, et al., 2024) who reported that maize production was positively associated with maize exports in the short run. Although this highly strong coefficient was not expected, there could be reasons supporting it. Firstly, this high responsiveness could potentially reflect periods of a bumper harvest, since excess maize is immediately exported. Secondly, it could be linked to South Africa's well-integrated maize value chain as well as better access to infrastructure for exports (ports, rails) allowing for highly efficient export trade (in the context of SSA). Couple these reasons with the fact that South Africa is a top maize supplier in sub-Saharan Africa, then this instantaneous production-trade relationship may be justified. Conversely, acknowledging the fact that these results may be influenced by model specification and the sample period is also plausible.

Furthermore, the ECM showed that the 67% of the disequilibrium of South Africa's maize export volumes is corrected annually.

Using the ARDL long-run form and bounds test to investigate the long-run relationship of the model. The results show that there are significant long-run relationships between maize export volumes and three of the explanatory variables namely: maize production volumes, maize producer price, and rainfall. Maize producer price had a significant, negative long-run relationship with maize export volumes at 1% level of significance. This implies that a 1% increase in maize producer prices leads to a 0.84% reduction in maize export volumes. This could be attributed to the fact that, when producer prices are high, farmers will opt to sell their maize to the local market since the domestic price is more attractive, leading to a reduction in the volume of maize exports. Furthermore, production shocks such as droughts creates scarcity and push maize prices up, due to the total reduction of the overall maize production and subsequently a reduction in the maize exported. These results are supported by (Kannan, 2013). Finding also shows that maize production volumes and rainfall both had a positive and significant long run relationships at 1% and 10% level of significance respectively. The positive significant relationship between maize export volumes and rainfall was expected considering that 90% of South Africa's maize is dryland and heavily dependent on rainfall (LDARD, 2022). Therefore, rainfall in major maize growing areas plays a vital role in maize production. The world maize price had an inverse yet, insignificant relationship with maize exports. Furthermore, the COVID-19 dummy variable incorporated in the study and the trade openness reflected a positive yet insignificant relationship with maize export volumes. In the case of COVID-19, this shows that maize exports were barely affected by the pandemic. This is partly due to the agricultural sector in South Africa that was not restricted during the lockdown as it had to export produce during the pandemic. These results are supported by (Meyer, et al., 2021) and (Statistics South Africa, 2020) who confirmed that South Africa's maize industry was not impacted by the Coronavirus pandemic (COVID-19).

4.8 Granger causality test

The Pairwise Granger Causality test was done to further understand the association between South Africa's maize export volumes and the independent variables in the study. After conducting the ADF stationary tests, the level of cointegration was determined to establish the level of stationarity. Thereafter, the Granger Causality test was conducted. The findings of the test could be a bidirectional causality from both variables, a unidirectional causality either from the predictor variables to the measured variable or from the measured variable to the predictor variable or no causality at all. The output from the Pairwise Granger Causality test is depicted in table 4.11 below.

Table 4.11: Results from the Pairwise Granger Causal Test

Null Hypothesis H_0	**F-statistic**	**Probability**	**Decision**
Maize exports do not Granger Cause Maize production	4.69419	0.0152**	Reject H_0
Rainfall does not Granger Cause Maize exports	3.52593	0.0397**	Reject H_0
World maize price does not Granger Cause Maize production	5.62238	0.0074***	Reject H_0

Trade openness does not Granger Cause maize production	4.53057	0.0174**	Reject H_0
Maize production does not Granger Cause world maize price	3.59673	0.0374**	Reject H_0
Rainfall does not Granger Cause Maize production	3.85419	0.0302**	Reject H_0
Producer price does not Granger Cause maize production	26.2445	8.e-0.8***	Reject H_0
Maize production does not Granger Cause producer price	4.68746	0.0153**	Reject H_0

*Note: */**/*** indicates 5%, 10% and 1% level of significance respectively*

Source: Authors own computation

The findings of the Pairwise Granger Causality test offer a more extensive comprehension of the causal association amongst the variables in the study. According to the results, we reject the null hypothesis stating that maize exports does not Granger cause maize production 5% level of significance This in turn leads to a unidirectional association between these two variables. We reject the null hypothesis that rainfall does not Granger cause maize exports at 5% level of significance. Another bidirectional association is presented as we reject both the null hypotheses that world maize price does not granger cause maize production and vice versa both at 1% and 5% level significance. We fail to reject the null hypothesis that producer price does not Granger cause maize production and vice versa at 1% and 5% level of significance. Trade openness reflects a unidirectional relationship with maize production as we fail to reject the null hypothesis that trade openness does not Granger cause maize production at 5% level of significance.

From the findings we see a unidirectional causal relationship flowing from rainfall to maize production volumes as well as from rainfall to maize export volumes. This causal relationship flowing from rainfall to maize production is because 90% of South Africa's maize production is rain fed and is heavily dependent on rainfall (LDARD, 2022). Furthermore, causal relationship of rainfall to maize exports was because there is a direct positive correlation between maize production and maize exports, thus the factors (in this case rainfall) that increase maize production will have a direct influence on maize exports. The unidirectional relationship flowing from maize exports to maize production could be because export volumes could be influenced by other factors beyond maize production such as local consumption, global demand, and trade policies. The is unidirectional causal relationship between world maize price and maize production is because increased prices push producers to increase production; and the same can be said about the producer price Granger causing maize production, higher prices will push farmers to grow more maize. On the other hand, maize production Granger causing producer price can be attributed to the law of supply and demand since there more maize is produced, the more maize will be sold, and given there are sufficient buyers, the price will decline.

4.9 Summary of Results

Chapter four discusses the findings of the several models, tests and procedures discussed in chapter three. The descriptive statistics were discussed, and certain variables were removed from the model in order to achieve more reliable results. Thereafter, the stationarity tests were conducted to ensure that only stationary variables at level and first order were present. The model diagnostic tests were performed thereafter to ascertain model stability and validity. The ECM was utilized to determine the short-run dynamics of the variables. The findings showed that both maize production and average rainfall were significant and positive against maize exports. The significant relationship of average rainfall and maize production against maize exports concludes that changes in these two variables have an immediate effect on export volumes. This was followed by the ARDL analysis to estimate the long-run dynamics amongst the variables. The results of the long-run dynamics indicated that maize production and rainfall had a significant positive relationship with maize exports whilst producer price and exports reported a significant yet negative relationship. Finally, the Pairwise Granger Causality test was also done to investigate the Granger Causal association amongst parameters.

CHAPTER 5: CONCLUSION

5.1 Overview

This study used time series econometrics to identify the main factors that determine South Africa's maize export volumes, using annual secondary time series data from 1980 to 2023 period. Maize is the largest produced grain in South Africa and the country is the largest exporter of maize on the African continent. Given the important function of the maize sector in the economy of South Africa, there is a need to comprehend the determinants that affect maize exports using econometric analysis for robust policy-based evidence. Furthermore, the study purposes to augment to the body of existing literature that the Coronavirus Pandemic (COVID-19) had minimal consequences on South Africa's maize exports, given the important role played by the sector in various parts of the world during the pandemic lockdown periods.

The ECM was applied to examine the short-run dynamics as well as the size and speed of adjustment of South Africa's maize export volumes back to equilibrium. Thereafter, the ARDL approach was applied to examine and understand the long-run dynamics of the parameters in relation to maize exports. This was followed by the Pairwise Granger Causality test to examine the causal link amongst the significant parameters. To conclude the analysis, various post-estimation tests were done to ascertain that the model is stable and valid.

5.2 Conclusions

This study aimed to identify which determinants influence South Africa's maize exports by using the ARDL model. The study showed that in the short-run, average rainfall and maize production had a direct and significant relationship with local maize exports. This implies that South Africa's maize exports are driven by short-term changes in average rainfall as well as maize production.

The determinants that affect South Africa's maize exports in the long term are maize production and rainfall, both directly, whilst producer price inversely affects exports. The positive relationship for maize production and rainfall were expected thus highlighting the need for long-term investment in agricultural productivity as well as infrastructure (for maize irrigation as mentioned above). The inverse relationship between producer prices and maize exports, indicates that an increase in producer prices leads to a decline in the competitiveness of South African maize on the international market. Thus, focusing on price stabilization mechanisms like ensuring consistent domestic maize supply which in turn will decrease the need to limit export in lower production years thus avoid price variability.

These results add to the body of existing literature, particularly expanding on the study by (Geyser, et al., 2024) whose focus was mainly on the effects of logistical inefficiencies on South Africa's maize exports. This study viewed the overall effects of maize over the short and long-term curtailing the importance of rainfall on export volumes. This in turn creates a preliminary guideline to ensure that policymakers are aware of the significant effects that average rainfall and maize production, as well as the producer price have against domestic exports. As a result, appropriate policy suggestions, primarily focused on irrigation development and promoting agricultural productivity as well as price stabilisation mechanisms can be drawn up to assist in the South African maize industry.

5.3 Recommendations

Based on the findings of this study, the following recommendations are proposed to policymakers and industry stakeholders.

5.3.1 Enhancing Climate Resilience and Maize Production: The positive association between rainfall and exports and production levels highlights efforts to improve maize production via sustainable agriculture. In order to mitigate the effects of changing rainfall patterns, policymakers should prioritize funding for climate-resilient agricultural interventions, including better irrigation systems and drought-resistant maize varieties.

5.3.2 Maintaining Market Prices to Promote Export Development: The higher price of maize on the domestic level may limit the export capacity, as the inverse relationship between maize price and export volume indicates. Therefore, there is a need for the policymakers to think in the direction to stabilize local maize price in order to avoid the price fluctuation through promoting supply chain management, reducing the cost of production, and storing facilities.

5.4 Limitations of the study

The current study focused on the determinants that influence South Africa's maize exports from 1980-2023. However, there were certain constraints experienced by this study. Firstly, the period chosen was selected because data was only available for this period. Therefore, future researchers can expand the period this study used. Expanding the sample size may result in more extensive findings. Secondly, by expanding the sample size, the use of the Cointegration model as opposed to the ARDL model will be more beneficial as it is recommended when using a larger sample size. Lastly, incorporating other variables such as production costs and logistical costs as well trade policies imposed by trading countries.

Adding these variables may enable us to obtain a broader understanding of the maize export factors in South Africa, particularly the costs and potentials barriers experienced by local suppliers. This study refrained from adding these variables as the data is not readily available for the duration of the period selected.

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APPENDICES

Appendix A: Correlation Matrix

	Exports	COVID-19	World Price	Production	Rainfall	Trade openness	Producer price
Exports	1	0.1886	0.1634	0.5772	0.2328	0.1978	-0.0312
COVID-19	0.1886	1	0.4148	0.4247	0.3108	0.3100	0.5658
World Price	0.1634	0.4148	1	0.5679	0.2103	0.6634	0.6521
Production	0.5772	0.4247	0.5679	1	0.0822	0.5751	0.5760
Rainfall	0.2328	0.3108	0.2103	0.0822	1	0.0820	0.1589
Trade openness	0.1978	0.3100	0.6634	0.5751	0.0820	1	0.6619
Producer price	-0.0312	0.5659	0.6521	0.5761	0.1589	0.6619	1

Appendix B1 Lag selection for maize exports

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-776.6906	NA	1.89e+12	31.10762	31.14586	31.12219
1 *	-773.1641	6.770933*	1.71e+12*	31.00656*	31.08304*	31.03569*
2	-773.1403	0.044646	1.78e+12	31.04561	31.16033	31.08930
3	-772.5359	1.106554	1.81e+12	31.06156	31.21452	31.11981
4	-772.5300	0.016036	1.88e+12	31.10120	31.29240	31.17401

Appendix B2 Lag selection for world maize price

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-274.2585	NA	3542.072	11.01034	11.04858	11.02490
1	-244.1634	57.78256	1106.218	9.84656	9.923017*	9.875661
2	-242.5973	2.944255	1081.560	9.823893	9.938614	9.867579
3*	-240.4570	3.938271*	1033.539*	9.778278*	9.931240	9.836572*
4	-240.4182	0.069809	1074.403	9.816727	10.00793	9.889538

Appendix B3 Lag selection for maize production

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-819.9850	NA	1.07e+13	32.83940	32.87764	32.85396
1	-815.3029	8.989539	9.24e+13	32.69212	92.76860	32.72124
2	-815.0790	0.420868	9.53e+12	32.72316	32.83788	32.76685
3*	-810.5516	8.330421*	8.28e+12*	32.58207*	32.73503*	32.64031*
4	-809.8037	1.346214	8.36e+12	32.59215	32.78335	32.66496

Appendix B4 Lag selection for rainfall

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-183.2905	NA*	93.10697	7.371621	7.409861*	7.386183
1*	-181.7612	2.936375	91.15961*	7.350446*	7.426927	7.379571*
2	-181.5403	0.415245	94.05486	7.381611	7.496333	7.425298
3	-181.4477	0.170311	97.55092	7.417909	7.570871	7.476158
4	-180.2651	2.128805	96.87251	7.410602	7.601804	7.483413

Appendix B5 Lag selection for producer price

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-416.1989	NA	1035177	16.68795	16.72620	16.70252
1	-371.4066	86.00122	179589.4	14.93626	15.01274	14.96539
2	-369.5797	3.434474	173764.5	14.90319	15.01791	14.94688
3*	-365.1117	8.221173*	151286.9*	14.76447*	14.91743*	14.82272*
4	-364.2977	1.465126	152466.9	14.77191	19.96311	14.84472

Appendix B6 Lag selection for trade openness

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-169.8909	NA	54.47624	6.835636	6.873877	6.850199
1*	-144.4789	48.79098*	20.51842*	5.859157*	5.935638*	5.88282*
2	-144.4167	0.116934	21.30489	5.896670	6.011391	5.940356
3	-144.0754	0.627978	21.87804	5.923018	6.075980	5.981267
4	-143.4796	1.072526	22.24189	5.939184	6.130386	6.011995

Appendix B7 Lag selection for the whole model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2565.565	NA	1.90e+37	102.8626	103.0921	102.9500
1*	-2445.824	205.9555*	6.73e+35*	99.51295*	101.1191*	100.1246*
2	-2412.804	48.86944	8.07e+35	99.63216	102.6149	100.7680
3	-2385.195	34.23497	1.33e+36	99.96780	104.3272	101.6279
4	-2356.395	28.80024	2.53e+36	100.2558	105.9919	102.4401