ANALYSING WHEAT PRICE VOLATILITY IN SOUTH AFRICA FROM 1996 TO 2015

BY

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DECLARATION

I, Mashita Rasenaka Majory, hereby affirm that the research project titled " ANALYSING WHEAT PRICE VOLATILITY IN SOUTH AFRICA FROM 1996 T0 2015," submitted to the University of Limpopo to fulfill the requirements for the degree of Master of Science in Agricultural Economics is entirely my work. This project has not been previously submitted by any other individual at the University of Limpopo or any other educational institution. I have appropriately cited and referenced all sources to acknowledge the authors whose information was utilised.

Student: Mashita Rasenaka Majory Date: 24/07/2023

Ms. Mashita RM

DEDICATION

To my late beloved, mother (Makwena Bedphina Mashita)

To my father (Maphuthi Alfred Mashita)

And as well as all people next to me

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I want to start by extending my sincere gratitude to the Divine Creator, whose guidance and blessings have empowered me to embark on this study with assurance, wisdom, and perseverance.

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ABSTRACT

In South Africa, the import of wheat exceeds its domestic production. The research aimed to examine the fluctuations in wheat prices within the country and evaluate the factors contributing to these price variations during the specified study period. This study used yearly data for wheat price, rainfall, temperature, and total production from 1996 to 2015. Climate conditions, power cuts, price fluctuations, and an increase in population pose a huge danger to the production of goods and services. To determine the volatility of wheat prices in South Africa from 1996 to 2015 and to identify and analyse the determinants (price, rainfall, temperature, and total production) of wheat price volatility in the South African market, where two primary objectives were used in this study.

The Johansen cointegration test was employed to investigate the possible long-term correlation between wheat price and variables including rainfall, temperature, and total production. Both trace and eigenvalue tests were conducted, and the cointegration results were positive, indicating a sustained connection among the variables over an extended period. As a result, the study's findings indicate that there is a long-term association among wheat price, rainfall, temperature, and total production, affirming the presence of cointegration among these variables. Rainfall has a positive impact while temperature and total production hurt the price of wheat, on average, ceteris paribus based on the VECM results. In this study, the positive coefficients for temperature and wheat total production were 7.472087 and 0.005639, respectively, showing that in the long run, increasing temperature and total production levels were associated with declining wheat prices or decreasing temperature, and total production is associated with increasing wheat price.

The study proposes that the government of South Africa implement subsidies to address high price volatilities and promote wheat production, considering the high consumption of wheat that is used to produce bread and is a staple food. Subsidies can help stabilise prices and ensure a reliable supply of wheat. Additionally, the study suggests that accessible information on wheat market dynamics, including prices and production technologies, should be provided to farmers to facilitate informed decision-making and encourage higher wheat production.

***Keywords**:* Wheat price, Volatility, Vector Error Correction Model

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ITAC	International Trade Administration Commission
ECM	Error Correction Model
OECD	Organization of Economic Cooperation and Development
FAO	Food Agriculture Organisation
DAFF	Department of Agriculture, Forestry and Fisheries,
SAWS	South African Weather Services
FPE	Final Prediction Error
AIC	Akaike Information Criterion
SC	Schwarz Criterion
HQ	Hannan-Quinn information criterion
OLS	Ordinary Least Squares
PROB	Probability
STATS SA	Statistics South Africa
NAMC	National Agricultural Marketing Council
SA	South Africa
VAR	Vector Autoregressive
ETU	Education and Training Unit
C V	Coefficient of Variation
ADF	Augmented Dickey-Fuller
DF	Dickey-Fuller
SAFEX	South African Futures Exchange
BFAP	Bureau for Food and Agricultural Policy
USAD	United States Agricultural Department

CHAPTER ONE

INTRODUCTION

1.1 Background

As reported by Wagner (2020), adverse weather conditions in the Western Cape as well as in parts of other provinces that include other South African provinces such as Northern Cape, Limpopo, and the Free State contributed to price increases domestically. Global exports of wheat and maize have been reported to be accounted for 29 percent from Russia and 19 percent from Ukraine (News24, 2022).

A significant commodity is wheat which helps feed the population, for food security and is one of the most widely used commodities in South Africa's agriculture sector (FAO, 2017). Wheat is one of the most widely used commodities since it is a key component in the creation of flour, which is used by most homes and the bakery sector to make handmade bread, vetkoek, and cookies, among other things. According to Braun et al. (2010), wheat provides roughly 21 percent of the protein and 19 percent of the calories that humans need to achieve their daily requirements.

Price volatility has been a problem in the market for agricultural products in addition to yearly price swings (Togun *et al.,* 2019). Diversifying the volatility of commodity prices is a challenge for many economic operators. The relationship between overall welfare impacts and monetary costs is causal (Gilbert and Morgan, 2010). The price volatility of food is a concern as it imposes an immediate on the nature of food security and the livelihoods of sizable segments of the worldwide population. Approximately R4 billion and 28,000 employment are supported by the wheat industry, which is a substantial contributor to South Africa's agricultural output (Bester, 2014). According to Van der Vyfer and Nordier (2013), in South Africa, wheat comes in second to maize in terms of agricultural importance

The agricultural production of wheat started in 1652 with the introduction of wheat by Jan van Riebeek as the nation's first winter crop (Du Plessis, 1933). This significant development in the 17th century laid the groundwork for all subsequent efforts to breed and produce wheat. According to Nhemachena and Kirsten (2017), although wheat has been cultivated since the 1600s, records of wheat varietal breeding did not begin to appear until 1891. The majority of wheat variabilities between the years 1891-2013 were prevalent in South Africa in the two provinces, namely Western Cape and Free State as they produce wheat mostly.

In the past 20 years it has been witnessed that the sustainability of the wheat industry was challenged by the large decline in wheat production (Van der Vyfer and Nordier, 2013). According to Visser (2010), for farmers, the financial sustainability of wheat as a crop has grown more difficult, with many finding it difficult to make ends meet. Other profitable commodities make farmers shift their focus and give up farming altogether as a result. Boonzaaier (2009) cautioned that the exit of producers from the market might have serious repercussions, threatening not only the nation's food security but also raising unemployment rates and impeding South African farmers' prospects for the future.

The International Trade Administration Commission of South Africa (ITAC) made recommendations for a higher for imported wheat (Tsengiwe, 2013). With a rise of R1207.64 from the previous level of R2287.17 per ton, the new reference price for wheat became R4495.01 per ton. This modification intends to increase industrial competition. To protect local producers through import charges, the price must be closer to R4495.01 than R2287.17, even though the worldwide reference price may still be more than the tariff rate of 4.15 percent (Tsengiwe, 2013). In South Africa, the wheat sector's limited supply is added by the worldwide market, which has a substantial impact on the cost of primary goods. As a result, the quality and supply of domestic wheat are also impacted by local pricing, which is further influenced by the global price of wheat.

As stated in the 2009 Food and Agricultural Organization (FAO) report, there is a projected need for global food production to rise by nearly 70 percent to meet the nutritional requirements of an estimated 9.1 billion individuals by the year 2050. This requires doubling agricultural output while simultaneously addressing various challenges such as a diminishing rural labor force, growing demand for biofuel feedstocks, and the necessity to contribute to overall agricultural development in countries heavily reliant on agriculture.

Furthermore, it is imperative to address the necessity of adopting efficient and sustainable production practices while also mitigating the effects of climate change (FAO, 2009). In addition to these global concerns, individual countries and industries face unique characteristics, challenges, and attributes. For instance, according to the OECD (2015), if Russia's wheat production were to be severely affected by adverse weather conditions, the global price of wheat would increase by approximately 10 percent. This highlights the negative impact of unfavorable weather conditions on wheat price volatility.

Abbott *et al*. (2011), highlighted biofuel demand, which led to an increased relationship between energy and food costs, exchange rate dynamics, and physical factors linked to supply, such as weather conditions, as the major forces influencing food commodity prices. Ensuring a steady supply to the world's increasing population, which is anticipated to reach 8.5 billion people by the year 2030 by providing inexpensive, wholesome, and nutritious (Enghiad *et al*., 2017), numerous significant challenges must be tackled. These challenges encompass climate change, urbanization, and conflicts, as well as the scarcity and deterioration of crucial resources like energy, land, and water. Successfully addressing these issues is vital for establishing secure food provisions that adequately cater to the requirements of the global population.

Moreover, South Africa is a net importer when it comes to wheat, so the oil market affects the price of wheat, and an increase in the price of oil drives up the cost of transportation for wheat. SAFEX introduced discounted prices to incorporate the quality of wheat into pricing mechanisms and assign appropriate values to specific quality levels (Van der Merwe, 2015). From 2019 levels, wheat prices were predicted to rise by up to 16 percent. In the short term, this anticipated price increase is expected to encourage more wheat produced to increase planting area and therefore lower import quantities (BFAP, 2020). Moreover, there will be a reduction in transportation costs from the production site to the consumption point.

The location difference is used by SAFEX in South Africa to analyse these costs, and this directly influences the price that local producers are paid.

Stats (2014), highlighted that in South Africa the significance of the wheat industry is emphasised by its rank and being the second mostly consumed commodity in the country. Consequently, the industry, along with local wheat processing sectors, generates numerous employment opportunities (StatsSA, 2014). In April and June that is where wheat planting occurs due to winter rainfall regions and in the regions where the rainfall occurs during summer from May until the end of July. Approximately 20 percent of South Africa's wheat cultivation relies on irrigation, while the remaining 80 percent is rainfed (DAFF, 2005). Although different wheat varieties have similar life cycles, they exhibit variations in their growth periods. From planting wheat takes from seven to eight to mature on average.

Moreover, as a crucial component used primarily in bread production, wheat flour holds the second most significant position among South Africa's food sources, making a vital contribution to addressing food insecurity (NAMC, 2005). As emphasized by the Education and Training Unit (2012), bread, especially brown bread, holds significant importance within the National School Nutrition Program. In addition to feeding the future workforce, the forefront of initiatives to battle food insecurity is the National School Nutrition program in South Africa.

1.2 Problem statement

Wheat producers are experiencing growing challenges due to the rising demand for wheat products, spurred by population growth and higher incomes in developing nations (Economic Research Service, 2015). Additionally, South Africa's wheat production is consistently impacted by obstacles such as climate change, power disruptions, and water scarcity (Wagner, 2020). According to Naledzani *et al.* (2019), in the Southern African Development Community it is underlined that the net importer of wheat is South Africa. The country has experienced a significant decline in wheat production, with yields decreasing to less than 2 million tonnes per year, representing a nearly 50 percent reduction (Naledzani *et al*., 2019). It is now recorded that 1.5 million tonnes of wheat production between the years 2019 to 2020, is the third lowest since deregulation in 1997. Moreover, wheat demand increased by 50 percent at the local level in the past 25 years to more than 3 million tonnes (Reidy, 2020). Additionally, this leads to food insecurity in countries that depend on South African wheat.

The pricing of wheat is influenced by the oil market through two primary channels: firstly, whereby it is affecting the costs of production inputs the direct way and through the demand for biofuels and the subsequent effects of substitution being the second indirect way (Baffes and Haniotis, 2016). The cost of crude oil affects various factors such as fertiliser prices, agricultural machinery expenses, and transportation costs, which in turn impact the production costs of wheat. In April 2020, the local price of wheat in South Africa reached a record high of R5,567 per ton, largely due to these factors (Esterhuizen, 2020). Any significant increase in wheat prices can negatively affect the food costs for consumers in South Africa. Additionally, adverse weather conditions in the Western Cape, as well as specific regions in the Free State, Limpopo, and the Northern Cape, along with increasing local costs and the effects of COVID-19, resulted in a notable increase in imports between 2019 and 2020 (Sihlobo, 2020).

The main problem this study was attempting to analyse the significant factors impacting the price increase of wheat that consequently have a negative impact on food expenditure. The study of Reidy (2020) stated that the price of wheat will still stay high locally which will have a negative inflationary impact on bread and wheat flour. This price increase hinder consumption as wheat is a mostly used to produce the by-products of wheat (FAO, 2017). The fixed incomes of the consumers will make it very difficult for families to obtain daily requirements (Drewnowski and Eichelsdoerfer, 2011). Hence, there will be food insecurity. According to Manning *et al.* (1974) it was found that the motives for high consumption of bread as one of wheat by-product was its availability and accessibility.

1.3 Rationale

The research aimed to investigate the significant price rise of wheat, which has negative implications for food expenditure. According to Reidy (2020), the local price of wheat is expected to remain high, leading to inflationary effects on bread and wheat flour. This price surge poses challenges for consumers as wheat is a key ingredient in various food products (FAO, 2017). The fixed incomes of consumers make it increasingly difficult for families to meet their daily nutritional needs (Drewnowski and Eichelsdoerfer, 2011), thus contributing to food insecurity. Addressing this issue requires improved social protection measures for food consumption stabilization, along with initiatives to educate consumers on cost-effective food choices, enabling households to access diverse and nutritionally balanced diets (Altman, 2009). Manning *et al*. (1974) highlight that the availability and accessibility of bread, a primary wheat by-product, contribute to its widespread consumption.

During May, global wheat prices showed a consistent upward trajectory, marking the fourth consecutive month of increases. The prices rose by 5.6 percent, reaching an average that was 56.2 percent higher than the previous year. Although the prices remained 11 percent below the all-time high observed in March 2008, this surge was significant (FAO, 2022). The primary catalyst for this price hike was India's decision to impose restrictions on wheat exports, which raised concerns about the state of crops in major exporting nations. Additionally, the ongoing conflict in Ukraine led to expectations of reduced wheat output, further contributing to the price escalation (FAO, 2022). Given these circumstances, it is essential to analyse the volatility of wheat prices specifically in South Africa.

1.4 Aim

The study aimed to analyse wheat price volatility in South Africa from 1996 to 2015.

1.5 Objectives

The objectives of the study were to:

1.5.1 Determine the volatility of wheat prices in South Africa from 1996 to 2015.

1.5.2 Identify and analyse the determinants (price, rainfall, temperature, and total production) of wheat price volatility in the South African market.

1.6 Research hypotheses

1.6.1 Wheat price was not volatile from 1996 to 2015.

1.6.2 The determinants (price, rainfall, temperature, and total production) do not influence wheat price volatility in the market.

1.7 Structure of the Study

Chapter 1 provided an introduction that encompassed various components such as background information, problem statement, rationale, aim, objectives, and hypothesis. The other chapters that are following are arranged as follows: Chapter 2 provides an extensive literature review that encompasses the elucidation of crucial concepts, an examination of factors impacting wheat price volatility, and an overview of pertinent studies conducted within South Africa and in international settings. Chapter 3 details the methodology employed in this research. Moving on to Chapter 4, the focus shifts towards presenting and discussing the obtained results. Lastly, the study's summary, final thoughts, and recommendations drawn from the findings are all included in Chapter 5.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter offers reviews of other researchers' studies and key concepts used in this study. An explanation of terminologies and approaches to time series was also given by a review of previous studies on price volatility in South Africa and worldwide.

2.2 Explanation of concepts

According to Bambang (2020), Price volatility, which refers to the fluctuation of prices or quantities, lacks a clear direction. The volatility problems that are faced in the market of agricultural commodities are explored in the following subsections.

Price volatility denotes the fluctuations in prices within a specific timeframe. It holds significance for national food security, and the level of correlation between local and global price volatility differs across countries (Daz-Bonilla, 2016). Between the years 2007-2008, in South Africa global food crisis happened whereby agricultural commodities witnessed substantial price volatility as underscored by Minot (2012). This study adopts Bambang's definition of volatility as an attribute that lacks a specific direction, representing the variability of prices or quantities.

Agricultural commodity price volatility can have a negative influence on producer income, but it can also cause issues, particularly when planning production. Overall, market price volatility can result in both a loss of trading position and a loss of customer welfare (Kemény *et al.*, 2012).

Price volatility can have a dual impact. Firstly, it can lead to a rapid decline in prices due to significant fluctuations. Secondly, high price volatility can cause prices to escalate rapidly, but if the volatility persists, prices can subsequently plummet at an even faster rate (Pietola *et al*., 2010).

The study adopted the Augmented Dickey-Fuller test to assess for the occurrence of the unit root and order on the integration of the variables. The mean, variance, and autocorrelation must be consistently stationary over time to say a time series is considered stationary. Nevertheless, during the estimation process, there may be additional autocorrelation beyond what is captured in the stationarity test equation (Mofema and Mah, 2021).

Brook (2008), highlighted that the method that provides a valuable framework for examining the dynamic connections among stationary variables is provided by The Vector Autoregressive (VAR) model. Changes are important when dealing with the VAR framework as the estimation of the relationships between the series and when dealing with non-stationary time series data will be guaranteed consistent, as highlighted by Brooks (2008).

In the model of Vector Error Correction (VEC), there is a variant that is specific to the Autoregressive (VAR) model when dealing with stationary variables differences, such as 1(1) this VAR model is suitable for analysing. It is important to do a cointegration test before employing Vector Error Correction Model (VECM), and this VECM is made specifically for a non-stationary with cointegration. According to Brooks (2008), there is a cointegration relation in the formulation of VECM confirming alignment of the co-integrating relationships with the long-term behavior of the endogenous variables, while maintaining the dynamics of short-term adjustments.

2.3 Factors affecting agricultural price volatility.

According to Gilbert (2010), demand factors such as taste, and preference changes can cause demand to shift from one commodity to another. Higher demand inevitably leads to higher pricing, which may have an impact on volatility. Domestic demand in emerging countries is mostly driven by population and income development (Gilbert, 2010).

The main reason for agricultural price volatility is widely thought to be supply shocks (Dehn *et al*., 2005). Crop output multiplied by area equals annual production. Consequently, variations in output deficits are primarily attributed to yield fluctuations resulting from weather-related events like droughts, high temperatures, floods, and other similar factors. Additionally, changes in input availability and disparities in planted areas can also contribute to production fluctuations. The market for agricultural commodities is significantly influenced by macroeconomic factors including inflation, interest rates, and exchange rates. These factors serve as key drivers of global prices for agricultural commodities.

Climate change has the potential to cause significant shifts in global agricultural production and increase the likelihood of local or regional supply disruptions, thereby contributing to future volatility in the market (FAO *et al*., 2011). Additionally, climate change can impact food production in various ways, including changes in the growing season length, average temperatures, and rainfall patterns in major agricultural regions (FAO *et al*., 2011).

Transaction costs have a pivotal role in enabling trade and influencing the overall size and robustness of a market (Rujis *et al*., 2004). When transaction costs change, market prices are likely to be affected until a new price equilibrium is reached. Among the various components of transaction costs, transportation expenses typically represent the largest portion. Additionally, trade taxes and other associated costs related to transportation can be significant and add to the overall expense of trade.

According to Minot (2011), it is widely recognized that global prices exert a substantial impact on the prices of tradable commodities. Contrarily, local supply and demand considerations have a greater influence on non-traded commodities. Export prices at important ports and futures prices at significant commodities exchanges are used as benchmarks for market participants around the world when observing international pricing. Given the recent changes in the value of commodities, it is important to recognise the role that international pricing plays in determining the volatility of local prices.

2.4 Review of previous studies on price volatility

The upcoming section of this chapter provides a wide-ranging evaluation of research that was carried out within South Africa and other countries, focusing on the research related to price volatility. It examines the findings and analyses from various studies that have explored the fluctuations in prices and their impacts. The aim is to gain a deeper understanding of the issue of price volatility and its implications, both in South Africa and in other contexts.

2.4.1 Previous studies conducted in South Africa

Moabelo (2019), researched the volatility of potato prices in South Africa from 2006 to 2017 and employed the coefficient of variation tool to evaluate the fluctuation of the price of potatoes. Moreover, the researcher further used the Johansen cointegration test and showed that changes in the land area dedicated to potato cultivation and variations in rainfall levels had a long-term impact on potato prices and were found to be cointegrated. This implies that a decrease in cultivated land or a decrease in rainfall would lead to higher potato prices, while an increase in these factors would result in lower prices. However, the study did not identify a significant relationship between temperature and potato prices.

The macroeconomic variables were investigated in the study conducted by Mofema and Mah (2021), the macroeconomic variables such as economic growth, interest rates, inflation, and the money supply. The study used the GARCH model to study the variation in oil prices from 2000-2020 in South Africa. According to the findings, changes in oil prices were positively impacted by higher interest rates and an expansion of the money supply. However, the analysis found no evidence of a substantial relationship between inflation or GDP growth and the volatility of oil prices in South Africa.

The impact of oil price volatility on economic growth in South Africa and the cointegration approach was conducted by Matekenya, 2013. This research was from the years 1994 quarter one (Q1) to 2010 quarter 4 (Q4). The volatility of the oil prices impact was studied on the nation's economic growth. To estimate the existing relationship between crude oil price and the GDP, gross fixed investment, real interest rate, and real exchange rate, this study relied on Vector Error Correction Model (VECM). The results showed a substantial link in both time frames between these variables. While there was a long-term positive correlation between the two variables, the short-term association between the oil price and GDP was negative. In the results, it was shown that every 1% increase in the volatility of oil prices resulted in a 0.029 percent increase in long-term GDP.

The researchers utilised the Aglink-Cosimo model and the Stochastic baseline from the OECD-FAO Agricultural Outlook, 2011-2020, to generate these scenarios in the study to analyse the volatility of international wheat prices in various scenarios (Thompson *et al*.,2012). The results indicated that both structural factors and specific conditions have contributed to the observed volatility in global wheat markets. However, the study suggests that the increase in market volatility resulting from economic development and income growth is expected to occur gradually. Additionally, the stabilising effect of larger stocks may only be temporary until there is a more permanent rise in stockholding demand. The study also explored the possibility of implementing a stylised wheat buffer stock scheme with a price band to mitigate market volatility, but it highlighted the challenges associated with such an approach.

Impulse Response Function and Granger-causality test as one of the post-estimation techniques were employed in the Vector-Autoregressive Model to examine the selected prices of commodities and the casual relationship in the short term. The results of the study highlighted that while there was no continuing association among the variables, a significant causal relationship occurs in the short term between oil prices and wheat prices (Sassi, 2017).

A recent research conducted in Poland, a relatively new member of the European Union, investigated the price volatility of agricultural commodities. The study employed descriptive statistics to evaluate the degree of price integration among these commodities. The results showed that the distribution of grain prices in Poland displayed a positive bias. Additionally, the study emphasised that the prices of wheat and rye in Poland are particularly influenced by global market pressures, making them more prone to fluctuations (Bórawski *et al*., 2015).

According to Chimaliro (2018) who carried out a research study in Malawi to pinpoint major causes of the volatility of soybean prices. To evaluate the variable's stationarity the study employed the statistics such as ADF and PP. The results revealed that, at a 1 percent level of significance, the null hypothesis of non-stationarity could be rejected and that the variables were stationary and integrated at order 1. The association of short-term as well as long-term was also considered amongst prices of soybean and the explanatory variables whereby the Vector Error Correction Model (VECM) was employed. In the results, it was shown that the exchange rate in Malawi and the soybeans price in South Africa have the biggest effects on the prices of soybean volatility in Malawi (Chimaliro, 2018).

To investigate how export restrictions, affect the pricing of maize and soybeans, Edelman and Baulch (2016) conducted a study in Malawi utilising monthly data from May 2004 to December 2015. The impacts of these limits were examined by the researchers using the coefficient of variation and the outcomes revealed that maize price volatility showed higher degrees as compared to prices regionally. Furthermore, the findings indicated that while export restrictions may provide short-term benefits for consumers, they have a detrimental impact on small-scale farmers who are already economically disadvantaged. Aragie *et al.* (2016) also observed that export restrictions lead to a decline in maize or soybean prices, which subsequently hampers the overall supply as there are fewer incentives for farmers to cultivate these crops.

The study conducted by Guo and Tanaka (2019) examined the determinants of international price volatility transmissions, the main goal was on wheat-importing countries' self-sufficiency role rates. This study aligns with the findings of Chimaliro (2018) regarding the stationarity test using the augmented Dickey-Fuller (ADF) test. In assessing stationarity, both studies used two statistical tests, namely the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test, to examine the return series. While the ADF test indicated non-stationarity in the series, the KPSS test suggested stationarity. When all variables were analysed in their first log-differenced forms, the results showed stationarity, indicating integration at order 1. Thus, both studies demonstrated integration at order 1 for the variables under investigation.

Tirado *et al*. (2010), whereby the investigations were carried into the effects of climate change and the development of biofuels on the security of food and nutrition through research. Their study involved a comprehensive review that provided an overview of how these factors specifically affect food costs and security.

2.4 Summary

Chapter two centered on providing a comprehensive explanation of key concepts related to price volatility, agricultural price volatility, and volatility in general. Additionally, the chapter delved into an exploration of the factors that contribute to agricultural price volatility. A thorough review of existing literature conducted by various authors in South Africa and internationally was also included in this chapter. Moving forward, chapter three focused on elucidating the methodology employed in this study. Previous studies conducted in South Africa and globally have highlighted instances of price volatility in several markets, particularly in grains, oil, and other commodities. However, there remains a dearth of data concerning other commodities. This research seeks to fill this void by analysing the grain market and specifically focusing on the discrepancies in South Africa based on wheat prices. Ultimately, the study concludes by summarising the insights derived from the literature review.

CHAPTER 3

RESEARCH METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Introduction

A comprehensive overview is presented regarding the research methods employed in conducting the study. The focus is on various aspects, including the selection of the study area, data collection methods, and the analytical techniques utilised. Furthermore, a summary is provided, outlining the study area, which encompasses all the provinces within the wheat-producing regions of South Africa. The methodology section commences by measuring wheat price volatility and subsequently introduces the concept of modeling wheat price volatility.

3.2 Study area

South Africa (SA) is the country where this study was conducted, which is located around 2,798 kilometers (1,739 miles) north of the Southern African coastline. South Africa, Namibia, Botswana, and Zimbabwe share borders as they are neighboring countries, and it is bordered by Mozambique and Swaziland to the east and northeast. It also encompasses the kingdom of Lesotho. As stated in the 2005 FAO - AQUASTAT report, South Africa is divided into nine provinces.

3.2.1 South Africa's wheat-growing regions

DAFF (2012) highlighted that there are provinces such as the Western Cape, Northern Cape, and Free State provinces that produce most of the cultivation of wheat spans across various regions in South Africa. The Western Cape contributed the most to overall wheat production output in 2012/2013, with an estimated half of 57 percent, followed by the Free State with 16 percent. According to Sihlobo (2022), there are only a few provinces that produce significant amounts of wheat, namely in the Northern Cape, Free State, Limpopo, and North West, which are mostly irrigated. Below, there is Figure 1, which shows the South African wheat production from 2016 to 2017 per tonne. The highest wheat-producing province is the Eastern Cape. Eastern Cape and the North West province can produce in dryland, unlike Northern Cape.

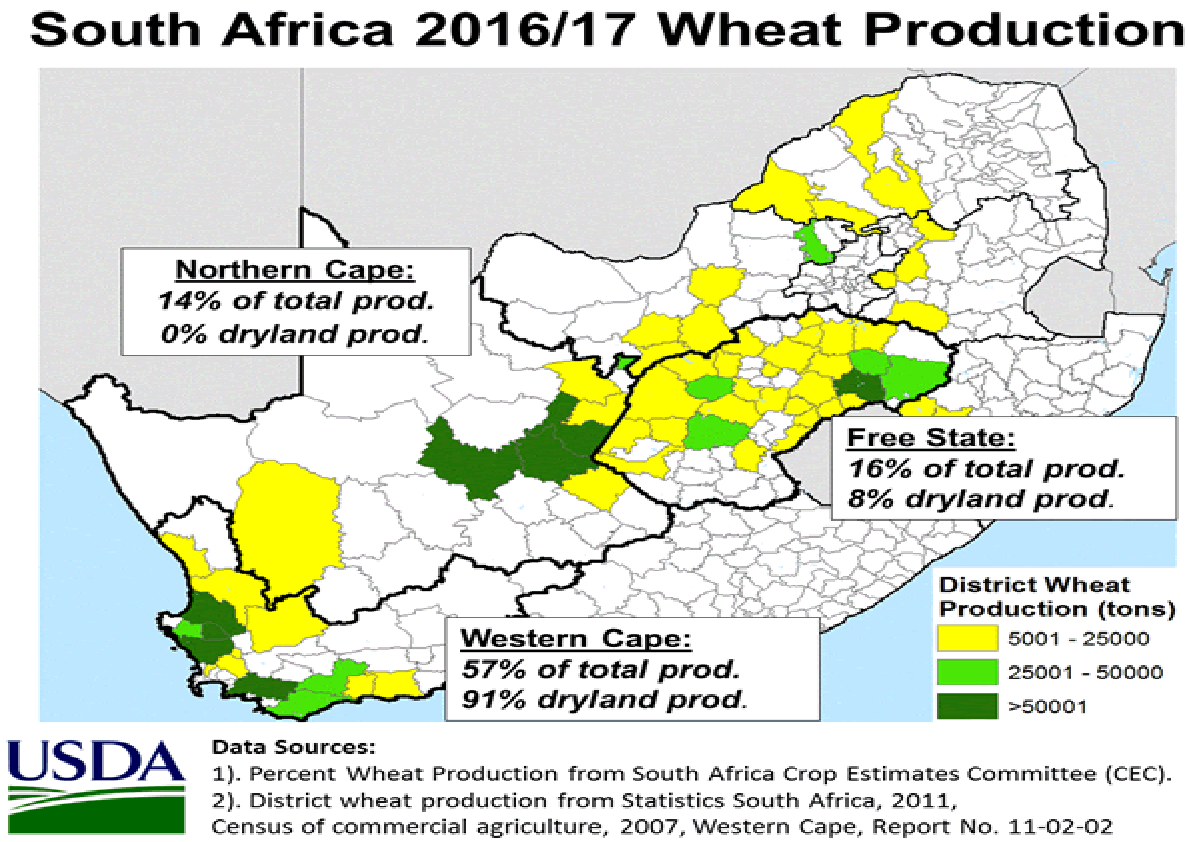

Figure 1: South Africa 2016/17 Wheat Production

Source: USDA (2017)

3.3 Data collected and source of data

Table 1: Variables description

Variable	Description	Units of measurements
Price	Producer price of wheat in (Rands per ton)	Rands
Total wheat production	Tonnes of wheat harvested	Tonnes
Rainfall	Average rainfall	Millimetres
Temperature	Average temperature	Degrees Celsius

3.3 Data collection

The study utilised secondary data acquired from various sources, including the South African Weather Services (SAWS), Grain South Africa, the Department of Agriculture, Forestry and Fisheries (DAFF), and the World Bank. All the independent data variables (wheat price, temperature and rainfall, and total production) were in years from 1996-2015. The study used data from 1996 to 2015 due to a shortage of rainfall data. The World Bank had up until 2016 mid-year. The highest production of wheat in South Africa is in the Western Cape province. Therefore, temperature data is for Western Cape's three weather stations (DAFF, 2012). Namely, George, Cape Town, and Paarl. Firstly, the yearly data minimum and maximum for all the weather stations were added, then averaged. It was followed by the addition of all the averages of all the weather stations for all the years and divided by 3. The study used EViews 11 student version lite a statistical package tool *to* run the data.

3.4 Analytical Techniques.

To assess the volatility of wheat prices in South Africa this study considered between the years 1996-2015, significantly, towards the coefficient of variation the stationarity of wheat prices was estimated using the Augmented Dickey-Fuller (ADF) tool for unit root test. Decide whether the data should be analysed in its original levels or differentiated form, this step was crucial. Objective two of the study was to identify and analyse the factors influencing wheat price volatility in the South African market, including price, rainfall, temperature, and total production. The study used an Autoregressive model that determines the appropriate lag order for cointegration analysis for the second objective to be achieved. Based on the results of the stationarity and cointegration tests, if the variables were found to be cointegrated, the Vector Error Correction Model (VEC model) was employed to further examine the relationships and dynamics among the variables.

3.4.1 Measures to evaluate volatility.

According to Brian (1998), to measure the level of difference between two data sets, you can use the coefficient of variation which is a statistical metric. This coefficient of variation is said to be the ratio of the standard deviation to the mean. In the present study, the coefficient of variation was used to assess the volatility of wheat prices. By serving as a fundamental indicator of price variability, the coefficient of variation offers an unconditional evaluation of the magnitude of variation in prices. The formula used to compute the coefficient of variation is as follows:

$$V = \frac{\sigma}{\mu} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_1-\mu)}}{\mu} \quad (1)$$

Where v is the coefficient of variation, σ is the standard deviation for the wheat price, μ is the mean prices of wheat, n is the number of observations and x_1 is denoting the observed wheat prices.

3.4.2. Unit root test

The study employed the Augmented Dickey-Fuller (1987) method to test whether the variables used to measure wheat price volatility in South Africa exhibit unit roots. These variables encompassed wheat price, total production, rainfall, and temperature. In cases where a variable was determined to be non-stationary, differencing was applied iteratively until stationarity was attained. If a variable required only one round of differencing, it was considered integrated of order one, denoted as I (1). The equations used in the Augmented Dickey-Fuller (1987) test are presented below.

$$\Delta WP_t = \propto_0 + yWP_{t-1} + \propto_2 t + \sum_{i=1}^{p} \delta_i \Delta WP_{t-i} + u_t \quad (2)$$

$$\Delta TP_t = \propto_0 + yTP_{t-1} + \propto_2 t + \sum_{i=1}^{p} \delta_i \Delta TP_{t-i} + u_t \quad (3)$$

$$\Delta R_t = \propto_0 + yR_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \Delta R_{t-i} + u_t \quad (4)$$

$$\Delta T_t = \propto_0 + yT_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \Delta T_{t-i} + u_t \quad (5)$$

Where WP is the wheat price, TP is the total production, R is the rainfall and T is the temperature.

Vector of determinist terms (constant, trend, etc.) $\propto_0$, the coefficient on a time series trend $\propto_2$, y is the coefficient of y_{t-1}, $+\Delta y_{t-1}$y are changes in the lagged values, y_{t-1} are lagged values of order one of y_t, P is the order of lag order in autoregressive process, and $_{it}$ is the error term. y_t, is I (1) under the null hypothesis, implying that $\delta = 0$

3.4.3 Testing cointegration

The presence of cointegration among the variables was investigated using the Johansen procedure, which consists of both a trace test and an eigenvalue test. The augmented Dickey-Fuller test is extended by the cointegration test, to multivariate settings and this procedure was originally established by Dwyer (2015). To select the lag order in the Vector Autoregressive (VAR) model automatic lag selection was employed to identify the optimal number of lags to be employed in the cointegration and Vector Error Correction Model (VECM) equations.

3.4.3.1 Johansen's procedure

To ascertain whether there was cointegration between the variables, the study first looked at their order of integration. The Johansen test, a commonly used cointegration test, was used to achieve this. The Johansen test enables the detection of several cointegrating relationships as opposed to the Engle-Granger test, which concentrates on a single cointegrating relationship utilizing the Dickey-Fuller test for unit roots in the residuals (Davison, 2000). The Johansen test is used to check for cointegration and is based on a Vector Autoregressive (VAR) model. Without a drift term, the generic form of the VAR (p) model can be written as follows.

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_k y_{t-k} + \mathcal{E}_t$$

This VAR can be written as

$$\Delta y_t = \mu + \prod y_{t-1} + \cdots + \sum_{i=1}^{k-1} \prod_i \Delta y_{t-1} + \mathcal{E}_t \quad (4)$$

Two tests were employed namely, trace and eigenvalue tests as two types of Johansen tests to assess the presence of long-run relationships among the variables.

Trace test

The null hypothesis of k cointegrating vectors against the alternative hypothesis of n cointegrating vectors is examined by trace test. The test statistic for this examination is calculated as follows.

$$J_{trace} = -T \sum_{i=k+1}^{n} \ln(1 - \hat{\lambda}_i) \quad (5)$$

Maximum Eigenvalue Test

The null hypothesis of k cointegrating vectors versus the alternative k + 1 vector is examined by the maximum eigenvalue test. Its test statistic is given by:

$$J_{max} = -T \ln\left(1 - \hat{\lambda}_{k+1}\right) \quad (6)$$

T is the number of observations and $\ln \hat{\lambda}_i$is the i^{th} largest canonical correlation.

Where the variables were found to be cointegrated, the VEC model was used to determine the long-run and short-run relationship.

3.4.3.2 Vector Error Correction Model (VECM)

The conventional approach to cointegration regression mainly emphasizes the long-term aspects of the model and does not explicitly account for short-term dynamics. The long-term association between wheat price and factors including rainfall, temperature, and total production was captured using the Vector Error Correction Model (VECM). The study used VAR lag order selection to determine the optimal number of lags to include in the system equation before conducting the cointegration test and VECM modeling. By considering the appropriate lag structure, this approach ensured a more precise analysis.

The following is the general form of the VAR (p) model without drift:

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_k y_{t-k} + \mathcal{E}_t \quad (6)$$

This VAR can be written as, by Hamilton (1994)

$$\hat{\Sigma} = \frac{1}{T-K} \sum_{t=1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}_t' \quad (7)$$

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Chapter 4 offers the findings of the analysis conducted on wheat price volatility in South Africa. It begins by examining the volatility of wheat prices between 1996 and 2015, to assess the level of volatility in the series. The study used the Augmented Dickey-Fuller test to ascertain the order of integration of the economic variables. In addition, a pretesting phase was carried out before this analysis to check for unit roots. The existence of long-term correlations between the variables was then investigated using the Johansen approach. The long-term association between wheat prices and numerous independent factors was a focus of the in-depth analysis and discussion of the Vector Error Correction Model (VECM) results.

4.2 Measure to evaluate volatility

The mean and standard deviation for all the variables of wheat price, rainfall, temperature, and total production from 1996 to 2015 for each variable are presented in Table 2.

Table 2: Measures to evaluate volatility

Variables	Standard deviation	Mean	Coefficient of variation
Wheat price	873.1851	1825.701	0.4783= 47.83%
Rainfall	14.52268	26.48700	0.5483= 54.83%
Temperature	0.324384	17.68600	0.0183= 1.83%
Total wheat production	360.5390	1991.800	0.1810= 18.10%

Wheat price and rainfall had the highest coefficient of variation of 47.83% and 54.835%, respectively while temperature and total wheat production indicated the lowest coefficient of variation 1.83% and 18.10%, respectively. This indicates that a coefficient of variation that is higher is represented by an increase in volatility. Significantly, a decrease in volatility is reflected by a lower coefficient of variation.

According to Edelman and Baulch (2016), to investigate the effects of export limits on maize and soybean prices in Malawi they used the coefficient of variation. The outcomes of this study concur with Edelman and Baulch because the coefficient of variation of the price of wheat is 47.83% and shows that the price of wheat is volatile.

4.3Testing for stationarity

Stating the null hypothesis as

H_0: Non-stationarity (the existence of unit root)

H_1: Stationarity (no unit root)

To assess the presence of non-stationarity and unit roots within the series, unit root tests were carried out. These tests encompassed various scenarios, such as tests with intercept and trend, as well as tests involving levels and first differencing. However, for this study, the focus was primarily on the intercept.

Table 3: Unit root at the level

Series	Levels	Test equation	ADF test statistic	Test critical value	Prob	Conclusion
Rainfall	At level	Intercept	-0.659853	-3.052169	0.8316	Non-stationary
		Trend and intercept	-2.669728	-3.673616	0.2257	Non-stationary
	1st differencing	Intercept	-4.208094	-3.052169	0.0053*	Stationary
		Trend and intercept	-4.057622	-3.710482	0.0272*	Stationary
Temperature	At level	Intercept	-3.996324	-3.040391	0.0075	Stationary
		Trend and intercept	-3.895467	-3.690814	0.0347*	Stationary
	1st differencing	Intercept	-3.945734	-3.098896	0.0111*	Stationary
		Trend and intercept	-6.528706	-3.791172	0.0007*	Stationary

Wheat price	At level	Intercept	1.552960	-3.081002	0.9984	Non-stationary
		Trend and intercept	-2.709189	-3.690814	0.2444	Non-stationary
	1st differencing	Intercept	-4.043602	-3.052169	0.0073*	Stationary
		Trend and intercept	-3.524377	-3.759743	0.0732	Non-Stationary
Total wheat production	Level	Intercept	-3.064223	-3.029970	0.0486*	Stationary
		Trend and intercept	-4.769331	3.710482	0.0076*	Stationary
	1st differencing	Intercept	-3.471619	-3.098896	0.0260*	Stationary
		Trend and intercept	-3.277628	-3.791172	0.1104	Non-stationary
* Significant at 5%						

Table 3 presents unit root test results in the series and shows the stationarity. The following figures -0.659853 and 1.55296 are the results for rainfall and wheat price at the levels, respectively and they were generated using the Augmented Dickey-Fuller (ADF). These values were higher as compared to the test critical values of -3.052169 and -3.081002, showing that the level's rainfall and wheat price were both non-stationary. The ADF statistics values for rainfall and wheat price, however, after applying the first differencing, were -3.996324 and -4.043602, respectively, exceeding the test critical limits of -3.040391 and -3.052169. Hence at a significance level of 5%, the null hypothesis was contradicted, proving that both variables became stable after initial differencing. On the other hand, temperature and total production were found to be stationary at both the level and first differencing, as their ADF statistics values exceeded the corresponding test critical values. The results imply that the variables that were tested are integrated at the I (0) level and show stationarity.

The study moved further to assess the presence of cointegration based on the stationarity results and used the Vector Error Correction Model (VECM) with a lag of 1. It is important to highlight that this approach differs from that employed by Chimaliro (2018).

4.3.1 VAR Lag Order Selection

To choose the best lag order for the analysis, the study used a VAR Lag Order selection technique. The results of the endogenous variable selection criteria, which include rainfall, temperature, and total production, are shown in Table 4.

Table 4: Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-356.4116	N/A	3.52e+11	37.93806	38.13689	37.97171
1	-328.2204	41.54486*	1.03e+11*	36.65478*	37.64893*	36.82303*

* indicates lag order selected by the criterion
LR: Sequential modified (each tested at 5% level)
FPE: Final Prediction Error
AIC: Akaike information criterion
SC: Schwarz criterion
HQ: Hannan-Quinn information criterion),

According to information criteria such as the Akaike information criterion (AIC), Schwarz criterion (SC), and Hannan-Quinn information criterion (HQ), lag 1 is the best lag order to use in the analysis, as shown in Table 4.

4.3.2 Johansen test for cointegration

In the Johansen test whereby both trace and maximum eigenvalue tests are adopted as displayed in Table 5 below. This test was carried out to study the occurrence of a relationship between the price of wheat and independent variables.

Stating null hypothesis as;

H_0: There is no cointegration

H_1: There exists cointegration

This table shows the trace and maximum eigenvalue.

4.3.2.1 Unrestricted cointegration rank tests

Table 5: Unrestricted cointegration rank test Trace and Maximum Eigenvalue

Unrestricted cointegration rank Test (Trace)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace statistic**	**0.05 critical value**	**Prob ****
None*	0.863620	52.11748	47.85613	0.0189
At most 1	0.480633	16.25593	29.79707	0.6942
At most 2	0.188962	4.463321	15.49471	0.8628
At most 3	0.037790	0.693401	3.841465	0.4050
Unrestricted cointegration rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Maximum Eigenvalue**	**0.05 critical value**	**Prob ****
None*	0.863620	35.86155	27.58434	0.0189
At most 1	0.480633	11.79261	21.13162	0.6942
At most 2	0.188962	3.769920	14.26460	0.8628
At most 3	0.037790	0.693401	3.841465	0.4050

Table 5, Johansen cointegration test results are presented, demonstrating that the price of wheat and another variable are cointegrated. At a significance level of 0.05, the rejected null hypothesis stated that there is no existence of cointegration among the series due to trace and the maximum eigenvalue statistics which were higher than the threshold. At a significance level of 5% whereby trace and maximum eigenvalue were less than the critical value. It was difficult to prove that at most 2 or most 3 equations to say the null hypothesis was false. It was found that there was one equation of cointegration at a significance level of 5 percent level. Moreover, it can be concluded there is the existence of a long-term association between wheat price, rainfall, temperature, and total production, showing the existence of a cointegration relationship among these factors. The approach also considers potential exogenous factors, such as real and financial economy variables, policy interventions, and exogenous occurrences, that may have an impact on volatility. The findings suggest that energy and financial markets, along with unpredictable events, can contribute to price destabilisation, while policy interventions may help alleviate instability in grain prices. These factors, which do not exhibit a long-run relationship with price volatility, form the basis for the specification of the VEC Model.

4.3.2.3 Long-run cointegration

The existence of a long-run cointegrating equation, which identifies the variables that are cointegrated in the long run, is demonstrated in Table 5.

4.3.3 VEC model

Error Correction Model (VEC Model) was used to examine the cointegrated series' long-run dynamics, the study used the Vector The results indicated a cointegration relationship among the variables of wheat price, temperature, and total production.

Table 6: Vector Error Correction Model (VECM) to determine the long-run dynamics of the cointegrated series

Variables	Coefficient	Standard error	T-stats
Coint Eq1	0.079059	0.03859	2.04868**
D (Rainfall (-1),2)	-0.605395	0.22453	-2.69652**
D (Temperature (-1),2)	7.472087	4.32855	1.72623
D (Wheat price (-1)2)	-0.008130	0.00581	-1.39854*
D (Total wheat production (-1)2)	0.005639	0.00587	0.96061
C	0.526118	2.09064	0.25165
R-square	0.597130		
Adjusted R-square	0.349462		
Log-likelihood	-56.91956		
F-statistics	3.812554		
AIC	7.402301		

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

Table 6 displays the finding for the VEC model. The lag order is indicated by the number in brackets, and the operator "D" denotes the first differencing. The error correlation coefficient showed the rate at which wheat prices move in the route of their long-run equilibrium, which is calculated to be 0.079059. Since there is no long-term correlation and the probability value for the error correction term is statistically significant at the 5% level, the null hypothesis is rejected.

The results of the coefficient analysis show a significant correlation between wheat price and rainfall. Additionally, there is a connection between wheat production overall, temperature, and indirect price. This implies that a 1 percent decrease in wheat price leads to a 7.472087 increase in temperature and a 0.005639 increase in total production, all else being equal. Rainfall has a positive impact on wheat prices, while temperature and total production have a negative impact.

Increased temperatures appear to be detrimental to economic growth, according to studies done by academics like Du *et al*. (2017). Similarly, when wheat stock prices reach minimal levels, they become highly vulnerable to minor shocks (Brian and Carlo, 2011). High prices in the free market may force impoverished consumers to allocate a significant portion of their resources to food, resulting in reduced consumption and significant personal costs (Brian and Carlo, 2011). In this regard, the coefficients for temperature and total production are 7.472087 and 0.005639, respectively, indicating that in the long run, increasing temperature and total production levels are associated with a decline in wheat prices, and vice versa.

The findings contradict those of Thompson *et al*. (2012), which suggested that both structural issues and market volatility have contributed to recent fluctuations in global wheat markets. Furthermore, the findings of the studies by Bansal *et al.* (2016) and Donadelli *et al*. (2017) suggest temperature shocks are associated with a positive premium in equities markets and have a significant negative impact on equity valuations by Zampieri *et al*. (2017) who identified excessive heat as a factor contributing to the decline in wheat yields. These findings are consistent with the studies conducted by Hanjra and Qureshi (2010) and Chartres and Noble (2015), which highlight the dependence of maize and wheat production in Sub-Saharan Africa on rainfed conditions and the adverse effects of weather variability. However, the development of irrigation systems is hindered by global water scarcity.

CHAPTER 5

SUMMARY, CONCLUSION, AND POLICY RECOMMENDATIONS

5.1. Introduction

This chapter presents the most important results from the study provided in the chapter's conclusion section. The presentation of helpful recommendations that consider the insightful discoveries made during the investigation comes next.

5.2 Summary of Findings

Two distinct research objectives were established and analysed in this study to analyse the volatility of wheat prices in South Africa. By using metrics to estimate volatility, the initial goal was to examine the volatility of wheat prices in South Africa from 1996 to 2015. With values of 47.83% and 54.835%, respectively, wheat prices and rainfall had the largest coefficients of variation, according to the data, while temperatures and total production had the lowest coefficients of variation, at 1.83% and 18.10%, respectively. Augmented Dickey-Fuller test for unit root tests was performed to evaluate the stationarity of wheat prices throughout the given period. A lag length of one was found to be ideal for analysing the relationship between variables, according to the VAR lag order selection criteria. As a result, one lag to test for cointegration was used under VECM.

To achieve the second objective the study used the Vector Error Correction Model (VECM) that was to identify and analyse the factors that contribute to wheat price volatility in the South African market, paying attention to (the price of wheat, the amount of rainfall, the temperature, and the overall amount of production). The results showed that three variables rainfall, temperature, and total production have a big impact on the variations in wheat prices that are seen in South Africa. To check for the existence of long-term links between wheat prices and the independent variables of rainfall, temperature, and total production, the study examined for cointegration using the Johansen approach. The findings showed that cointegration existed, demonstrating a long-term relationship between the variables and highlighting their interconnectedness and influence on wheat prices.

5.3 Conclusion

Two hypotheses were examined. Whereby, wheat prices did not exhibit volatility during the period from 1996 to 2015 was the first hypothesis. The second hypothesis stated that the determinants (rainfall, temperature, and total production) did not influence wheat price volatility in the market.

Two hypotheses were looked at in the study. According to the first hypothesis, the price of wheat did not fluctuate between 1996 and 2015. Therefore, the first hypothesis is rejected, and the alternate hypothesis is accepted. The second hypothesis claimed that market volatility in wheat prices was unaffected by the determinants (rainfall, temperature, and total production). According to the null hypothesis, the volatility of the independent variables had no bearing on the volatility of wheat prices. The second hypothesis claimed that market volatility in wheat prices was unaffected by the variables, such as rainfall, temperature, and total production. According to the results, the second null hypothesis is also rejected. The null hypotheses for Trace and Maximum Eigenvalue tests all recommended the absence of cointegration. But the relationship between the variable indicated the presence of cointegration and a long-term correlation.

The cointegration test verified that the variables looked at in the study had a lasting link. The analysis showed a long-term positive link between wheat prices and rainfall. The Vector Error Correction Model (VECM) study also demonstrated a short-term link between these series variables.

5.4 Recommendations

In South Africa, the government should place a high priority on defending its native wheat growers from foreign competition. The South African government can implement policies such as subsidies or tariff protection to stabilise wheat prices and promote a fair market, considering the long-term outlook for wheat prices and the way other countries' governments provide care to their local producers of wheat. In Africa to defend the viability of wheat producers this tactic is very vital and the presence of knowledgeable and successful wheat growers. Government must provide comprehensive farmer support programs through the Department of Agriculture, so farmers' production costs rise can be mitigated. Furthermore, the state must build an industry-specific information system to ensure markets are well informed to minimise asymmetric information that could aid wheat price volatility. This could include a compulsory declaration of wheat importers' information, through a statutory measure in terms of the Marketing of Agricultural Products Act of 1996, to ensure the domestic market is well-informed and price changes are moderated.

The study shows that wheat price, rainfall, temperature, and total production have a long-term relationship, this study then recommends that there should be more wheat crops that are resilient to harsh climatic weather conditions such as drought, floods, veld fire, etc. to avoid a rise in the wheat price as temperature and rainfall have many influences. There is a need to diversify the production areas beyond the Western Cape and Free State provinces because climate change has made Eastern Cape and other Provinces suitable for wheat production. This also creates an opportunity for new entrants in the wheat production in SA beyond the traditional production areas.

The agricultural extension personnel should actively collaborate with farmers to assist them in making informed decisions regarding various aspects of their farming activities. This includes addressing questions such as what crops to cultivate, when to engage in production, how to optimise production methods, and determining the appropriate quantity of production. By providing guidance and support in these areas, extension workers can help farmers effectively manage price volatility and identify the factors that contribute to it.

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7. APPENDIX

Secondary data variables

	R_MM	TTP_T	PP_T	T_C
1996	47.3	2712	966.02	16.96
1997	40.78	2429	817.75	17.48
1998	41.19	1892	808.19	17.62
1999	36.16	1733	960.6	18.22
2000	52.04	2428	1165.35	18.11
2001	44.88	2504	1421.61	17.81
2002	34.08	2438	1572.05	17.28
2003	30.05	1547	1428.14	17.37
2004	38.98	1687	1091.43	17.83
2005	32.08	1913	1033.99	17.66
2006	16.13	2114	1524.19	17.53
2007	16.49	1913	2505.58	17.59
2008	12.1	2149	2307.46	17.5
2009	13.49	1967	1608.02	17.91
2010	13.27	1436	2314.44	18.02
2011	15.37	2014	2369.08	17.5
2012	12.71	1878	2914.51	17.49
2013	11.28	1878	2880.31	18.26
2014	12.79	1758	3052.85	17.84
2015	8.57	1446	3772.44	17.74

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R_MM – Rainfall in millilitres

TTP_T – Total Production in Tonnes

PP_T – Product Price per Tonnes in Rands

T_C Temperature in Degrees Celsius