ANALYSING POTATO PRICE VOLATILITY IN SOUTH AFRICA

BY

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DECLARATION

I, Moabelo Julith Tsebisi, declare that the research report entitled: **ANALYSING POTATO PRICE VOLATILITY IN SOUTH AFRICA**: submitted to the University of Limpopo in partial fulfilments for the requirement of the degree of Master of Science in Agricultural Economics, has not been submitted before and that all sources or materials used have been duly acknowledged.

Student: …………………………… date:………………….

Ms Moabelo JT

DEDICATION

I wish to dedicate this paper to my departed fiancé, Lungelo Andries who believed so much in me and my education unfortunately Almighty has called him in the first year of my master's studies and would not see much of my success.

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I firstly thank the master of all creation (Almighty) for his abundant grace. If it was not of him, I could not have been where I am today. Special thanks go to my supervisor Mrs CL Muchopa and Co-supervisor Prof A Belete for their words of encouragement and support. I extend my sincere appreciation to Laryssa van der Merwe from Potato South Africa (PSA) who provided me with all the data needed in this dissertation pertaining to potatoes. To my parents Moabelo Lesiba and Moabelo Raisibe thank you for your support. Mme Motswadi you have been a pillar of my strength, thank you for supporting me in every way, it is true when they say Mmago ngwana o swara thipa ka bogaleng. My children Katlego and Unako, you have been my inspiration. My siblings, Lusty, Lamenta, Monica, Phillipine and Mawina Moabelo, thank you all for your support.

ABSTRACT

Potato is perceived as an excellent crop in the fight against hunger and poverty**.** The recent high potato price in South Africa has pushed the vegetable out of reach of the poorest of the poor. The study attempts to analyse potato price volatility in South Africa and furthermore assess how various factors were responsible for the recent potato price volatility. Quarterly data for potato price, number of hectares planted, rainfall and temperature levels from 2006q1 to 2017q4 was collected from various sources and were used for analysis. The total observation of 48.

The volatility in the series was determined by performing ARCH/GARCH model. GARCH model indicates an evidence of GARCH effect in the series, meaning that GARCH model influences potato price volatility in South Africa. The Johansen cointegration used both trace and eigenvalue to test the existence of a long run relationship between potato price and various variables. The cointegration results were positive indicating that there exists long run relationship amongst variables. The study further used Johansen cointegration as well as standard error to determine the number of cointegrating variables in the long run. The results indicated that the number of hectares planted and rainfall level have significant relationship with potato price. Wald tests was used to check whether the past values of number of hectares planted and rainfall level influenced the current value of potato price. The Walt test results concluded that there is no evidence of short run causality running from number of hectares planted and rainfall level to potato price. In the study, ECM model was used to forecast the potato price fluctuation in South Africa.

The study recommends that farmers need to engage in contract market so as to minimize the risk of potato price volatility. The Department of Agriculture should forecast agricultural commodities price volatility and make information accessible to the farmers so that they are able to adopt strategies that will assist them to overcome crisis.

Keywords: Potato price, GARCH model, VECM, Volatilities, ECM model, Forecasting

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LIST OF ACRONYMS

DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agriculture Organization
WTO	World Trade Organization
IMF	International Monitory Funds
IFPRI	International Food Policy Research Institute
OECD	Organization of Economic Cooperation and Development
UNCTAD	United Nations Conference on Trade and Development
WFP	World Food Programme
UN HLTF	United Nations High-Level Task Force
IFAD	International Food Policy Research
BC	Before Christ
PSA	Potato South Africa
CIP	International Potato Center
NDA	National Department of Agriculture
SAWE	South African Weather Service
NAMC	National Agricultural Marketing Council
ARCH	Autoregressive Conditional Heteroscedasticity
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
CV	Coefficient of Variation
AR	Autoregressive
DF	Dickey-Fuller
ADF	Augmented Dickey-Fuller
ECM	Error Correction Model
VECM	Vector Error Correction Model
VAR	Vector Autoregression

ADL	Autoregressive Distributed Lag
RMSE	Root Mean Square Error
MPE	Mean Pricing Error
MAPE	Mean Absolute Pricing Error
MARPE	Mean Absolute Relative Pricing Error
Kg	Kilogram
R	Rand
Ha	Hectare
R	Rand
BFAP	Private Farmers Assistance Program
Q1	First quarter
Q2	Second quarter
Q3	Third quarter
Q4	Fourth quarter
NPK	Nitrogen, Phosphorus and Potassium
Rwf	Rwandan Francs
Usd	United States Dollar
SQRT	Square Root
CUSUM	Cumulative Sum
AIC	Akaike Information Criterion
SC	Schwarz Criterion
HQ	Hannan-Quinn Information Criterion
LR	Likelihood Ratio
FPE	Final Prediction Error

CHAPTER ONE

INTRODUCTION

1.1 Background

An unacceptably high number of people suffer from food and nutrition insecurity in the world. Multiple episodes of food crises in the last decade have made the situation worse (Kalkuhl *et al.,* 2017). During periods of excessive price volatility, it is the poor and vulnerable population that are mostly affected. In South Africa, majority of the people particularly those residing in rural areas depend on agriculture for their living. Potato industry has become an important food provider and this has then led to the establishment of Potatoes South Africa that operates as an industry. The industry aims to support potato producers within the regional context in South Africa to ensure viability of potato industry. However, price fluctuations have become large and unexpectedly volatile and this can have a negative impact on the food security of consumers, farmers and the entire country.

Since 2007, the agricultural commodity markets have experienced extreme price fluctuations more and more frequently (Kalkuhl *et al.,* 2017). Food prices today remain high, and are expected to remain volatile (FAO, 2009). The price volatility of agricultural commodities has been exceptionally high during the commodity boom of 2006-2008 (Schnepf, 2008). Food prices increased between late-2006 and mid-2008 to their highest level in thirty years, fell sharply through 2009 then regained their 2008 peak in late 2010-early 2011 FAO (2012). Since the high record of food prices in 2009, potato prices have traded softer over the year 2010-2012 in a relatively constant band of R23 to R26 per 10 kg bag BFAP (2012). Due to a shorter cropping season in 2013, prices traded higher than in 2012 by an annual average market price of R31 per 10 kg BFAP (2013). For 2014, prices traded around R36 per 10kg bag BFAP (2014). The price decreased in 2015 from R36 to R33 and Potatoes South Africa (PSA) reports that potatoes reached a record price of R60 per 10kg on 19 January 2016, the highest average weekly price on record for potatoes (DAFF, 2016).

Potato is the world's number one non-grain food commodity FAO (2010) and the fourth largest crop in terms of fresh produce after rice, wheat and maize (Sopib, 2011). Potatoes have also established itself over time as a worthy alternative in the staple food category PSA (2015) and an excellent crop in the fight against hunger and poverty. The potato was first domesticated in the region of modern-day southern Peru and extreme north-western Spooner *et al. (*2005) between 8000 and 5000 B.C. it has since spread around the world and become a staple crop in many countries. It is generally believed that potatoes entered Africa with colonists, who consumed them as a vegetable rather than as a staple starch (Ornelas, 2000).

According to legend, the first potatoes for planting purposes in South Africa came from Holland to provide food for mariners visiting the Cape. Since then the potato industry has grown to become one of the important food providers in South Africa (NDA, 2003). Potatoes play a role in the South African economy in terms of its contribution to the gross domestic product (PSA, 2015). Taking the combined value of the field crop and horticultural sectors, potatoes is the fifth biggest agricultural sub-sector, and this when merely between 50 000 and 54 000 hectares are used for potato production (PSA, 2015).

Potatoes yield food that is more nutritious more quickly, on less land and in harsher climates than most other major crop (Wikinson, 2001). Potato crops are also highly adaptable to a wide variety of farming systems. Their short and highly flexible vegetative cycle, which brings yields within 100 days, fits well with double cropping and intercropping system FAO (2010). South Africa Potatoes are grown all year-round owing to the country's unique geography and climate. Potatoes are produced all over South Africa in different climatic regions. This results in a continuous supply of potatoes throughout the year (DAFF, 2013).

In South Africa, potatoes are not categorised as a seasonal product. Due to the different climatic conditions, e.g. temperature, rainfall and soil type. In the 16 production regions, potatoes are planted and marketed at different times by the relevant regions to ensure a continuous supply of fresh potatoes throughout the year. Potatoes are grown mainly under irrigation, but in some of the production regions potatoes are grown successfully under dry land conditions. As potato is a cool climatic crop, most production regions takes place in a climate not optimal for potato production. Temperatures in excess of 30^0C and fluctuating daily temperatures cause stress in plants, which in turn limits yield potential of even the best adapted cultivars (PSA, 2015).

1.2 Problem statement

Gilbert and Morgan (2011) defined price volatility as the quantitative measure of the directionless extent of the variability of the price of a given asset. FAO (2011) purely gave a descriptive sense of volatility as a variation in economic variables over time.

The main problem this study attempts to analyse is the extreme potato price volatility that is more likely to hurt the consumer' pockets. Poor households spend a large amount of their total income, often more than 60% on food, so a given variability in food prices has a large effect on purchasing power (FAO *et al*., 2011a and FAO *et al.,* 2011b). Food price increases naturally become an issue to poor consumer resulting in them cutting expenditures on other domains such as health or on the quality of food, which ultimately can contribute to micronutrient deficiencies (Kalkuhl *et al.,* 2017). Many consumers are being forced to take only the essentials from the store shelves. Shoppers have noticed a sharp increase in the price of basic food staples. The cost of potatoes has pushed the vegetable out of reach for the poorest of the poor (Epstein, 2016).

The 2015 harvest delivered 250 million bags of potato as reported at the end of November 2015. An oversupply of an additional 12, 9 million bags of potatoes was made (Elsenburg, 2016). However due to the 2016 heat waves resulting in dry hot weather the quality of potatoes was affected. This created a limited supply of good quality potatoes and resulted in a price increase above normal seasonality (Willemse *et al.,* 2015). According to Hartigh (2016), prices have more than doubled in 2016 from a year earlier and the price for 10kg potatoes packet has increased from R33.30 by January 2015 to R73.32 by January 2016**.**

The extreme price volatility means insecurity and financial risks for all the commercial operators involved (Wellard, 2012). In 2016, seed potato producers would not sell their seed potatoes because the commercial producers were discouraged to plant potatoes due to lack of soil moisture. This result in high production costs, which affect potato production, pushing up potato price that have already increased. Yet again, the poor were mostly affected (Willemse *et al.,* 2015). This study, therefore, attempts to examine the various factors that are responsible for potato price volatility in South Africa.

1.3. Motivation

The rationale behind the study is due to the enormous potato price hike experienced in year 2016, which was widely felt by Farmers, consumers and entire country. The study analyses the possible cause of the recent potato price spike. The study also provides a forecast for potato price for the period 2018-2019 to determine the level of potato price volatility. The results from the study will also assist policy makers to come up with strategies to curb potato price volatility.

1.4 Aim of the study

i. The aim of the study is to analyse potato price volatility in South Africa.

1.5 Study objectives

The specific objectives of the study were to:

i. Determine the variability of potato price from 2006 to 2017.
ii. Identify and analyse the determinants of potato price change in the market.
iii. Forecast potato price from 2018 to 2019.

1.6 Hypotheses

i. Potato price volatility cannot be influenced by volatility of independent variables.
ii. Potato price cannot be cointegrated with the independent variable

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of some of the studies that have been undertaken in the past. The chapter begin by giving a definition of price volatility and then outline what volatility is. The study assessed the recent causes of potato price volatility in South Africa, and then continued to assess the determinants or factors affecting potato price volatility.

2.2 Defining price volatility and volatility

Price Volatility simply means the degree of change in the price of a stock over time. Some investment opportunities have a high degree of change, or high price volatility, and some have a low degree of change, or low-price volatility. The concept of price volatility on agriculture describes how frequently the prices of agricultural products change over time, both upwards and downwards. While some variation in prices is considered to be a normal aspect of well-functioning markets, volatility becomes problematic when price movements are large and unpredictable.

High levels of price volatility can create financial risks for farmers, since their incomes will be less predictable and can be threatened by sudden price drops. Price volatility also reduces capacities for long-term investments, particularly for young farmers. Moreover, increases in agricultural prices can reduce the ability of lower-income households to fulfil their basic needs, especially in developing countries, as the cost of food represents a large share of their income (Tropea and Devuyst, 2016).

Volatility is the conditional standard deviation of the underlying assets return (Grek, 2014). Volatility is usually referred to as a measure of variability. In financial time series, when we say that the market is volatile, we mean that there is uncertainty on investments. High volatility means uncertainty in the periods of time while in financial time series, high volatility means that the investments carry high risk of losses (Serrano *et al*., 2011).

2.3 Factors affecting potato price volatility

The prices of potatoes are highly fluctuating. There are number of factors that explain why agriculture is confronted with higher levels of price volatility than other economic sectors. The factors which affect the prices of potatoes are mainly fluctuations in area of production, weather, production level and yield, irrigation facility, demand for potato in cities and from food processing industries, input cost for potato cultivation, transportation charges, labour availability during planting and harvesting, storage capacity and stock position in cold storage (Mumtaz *et al*., 2015). The following are some of the factors affecting potato price volatility.

2.3.1 Weather condition.

Climate change (extreme weather conditions) is one of the root causes for the recent high and volatile food prices (Waschkeit *et al.,* 2011). Climatic factors have indisputably contributed to the price rises in 2007/2008 (FAO *et al.*, 2011). Weather shocks are considered to be one of the important sources of variability in agricultural commodity prices (Morgan and Gilbert, 2010). Disasters such as drought and flooding can cause catastrophic damage to crop (Mirzabaer and Tsegai, 2012). Drought is the most common cause of stress in potato (Onder *et al.,* 2005). Drought stress is important and farmers in the east of Ireland have to flood irrigate potato fields to ensure adequate yields. Given that, an increased seasonality of water supply is predicted (Sweeney and Fealy, 2001). Vulnerability of potato to drought has been attributed mainly to the crop's shallow root system and low capacity of recuperation after a period of water stress (Iwama and Yamaguchi, 2006).

Climate change will provoke some adjustment of production patterns around the world, as well as increased risks of local or regional supply problems that could add to future volatility (FAO *et al.,* 2011).

Potatoes are essentially a crop that thrive in cooler conditions, despite being very susceptible to frost (Bill, 2012). According to PSA (2014), the potato is a temperate crop and is sensitive to water and high temperature stresses. Higher daily temperatures and changes in rainfall increases crop stress, and may render production areas less suitable for potato production, resulting in lower tuber yields and quality. Hijmans (2003) studied the effect of climate change on global potato production between year 1961-1990 and 2040-2069.The study showed that temperature increase is smaller when changes are weighted by the potato area and particularly when adaptation of planting time and cultivars is considered a predicted temperature increase between 1 and 1.4 C. For this period, global potential potato yield decreased by 18% to 32% without adaptation and by 9% to 18% with adaptation.

Extreme weather events, such as high intensity rainfall events, can be damaging to potatoes. Waterlogged conditions in the soil, particularly in summer rainfall areas, can result in tubers rotting, as these are optimal conditions for development of soft rot and blackleg (Steyn *et al.,* 2014).

2.3.2 Market factors

In the short-term, because the market fundamentals of supply and demand are inflexible towards agricultural products, reconciling these two forces can be hard when it comes to such products. Demand is rather fixed because food is a basic human necessity, while supply is unable to adapt quickly because food takes time to be produced. As a result, even small changes in agricultural supply or demand can cause large variations in prices, causing permanent market instability. Apart from these microeconomic fundamentals, changes in macro-economic factors, such as exchange rates and oil prices, can also have a substantial influence on food prices.

In their study, Mwangi *et al.* (2013) on “Effect of market reforms on Irish potato price volatility in Nyandarua district” an autoregressive econometric technique was used to examine the effects of the implementation of market reform policies by the Kenyan government on the Irish potato sub-sector. The results indicated that the implementation of market reform policies favoured the Irish potato producers but made the consumers worse off. The study showed that price volatility in the Irish potato sector is as a result of factors having effects on supply and demand. The supply increased as a result of increased production while the demand rose due to increase in population, rapid urbanization and change in tastes and preferences. However, the variability in value of production was found to be a major contributor to Irish potato price volatility because production follows the natural rainfall pattern.

Guenthner *et al.* (1991) conducted study to determine factors affecting the demand for potato product in the United States. The study stated that the economic theory suggests the demand for potato is influenced by price of complimentary product, consumer debt, change in consumer tastes and preferences, own price and population. The study showed that explanatory variables had opposite impact on the demand for different potato products. The amount of income that consumers have available to spend was found to be the most important variable among all other variables.

Thorne (2012) studied potato price as affected by supply and demand factors: An Irish case study, the main objective of the paper was to evaluate the factors influencing potato price formation at farm level in Ireland over the period 1992 to 2011. The study used OLS regression to determine relationship between yearly potato price, production of potatoes produced and consumption of potatoes produced nationally. The results indicated that potato prices decrease with increasing volumes and increase with increasing consumption levels. The estimated demand function for potatoes in Ireland has shown a structural break during the last two decades. While the demand for potatoes decreased, the price adjustments to changes in demand decreased significantly. Hence, it can be concluded that the demand for potatoes has become notably more price elastic.

Goodwin *et al.* (1988) analysed factors affecting fresh potato price in selected terminal markets. The general objective of this study is to identify and assess factors affecting fresh potato price at terminal markets. The model specification was builds on the theoretical framework of Ladd and Suvannunt and the hedonic price.

2.3.3 Production cost

Mumtaz *et al.* (2015) studied the determinants of potato prices and its forecasting: A case study of Punjab, Pakistan. The objective of this study was to analyse various factors that affect the prices of potatoes in Punjab over a period of time. The study used general empirical model for the price of fresh potato that consist of production area, production costs, price of crude oil, support price and temperature as independent variables and the study concluded that the cost of production has the major impact on the prices of potatoes in Punjab. For forecasting SARMA model has been applied since the prices of potato have a seasonal trend.

Nsabimana *et al.* (2015) used GARCH and VECM in forecasting price of Irish potatoes volatility from 2007 – 2015. The result showed that price of Irish potatoes is highly peaked and moderately skewed. The volatility of fertilizers especially NPK1515 does not granger cause the volatility of Price of Irish potatoes. The volatility of pests does not have a long run associationship with the volatility of Irish potatoes and the exchange rate doesn't granger cause the volatility of Irish potatoes in the studied areas.

In their study, Duyan and Tagarino (2015) on "Price volatility of selected high value vegetables in Cordillera administrative region, Philippines" focused on the price trend of cabbage, carrot and potato for the period of 2002 to 2011. They found that the prices of the selected vegetables involving farm, local retail and Metro Manila retail were erratic for the whole periods covered and that there was no consistent surge and decline of prices observed except for potato that exhibits increasing trend from 2005 to 2011. Vegetable prices specifically farm and retail are affected significantly by several factors such as the weather conditions including rainfall amount and temperature, the production area, and volume of imports. The relationship of the selected variables to the vegetable prices indicates positive slight to very high correlation.

Habyarimana *et al.* (2014) conducted the study on Food price volatility in Rwanda to explore the long and short run relationship between food prices volatility and forecast food prices volatility in Rwanda using Vector Autoregressive (VAR) Model for Multivariate Time Series. The paper used six agriculture commodities (Sorghum, Maize, Rice, Wheat, Beans, and Irish Potato), to conclude on which variables can help to explain food price volatility in the last seven years. The paper showed that forecasted food price in one commodity can be gradually attributed to the past price volatility of the same commodity and that of others. The granger causality test showed that there exists food prices granger causality in the selected food commodities. Thus, the impulse response analysis showed that shock to the price of one food commodity create smaller, but significant response and temporary oscillations in other food commodities and itself but which impact on other food process do not persistent and that their effects eventually die out.

CHAPTER THREE

RESEARCH METHODOLOGY

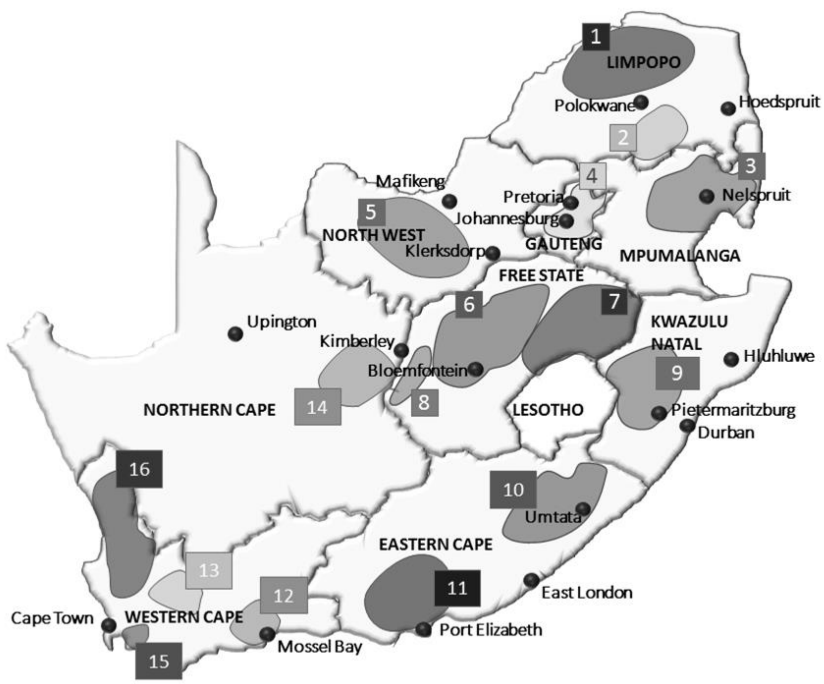
3.1 Introduction

This chapter describes methodology on data collection. A secondary data was collected from Potatoes South Africa (PSA) and South African Weather Service (SAWS). Eviews statistical tool was used to run and analyse the data. Data collected was for quarterly potato price (PP), quarterly number of hectares planted (HA), quarterly rainfall (R) and quarterly temperature (T) level from year 2006 to 2017 making the total observation of 48.

It further gives an overview background description on the study area which covers all provinces of South African potato producing regions. The first part of methodology in this chapter measures the variability of potato price,followed by introducing the element of modeling potato price volatility. The second part introduces the VECM model used to examine relationship between potato price as the dependent variable in this study and the various independent variables. Later in this chapter, the study provides forecasting of potato price using ECM model.

3.2 Potato production regions

Potatoes are produced from sixteen production regions which are spread throughout South Africa. The main producing regions are situated in the Limpopo, Free State, Western Cape, Mpumalanga, Kwa-zulu Natal and Eastern Cape DAFF (2012). South African potato production is mainly under irrigation. Potatoes are produced without supplementary irrigation (dryland) only during spring and early summer plantings in regions with a cool temperate climate and a proven reliable summer rainfall such as in the Mpumalanga Highveld and Eastern Free State DAFF (2012).



1	Limpopo
2	Marble Hall
3	Mpumalanga
4	Gauteng
5	North West
6	Western Free State
7	Eastern Free State
8	South Western Free State
9	KwaZulu-Natal
10	North Eastern Cape
11	Eastern Cape
12	Southern Cape
13	Ceres
14	Northern Cape
15	South Western Cape
16	Sandveld

Figure 1: Potato production in 16 regions
Source: Potato South Africa

Figure 1, shows the potato production in 16 regions, where potatoes are produced both under irrigation and under dry land.

Planting of potatoes is done almost throughout the year in different regions of South Africa consequently resulting in continuous access to fresh potatoes. The season is divided into two production periods. The early crop is planted from January to March and the main crop is planted from April to August. The months of November and December are avoided because of high temperatures combined with long day lengths, which are not conducive for planting.

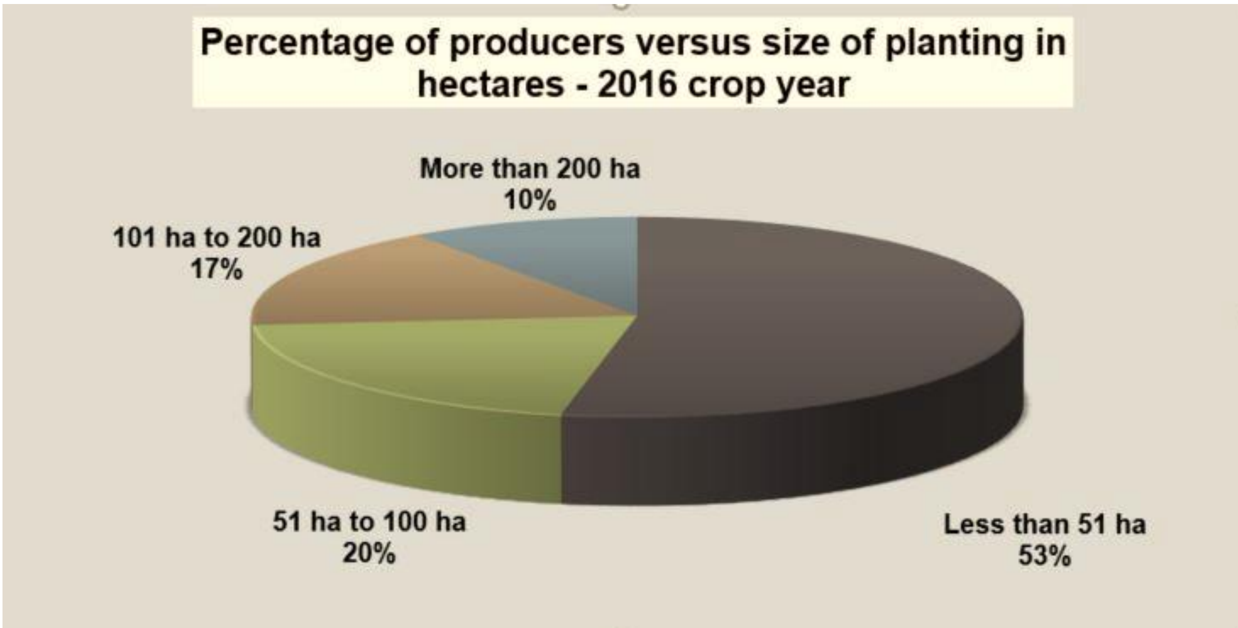


Figure 2: The percentage of producers versus size of planting in hectares in 2016
Source: Potato South Africa

Figure 2 indicate the percentage of producers versus size of planting in hectares in 2016 crop year across all planting regions in South Africa. The high percenatge of producers contributing about 53% planted potatoes on less than 51 ha and 10% producers planted their potatoes on more than 200 ha.

3.3 Data collected and source of data

Table 1: Data collection and source

Data collected (all in Quarterly)	**Source of the data**
Potato price from 2006q1-2017q4	(PSA) Potato South Africa
Number of hectares planted from 2006q1-2017q2	(PSA) Potato South Africa
Rainfall from 2006q1-2017q2	(SAWE) South African weather service
Temperature from 2006q1-2017q2	(SAWE) South African weather service

3.4 Methods of data analysis

The study used coefficient of variation to measure variability of potato price from 2006 to 2017. To analyse potato price volatility from year 2006 to 2017 the study used the Autoregressive Conditional Heteroscedasticity model (ARCH) and the General Autoregressive Conditional Heteroscedasticity model (GARCH). The study, firstly described clustering volatility followed by ARCH and GARCH effect in the series. The graph was used to describe fluctuating residuals of potato price from 2006 to 2017. Also the tables were used to describe ARCH and GARCH effect. The GARCH effect used mean equation model to test as to whether volatility of independent variables have an influence on potato price volatility. ARCH effect used variance equation model to analyse volatility of independent variables on potato price volatility. Diagnostic check was performed to check whether the estimated model has ARCH effect and serial correlation or not.

Augmented Dickey Fuller test was used to check whether the time series is stationary or non-stationary. When time series are integrated of the same order I(1),the study run Johansen test of cointegration using both trace and eigenvalue test to check if variables have a long run relationship. Having found variables that are cointegrated, the study proceeds to use vector error correction model (VECM) to determine short run relationship between potato price and various variables. However, before performing cointegration test and VECM modeling, the study undertaken VAR lag order criteria to determine optimal number of lags to use in the system equation. Granger causality was used to examine the causal relationship amongst the variables. The residual diagnostic was used test to check if there is serial correlation. The cumulative sum (CUSUM) test was used to assess the stability in the coefficient of estimated ECM.ECM model was also used for forecasting.

3.4.1 Measures to evaluate volatility

The coefficient of variation was used to evaluate the quarterly potato price volatility. The coefficient of variation (CV) is defined by (Brian, 1998) as the ratio of standard deviation δ to the mean μ and it is a useful statistical tool for comparing a degree of variation from one data series to the other. The coefficient of variation is a simple unconditional measure of price variability. The following coefficient of variation formula was used.

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

Where: v been the coefficient of variation, σ been the Standard deviation for potato price,μ are the Mean prices for potato and x_1 been observed potato prices.

3.4.2 Modeling Volatility

This study attempted to model the volatility of quarterly potato price and the independent variables using both ARCH/GARCH model proposed by Engle (1982) and Bollerslev (1986) models respectively;

3.4.2.1 Clustering volatility

In order to run ARCH model, the study, firstly describe clustering volatility and ARCH effect in the series. Clustering volatility was analysed by checking if there is an evidence of high or low volatility in the time series. When there is evidence of clustering volatility and ARCH effect in the time series, the study proceeds to perform ARCH and GARCH model.

3.4.2.2 The (ARCH) Autoregressive Conditional Heteroscedasticity Model

The autoregressive conditional Heteroscedasticity is a statistical model for the time series data that describes the variance of the current error term as a function of the actual sizes of the previous time period' error terms Engle (1982). The ARCH specification helps to focus on the mean and the variance of time series, which are useful to understand the magnitude of volatility in time series data. Engle (1982) offered modeling conditional volatility by using ARCH process; which is in simple words a function of lagged squared residuals, and the general form of the model is:

$y^2{}_t = \alpha_0 + \alpha_1\varepsilon^2{}_{t-1} + \ldots + \alpha_q\varepsilon^2{}_{t-q}$

That is:

$y^2{}_t = \alpha_0 + \sum_{j=1}^{q}\alpha_1\,\varepsilon^2{}_{t-i}$ (2)

Where α_0 is a mean, α_1 is conditional volatility and ε_{t-1} is white noise representing residuals of time series and $y^2{}_t$ is conditional variance.

3.4.2.3 The (GARCH) General Autoregressive Conditional Heteroscedasticity Model

In the ARCH model, there are certain limitations that may result in an insufficient estimation on volatility however, Bollerslev (1986) proposed a modified form through Generalized ARCH (GARCH) that will permit a longer memory and a more flexible lag structure to overcome those limitations. GARCH is a statistical model used in analysing financial time series data. The model was estimated in the following form:

$y^2{}_t = \alpha_0 + \alpha_1\varepsilon^2{}_{t-1} + \ldots + \alpha_q\varepsilon^2{}_{t-q} + \beta_1 y^2{}_{t-1} + \ldots + \beta_p y^2{}_{t-p}$

That is:

$y^2{}_t = \alpha_0 + \sum_{j=1}^{q}\alpha_1\,\varepsilon^2{}_{t-i} + \sum_{i=1}^{p}\beta_i\; y_{t-i}$(3)

Where $y^2{}_t$ is conditional variance, α_0 is a mean, $\sum_{j=1}^{q}\alpha_1\,\varepsilon^2{}_{t-i}$ is the ARCH effect and $\sum_{i=1}^{p}\beta_i\; y_{t-i}$ is GARCH effect.

The GARCH (p,q) model with constraint, $\alpha_0 > 0$, $\alpha_1 \geq 0$, i= 1,…q and $\beta_i \geq 0$, $j = 1\ldots$,p with, $\alpha_1 + \beta_i < 1$, α_1 and β_i are ARCH and GARCH parameters respectively, unconditional variance $y^2{}_t$ evolve over time t.

3.4.2.4 Diagnostic check

The study performed heteroscedasticity and serial correlation tests to check whether the estimated model has ARCH effect and serial correlation or not. If there exist the evidence of heteroscedasticity and serial correlation, the results drawn from model will not be reliable. Model may be poorly defined.

3.4.3Unit roots tests

Unit root test tests whether a time series variable is non-stationary and possesses a unit root. The test was carried out to feature some stochastic (such as random walks) that can cause problems in statistical inference involving in the series model**.** The study used Augmented Dickey-Duller (1979) method to test for the existence or non-existence of unit roots in the variables used in estimating the South African potato price volatility namely; potato price, number of hectares planted, rainfall and temperature level. If the variable is non-stationary, it need to be differenced until it become stationary. If it is differenced once, it is said to be integrated of order one I(1).

$$\Delta PP_t = \alpha_0 + \gamma PP_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \, \Delta PP_{t-i} + u_t$$

$$\Delta HA_t = \alpha_0 + \gamma HA_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \, \Delta HA_{t-i} + u_t$$

$$\Delta R_t = \alpha_0 + \gamma R_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \, \Delta R_{t-i} + u_t$$

$$\Delta T_t = \alpha_0 + \gamma T_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \delta_i \, \Delta T_{t-i} + u_t$$

Where: α_0 is a vector of deterministic term (constant, trend etc.), α_2 is the coefficient on a time trend series, γ is the coefficient of y_{t-1}, Δy_{t-i} are the changes in lagged values, y_{t-1} are lagged values of order one of y_t, P is the lag order of autoregressive process, u_t is an error term.

Under null hypothesis y_t is I (1) which implies that δ = 0

3.4.3.1 Testing for cointegration

Das (1973) Cointegration is a statistical property possessed by some time series data that is defined by the concepts of stationarity and the order of integration of the series. If there exists a stationary linear combination of non-stationary random variables, then the variables combined are said to be cointegrated and may have a stable long run relationship. The study used Johansen procedure to test for cointegration relationship amongst variables. The VAR Lag order selection process was undertaken in order to determine the optimal number of lags to use in the cointegration and VECM equation.

Johansen's procedure

The study firstly establishes the order of integration of the modelled variables to determine whether two variables are cointegrated. This was done by performing unit root test as indicated in section 3.4.3. If the two variables are integrated of the same order, then the study proceed to estimating the long run equilibrium relationship using Johansen test of cointegration. The Johansen test can be seen as a multivariate generalization of the augmented Dickey Fuller test Dwyer (2015). This test permits more than one cointegrating relationship so is more generally applicable than the Engle–Granger test which is based on the Dickey–Fuller (or the augmented) test for unit roots in the residuals from a single cointegrating relationship Davidson (2000).The Johansen test is a VAR-based cointegration test. The general form of the VAR (p) model, without drift, was given by:

$$y_t = \mu + A_1 y_{t-1} + \ldots + A_k\, y_{t-k} + \varepsilon_t$$

This VAR can be re-written as

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{k-1} \Pi_i\, \Delta y_{t-i} + \varepsilon_t (4)$$

Two types of Johansen test, the trace and the eigenvalue were used to determine if there exist long run relationship amongst variables.

Trace test

The trace test examines the null hypothesis of k cointegrating vectors against the alternative hypothesis of n cointegrating vectors. The test statistic was given by

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

Maximum Eigenvalue Test

The maximum eigenvalue test examines the null hypothesis of k cointegrating vectors versus the alternative $k+1$ vectors. Its test statistic was given by,

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

Where T is number of observation,$\hat{\lambda}_i$ is the i^{th}largest canonical correlation

If the variables are cointegrated, the study proceed to run Vector Error Correction Model to determine long run and short run relationship.

3.4.3.2 Vector error correction model (VECM)

The cointegrating regression so far considers only the long-run property of the model, and does not deal with the short-run dynamics explicitly. The study used vector error correction model (VECM) to describe short-run dynamics of the cointegrating variables respectively. VECM can be used to granger causality when the variables are cointegrated and have unit roots. Granger causality is a statistical concept of causality that is based on prediction (Seth, 2007). The study used Wald tests to check if current value of potato price (PP) was caused by past value of number of hectares planted (HA) and rainfall level (R) respectively:

$$\Delta PP_t = \alpha + \delta t + \lambda e_{t-1} + \gamma\Delta HA_{t-1} + \ldots + \gamma\Delta HA_{t-p} + \omega_1\Delta HA_{t-1} + \ldots + \omega_q\Delta HA_{t-q} + \varepsilon_t \quad (7)$$

$$\Delta PP_t = \alpha + \delta t + \lambda e_{t-1} + \gamma\Delta R_{t-1} + \ldots + \gamma\Delta R_{t-p}$$

$$+ \omega_1 \Delta R_{t-1} + . . . + \omega_q \Delta R_{t-q} + \varepsilon_t \qquad (8)$$

HA Granger causes PP if past values of HA have explanatory power for current values of PP.

3.4.3.3 Diagnostic check

The study adopted residual diagnostic test to check if there is serial correlation in the model or not, the results are displayed on a table form. It further used cumulative sum (CUSUM) test to check whether the model is stable or not.

3.4.4 Forecasting with ECM model

The study used out of sample forecasts. ECM model was used for forecasting since its based techniques result in lowest forecast error in long run forecasting.

To forecast $\Delta X_{t+\tau}$. The forecast of $X_{t+\tau}$(τ is the step ahead) are obtained recursively:

$$\widehat{X}_{t+\tau} = \widehat{\Delta X}_{t+\tau} + \widehat{X}_{t+\tau-1} \qquad (9)$$

3.4.4.1 Forecasting accuracy+

After forecasting, the standard statistical measures such as Mean pricing error (MPE), mean absolute pricing error (MAPE), mean absolute relative pricing error (MARPE), and root mean squared error (RMSE) were calculated to determine the effectiveness of the forecasts.

This study focused primarily on RMSE, which gives a measure of the magnitude of the average forecast error, as an effectiveness measure. The RMSE depends on the scale of the dependent variable. The RMSE may be estimated as:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_1 - FP_i)^2} \qquad (10)$$

And Theil's inequality coefficient (U)

$$U = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_1 - FP_i)}^2}{\sqrt{\frac{1}{n}\sum_{i=1}^{n} S^2{}_1} + \sqrt{\frac{1}{n}\sum_{i=1}^{n} FP^2{}_1}} \quad (11)$$

Where S_1 , is the actual potato price.

FP_i , is the future potato price.

3.5 Table 2: Analysis of objectives

Study objectives	Model	Reasons for model
To determine the variability of potato price from 2006 to 2017	The (ARCH) Autoregressive Conditional Heteroscedasticity and (GARCH) General Autoregressive Conditional Heteroscedasticity model	To model conditional volatility
To identify and analyse the determinants of potato price change in the market	(VECM) Error Correction Model	Addresses both short run dynamics and long run equilibrium relationship amongst variables.
To forecast potato price from 2018 to 2019	(ECM) Model	Forecast results in lowest forecast error in long run forecasting.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the analyses of potato price volatility in South Africa. The chapter begins by measuring variability of potato price from year 2006 to 2017. ARCH and GARCH model were run to determine volatility in the series. Diagnostic check was performed to check the Heteroscedasticity and serial correlation. Pretesting for unit roots test was carried out using Augmented Dickey fully test to determine the number of integration order amongst economic variables. Johansen procedure tested long run relationship amongst variables. The VECM results for both long run and short run relationship between potato price and various independent variables were analysed and discussed. The study further forecasted potato price using ECM.

4.2 Measures to evaluate volatility

Table 3: Coefficient of variation

Year	Standard deviation(σ)	Mean(μ)	Coefficient of variation (CV)
2006	2,265809	17	0,132639*100= 13.26%
2007	7,338585	22	0, 33361*100= 33.36%
2008	3,605065	21	0,173759*100= 17.38%
2009	4,903363	31	0,155687*100= 15.57%
2010	4,371372	26	0,166038*100= 16.60%
2011	4,837509	26	0,186076*100= 18.61%
2012	4,597633	26	0,174103*100= 17.41%
2013	7,748931	35	0, 21933*100= 21.93%.
2014	2,996636	34	0, 08708*100= 8.70%
2015	3,717028	28	0,131973*100= 13.19%
2016	7,277465	48	0,152687*100= 15.26%
2017	4,981003	26	0,191577 * 100=19.15%

Table 3 indicate potato price variation for each year from 2006 to 2017. A data set of 2007 has more variability, giving the coefficient of variation of 31.361% as compared to 13.2636% of 2006. Although 2008 has low coefficient of variation of 17.3579% compared to 31.361% of 2007, however when comparing 2008 with 2009 which is given by 15.5687%, 2008 has high variation of coefficient. The study evident that when dispersion is lower in the first data set, the second dataset will be higher and vice versa. The lower coefficient of variation indicates a decrease in volatility whereas the higher coefficient of variation indicates an increase in volatility. In their study, Vigila *et al.* (2017) observed a large variation in the prices of potato in four major states namely, Maharashtra, Tamil Nadu, Uttar Pradesh and Gujarat between years 2005-2016. The results showed that among the four states, Tamil Nadu (TN) had a smaller variation in the potato price of 35.49% of CV than other three states.

4.3Testing for clustering volatility

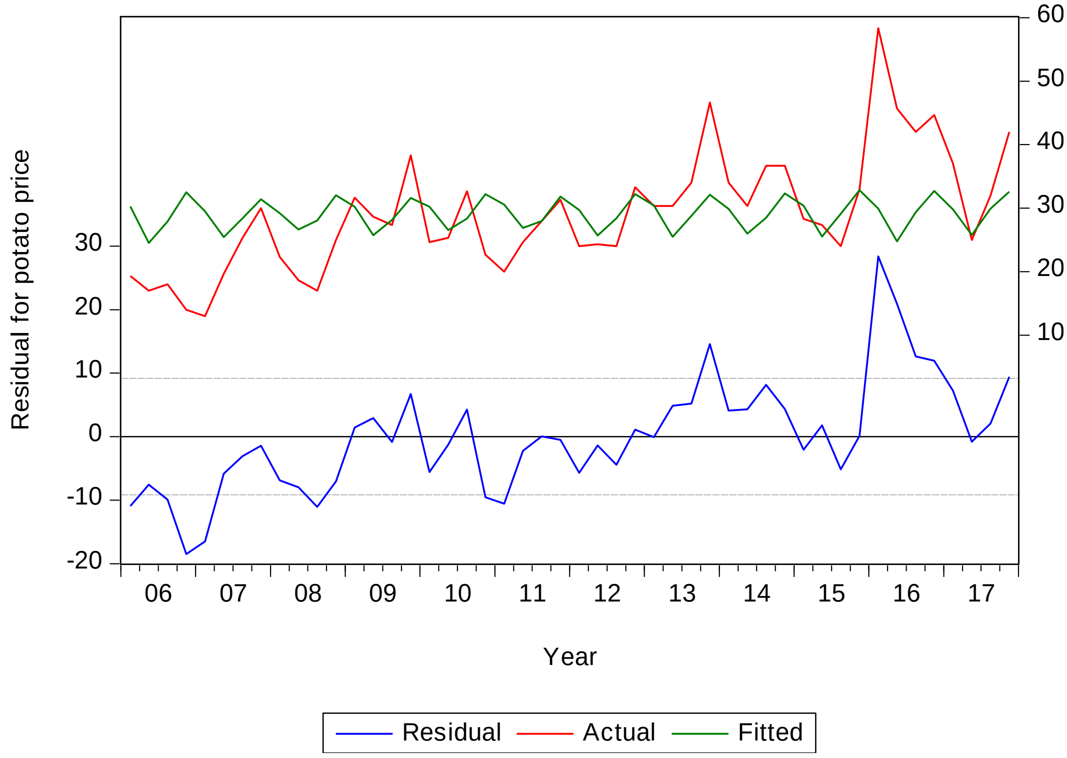


Figure 3: Fluctuating Residual for potato price form year 2006q1 to 2017q4

Clustering volatility means that the period of low volatility followed by period of high volatility for a long period of time and vice versa. From figure 3, the results show that from 2006(q1) to 2006(q4) low volatility was followed by another low volatility for a long period and volatility started to peak from 2007(q1) to 2007(q4), meaning period of high volatility was followed by period of high volatility. The study noticed period of low volatility from 2008(q1) to 2008(q2), period of high volatility peaks again from 2008(q3) to 2009(q3). In 2009(q4) to 2012(q3) there was an evidence of low volatility. This was supported by Nsabimana *et al.* (2015) in their study on forecasting price of Irish potatoes volatility using GARCH and VECM Models in Rwanda were it was observed that the Irish potatoes goes by decreasing from +32% in 2010; + 21.1% in 2011 and +13.4% in 2012 up to -4.2% in 2013. It shot up again to high volatility in 2014(q4) to 2014(q3). 2014(q4) to 2015(q4) the period of low volatility was observed on figure 3 and period of high volatility was followed from 2016(q1) to 2016(q4). In 2017(q1) to 2017(q4), there was an evidence of low volatility. The study concludes that there is clustering volatility, therefore the study proceeds to run ARCH model. Nsabimana *et al.* (2015) concluded that there was an indication of clustering volatility price of Irish Potatoes because on figure 2, the graph showed that the high volatility tends to be followed by high volatilities and low volatility was followed by low volatility. The study proceeds to run ARCH model

4.3.1 Testing for ARCH effect

Stating null hypothesis as:
H_0: There is no ARCH effect
H_1: There is ARCH effect

Table 4: Heteroscedasticity Test: ARCH

F-statistic	9.540098	Prob. F (1,41)	0.0036
Obs*R-squared	8.116807	Prob. Chi-Square (1)	0.0044

Under null hypothesis stating that there is no ARCH affect, the study observed results from table 4 indicating that prob.chi-square is 0.0044 meaning is less than 5%, therefore; we can reject null hypothesis, there is ARCH effect. Therefore, the study have valid reason to run ARCH model because there is clustering volatility observed from figure3 and ARCH effect was tested on table 4.

4.2.4 Testing GARCH effect

Stating null hypothesis as:
H_0: There is no GARCH effect
H_1: There is GARCH effect

Table 5: Mean equation and variance equation model: GARCH affect
GARCH = C(7) + C(8)*RESID(-1)^2 + C(9)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
@SQRT(GARCH)	1.415233	0.741541	1.908502	0.0563
C	65.41427	6.585095	9.933687	0.0000
R_RAINFALL_MM	0.003024	0.033417	0.090491	0.0092
HA_HECTARE	-0.000160	4.79E-05	-3.343709	0.0008
T_TEMP	-0.198444	0.180027	-1.102303	0.2703
C	10.59822	8.238053	1.286496	0.1983
RESID (-1) ^2	-0.907232	0.703838	1.288979	0.1974
GARCH (-1)	1.078374	0.021077	51.16459	0.0000
T-DIST. DOF	2.032925	0.024201	84.00289	0.0000

R-squared	0.841806	Mean dependent var	28.69318
Adjusted R-Squared	0.820991	Mean dependent var	9.287120
S.E. of regression	3.929326	S.D. dependent var	5.575094
Sum squared resid	586.7050	Akaike info criterion	5.980592
Log likelihood	-112.6521	Schwarz criterion	5.725472
Durbin-Watson stat	2.366591	Hannan-Quinn criter.	

On table 5, SQRT(GARCH) as standard deviation for potato price has positive sign of coefficient and p-value is 0.0563, it is not statistically significant. The results observed shows that when standard deviation goes up by 1.415 % so is volatility for potato price. P-value for temperature is 0.2703 and is greater than 5%, meaning volatility of temperature cannot influence volatility of potato price. The study shows that volatility for number of hectares planted and rainfall level can influence the volatility of potato price because their p-values is less than 5% however, number of hectares planted is able to influence volatility of potato price negatively because their coefficient have negative sign. Rainfall level can influence potato price positively because their coefficient have positive sign. Residual (-1)^2 reflecting ARCH effect, p-value is 0.1974, it is more than 5%, meaning ARCH effect cannot influence volatility of potato price whereas p-value for GARCH(-1) is 0.0000 and it is less than 5%, internal causes of GARCH influence volatility of potato price. Akaike info criterion is 5.575094 and Schwarz criterion is 5.980595, the lower the value for Akaike and Schwarz criterion, better the model.

4.3.2 Diagnostic check

4.3.2.1 ARCH effect test

Stating null hypothesis as:

H_0: There is no ARCH effect

H_1: There is ARCH effect

Table 6: Heteroscedasticity Test: ARCH

F-statistic	2.295563	Prob. F (1,41)	0.1374
Obs*R-squared	2.279892	Prob. Chi-Square (1)	0.1311

Under null hypothesis stating that there is no ARCH affect, the study observed results from table 6 indicating that prob.chi-square is 0.1311, it is more than 5%, meaning we cannot reject null hypothesis, there is no ARCH effect. Therefore, the model does not have an ARCH effect.

4.3.2.2 Serial correlation

Stating null hypothesis as:

H_0: There is no serial correlation

H_1: There is serial correlation

Table 7: Partial and Autocorrelation for the dependent and independent variables

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
. |** |	. |** |	1	0.222	0.222	2.3239	0.127
.*| . |	**| . |	2	-0.147	-0.206	3.3620	0.186
.*| . |	. | . |	3	-0.140	-0.061	4.3336	0.228
. | . |	. | . |	4	-0.057	-0.039	4.4987	0.343
. | . |	. | . |	5	-0.018	-0.033	4.5149	0.478
. |*. |	. |*. |	6	0.187	0.193	6.3726	0.383
. |*. |	. | . |	7	0.135	0.031	7.3662	0.392
. | . |	. | . |	8	0.049	0.069	7.5007	0.484
. | . |	. | . |	9	-0.062	-0.033	7.7225	0.562
.*| . |	. | . |	10	-0.180	-0.025	8.1048	0.619
. | . |	. | . |	11	-0.051	-0.016	8.2622	0.690
. | . |	.*| . |	12	-0.043	-0.088	8.3802	0.755
.*| . |	.*| . |	13	-0.074	-0.100	8.7351	0.793
. | . |	. | . |	14	0.009	-0.005	8.7403	0.847
. |*. |	. |*. |	15	0.104	0.178	9.4959	0.850
. |*. |	. |*. |	16	0.111	0.189	10.393	0.845
. | . |	. |*. |	17	0.069	0.186	10.749	0.869
.*| . |	. | . |	18	-0.181	-0.056	11.261	0.883
.*| . |	. | . |	19	-0.174	0.040	11.705	0.898
.*| . |	.*| . |	20	-0.187	-0.185	12.339	0.904
. | . |	. | . |	21	0.009	0.000	12.346	0.930
. | . |	.*| . |	22	0.009	-0.096	12.353	0.950
. | . |	. | . |	23	0.061	-0.001	12.715	0.958
.*| . |	.*| . |	24	-0.094	-0.138	13.618	0.955
.*| . |	. | . |	25	-0.091	-0.024	14.506	0.952
.*| . |	. | . |	26	-0.080	-0.037	15.218	0.953
. | . |	. | . |	27	-0.063	-0.055	15.697	0.958
. | . |	. | . |	28	-0.013	0.043	15.719	0.970
. | . |	.*| . |	29	-0.064	-0.123	16.269	0.972
. | . |	. | . |	30	-0.041	0.032	16.508	0.978
. | . |	. | . |	31	0.036	0.004	16.712	0.983
. | . |	. | . |	32	-0.003	-0.036	16.713	0.988
. | . |	. | . |	33	-0.031	-0.011	16.885	0.991
. | . |	. | . |	34	-0.021	-0.033	16.972	0.993
. | . |	. | . |	35	-0.055	-0.030	17.644	0.994
. | . |	. |*. |	36	0.040	0.079	18.050	0.995

|* Significant at 10%
|** Significant at 20%
|. Significant at 1%

The study performed diagnostic check to test whether there exists serial correlation or not. On Table 7, results show that p-values for both dependent and independent variables is more than 10%. Therefore, we cannot reject null hypothesis stating that there is no serial correlation. The study concludes that there is no serial correlation in the model.

4.4 Testing for stationarity

Unit root test

Stating null Hypothesis as:

H_0: Non-stationarity (the existence of unit root)
H_1: Stationarity (No unit root)

Table 8: Unit root test at level

Series	**ADF test statistic**	**Test critical value**	**Conclusion**
Potato price (p)	-2.641843	-2.93	Non-stationary
Hectares planted (HA)	-1.781555	-2.94	Non-stationary
Rainfall (R)	-3.958926	-2.94	Stationary
Temperature (T)	-1.671012	-2.94	Non-stationary

Unit root test was performed to tests whether the series is non- stationary and possesses unit root. The Augmented Dickey Fuller statistics value for potato price was – 2.641843, number of hectares planted was -1.781555, temperature was -1.671012 and are greater than critical value (-2.94) at 5% level, so we do not reject null hypothesis in the above-mentioned series, since time series has a unit root and considered to be non-stationary at level. However, Augmented Dickey Fully statistic value for rainfall level is less than critical value and they possess stationary at level.

Table 9: Unit root test at the first differencing

Series	**ADF test statistic**	**Test critical value**	**Conclusion**
Potato price (p)	-7.204999	-2.94	Stationary
Hectares planted (HA)	-8.441654	-2.94	Stationary
Rainfall (R)	-18.97811	-2.94	Stationary
Temperature (T)	-24.87664	-2.94	Stationary

First differencing was performed. Eviews report that test critical values (- 2.93) at 5% level for all variables were less than their Augmented Dickey Fully values respectively, so the study reject null hypothesis and time series does not have unit root. Therefore, it is stationary. The study confirms that potato price (PP), number of hectares planted (HA) and temperature (T) are non-stationary at level but after first difference, they became stationary whereas rainfall (R) became stationary at level. Nsabimana *et al.* (2015) who confirmed that all those four series were not stationary at level but they were all stationary after one differencing support the results. Now that all variables are stationary, the study proceeds to the second step, which is to determine cointegration relationship amongst variables. In order to perform cointegration test and VECM model, firstly the study determine the number of optimal lag to be used.

4.4.1 VAR Lag Order Selection

The study has undertaken VAR Lag Order selection process. Various selection criteria results are listed in a table below,

Table 10: Lag order selection criteria
Endogenous variables: Number of hectares planted (Ha), Rainfall (R), and Temperature (T).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1399.505	NA	8.74e+25	73.92130	74.13677	73.99796
1	-1257.993	238.3358	1.92e+23	67.78910	69.08193	68.24908
2	-1181.598	108.5617	1.38e+22	65.08408	67.45427	65.92738
3	-1157.449	27.96161	1.75e+22	65.12889	68.57644	66.35550
4	-1112.899	39.86078	9.50e+21	64.09993	68.62484	65.70986
5	-1051.638	38.69065	3.24e+21	62.19150	67.79377	64.18474
6	-974.8837	28.27807	1.23e+21	59.46756*	66.14719*	61.84412*

* indicates lag order selected by the criterion

The table 10 indicates information criteria where; AIC (Akaike information criterion), SC (Schwarz criterion) and HQ (Hannan-Quinn information criterion), confirm the lag 6 as the appropriate lag to be used. Therefore, the study proceeds to test for cointegration and VECM using lag 6. Nsabimana *et al.* (2015), support the results.

4.4.2 Johansen test for cointegration

The study performed Johansen cointegration test using both unrestricted cointegration rank test(Trace) and unrestricted cointegration rank test (Maximum Eigenvalue) to check if there exist relationship between potato price and independent variables. The results are listed in the table below,

Stating null hypothesis as;
H_0: There is no cointegration
H_1: There exist cointegration

4.4.2.1 Unrestricted cointegration rank test (Trace)

Table 11: Unrestricted cointegration rank test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.691675	88.27269	69.81889	0.0009
At most 1	0.473453	41.20871	47.85613	0.1821
At most 2	0.262203	15.55214	29.79707	0.7433
At most 3	0.080689	3.388688	15.49471	0.9465
At most 4	0.000586	0.023461	3.841466	0.8782

4.4.2.2 Unrestricted cointegration rank test (Maximum Eigenvalue)

Table 12: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.691675	47.06398	33.87687	0.0008
At most 1	0.473453	25.65656	27.58434	0.0865
At most 2	0.262203	12.16346	21.13162	0.5316
At most 3	0.080689	3.365228	14.26460	0.9195
At most 4	0.000586	0.023461	3.841466	0.8782

The null hypothesis in the first column of both table 11 and 12 states that there was no cointegration between the series and was rejected at 0.05 since the trace and maximum eigenvalue statistic were greater than the critical value. However, null hypothesis at most 1, at most 2, at most 3, at most 4 equations cannot be rejected at 0.05 since the trace and maximum eigenvalue statistic were less than the critical value meaning that the study have one cointegrating equation at 5%. The study concludes that there exist long run relationship between potato price, number of hectares planted, rainfall and temperature. Meaning there is cointegration relationship among variables. The results are in contrast with Nsabimana *et al.* (2015) who concluded that the price of Irish potatoes, price of fertilizers (NPK), price of pests (Dithan), and exchange rate (Rwf/Usd) does not have long run relationship.

4.4.2.3 Long run cointegration

Long run cointegrating equation was observed from table 13 to determine cointegrating variables in a long run.

Table 13: Long run cointegrating equation (normalized cointegration coefficient)

Normalized cointegration coefficients (standard error in parentheses)				
P_PRICE	HA_HECTARE	R_RAINFALL _MM_	T_TEMP	Y_TOTAL_10K G
1.000000	0.026880	5.675533	85.29693	-8.54E-06
	(0.00397)	(0.92184)	(19.5474)	(2.1E-06)
Adjustment coefficients (standard error in parentheses)				
D(P_PRICE)	-0.037725			
	(0.03574)			
D(HA_HECTA RE)	-47.10903			
	(19.5316)			
D(R_RAINF .ALL_MM_)	-0.247190			
	(0.09578)			
D(T_TEMP)	0.002877			
	(0.00451)			

Potato price was positioned as dependant variable and coefficient of number of hectares planted, rainfall and temperature level were reversed in the long run. In this case there was negative coefficient -47.10903 for hectares and -0.247190 for rainfall indicating that in the long run, falling of number of hectares planted and rainfall level was associated with rising value of potato price and vice versa. The results are supported by Tunku *et al*. (2013) who revealed that the negative sign of -0.0928 in their study, indicates a long-run equilibrium among the variables. There is no significant relationship between temperature and potato price because potato is not easily affected by extreme temperature which may be due to its storability (Duyan and Tagarino 2014). To further find cointegrating variables in a long run, the study used standard error, based on standard error we can determine

T-statistic for each explanatory variable by dividing coefficients by standard error. The calculations were done respectively,

T-statistic for hectares (ha) $=\frac{0,026880}{0,00397}$

= 6,8%

T-statistic for rainfall (r) $=\frac{5.675533}{0.92184}$

= 6.2%

T-statistic for temperature (t)$=\frac{85.29693}{19.5474}$

= 4.4%

Source: Author's calculations

Null hypothesis for number of hectares planted and rainfall was rejected because t-statistics was greater than 5%, this indicate that potato price has a long run relationship with number of hectares planted and rainfall. Null hypothesis for temperature was accepted because t-statistic was less than 5%, therefore, there was no evidence of long run relationship between potato price and temperature. In conclusion, Johansen cointegration test confirms that potato price, number of hectares planted and rainfall have long run equilibrium relationship. Non- stationary series were integrated of first order I (1), number of hectares planted and rainfall level are cointegrated to potato price. The study proceeds to run VECM with cointegrated variables.

4.4.3 VECM

Having a cointegration relationship in potato price, number of hectares planted and rainfall, the study used Vector Error Correction Model (VECM) to determine short run dynamics of the cointegrated series. Granger causality to examine the Granger cause of potato price (P), number of hectares planted (Ha), and rainfall (R) respectively.

4.4.3.1Short run causality

Stating null hypothesis as;

H_0: There is short run causality

H_1: There exist short run causality

Table14: short run causality (coefficient for number of hectares planted)

Equation: Null hypothesis: C(5) =C(6)=C(7)=0

Test Statistic	Value	Df	Probability
F-statistic	0.646973	(3, 29)	0.5912
Chi-square	1.940919	3	0.5848

Wald test was performed to determine whether there was short run causality running from number of hectares planted and rainfall granger to potato price respectively. Table 13 the study observed short run coefficient associated with lagged values of C(5), C(6), C(7) for number of hectares planted. The results indicate that null hypothesis cannot be rejected because *p-value* for Chi-Square was 1.940919 and was greater than 0.05%. The study concludes that there was no evidence of short run causality running from number of hectares planted to potato price, therefore, number of hectares planted does not granger cause potato price in short run. Meaning, potato price cannot be influenced by the number of hectares planted.

Table15: short run causality (coefficient for rainfall)

Equation: Null hypothesis: C(8)=C(9)=C(10)=0

Test Statistic	Value	Df	Probability
F-statistic	2.143293	(3, 29)	0.1163
Chi-square	6.429880	3	0.0925

On Table 15, the study observed short run coefficient associated with lagged values of C(8),C(9),C(10) for rainfall. The results indicate that null hypothesis cannot be rejected because *p-value* for Chi-Square 6.429880 and was greater than 0.05%. The study concludes that there was no evidence of short run causality running from rainfall to potato price, therefore, rainfall does not granger cause potato price in short run. Meaning that rainfall level does not have an influence on the potato price. The results on table 14 and 15 are in contrast with Vigila *et al*. (2017) who concluded that, there was a bidirectional relationship between Tamil Nadu and Gujarat potato markets. Meaning, a change in these market prices of potato significantly affects each other in the short run.

4.4.2 Testing for serial correlation

Stating null hypothesis as;

H_0: There is no serial correlation

H_1: There is evidence of serial correlation

Table 16: serial correlation

F-statistic	0.482856	Prob. F (3,26)	0.6971
Obs*R-squared	2.110955	Prob. Chi-Square (3)	0.5497

The results on table 16 for serial correlation were not statistically significant, stating that null hypothesis cannot be rejected because *p-value* (Chi-Square) is 0.5497and it is greater than 0.05%. The study concludes that there is no evidence of serial correlation, indicating that model is appropriate.

4.4.4 Testing for stability

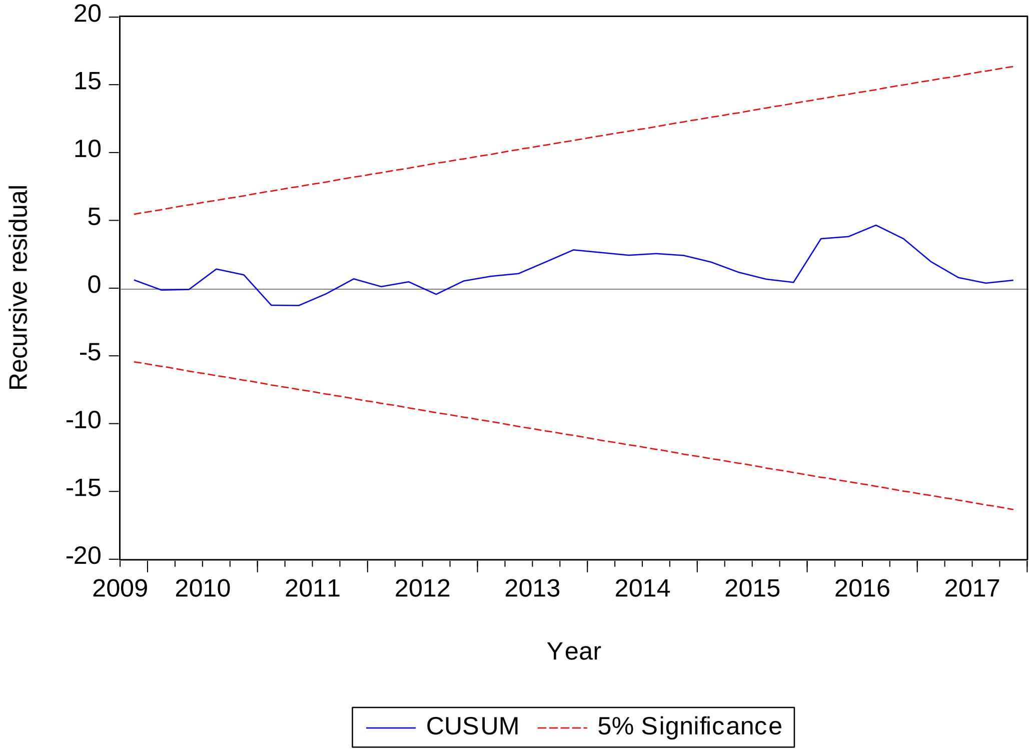


Figure 4: Plot of CUSUM for the estimated ECM model

Furthermore, the study used cumulative sum (CUSUM) to assess stability in the estimated ECM coefficient. The results observed in figure 4 shows that the blue trend lies within red boundary, meaning the model was dynamically stable with 95% critical bounds. The results are in consistent with Vigila *et al*. (2017)

4.4.5 ECM Forecasting

Table 17: four period lagged potato price (q1-q4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	68.31969	23.99465	2.847288	0.0653
P_PRICE (-1)	0.226215	0.400321	0.565083	0.6115
P_PRICE (-2)	-0.554663	0.384447	-1.442756	0.2448
P_PRICE (-3)	0.170094	0.435273	0.390775	0.7221
P_PRICE (-4)	-0.570634	0.355415	-1.605542	0.2067

Table 17 indicate that four period lagged term is significant because their p-value(S) are greater than 5%. The coefficients indicate seasonality.

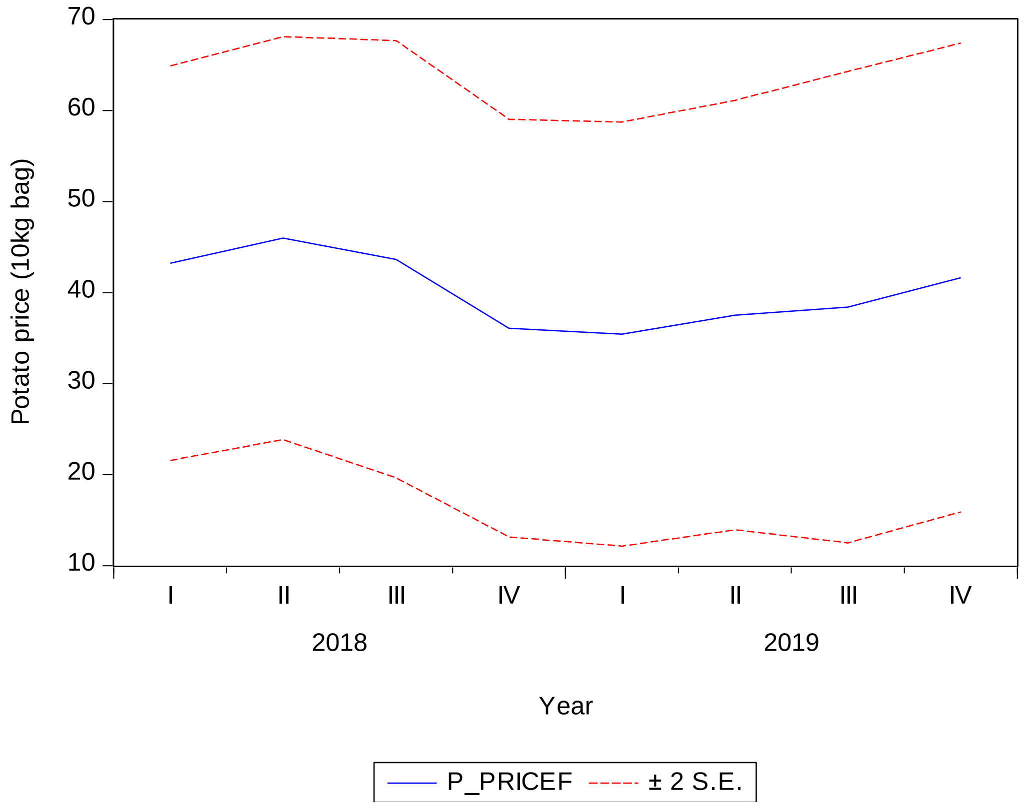


Figure 5: Forecasted quarterly potato price from 2018q1 to 2019q4 (10kg)

Figure 5 shows the results where red line was confident interval around forecast and blue line is the forecast of the study. The results indicate that from first quarter of 2018, potato price was about R45 per 10kg and then dropped on the second to R41 per 10kg. Potato price will range between R38 to R39 per 10kg on the third quarter of 2018. The fourth quarter of 2018 to first quarter of 2019, potato price was forecasted to be R35 per 10kg. An estimated potato price of the second and third quarter of 2009 was R38 per 10kg, then on fourth quarter would be around R41 per 10kg.

Figure 6: Forecasted quarterly potato price from 2006q1 to 2019q4 (10kg bag)

The study used sample from 2006q1 to 2017q4 that is the actual values of potato price to make forecast on 2018q1 to 2019q4 potato price values. In figure 6, the red line shows actual potato price value whilst the blue line shows forecasted potato price. Figures 6 shows that on the last quarter of 2018(q4) potato price decreases from R40 to R35 per 10kg. In year 2019q1 –q2 potato price will range between R38 to R41 per 10kg bag. The results are in consistent with Suppanunta (2014), who studied market efficiency and forecasting of rubber future, the study concluded that rubber future price is volatile. In March 2009, the price dropped to 50.56. During April and May, the price increased to 57.75 and increased back for two months until August 2009. Haiying and shengchu (2011) forecasting international oil price using ECM model. The result was that oil future price would hold around 84 dollars per barrel through 2011, this supported the results.

Table18: Measuring forecast accuracy

Forecast	RMSE	MAE	MAPE	Theil
P_PRICE	7.924994	6.135318	20.13507	0.127643
C	29.77374	29.69668	96.72066	0.937129
P_PRICEF	7.335438	5.431870	17.80015	0.117392
P_PRICES	7.866587	6.101539	20.01299	0.126434
Simple mean	9.607784	8.616569	28.48663	0.176406
Simple median	9.245066	7.419070	24.10426	0.152890
Least-squares	NA	NA	NA	NA
Mean square error	24.47410	24.38325	79.89334	0.661745
MSE ranks	7.788335	6.517924	21.49421	0.131921

After forecasting, the study evaluated forecasting accuracy using Mean pricing error (MPE), mean absolute pricing error (MAPE), mean absolute relative pricing error (MARPE), and root mean squared error (RMSE), however the study drew conclusion based on RMSE as an effective measure since it gives a measure of the magnitude of the average forecast error. Table 18 Shows that RMSE is gradually going town from 7.92 to 7.33, meaning the lower the value of RMSE becomes the predictive ability of the estimated regression model become. The results are in consistent with Suppanunta (2014).

CHAPTER FIVE

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

5.1. Introduction

This chapter provides conclusion on the study by summarise the main findings. The chapter further provide conclusion and then followed by recommendations based on the results.

5.2 Summary of findings

The study aims to analyse potato price volatility in South Africa. Three study objectives were observed and analysed. The first objective was to determine the variability of potato price from 2006 to 2017, which was addressed by ARCH and GARCH model. The study undertaken the measurement to evaluate volatility using coefficient of variation before performing ARCH and GARCH model to check the variation level of potato price from year 2006 to 2017. The study evident that when dispersion was lower in the first data set, the second data set would be higher and vice versa this indicate that potato price volatility varies from one year to the other. The study concludes that the regressed model has an evidence of clustering volatility and that the GARCH model influences potato price volatility in South Africa.

The second objective which was to identify and analyse the determinants of potato price change in the market was addressed by VECM. The study identified three determinants of potato price change in South Africa namely; number of hectares planted, rainfall and temperature level. In order to test for cointegration relationship, the study used Johansen procedure to check if there exist long run relationship between potato price and independent variables. The Johansen test of cointegration has revealed that a change in number of hectares planted and rainfall level significantly affects potato price in a long run and are cointegrated. Therefore, any decrease in number of hectares planted and rainfall would cause higher potato prices and vice versa. However, the study concludes that there was no significant relationship between temperature and potato price.

To determine the short run causality, the study used VECM model. The study shows that there was no evidence of short run causality running from number of hectares planted and rainfall to potato price. Therefore, hectares planted and rainfall level does not granger cause potato price in short run, meaning that the number of hectares planted and rainfall level does not influence potato price volatility.

The third objective which was to forecast potato price from 2018 to 2019 was addressed by ECM forecasting. Eviews results indicated that future potato price hold between R45 from first quarter of 2018 then goes down to be R39 to R38 toward the last quarter of 2018. In 2019, estimated potato price would range between R35 to R41 per 10kg from first quarter to fourth quarter.

5.3 Conclusion

The two hypotheses of the study were tested, the first one was that the potato price volatility cannot be influenced by the volatility of the independent variables. The second one was that potato price cannot be cointegrated to the independent variables

Hypothesis one: Potato price volatility cannot be influenced by volatility of independent variables. Null hypothesis stating that potato price volatility cannot be influenced by volatility of independent variables cannot be rejected for temperature level, as one of the independent variable because their p-value is 0.2703 and is greater than 5%, meaning volatility of temperature cannot influence volatility of potato price. Null hypothesis for number of hectares planted and rainfall level was rejected because their p-values is less than 5%. The study shows that volatility for number of hectares planted and rainfall level can influence the volatility of potato price.

Hypothesis two: Potato price cannot be cointegrated with the independent variables. Null hypotheses for both unrestricted cointegration rank test (Trace) and unrestricted cointegration rank test (Maximum Eigenvalue) stating that there was no cointegration between the series was rejected at 0.05% because their p value(s) is less than 5%, this indicate that there was cointegration amongst variables and have a long run relationship.

RECOMMENDATION

- South African potato farmers currently grow a very limited range of cultivars PSA, (2011). The extreme dry condition in year 2015/2016 had a huge impact on potato price volatility. Researcher should adopt cultivars that are tolerant to extreme weather condition, this will enhance potato production thus reducing high potato price volatility.
- The predicament of South African farmers can be tackled by investments in farm infrastructure promoting irrigation and financial support to ensure continuous potato production.
- The Department of Agriculture should forecast agricultural commodities price volatility and provide information to farmers so that they are able make sound decision concerning their production plan and to adopt strategies that will assist them to overcome crisis.

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