PRICE TRANSMISSION WITH ERROR CORRECTION REPRESENTATION – AN APPLICATION TO THE SOUTH AFRICAN GARLIC MARKET

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PRICE TRANSMISSION WITH ERROR CORRECTION REPRESENTATION – AN APPLICATION TO THE SOUTH AFRICAN GARLIC MARKET

by

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A MINI-DISSERTATION submitted in partial fulfilment of the requirements for the degree

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ABSTRACT

There is a high demand for garlic both from the local and international markets. South Africa and the world as a whole have seen a sharp/significant increase in the consumption of garlic during the Corona Virus (COVID-19) era. South African garlic farmers are subjected to exploitation by middlemen such as retailers and wholesalers. This is usually exacerbated by the lack of market information presented to these farmers. This study attempted to test whether there is indeed price transmission in the South African garlic market or not.

The aim of this study was to analyze price transmission in the South African garlic market. The study was conducted in South Africa. The objectives were to provide a description of farmgate, wholesale and retail prices in garlic markets; to determine correlation between farmgate, wholesale and retail prices; to determine the responsiveness of retailers towards a change in farmgate and wholesale garlic prices in South Africa; to determine the direction of price linkage between the farmgate, wholesale, and retail prices of garlic in South Africa and lastly, to determine price transmission in the South African garlic market. This study was conducted in South Africa following a quantitative approach. Secondary data on monthly garlic prices were sourced from the South African Department of Trade, Industry and Competition (DTIC); Joburg Market; National Agricultural Marketing Council (NAMC); and the South African Department of Agriculture, Land Reform, and Rural Development (DALRRD) covering the periods 2011 to 2021. Error Correction Model was used to analyze price transmission, preceded by Augmented Dickey-Fuller and Phillips-Perron tests for data stationarity. The Granger Causality test was also carried out.

The study found the existence of Granger Causality in the South African garlic markets, with retailers responding quickly to price increases at farm and wholesale levels. The outcomes from Granger Causality test revealed a bidirectional price linkage between farmgate and wholesale prices, whereas there is a unidirectional linkage from the farmers and wholesalers to retailers. Through impulse response functions, the study found that retail prices respond faster to changes in wholesale prices than changes in farmgate prices. Additionally, variance decomposition revealed that wholesale prices are major determinants of retail prices in the South African garlic value chain. Through time series forecasting, the study found that farmgate, wholesale and retail prices in the South African garlic market are likely to continue fluctuating due to risks and uncertainties in the market.

The study recommends that the government strengthens its efforts of regulating garlic markets, including other agricultural markets, in order to ensure a fair distribution of income along the marketing chain. It is further recommended that the government invests in the development of modern infrastructure and processing technology to enhance garlic production levels.

Keywords: Price transmission, Garlic markets, Error Correction model, Granger Causality tests, Co-integration, Value chain, Variance decomposition, Impulse response functions

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I would first like to thank The Almighty God and my ancestors for granting me the strength and wisdom to undertake this study. I would also like to humble myself before my late mother who is always with me spiritually and grandmother for always being there for me whenever I needed her support.

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To the staff of the South African Department of Agriculture, Land Reform, and Rural Development; Joburg market; National Agricultural Marketing Council; Department of Trade, Industry, and Competition; Statistics South Africa; and the University of Limpopo ICT and Library staff, I will forever be grateful for the humanity you have shown when I came, knocking on your doors looking for help, you never sent me back. May you do unto

others the goodness you have shown to me. To my family, words alone are not enough to express how grateful I am for having a strong support structure like you. This project is for you. Much love to you all!

“This is what the LORD says: “When seventy years are completed for Babylon, I will come to you and fulfill my good promise to bring you back to this place. For I know the plans I have for you,” declares the LORD, “plans to prosper you and not to harm you, plans to give you hope and a future. Then you will call on me and come and pray to me, and I will listen to you. You will seek me and find me when you seek me with all your heart. I will be found by you,” declares the LORD, “and will bring you back from captivity. I will gather you from all the nations and places where I have banished you,” declares the LORD, “and will bring you back to the place from which I carried you into exile.””- Jeremiah 29 verses 10 to 14.

DECLARATION

I, Tumelo Arthur Mohale, affirm that the mini-dissertation presented to the University of Limpopo for the Master of Science degree in Agricultural Economics is my original work. It has not been previously submitted for a degree at this university or any other institution. I take full responsibility for its design and execution, and I have duly acknowledged all the materials incorporated in this document.

Surname, Initials (Title)	Signature	Date
Mohale, TA (Mr)		02/04/2024

DEDICATION

This project is dedicated to my younger brothers Lefa Dennis Mohale and Ngoako Andrias Mohale, my grandmother Mmasutane Sarah Mohale, including the rest of my family members. I also dedicate this project to the residents of Botlokwa at large.

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
AoR	Asymmetry of Response
APT	Granger Causality
APV	Adjusted Present Value
ARIMA	Auto Regressive Integrated Moving Average
ArPT	Arbitrage Pricing Theory
AvPT	Average Profit Turnover
AvPTi	Average Production Time
CAM	Correlation Analysis Matrix
CCA	Co-movement and Completeness of Adjustment
CPI	Consumer Price Index
COVID-19	Corona Virus
DALRRD	Department of Agriculture, Land Reform and Rural Development
DSA	Dynamics and Speed of Adjustment
DTIC	Department of Trade, Industry and Competition
ECM	Error Correction Model
ECT	Error Correction Term
EViews	Econometric Views
FAOSTAT	Food and Agriculture Organization Statistics
GDP	Gross Domestic Product
GIRF	Generalized Impulse Response Function
IRF	Impulse Response Function
LOP	Law of One Price
MarketsSA	Markets South Africa
NAMC	National Agricultural Marketing Council
NFPM’s	National Farmers' Produce Markets

OLS	Ordinary Least Squares
PP	Phillips-Peron
PVECM	Panel Vector Error Correction Model
SA	South Africa
SACU	Southern African Customs Union
SCP	Structure-Conduct-Performance
SIC	Schwarz Information Criterion
StatsSA	Statistics South Africa
UNCTAD	United Nations Conference on Trade and Development
US	United States
VAR	Vector Autoregression
VECM	Vector Error Correction Model
WHO	World Health Organization

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CHAPTER 1: INTRODUCTION

1.1. Background

Garlic, as a widely cultivated crop, holds a prominent place within the South African agricultural landscape, which is diverse in nature. The garlic market is characterized by a complex supply chain involving farmers, wholesalers, and retailers, each playing a role in shaping the final retail price. Previous research by Sisodiya *et al.* (2018) suggests that understanding the dynamics of price transmission is crucial for stakeholders in the garlic industry, as it can provide insights into issues such as market power, pricing strategies, and the impact of external factors like weather and international trade agreements. Furthermore, given the significance of garlic in South African cuisine and the increasing global demand, comprehending how price movements affect all involved parties is essential for economic stability and food security (UNCTAD, 2019).

The research conducted on price transmission signals is grounded on the theoretical framework of competitive pricing behavior, as demonstrated by Fackler and Goodwin (2001). From a spatial perspective, the classical concept of the Law of One Price, along with the forecasts made by conventional spatial price determination models (Takayama and Judge, 1972), propose that price transmission is fully achieved when the equilibrium prices of a commodity sold in competitive foreign and domestic markets differ solely due to transfer costs, once converted into a shared currency. The lack of market integration or the incomplete transmission of price changes from one market to another has significant implications for economic wellbeing (Barrett, 2001). Incomplete price transmission can occur as a result of several factors, such as inadequate transport and communication infrastructure. This can lead to a decrease in the availability of price information for economic agents. Consequently, these agents may make decisions that contribute to inefficient outcomes.

Price transmission studies test economic theory predictions and reveal how changes in one market affect others, indicating market integration and efficiency. Economic theories are tested using price transmission, as seen in the World Food Model by the UN Food and Agriculture Organization and other models like Tyers and Anderson (1992). Increasing usage of price transmission models for sensitive policy issues including trade liberalization and benefit/cost distribution across countries and populations demonstrates its adaptability. This study seeks to analyze price transmission in the South African garlic markets using error correction representation.

1.2. Problem Statement

There is a high demand for garlic both from the local and international markets (MarketsSA, 2022). According to World Health Organization (WHO) (2020), South Africa and the world have seen a sharp/significant increase in the consumption of garlic during the Corona Virus (COVID-19) era. This is due to the belief that agricultural products such as garlic and ginger have the capability of curing or preventing the catching of respiratory-related conditions such as flu, and COVID-19, among others. Therefore, garlic is mainly used in the field of culinary, even though it has been widely used in the medical field due to its ability and quality to contain/dull diseases such as COVID-19, also serving as a pesticide and fungicide (Cutts & Kirsten, 2020). At the present, the field of human medicine for garlic has been developing, and there are also claims made by WHO (2020) that garlic can also help reduce cholesterol in the human body. The commercialization of these developments could lead to a massive increase in garlic production (Elizabeth *et al.*, 2019).

A garlic farming business is considered a profitable enterprise that earns a reasonable income for a thousand entrepreneurs. It is also opined that although garlic can be successfully produced, its farming has a lot of risks and is also labor intensive (Elizabeth *et al.,* 2019). For a successful business, every garlic producer must ensure that they attain the highest possible yield at the lowest possible production costs (Acquah, 2010). A study conducted by Elizabeth *et al.* (2019) has also found that garlic marketing is not easy, especially for small-scale farmers mainly because they tend not to perform additional marketing functions on their garlic. Marketing functions referred to in this discussion include, *inter alia*, grading, packaging, cleaning, branding, and processing. Recent statistics published by Markets South Africa (MarketsSA) (2022) show that in the market, the demand is mainly for the large, fresh bulbs that are value-added, that is to say, that are graded and well-packaged, hence this stimulated the number of participants that must constitute the marketing chain of garlic. Consequentially, Peltzman (2000) argues that the prices of garlic increase as the number of intermediaries in the market rise. Intermediaries are those people who bridge a gap between the primary producers of garlic and their consumers, this includes *inter alia*, speculative middlemen, agents, retailers, wholesalers, processors, informal traders, among others. StatsSA (2021) has shown that South African garlic producers are faced with the problem of competing with cheaper garlic imports in the country. MarketsSA (2020) further reports that South Africa is no longer competitive when coming to garlic exportation since 2018 and it was sitting at number 23 of world exporters of garlic. In 2019, SA had its garlic exported mainly to Botswana (33.2%), succeeded by Namibia (22.6%) and Mozambique (10.4%) as the major garlic trade partners.

Several factors leading to price transmission have been identified in various literatures. Firstly, Kinnucan & Forker (1987), Miller & Hayenga (2001); McCorrisston (2002) and Lloyd *et al.* (2003) submit that market power is the most cited cause of price transmission. For instance, processers in the oligopolistic market tend to respond quickly in collusion to shocks that reduce their returns than shocks that add more to their returns, leading to short-run price asymmetry in a trial to cover market power execution, and processors may also act in the same way, leading to a long-run Granger Causality. Therefore, it was imperative to highlight that market concentration is possibly a necessary although definitely not a sufficient condition for market power exercise since theoretically and empirically, in accordance with the studies of Weaver *et al.* (1989) & Goodwin (1994), the association among these phenomena is not justifiable nor conclusive. Bailey and Brorsen (1989) assert that it is still unclear as to whether indeed market power can lead to price transmission.

Kinnucan & Forker (1987) proposed that price transmission could arise as a result of government intervening in the markets for agricultural commodities. This could be when such intervention could lead to price asymmetry if it makes retailers or wholesalers think that a drop in prices offered at a farm level will be a temporal event since it will only call for political intervention, whereas a rise in prices offered at a farm level could possibly be a long-lasting occurrence. Therefore, this study also attempted to validate all these assertions including identifying other possible sources of price transmission.

1.3. Rationale

Unhealthy diet consumption and bad eating habits lead to a lot of diseases globally, such as cardiac disease, diabetes mellitus, respiratory complications as well as strokes. (WHO, 2011). Given the health benefits that come with garlic, particularly its popularity to fight against Corona Virus draws the need to research more about the behavior of retailers in setting the prices for consumers. Kohls and Uhl (2001) have noted that farmers usually get lower returns compared to retailers. Garlic, like other agricultural products, undergoes various marketing activities such as transportation, processing, packaging, and grading., before reaching the ultimate consumers. Consequentially, consumers pay more for this garlic due to its increased demand (StatsSA, 2021).

Tests for price transmission were done in a number of agricultural markets. The study conducted by Appel (1992) noted that, mutually, the price transmission degree and speed from farmers to retailers in Germany for broilers is not symmetric. On the other hand, Boyd and Brorsen (1988) have not found any proof of price transmission in the United States (US) pork market. This study, was, however, proven otherwise by the study of Hahn (1990) which noted that there is more sensitivity to the price increase shocks than to price decrease shocks at all levels of value chain for beef and pork in the US. Notably, the market for apples in New York showed that farm-retail prices are asymmetric (Hansmire & Willett, 1992) and the same inference pertinent to dairy products markets in the US was made by Kinnucan & Forker (1987). There is proof that the citrus market in the US showed the presence of vertical short-run price asymmetry and the absence of long-run price transmission. (Pick *et al.*, 1990). Conclusively, Ward (1982) markets for fresh vegetables in the US showed both vertical Granger Causality, whereas the study by Zhang *et al.* (1995) observed a short-run Granger Causality in the market for peanut-peanut butter and a long-run symmetric price transmission. All these studies show a certain aspect of an econometric procedure for approximating irreversibility established in the work of Wolfram (1971) as a reaction to the establishments of a supply response that is irreversible by Tweeten & Quance (1969). An investigation of output-input price relationship considers a predictor variable to divide an input price into two: P_B^+ which captures increasing input price and the second one P_B^- which captures a decreasing input price (Tweeten & Quance, 1969).

This study, therefore, attempted to highlight the price transmissions between garlic farmers, wholesalers, and retailers. The outcomes may draw the attention of the policymakers in ensuring that they regulate the garlic market to eliminate the exploitation of garlic farmers by various middlemen and also ensure that consumers pay a reasonable price for garlic since it has some medicinal uses as highlighted by (WHO, 2021).

1.4. Scope of the study

1.4.1. Study aim

This study primarily intended to analyze price transmission with the error correction representation- an application to the South African garlic market.

1.4.2. Objectives

With this study, the researcher hoped to accomplish the following objectives:

I. To provide a thorough description of farmgate, wholesale and retail prices in the South African garlic markets.
II. To determine the correlation between farmgate, wholesale and retail prices of garlic in South Africa from 2011 to 2021.
III. To determine the responsiveness of retailers towards a change in farmgate and wholesale garlic prices in South Africa.
IV. To determine the direction of price linkage between farmgate, wholesale, and retail prices of garlic in South Africa.
V. To determine whether there is price transmission in the South African garlic market.

1.4.3. Study Hypotheses

Before conducting this study, the researcher postulated the following hypotheses:

I. There is no correlation between farmgate, wholesale and retail prices of garlic in South Africa from 2011 to 2021.
II. Retailers do not respond promptly to a change in farmgate and wholesale garlic prices in South Africa.
III. There is no direction of price linkage between the farmgate, wholesale, and retail prices of garlic in South Africa.
IV. There is no price transmission in the South African garlic market.

1.5. Organizational structure

The subsequent sections of this mini-dissertation are organized into the following chapters: Chapter two, Chapter three, Chapter four, Chapter five and Chapter six. Chapter two, dedicated to the literature review, delves into concepts and presents critiques of how various authors have approached the topic of price transmission in both South Africa and globally. Chapter three captures a comprehensive overview of the South African garlic market whereas Chapter four elucidates the methodology for this study, encompassing the study area, methods of data collection, data analysis, and the models used. Chapter five encompasses the quantitative analyses conducted, highlights the key findings of this investigation and lastly makes forecast of time series. Finally, Chapter six furnishes a summary, draws conclusions, and proposes potential recommendations for policymakers.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter entails a detailed review of previous studies which laid a foundation for all the concepts and theories pertinent to this study. The sections begin with the review of price theory and its relation to agricultural markets, followed by a review of the marketing chain analysis and its importance, review of national and international studies relevant to this study, review of various methods relevant to price transmission analysis in agricultural markets and lastly methodological issues in price transmission analysis.

2.2. Price theory and its relation to agricultural markets

The theory of pricing is a fundamental concept in neo-classical economics, which, in conjunction with Keynesian economics, constitutes the neo-classical fusion that now prevails in contemporary mainstream economics. Scheepers (2018) submits that the field of price theory encompasses the examination of supply and demand dynamics in order to ascertain an appropriate price level for a given commodity, using the principle of equilibrium or the “invisible hand” which uses forces of demand and supply in the determination of prices and quantities of commodities to be traded in the markets. The primary goal is to attain a state of balance wherein the quantity of a given product supplied aligns with the quantity of that product sought by consumers. This idea facilitates the ability to modify prices in response to fluctuations in market conditions (Schnepf, 2006). According to the aforementioned theory, prices play a crucial role in facilitating the efficient allocation of resources and determining the output mix decisions made by economic agents.

In food value chains, the concentration levels at the farm level are typically lower when contrasted with the downstream segments. The concentration observed downstream is primarily a consequence of economies of scale, limiting the number of viable participants in wholesale, processing, and retail sectors (Cutts & Kirsten, 2006). This indicates that intermediaries in the downstream segments, often organized in an oligopolistic manner, may have a more advantageous position in responding opportunistically to various price shocks compared to producers. For instance, oligopolistic intermediaries may react more swiftly and significantly to shocks that decrease their profit margins than to shocks that increase their margins (Cutts & Kirsten, 2006).

As previously mentioned, prices in these systems represent the point at which buyers and sellers agree or reach a mutually acceptable position regarding the value of goods and services at the time of exchange. The effective functioning of food marketing systems relies on efficient coordination, communication, and conflict resolution. The system must convey signals to buyers and sellers that serve as the basis for their business decisions. Additionally, the extent of market concentration significantly influences pricing behavior and the responses of different value chain participants to price shocks. Markets with higher concentration levels are linked to increased market power and decreased competition. Therefore, the observation that food value chains are less concentrated at the farm level and more concentrated downstream, as highlighted in Cutts & Kirsten (2006), implies that intermediaries may wield more influence on market outcomes, such as prices, compared to farmers.

2.3. The concept of price transmission

The exploration of price transmission and market integration analysis has attracted substantial scholarly attention over the past five decades in the field of agricultural economics (Amikuzuno & Ogundari, 2012). Once a price is established at one point within the marketing chain, it must be communicated to other levels in the chain. Price transmission is a multifaceted concept with various interpretations. Colman (1995) defines price transmission as the extent to which changes in prices at one location led to modifications in, or correlate with, price fluctuations at another location. Rapsomanikis *et al.* (2003) further break down this concept into three components: co-movement and completeness of adjustment (CCA), dynamics and speed of adjustment (DSA), and asymmetry of response (AoR). CCA involves the consistent transmission of price changes in one market to other markets. DSA pertains to the process and rate at which price changes in one market spread to other markets or levels. AoR examines whether upward and downward price movements at one level are symmetrically or asymmetrically conveyed to other levels.

Similarly, Vavra & Goodwin (2005) identify four aspects for evaluating Granger Causality. The first aspect, magnitude, examines how substantial the response is at each level when subjected to a shock of a certain magnitude from another level. The speed aspect considers the swiftness or delay in the adjustment process and whether there are significant delays in the response. The nature of price transmission investigates whether adjustments following positive and negative shocks at a specific marketing level exhibit asymmetry. The fourth aspect, direction, assesses the extent to which adjustments differ based on whether a shock is transmitted upward or downward along the supply chain.

Considering these aspects, four types of asymmetries can be analyzed: positive and negative asymmetry, asymmetry in magnitude, asymmetry in speed, and asymmetry in both speed and magnitude. Positive asymmetry occurs when downstream prices react more extensively or swiftly to an increase in upstream prices than to decreases. Negative asymmetry arises when downstream prices respond more significantly or rapidly to a decrease in upstream prices than to increases (Karantininis *et al.*, 2011; Meyer & von Cramon-Taubadel, 2000).

Price transmission across different levels of the value chain serves to integrate markets both vertically and horizontally (Peltzman, 2000; Meyer & von Cramon-Taubadel, 2002). The inception of the study of geographical price relationships can be traced back to more than six decades ago. This analysis was primarily based on the Enke-Samuelson-Takayama-Judge equilibrium model, widely recognized as the blueprint for understanding spatial price equilibrium relationships. Enke (1951), Samuelson (1952), and Takayama & Judge (1964) were the key contributors who established this model.

Price transmission studies are valuable and significant in various aspects. They offer insights into the speed, direction, and magnitude with which changes in product prices in one market are vertically communicated to another. These studies also shed light on the role played by profit-seeking individuals in the value chain in facilitating this transmission process. Additionally, they provide insights into the degree of market integration and the efficiency of various markets (Goletti & Babu, 1994; Rapsomanikis *et al.*, 2003). The phenomenon of incomplete price transmission, commonly referred to as Granger Causality (APT), holds particular significance in the realm of price transmission research, especially within the context of agricultural value chain levels. In simpler terms, the concept of price transmission answers questions about how fast and to what extent the responses in farm prices are communicated to the successors of farmers in the marketing chain of a certain agricultural commodity, such as garlic, namely wholesalers and retailers. Price transmission takes two forms, namely, symmetric and asymmetric.

Meyer & Von Cramon-Taubadel (2004) submit that symmetric price transmission refers to a situation where price changes at different levels of the marketing chain are proportional and move in the same direction. For example, if the price of raw materials increases by 10%, the price of finished products also increases by 10%. Granger Causality, on the other hand, occurs when price changes at different levels of the supply chain are not proportional or do not move in the same direction. For example, if the price of raw materials increases by 10%, but the price of finished products only increases by 5% or remains unchanged. Symmetric price transmission implies a complete pass-through of price changes along the supply chain, while Granger Causality indicates that the pass-through is incomplete or varies depending on the direction and magnitude of the price changes.

2.4. Classifications of Granger Causality

Figures 2.1 and 2.2 below illustrate two significant forms of asymmetry within the context of price transmission. The price (P_out) is assumed to be dependent on another price (P_in) that experiences either an upward or downward trend at a specific moment in time (Meyer & von Cramon-Taubadel, 2004). The extent of the response by “P_out” to a change in “P_in” is determined by the direction of the price change, as depicted in Figure 2.8. The phenomenon of price transmission demonstrates a symmetrical relationship in terms of size, where an increase in producer prices (P_in) is fully transmitted as an increase in consumer prices (P_out). However, the transmission of a decline in “P_in” to a decrease in “P_out” is only partially achieved, as denoted by the amplitude partial transmission (APT). The yellow shaded region represents the magnitude of the “P_in” reduction that is not translated to the “P_out”. As highlighted by Meyer & von Cramon-Taubadel (2004), the magnitude of the transfer depends on the fluctuations in prices and transaction volumes.

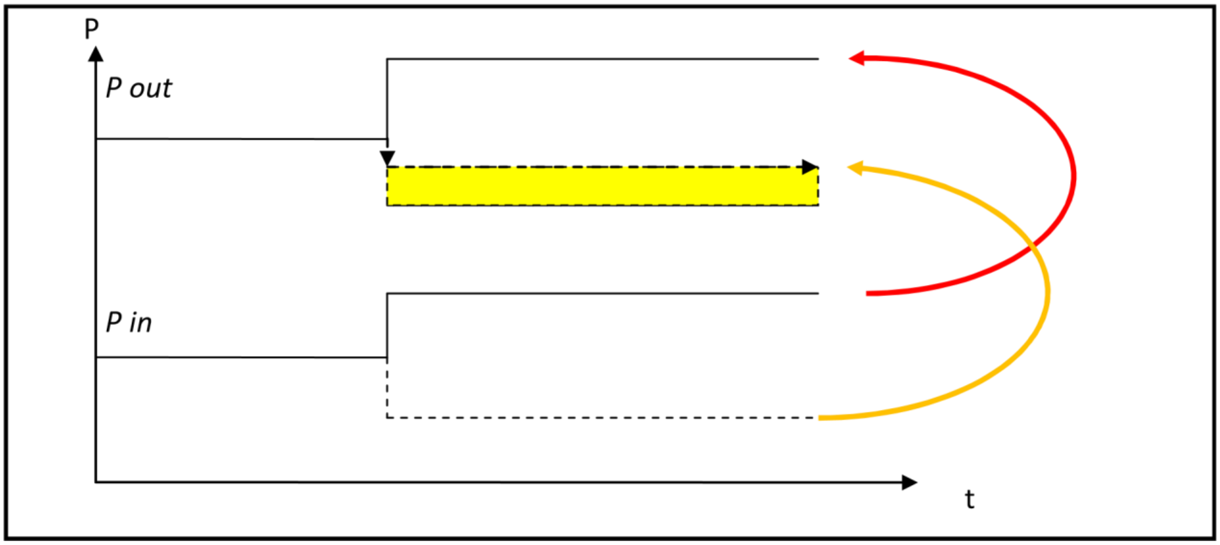

Figure 2. 1.: Granger Causality (magnitude)

Source: Meyer (2002)

The speed at which the output variable “P_out” responds depends on the direction of the change in the input variable “P_in”, as depicted in Figure 2.2. The transmission of a price increase is symmetrical in both speed and size; the rise in producer price (P_in) is fully and immediately transmitted as an increase in consumer price (P_out). In contrast, the transmission of a “P_in” decrease is fully realized but with a temporal delay, mirroring the transmission of a “P_out” decrease. This transmission exhibits asymmetry in speed but symmetry in magnitude. The yellow shaded region represents the extent of the “P_in” decline resulting from the time lag in price transfer that has not been transferred to “P_out” (Meyer & von Cramon-Taubadel, 2004).

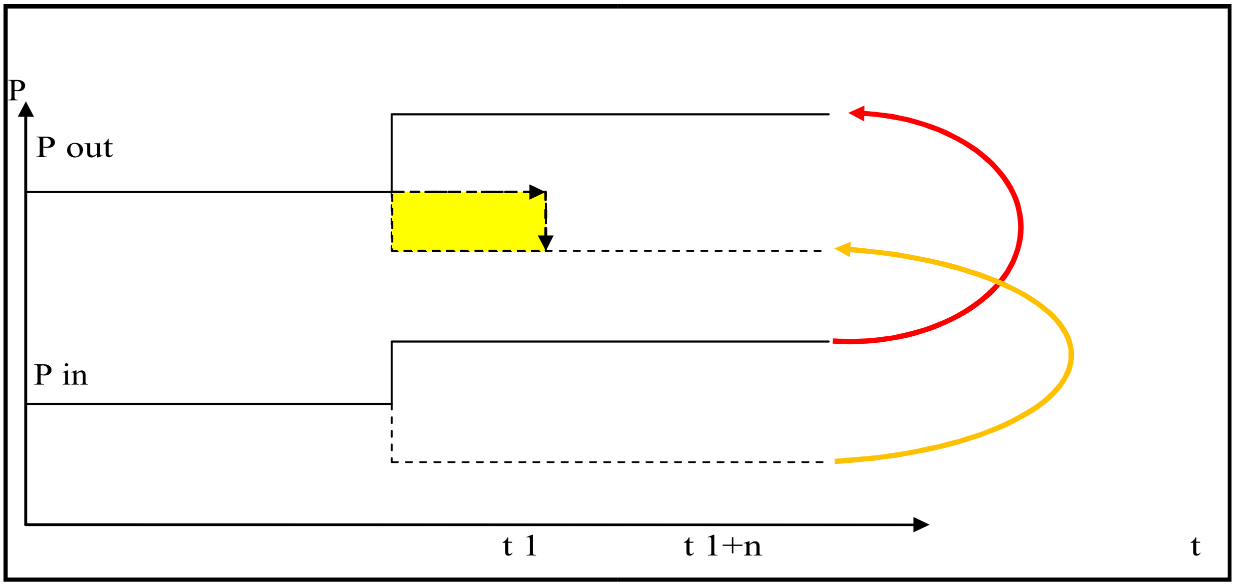

Figure 2. 2.: Granger Causality (Speed)

Source: Meyer (2002)

It is evident that various combinations of these two fundamental asymmetries are possible. Figure 2.3 below illustrates the complete transmission of an increase in input pressure (P_in) with a time lag of two periods (t_1 and t_2), resulting in an increase in output pressure (P_out), a phenomenon referred to as Asymmetric Pressure Transmission (APT). This transmission demonstrates a symmetrical relationship in terms of magnitude but varies in terms of speed. In the context of a decrease, denoted by the letter "P," partial transmission occurs, with a time lag spanning three distinct periods (t_1, t_2, and t_3), leading to the emergence of a transmitted "P_out" decrease. This transmission is characterized by both the speed and amplitude of the decrease. The yellow shaded area represents the extent of the price drop induced by the time lag of price transfer that is not transferred to the final price output (Meyer & von Cramon-Taubadel, 2004).

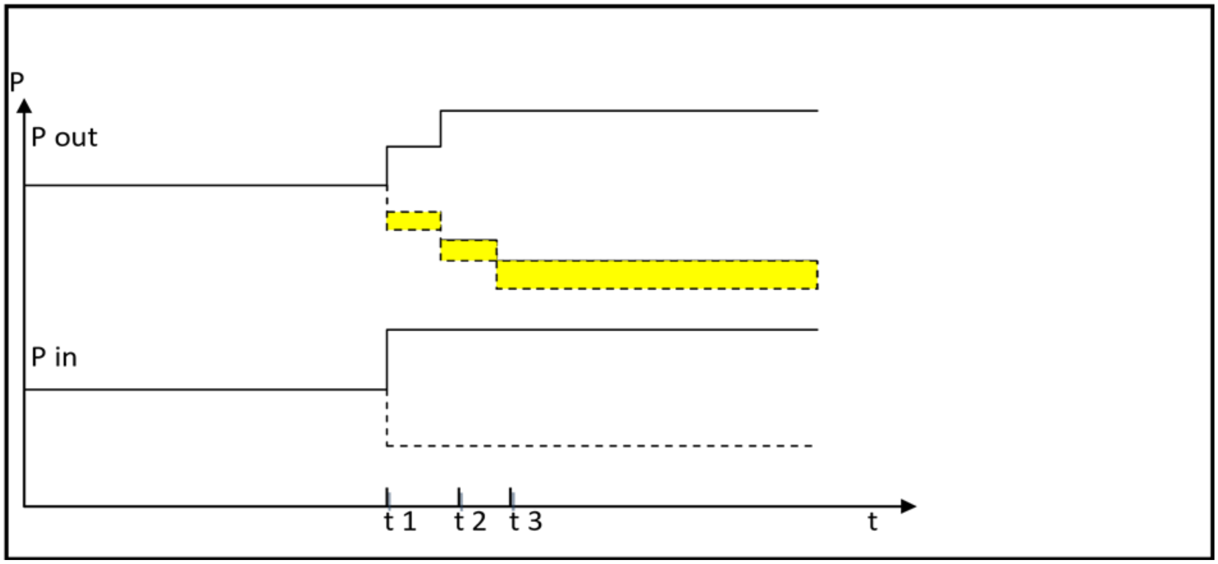

Figure 2. 3.: Granger Causality (Magnitude and speed)

Source: Meyer (2002)

Asymmetry can be further classified into positive or negative forms. Figure 2.4 below illustrates the manifestation of Positive Granger Causality (APT). According to Meyer and von Cramon-Taubadel (2004), if the response of variable “P” to an increase in P is more pronounced or occurs more rapidly compared to its response to a reduction, this asymmetry is referred to as positive. Positive APT can be characterized as a sequence of responses in which any fluctuation in prices that narrows or diminishes the profit margin (such as an increase in input prices, denoted as “P_in”, or a decrease in output prices, denoted as “P_out”) is transferred more swiftly and comprehensively to “P_out” or “P_in”, respectively. According to Vavra and Goodwin (2005), positive asymmetry is considered unfavorable from the consumer's perspective.

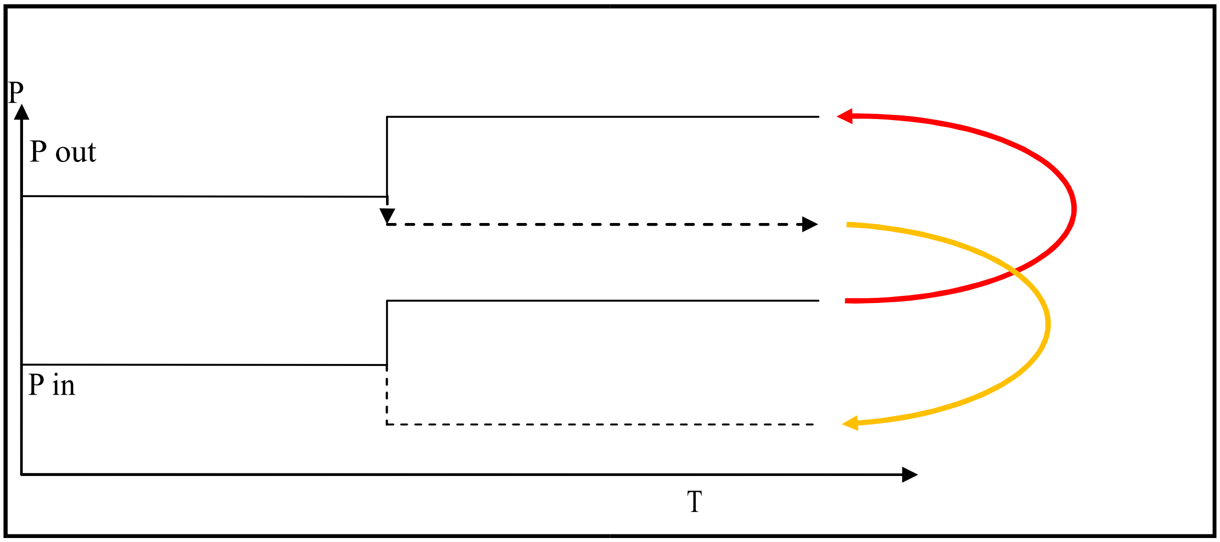

Figure 2. 4.: Positive Granger Causality

Source: Meyer (2002)

Displayed below is Figure 2.5, providing an illustration of negative Granger Causality (APT). Meyer & von Cramon-Taubadel (2004) indicated that when the response of “P_out” is more pronounced or quicker in response to a reduction in “P_in” compared to an increase, this imbalance is referred to as negative asymmetry. Negative APT can be described as a series of reactions in which any changes in prices that result in a wider profit margin (such as a fall in input prices or an increase in output prices) are transmitted more quickly and fully to the respective output or input prices. Negative asymmetry is perceived as advantageous from the consumer's perspective (Vavra & Goodwin, 2005). It is important to note that the flow of price transmission is not necessarily limited to the movement of input prices (P_in) to output prices (P_out). There is potential for upstream or reverse price transmissions, wherein changes in output prices might influence input prices (Vavra & Goodwin, 2005).

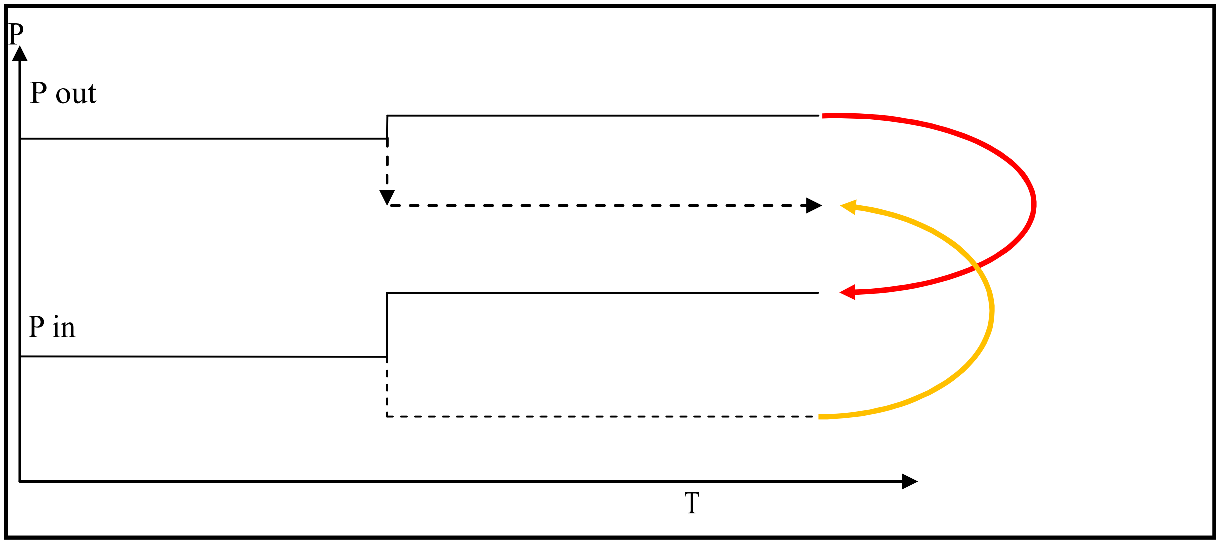

Figure 2. 5.: Negative Granger Causality

Source: Meyer (2002)

The final factor determining the classification of Granger Causality (APT) is whether it influences the vertical or spatial transfer of prices. Vertical price transmission pertains to the process of price transmission within the value chain, encompassing both upward and downward movements. On the other hand, spatial price transmission refers to the phenomenon of price transmission occurring among manufacturers of a certain product operating at the same level of the value chain but located in various geographical areas (Meyer & von Cramon-Taubadel, 2004). An illustration of geographical analysis of price transmission (APT) can be observed when there is a rise in the export prices of product A from nation A, leading to a noticeable response in the export price of the same product from country B. Similar to vertical APT, spatial APT can also be classified based on factors such as speed, magnitude, and polarity (Vavra & Goodwin, 2005).

2.5. Factors influencing Granger Causality.

There is a widespread belief that responses to price increases differ from reactions to price decreases. In particular, merchants tend to quickly pass on price hikes to consumers, while the adjustment of consumer prices to align with producer prices takes a more extended period when the latter decreases. Several substantial reasons account for the existence of price asymmetry.

a) Search costs

Granger Causality denotes the ability of enterprises to capitalize on swift and fluctuating pricing. This phenomenon is explained through the theory of search costs, as proposed by Miller & Hayenga (2001). It occurs in markets with imperfections at the local level, allowing retailers to wield influence within the local market. Customers may face difficulties in obtaining pricing information from competing stores efficiently due to the presence of search expenses, even though their options are limited. Consequently, companies can rapidly raise retail prices in response to an increase in producer prices, while the adjustment in retail pricing is comparatively delayed when upstream costs decrease.

b) Perishability of the product

Moreover, the occurrence of Granger Causality is attributed to the challenge presented by perishable items, limiting retailers from raising prices in response to increased producer costs (Ward, 1982). Wholesalers and merchants dealing in perishable goods may be hesitant to increase prices due to potential repercussions such as diminished demand and the associated risk of having unsellable, spoiled products.

c) Menu (or adjustment) costs

It is important to highlight that adjustments in asymmetric pricing may be linked to either adjustment costs or menu costs, as proposed by Goodwin & Holt (1999). Menu costs encompass all expenses related to the process of modifying prices and implementing a revised pricing strategy. Similar to the effect on perishable commodities, menu costs act as a discouraging factor for retailers when considering price alterations.

d) Market power

The exercise of market power has the capacity to enable an uneven transfer of prices. Numerous food chains display organizational characteristics commonly found in markets characterized by highly inelastic demand and concentrated supply. It is crucial to recognize that maintaining collusive behavior over an extended period poses challenges due to the inherent temptation for a firm to resort to deceptive practices against others (Miller & Hayenga, 2001).

e) Inventory management

The effective management and control of inventory play a pivotal role in a company's strategic response to external price fluctuations and are recognized as a potential contributor to the Adjusted Present Value (APV) phenomenon (Meyer & von Cramon-Taubadel, 2004). The presence of inventories enhances price rigidity by absorbing and mitigating the impact of supply and/or demand shocks on commodity prices. The ability of a product to endure wear and tear, coupled with the capability to produce and/or distribute a stock of a storable product during periods of reduced demand and/or excessive supply, allows for the maintenance of pricing at satisfactory levels.

In times of reduced demand, enterprises often adjust their production levels and increase their inventory instead of lowering the prices of their output. Firms holding stocks typically exhibit a slower rate of price reduction compared to those solely supplying, aiming to mitigate the risk of depleting their inventory. Conversely, during periods of high demand, stock-holding corporations tend to raise the prices of their stocks, thereby expanding profit margins and resulting in a negative Arbitrage Pricing Theory (ArPT) outcome. The decision to maintain inventory levels as a precaution against stockouts incurs associated inventory expenses that tend to reduce profit margins, resulting in a favorable Average Profit Turnover (AvPT) outcome (Reagan & Weitzman, 1982). The process of inventory management, encompassing the strategic buildup of inventory and the controlled release of products from stock, significantly contributes to achieving optimal levels of average production time (AvPTi) and maximizing profits (Reverodo *et al.*, 2004).

Numerous recent research studies have specifically examined the influence of stocks and inventory levels on the phenomenon of price transmission. Deaton & Laroque's (1992) analysis focused on the dynamics of commodity prices concerning inventory holdings, revealing that the elasticity of inventory demand increases as prices decrease. Consequently, the occurrence of a price shock in the value chain is more pronounced when inventory levels are low, leading to a greater price reaction compared to an equivalent shock in a low-price scenario. Another study by Abdessalem *et al.* (2011) aimed to explore the influence of inventories on price transmission within the Canadian chicken industry. The research found that there is a decrease (increase) in price transmission when stocks fall below (rise over) a predetermined goal, a target influenced by the level of domestic sales.

f) Miscellaneous

Various additional factors contributing to Granger Causality have been proposed in academic literature, extending beyond categories like market power or adjustment costs. Price support, a frequently observed phenomenon in agricultural economics, often takes the form of floor prices. Kinnucan & Forker (1987) argue in their scholarly article that political intervention could induce Granger Causality. This occurs when wholesalers or retailers believe that a decrease in farm prices is only temporary due to anticipated government intervention, while an increase in farm prices is perceived as more enduring. Blinder *et al.* (1998) noted in their research article that psychological pricing cues may have a similar impact on price transmission from a different perspective.

Renowned scholars such as Kinnucan & Forker (1987) & von Cramon-Taubadel (1998) have examined Granger Causality within Gardner's (1975) marketing margin model. They contend that changes in both consumer demand at the retail level and agricultural supply at the farm level influence the disparity between farm and retail prices. Gardner (1975) concludes that, in the context of perfect competition and constant returns to scale, changes in retail-level demand have a more significant effect on the farm-retail price spread than shifts in farm-level supply. Kinnucan & Forker (1987) argue that this impact discrepancy could lead to Granger Causality.

Von Cramon-Taubadel's (1998) study suggests that the occurrence of Granger Causality depends on the prevalence of largely positive or negative shifts, indicating a skewed distribution of demand and/or supply shifts (Gardner, 1975). If not specified otherwise, there will be an equal number of episodes characterized by higher demand-driven transmission and lower supply-driven transmission in both directions, according to von Cramon-Taubadel (1998). An illustrative example is seen in the European beef market, where significant adverse fluctuations in retail demand resulting from food crises have been frequently observed recently. Within Gardner's theoretical paradigm, this outcome would manifest as a predominance of instances characterized by robust downward price transmission.

Bailey & Brorsen (1989) suggest in their scholarly publication that asymmetric information can lead to the Arbitrage Pricing Theory (APT). They proposed that economies of scale in information collection within larger organizations may result in an information imbalance among competing enterprises. Bailey & Brorsen (1989) referenced the US broiler market as an illustrative case and cited a spokesperson representing a prominent broiler purchaser who argued that price cuts are not promptly disclosed to the same extent as price rises. Von Cramon-Taubadel *et al.* (1995) suggest that institutional arrangements, where committees of observers, often industry representatives with vested interests, regularly determine and quote reference or indicative prices, can lead to comparable Granger Causality.

2.6. Empirical evidence on price transmission.

For many years, researchers and policymakers have been interested in understanding how changes in commodity prices at one level of the supply chain impact prices at other levels in agricultural markets. This section provides an overview of recent studies on this topic.

In recent years, various studies have explored practical evidence regarding price transmission in agricultural markets. For instance, Rezitis & Tsionas (2019) conducted a study using a sophisticated model called a multivariate panel error correction model (PVECM). Their focus was on understanding Granger Causality across the European food supply chain, considering the farm, processor, and retail components. Analyzing data from 2005 to 2016, the study found that both in the long-term and short-term, retail pricing is more sensitive to increases in processor prices than to decreases. Similarly, processor prices also respond more to changes in farm prices. This implies the presence of positive asymmetrical price transmission within the food supply chain in Europe. The study also highlights significant variation in how changes in food prices affect different product categories and nations. Moreover, it underscores that the impact of price changes on producer prices is more noticeable compared to consumer prices.

On a different note, Ricci *et al.* (2019) delved into the vertical price transmission within two representative Italian wheat chains – the pasta and bread chains. These chains have witnessed substantial market volatility in recent years. The study utilized a cointegration methodology, considering potential unexpected structural changes, and divided the chains into upstream (farm–wholesale) and downstream (retail–wholesale) segments. The researchers scrutinized the evolving price transmission elasticities in different sub periods marked by break dates, revealing signs of Granger Causality. In the pasta supply chain, it seems that farmers play the role of price-takers. Conversely, in the bread supply chain, the transmission of prices appears to be influenced by market structure and the presence of both small and major retailers.

Likewise, Rose *et al.* (2019) conducted a study to examine the presence of price transmission asymmetry within the broiler market chains in the United Kingdom and the United States, serving as an indicator of market efficiency. The heightened attention on price transmission is due to significant price surges impacting agricultural markets, notably during the food crises in 2007 and 2008. According to the authors, traditional economic theory suggests perfect transmissions within markets, where any price changes are fully and immediately transmitted to all levels of the chain. Empirical findings indicate that the rate of price recovery for UK retailers is 16% per month, whereas for USA retailers, it stands at a rate of 15% per month. Moreover, the findings suggest no evidence of long-term asymmetry within the value chains, implying efficient market operation.

The research by Louw *et al.* (2017) yields intriguing results applicable to the two value chains under consideration. South Africa often experiences a surplus in maize production, functioning as a net-exporter. As a result, domestic maize farmers act as price takers in competition for the existing market. However, middlemen and retailers, acknowledged to possess market power, significantly influence pricing within the maize value chain. Wheat prices at the commodity level in South Africa, being a deficit producer of wheat, are determined by domestic producers, although import prices notably impact domestic producer prices.

On a different front, Lombard (2015) applied the Error Correction Model to investigate the dynamics of price transmission within the beef value chain in Bloemfontein, South Africa. The study brought to light the existence of a long-term asymmetrical connection between producer and retail prices for beef in the specified region. Shifting focus to tomato marketplaces, scholarly interest has been drawn to the phenomenon of price transmission.

In a study led by Mandizvidza *et al.* (2013), the examination centered on the price transmission dynamics among producer, wholesale, and retail tomato prices in the Limpopo Province of South Africa. The findings from Mandizvidza *et al.*'s investigation are as follows: utilizing the Granger Causality test, Mandizvidza *et al.* (2013) aimed to establish a causal relationship between producer and retail prices, as well as between producer and wholesale prices, specifically in the context of tomatoes in the Limpopo Province. Surprisingly, there was a lack of evidence supporting a causal relationship between wholesale and retail pricing. This suggests that fluctuations in wholesale tomato prices did not significantly impact retail tomato prices, and vice versa. The study determined the existence of an asymmetrical price transmission link between farmgate and retail prices. Specifically, it was observed that retailers promptly react to increases in farmgate prices, while they exhibit a slower response when farmgate prices decrease, a phenomenon known as positive asymmetry. In contrast, Mandizvidza *et al.* (2013) discovered that the price transmission process between wholesale and farmgate prices exhibited symmetry.

Mosese *et al.* (2020) delved into uncovering the dynamics of price transmission within the potato market in South Africa. The research utilized the Error Correction Model and Granger Causality test methodologies. The empirical findings highlight the existence of pricing disparity within the potato value chain in South Africa. Furthermore, the results suggest that retail prices are more responsive to increases in producer prices compared to decreases in producer prices. The Granger Causality test points to wholesale-level factors, particularly those at the National Fresh Produce Markets, as the primary influencers of prices within the potato value chain.

Lastly, Scheepers (2018) examined the vertical coordination and integration within the South African macadamia industry, focusing on market power and its impact on price transmission along the value chain. Granger Causality, particularly concerning the backward transmission of increased wholesaler prices to producers, was identified in the case of processors/marketers following vertically coordinated price transmission. In contrast, symmetric price transmission was observed when processors/marketers followed vertically integrated price transmission. The error correction model revealed that both vertically coordinated, and vertically integrated price transmissions undergo discrepancy corrections within a one-year period, but the vertically integrated approach demonstrated greater efficacy in handling magnitude discrepancies between producer and wholesaler prices. Causality tests confirmed the presence of unidirectional causality in both vertically coordinated and vertically integrated price transmissions, indicating a lack of information flow in the market, whereby producer and wholesale prices do not exert influence on each other.

2.7. Forecasting Time Series

Forecasting time series involves predicting future values based on historical data patterns. This method is widely applied in diverse fields such as finance, sales and marketing, supply chain management, healthcare, and weather forecasting. Time series data comprises observations or measurements taken at regular intervals over a period. The primary objective of time series forecasting, as outlined by Fajar (2019) & Aini (2020), is to analyze the relationship between variables and time quantitatively. The ultimate goal is to unveil patterns, trends, and relationships within the data, enabling informed predictions about future values.

Several critical aspects need consideration when dealing with time series data forecasting. Firstly, comprehending the data's nature and identifying any underlying patterns or trends is crucial. Visual analysis, including plotting data points over time, aids in observing consistent patterns, trends, and seasonality (repeating patterns at regular intervals), while trend refers to the long-term direction of the series (Majhi, 2023). Once these patterns and trends are recognized, various time series forecasting techniques can be applied. These include the moving average, weighted moving average, single exponential smoothing, and the Auto Regressive Integrated Moving Average model (ARIMA). Each method has its strengths and limitations, allowing for the smoothing of fluctuations, identifying trends, and capturing seasonality.

Furthermore, machine learning techniques, particularly deep learning algorithms like Long Short-Term Memory and Recurrent Neural Networks, are increasingly utilized in time series forecasting (Chintapalli *et al.*, 2020). These techniques have demonstrated effectiveness in capturing complex patterns and relationships in data, providing promising results for predicting future values by learning from the sequential nature of time series data.

2.7.1. The Components of a Time Series

As Wegner (1993) outlines, time series analysis operates under the assumption that the data values of a time series variable are influenced by four distinct environmental forces, each operating individually and collectively over time. These forces are identified as trend (T), cycles (C), seasonality (S), and irregular (random) influences (I). The objective of time series analysis is to separate and statistically quantify each of these components, a process known as the decomposition of the time series. Once these components are isolated and measured, they are combined to estimate future values of the time series variable.

a) Trend (T)

Trend is characterized as a long-term smooth underlying movement in a time series, representing the impact of enduring factors on the series. These factors typically operate gradually and persistently in one direction for an extended period. Consequently, the trend component is often depicted by a smooth, continuous curve or a straight line, as illustrated in the figure below:

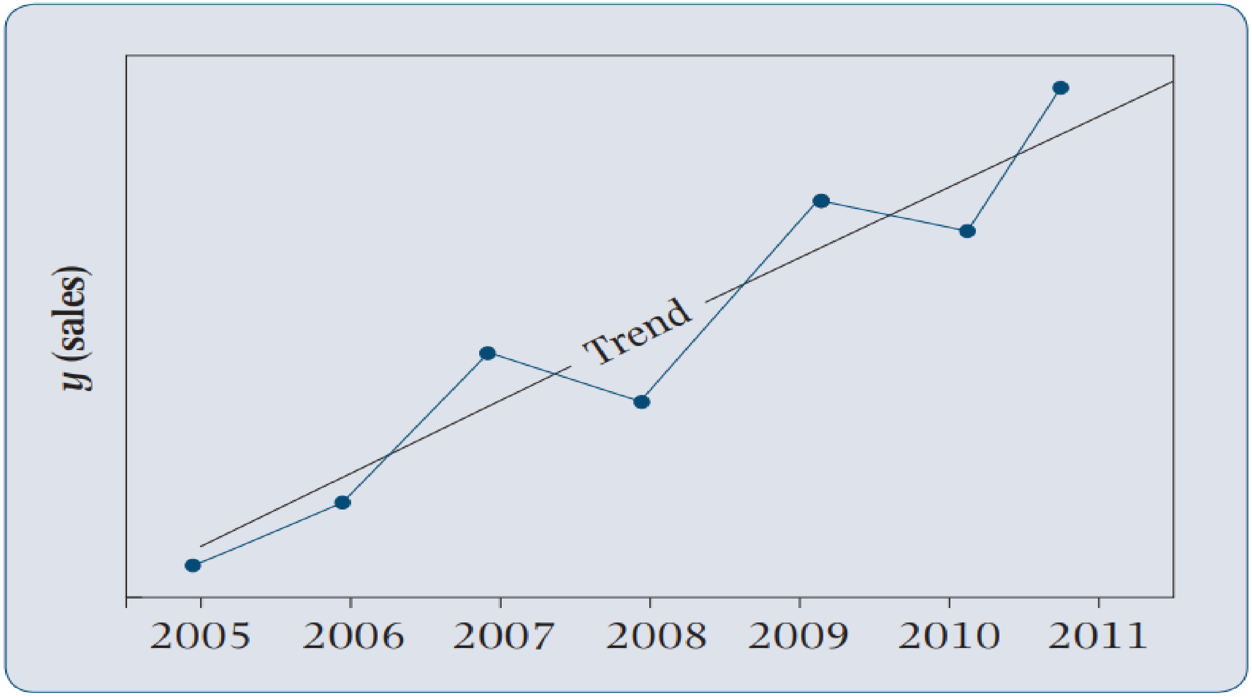

Figure 2. 6.: Illustration of a trendline in time series data

Source: Wegner (1993)

According to Wegner (1993), significant factors contributing to long-term trend movements in a time series include population growth, urbanization, technological advancements, economic progress, and shifts in consumer habits and attitudes. Trend analysis, a statistical technique, is employed to discern and isolate these underlying long-term movements.

b) Cycles (C)

Econometrically, cycles represent medium- to long-term deviations from the trend, indicating alternating phases of relative expansion and contraction in economic activity. These cycles manifest as wave-like movements in a time series, exhibiting considerable variation in both duration and amplitude, as depicted in the subsequent figure. It's important to note that while historical cycles can be measured, their past patterns offer limited assistance in forecasting future cycle patterns.

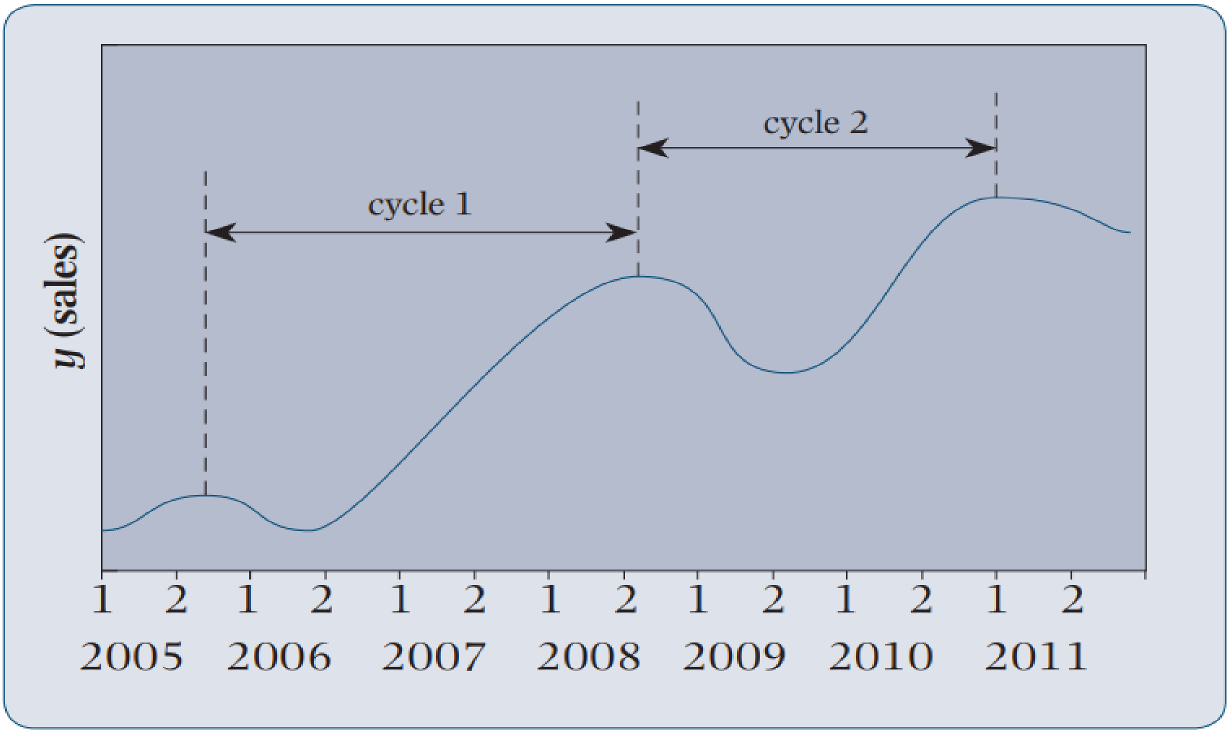

Figure 2. 7.: Illustration of economic cycles in time series data

Source: Wegner (1993)

Identifying and explaining the causes of cycles in a time series can be challenging, but their impact typically involves either stimulating or depressing levels of activity in the series. Cycles are often attributed to "mass psychological hysteria," with actions by entities like governments, trade unions, global organizations, and financial institutions capable of inducing varying levels of optimism or pessimism into an economy. These shifts are reflected in changes in the levels of the time series, such as those witnessed during events like the 2008 world financial crisis. Although index numbers are employed to describe and quantify cyclical fluctuations, their utility as a forecasting tool is limited, as they cannot predict turning points in cycles.

c) Seasonal variations (S)

These refer to fluctuations in a time series that recur at regular intervals within a year (e.g., daily, weekly, monthly, quarterly). These fluctuations exhibit a high degree of regularity and can be effectively isolated through statistical analysis, as illustrated in the figure below:

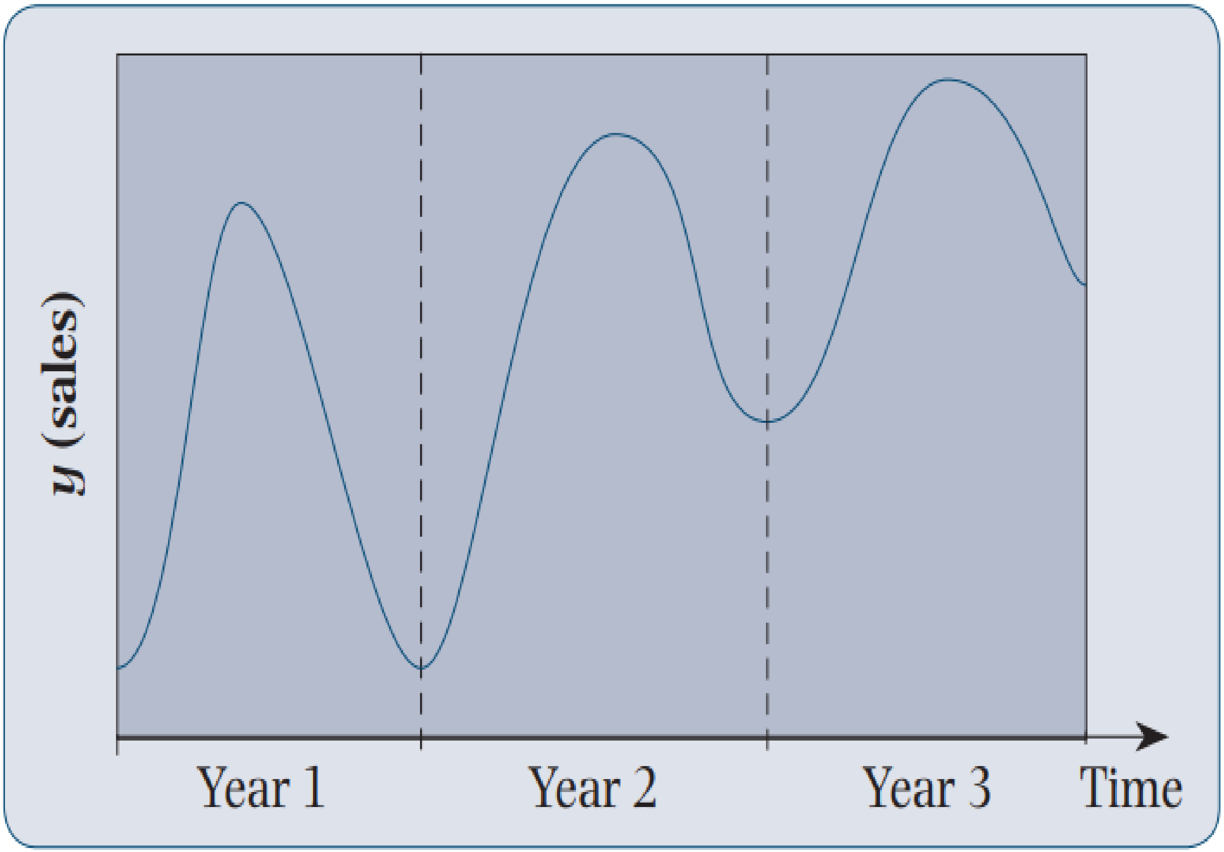

Figure 2. 8.: Illustration of seasonal variations in time series data

Source: Wegner (1993)

Seasonal variations result from recurring environmental influences, including climatic conditions (such as the changing seasons) and specific recurrent events like annual festivals, religious observances, and public or school holidays. To quantify the regular pattern of these seasonal fluctuations, seasonal indexes, distinct from those used for cyclical fluctuations, are employed. These seasonal indexes can prove highly valuable in preparing short- to medium-term forecasts for time series data.

d) Random effects, also known as irregular fluctuations (I)

In econometric terms, random effects in time series stem from unpredictable events. These events are often singular and unforeseen, encompassing natural disasters like floods, droughts, or fires, as well as man-made disasters such as strikes, boycotts, accidents, and acts of violence (war, riots). Given their unpredictable nature and lack of specific patterns, these irregular fluctuations cannot be captured through statistical analysis or integrated into statistical forecasts. The graphic representation in the following figure illustrates the irregular behavior in a time series.

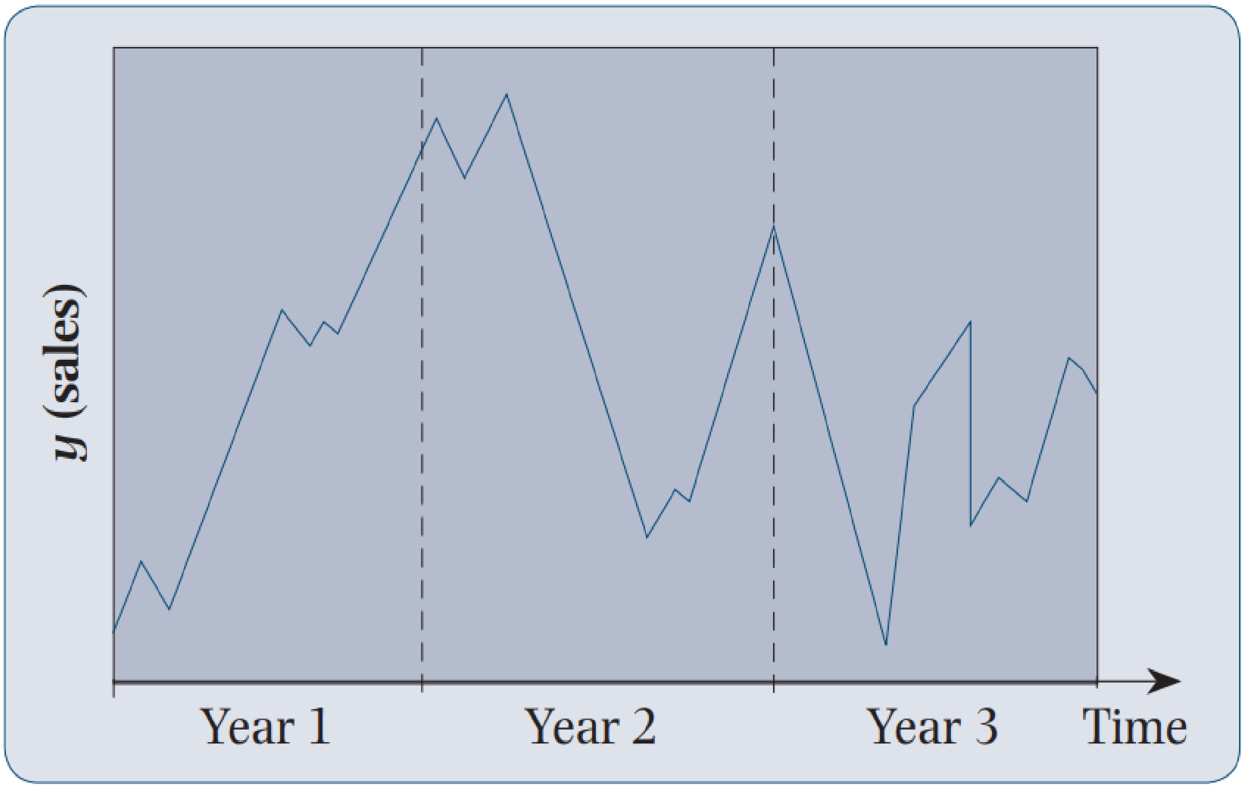

Figure 2. 9.: Irregular (or random) fluctuations in time series data

Source: Wegner (1993)

2.8. Chapter Summary

Recent academic publications focusing on price transmission in agricultural markets have produced noteworthy insights into the factors influencing price transmission, the degree and speed of price transmission, and the relationship between price transmission and price volatility. The implications of these discoveries are highly relevant for policymakers, underscoring the need for a thorough comprehension of how changes in commodity prices are transmitted throughout the supply chain. Such understanding is pivotal for crafting effective policies aimed at strengthening agricultural markets.

CHAPTER 3: OVERVIEW OF THE SOUTH AFRICAN GARLIC INDUSTRY

3.1. Introduction

This chapter encompasses a comprehensive discussion of the South African garlic industry. Economic theory suggests that for a market to exist, there must be a buyer, seller, commodity, price and intercourse, amongst other requirements. With that being said, a specific focus is given to production and consumption of garlic in South Africa and abroad. The chapter provides a concise overview of the progression of garlic through various marketing levels. Additionally, it delves into the contributions made by the garlic industry into South Africa's economy, considering aspects such as its impact on GDP, employment generation, and export earnings. The discussion extends to different production regions and explores the various marketing channels employed for potatoes.

3.2. Description of the industry

Garlic is taxonomically classified as a member of the Allium genus, which encompasses various other plants such as onions, leeks, chives, and shallots (Dhall *et al.*, 2023). Garlic exhibits similarities to the onion in terms of its physical dimensions and patterns of development. Shinde *et al.* (2021) submit that garlic possesses a historical record of human utilization spanning more than 7 000 years, with its origins tracing back to central Asia. In addition to onions, garlic is a highly significant bulbous crop cultivated extensively throughout South Asia. The utilization of garlic has been documented throughout historical records, serving both medicinal and culinary functions. The utilization of this substance is prevalent in the enhancement of taste and seasoning in many culinary preparations, including dishes, pickles, and sauces. Although garlic is largely cultivated for culinary purposes, its potential health benefits have also been recognized.

According to DALRRD (2021), China and India are major producers of garlic on a significant scale. In recent years, garlic has experienced a surge in popularity among growers, marketers, and consumers. The long-standing recognition of its nutritional and therapeutic benefits is being substantiated. Various fields of traditional medicine and scientific research have identified garlic as possessing antibacterial properties, the ability to enhance immunity, and the capacity to regulate blood pressure.

The practice of preserving garlic in oil is commonly employed to create oil infused with its distinct flavor. Nevertheless, it is necessary to implement precautionary steps in order to mitigate the potential spoilage of garlic. An increasing number of individuals are becoming acquainted with the culinary excellence of garlic, while farmers have identified it as a potentially lucrative crop.

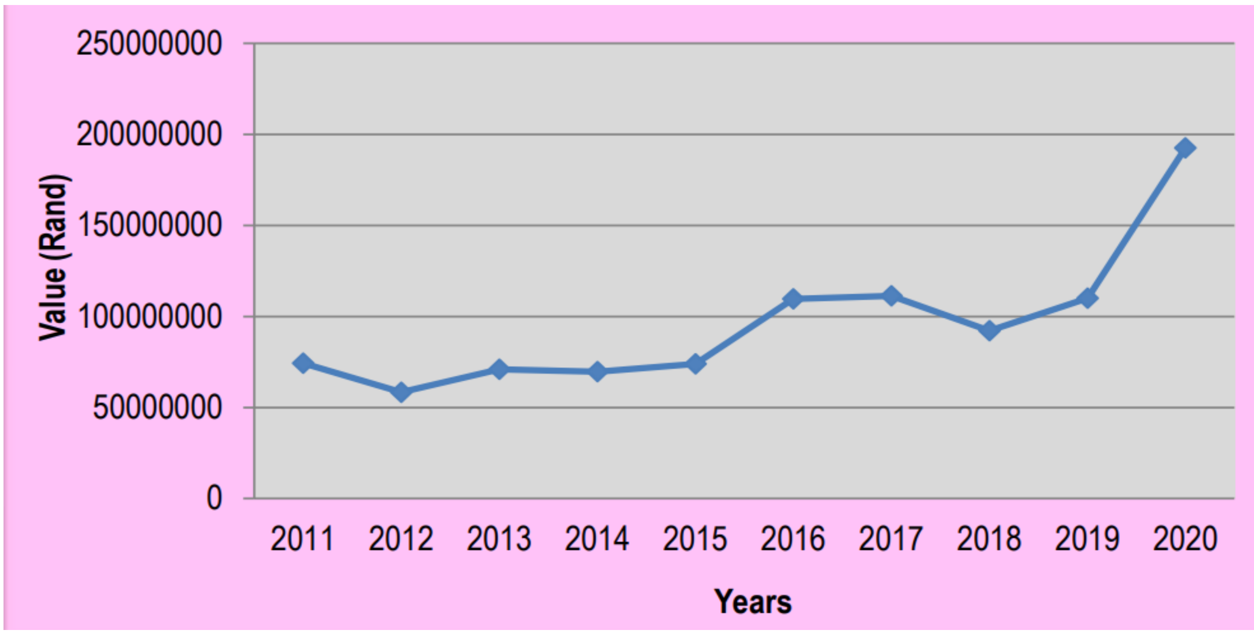

Figure 3. 2.: Gross value of garlic production from 2011 to 2020

Source: Statistics and Economic Analysis, DALRRD

The agricultural gross value of the garlic industry in South Africa fluctuated over a decade, with a notable 21% decrease in 2012 attributed to a fall in producer pricing. In 2013, there was a 21.3% increase in gross value, mainly due to rising producer prices. The following year, 2014, saw a marginal 1.9% decline in gross value, associated with reduced producer pricing. A 6% increase in 2015 correlated with a 12% rise in production output. The gross value surged by 48% in 2016, driven by favorable producer prices. In 2017, a marginal 1.6% increase in garlic production or consumption was observed. Compared to 2016, the current gross value indicates a 4.6% rise in production output. However, in 2018, there was a significant 17% decline in gross value, attributed to reduced producer prices. In 2019, garlic production in South Africa grew by 19.4%, linked to elevated producer prices. Finally, in 2020, the gross value soared by 75% compared to 2019, driven by favorable consumer pricing within the same calendar year.

3.3. Production areas

Generally, the environmental conditions that are conducive to onion cultivation are likewise conducive to the cultivation of garlic. The production of garlic of superior grade is mostly concentrated in the chilly and arid regions of South Africa. The producing areas encompass many regions in South Africa, such as the Polokwane Plateau in the Limpopo province, Northwest province, Gauteng, some areas in the Free State province (namely the northern, western, and southern parts), a portion of KwaZulu Natal, the Karoo region in the Western Cape province, and sections of the Northern Cape (specifically the Douglas area). On a global scale, it is evident that China holds a dominant position as the primary producer of garlic, contributing to more than 80% of the total global output. According to FAOSTAT (2019), India has the position of the second-largest production, with Bangladesh, South Korea, Egypt, Spain, the United States of America, Algeria, Uzbekistan, Spain, and Ukraine following suit. Egypt and Algeria are the sole African nations that rank within the top ten global garlic producers. Figure 3.2 below illustrates the aggregate quantities of garlic cultivated in South Africa throughout the course of the previous decade.

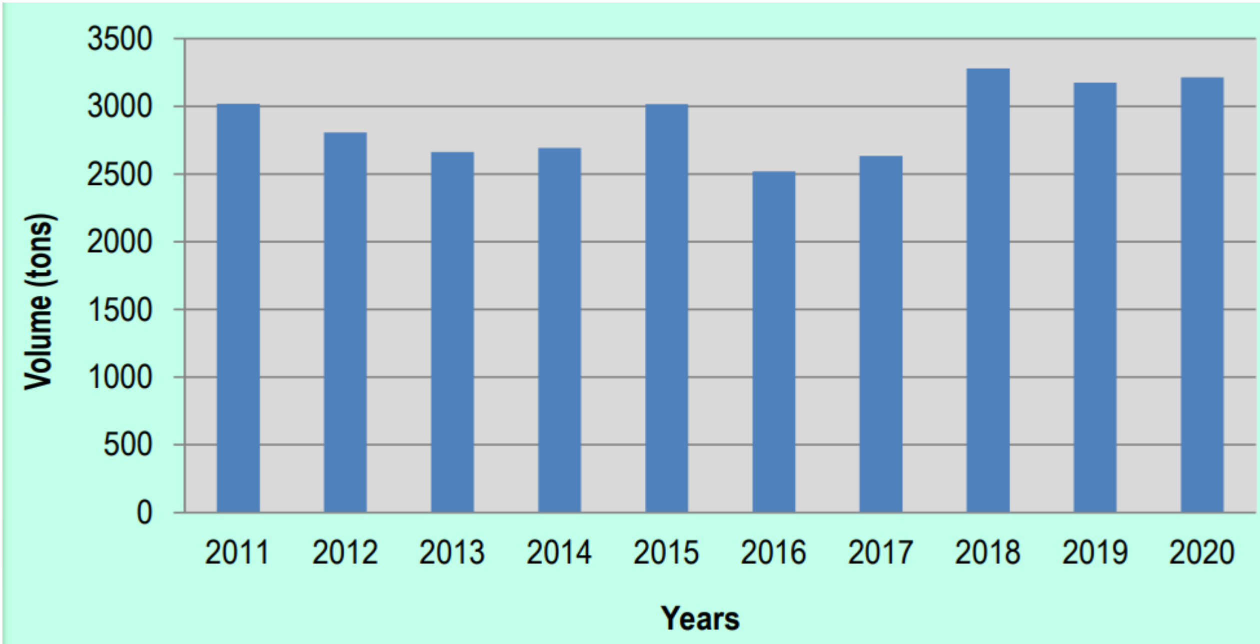

Figure 3. 2.: South African garlic production

Source: Statistics and Economic Analysis, DALRRD

The production of garlic has exhibited a notable degree of volatility during the analyzed time frame. The garlic crop output in 2011 was just over 3 018 tons. The garlic production output experienced a marginal decline of 7% in 2012 as compared to the production output in 2011. The manufacturing volumes experienced a further decline of 5.1% in 2013, as compared to the production output of 2012. In 2014, there was a marginal increase of 1% in production output compared to the previous year. In the year 2015, there was a notable increase of 12% in the production output compared to the production output observed in the year 2014. The year-on-year comparison reveals a decline of 16.5% in garlic production during 2016 in comparison to the preceding year. The garlic production output experienced a 4.6% increase in 2017 when compared to the production output of the previous year. In 2018, there was a notable increase of 24% in garlic production output compared to the production output observed in 2017. In 2019, there was a marginal decrease of 3.2% in the garlic production of South Africa compared to the output of the preceding year, 2018. In the year 2020, South Africa experienced a marginal growth of 1.2% in its garlic production, as compared to the production levels observed in the preceding year of 2019.

3.4. Domestic market and prices

In the South African context, garlic is distributed and marketed through many marketing channels, including the National Fresh Produce Markets (NFPMs), independent street vendors, direct sales to shops, restaurants, and processors (DALRRD, 2021). Garlic is commonly promoted and sold in several forms, including fresh produce, dehydrated products, and certified seed. Additionally, it is worth noting that this product is shipped to many nations via export agencies and marketing businesses. The majority of garlic production in the commercial sector occurs through a contractual arrangement between producers and purchasers. The market for garlic in South Africa is constrained, with an annual consumption of only 3 000 tons. Figure 3.3 depicts the sales quantities of garlic at the National Farmers' Produce Markets (NFPMs) alongside the corresponding prices throughout the course of the previous decade.

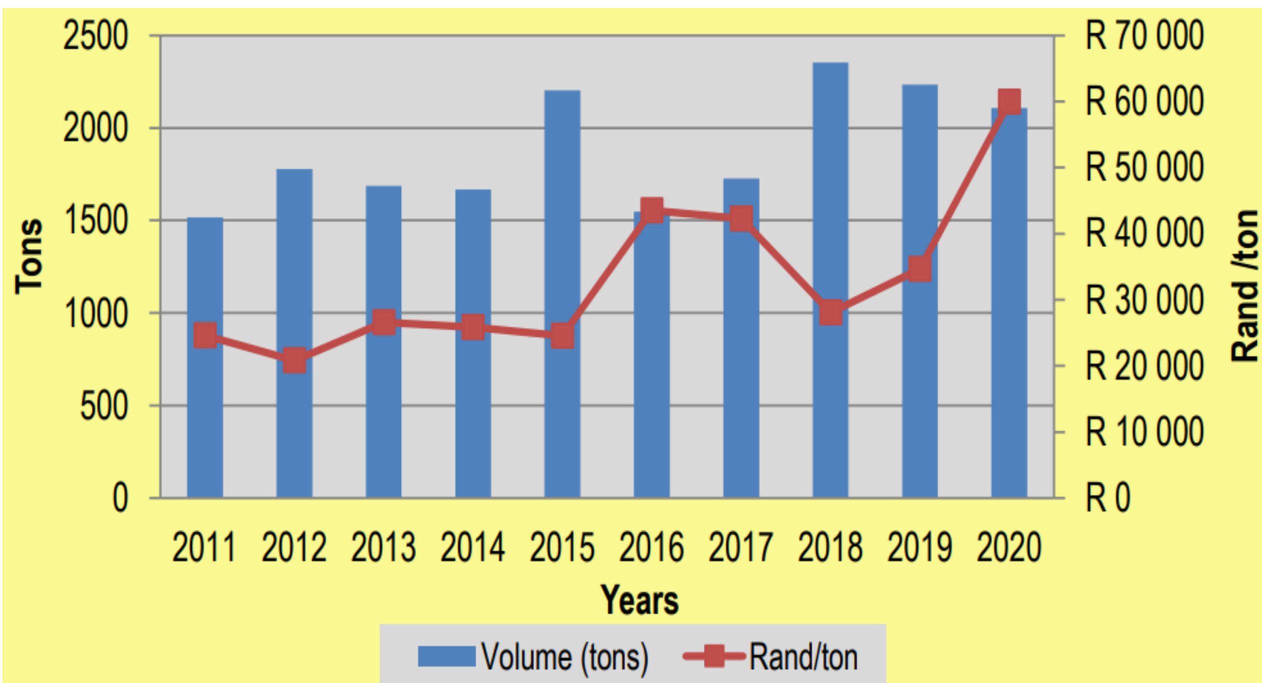

Figure 3.3.: Garlic producer prices Source: Statistics and Economic Analysis, DALRRD

The fresh produce markets for garlic witnessed fluctuations in both quantities and prices, aligning with economic principles, particularly the law of demand. In 2011, the garlic supply slightly exceeded 1 516 tons. A 17% increase in 2012 supply led to a 15% price decrease. Producer prices surged by 27.9% in 2013, attributed to a marginal supply decline. Despite a 1.2% drop in 2014 garlic volume, a 2.9% market price decline occurred due to low demand. The 2015 market saw a 32% rise in garlic supply, resulting in a 5% price fall. A substantial 29.7% supply decrease in 2016 led to a 77% price increase. In 2017, a supply increase of 11.65% caused a 2.8% price drop. 2018 experienced a 36% supply hike, leading to a 33% price decrease. 2019 witnessed a 5% supply decrease, correlating with a 23% price increase. In 2020, a 5.7% volume reduction prompted a 76% price surge, attributed to increased garlic usage during that year.

3.5. Domestic share analysis

Table 3.1.: Share of provincial garlic exports to the total RSA garlic exports (%)

Year Provinces	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Western Cape	18.12	12.56	12.79	21.87	26.93	49.78	47.53	34.16	27.13	35.29
Eastern Cape	0.01	0	0	0.01	0.04	0.33	0.42	0.45	0	0
Free State	0	0.08	0.40	0.68	1.72	1.24	1.36	1.49	0	0.50
KwaZulu-Natal	0.35	0.35	2.13	3.68	4.28	2.76	6.86	5.42	4.71	8.34
North West	0.00	0	1.01	0	0	1.95	2.16	3.04	0.33	0.29
Gauteng	81.37	86.83	83.55	60.74	65.79	40.69	32.30	43.52	51.46	50.87
Mpumalanga	0.02	0.12	0.37	0.44	1.08	2.98	9.27	11.08	14.72	4.28
Limpopo	0.14	0.09	0.05	0.06	0.11	0.07	0.11	0.84	0.40	0.43
RSA	100	100	100	100	100	100	100	100	100	100

Source: Calculated from Quantec Easydata (2021)

Table 3.1 outlines the distribution of garlic exports across provinces in South Africa from 2011 to 2020, revealing that Gauteng and Western Cape consistently dominated the market. Limited contributions from North-West, Limpopo, and Northern Cape were attributed to deficient marketing infrastructure and a scarcity of registered exporters in those regions. Proximity to exit points positioned Western Cape, Gauteng, and KwaZulu Natal as strategic leaders with efficient transportation. In 2011, Gauteng constituted

81.37% of exports, while Western Cape contributed 18.12%. By 2016, Western Cape's export share surged to 49.97%, while Gauteng declined to 40.69%. In 2018, Gauteng briefly led with 43.52%, Western Cape dropped to 34.16%, and Mpumalanga increased to 11.08%. In 2019, Gauteng's share rose to 51.46%, and Western Cape declined to 27.13%. In 2020, Gauteng's share fell to 50.87%, while Western Cape, KwaZulu Natal, and Mpumalanga had 35.29%, 8.34%, and 4.28%, respectively.

3.6. South African garlic exports

South Africa does not hold a significant position as a garlic exporter (DALRRD, 2020). According to International Trade Centre (ITC) (2020), as of 2020, the garlic export from South Africa continues to account for a mere 0.1% of the global exports for this particular commodity. Furthermore, South Africa has the 26th position in terms of its ranking among countries engaged in garlic exports worldwide. In 2019, South Africa's global garlic exports were rated 26th, indicating a decline in its competitiveness in this sector. In the year 2020, South Africa engaged in the exportation of garlic to many nations, mostly included Botswana, Namibia, Eswatini, Lesotho, Mozambique, Netherlands, Malawi, Angola, and Zambia. In the year 2020, Botswana emerged as the primary trading partner for garlic exports, accounting for 38.4% of the total. Namibia followed closely behind with a share of 29%. Eswatini contributed 10% to the overall export volume, while Lesotho received 7.6% of South Africa's garlic exports. China holds the top position globally as the leading exporter of garlic, owing to its status as the greatest garlic producer worldwide. Following China, the subsequent countries in the ranking of garlic exporters are Spain, Argentina, Netherlands, France, Italy, Chile, and Egypt, in that order.

3.7. South African garlic imports

In 2020, South Africa's role as a garlic importer remained modest, constituting only 0.3% of global imports, maintaining its position at 47 globally. Spain dominated the import landscape, contributing 65% to South Africa's garlic imports, followed by China at 16.6%. Other contributing countries included Egypt, India, Vietnam, Portugal, Argentina, and Thailand. Indonesia held the top spot globally in garlic imports, with Brazil, the United States of America, Malaysia, Germany, Pakistan, Russia, and France following suit.

Figure 3.4 illustrates South Africa's garlic imports over a decade. In 2011, imports slightly surpassed 1,750 tons. Despite a 7% domestic production decrease in 2012, garlic imports increased by 0.3%. The import quantity grew by 10.3% in 2013, accompanied by higher import costs. A 2% import increase aligned with a 1% growth in domestic production in 2014. Notably, 2015 saw a 19% surge in imports, paralleled by a 12% rise in domestic production. In 2016, despite a 16.5% drop in agricultural output, garlic imports decreased by 15%, accompanied by increased costs. In 2017, imports spiked by 31%, despite a 4.6% increase in domestic production, with lower import costs compared to 2016. In 2018, imports decreased by 5%, with substantially lower costs. In 2019, there was a 17.7% import increase, accompanied by higher costs. Lastly, 2020 witnessed a remarkable 56% import surge, with costs higher than the previous year.

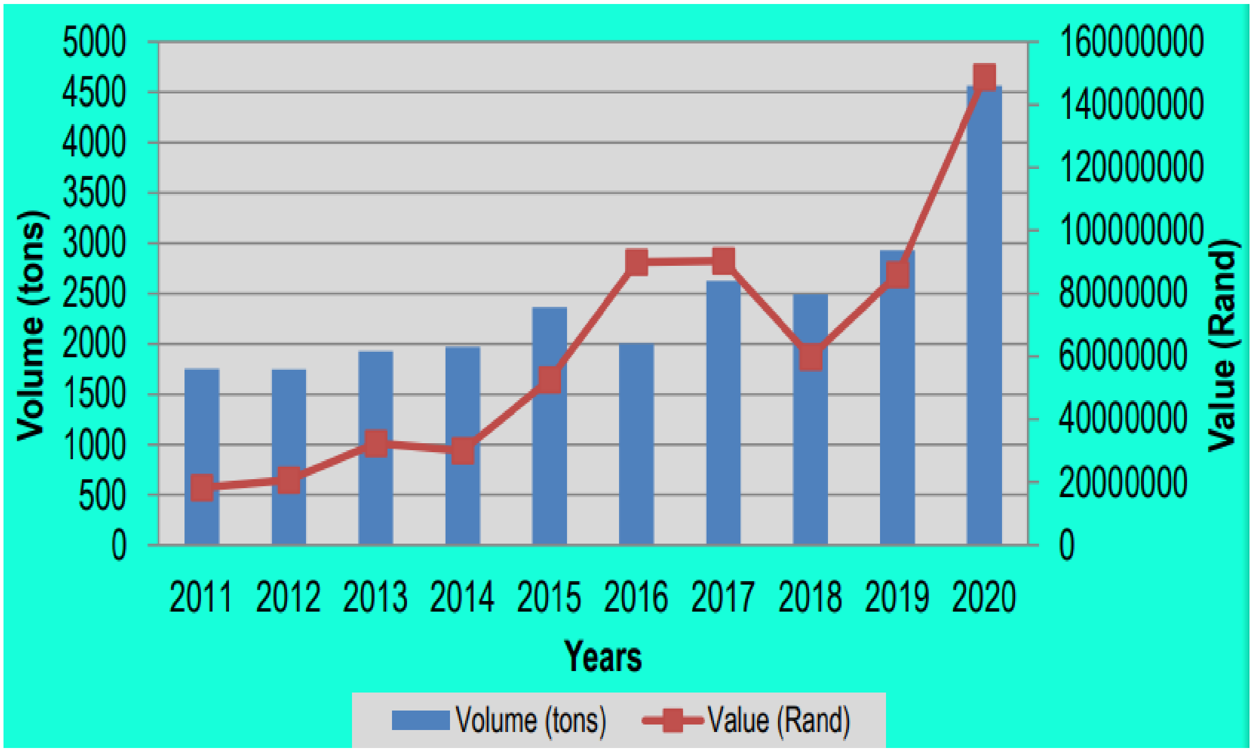

Figure 3. 4.: South African garlic imports

Source: Quantec Easydata (2020

3.8. Processing of garlic in South Africa

The Department of Agriculture, Land Reform, and Rural Development (DALRRD) (2021) posits that garlic is considered a valuable agricultural commodity that can be commercially promoted in several forms, including fresh produce, dehydrated products, and certified seed. The utilization of this substance on a global scale is prevalent due to its robust taste, serving as both a spice and condiment. The predominant proportion of garlic undergoes dehydration and is thereafter employed in a diverse range of processed food products. According to Kekana *et al*. (2021), the garlic bulb possesses the capability to undergo the processes of peeling, slicing, flaking, and drying. The aforementioned substance has the potential to undergo additional processing and packaging for utilization as a culinary spice, as well as in the creation of vegetable combinations and sprays. In addition, India is known for its production of odorless oil and oleoresin derived from garlic. The external use of garlic has been found to be effective in treating many skin conditions including fungal infections. Garlic is said to possess potential benefits in reducing the risk of heart disease, including conditions such as atherosclerosis, elevated cholesterol levels, and hypertension, as well as in mitigating the development of cancer. Garlic is employed as a preventive measure against specific forms of cancer, such as stomach and colon tumors. Furthermore, it is employed as a means of deterring insects.

The output of the garlic processing industry in the Republic of South Africa (RSA) has seen a remarkable growth in recent years (DALRRD, 2021). The country has favorable conditions for garlic cultivation, and the farmers have become more aware of the potential benefits of processing garlic. As a result, the production of processed garlic products, such as garlic powder, garlic paste, garlic oil, and garlic juice, has increased substantially. These products are not only used for culinary purposes but also find applications in the pharmaceutical and cosmetic industries (WHO, 2020). The output of garlic processing has not only contributed to the economic growth of the country but has also provided employment opportunities for many South Africans.

The processed garlic products from RSA have gained popularity in both local and international markets. According to ITC (2020), RSA exports a significant quantity of garlic products to various countries, including the United States, Europe, and neighboring

African nations such as Malawi, Zimbabwe and Botswana. The high-quality standards and advanced processing techniques used in RSA have made its garlic products highly sought after. Moreover, the diversification of garlic products has expanded the market reach of South African farmers and processors. Apart from the exports, the domestic consumption of garlic products has also seen a rise as more people become aware of the health benefits associated with garlic.

Although some garlic processors in South Africa have adopted advanced technologies, there is still lack of advanced processing technology and infrastructure hinders efficient garlic processing (DALRRD, 2020). Many small-scale farmers still rely on manual labor, leading to slower processing times and increased costs. Additionally, the shortage of skilled workers in the processing industry exacerbates the problem. Without adopting modern processing techniques and addressing the shortage of skilled labor, South Africa's garlic processing industry may struggle to meet increasing demand (Farmer's Weekly, 2019).

In terms of volume consumed, WHO (2020) mentioned that garlic holds a prominent place in South African cuisine and is widely used for its distinct flavor and health benefits. The consumption of garlic in the country has steadily increased over the years, reflecting its importance in local diets. According to recent data from DALRRD (2021), South Africa consumed approximately 30,000 metric tons of garlic in a year, making it a significant market for both local farmers and imported garlic. The higher demand for garlic consumption necessitates an increased focus on the processing capabilities within the country to ensure a continuous supply of quality garlic products.

There are claims suggesting that garlic may have the ability to manage blood sugar levels. Figure 3.5 illustrates several end products resulting from value addition and processing.

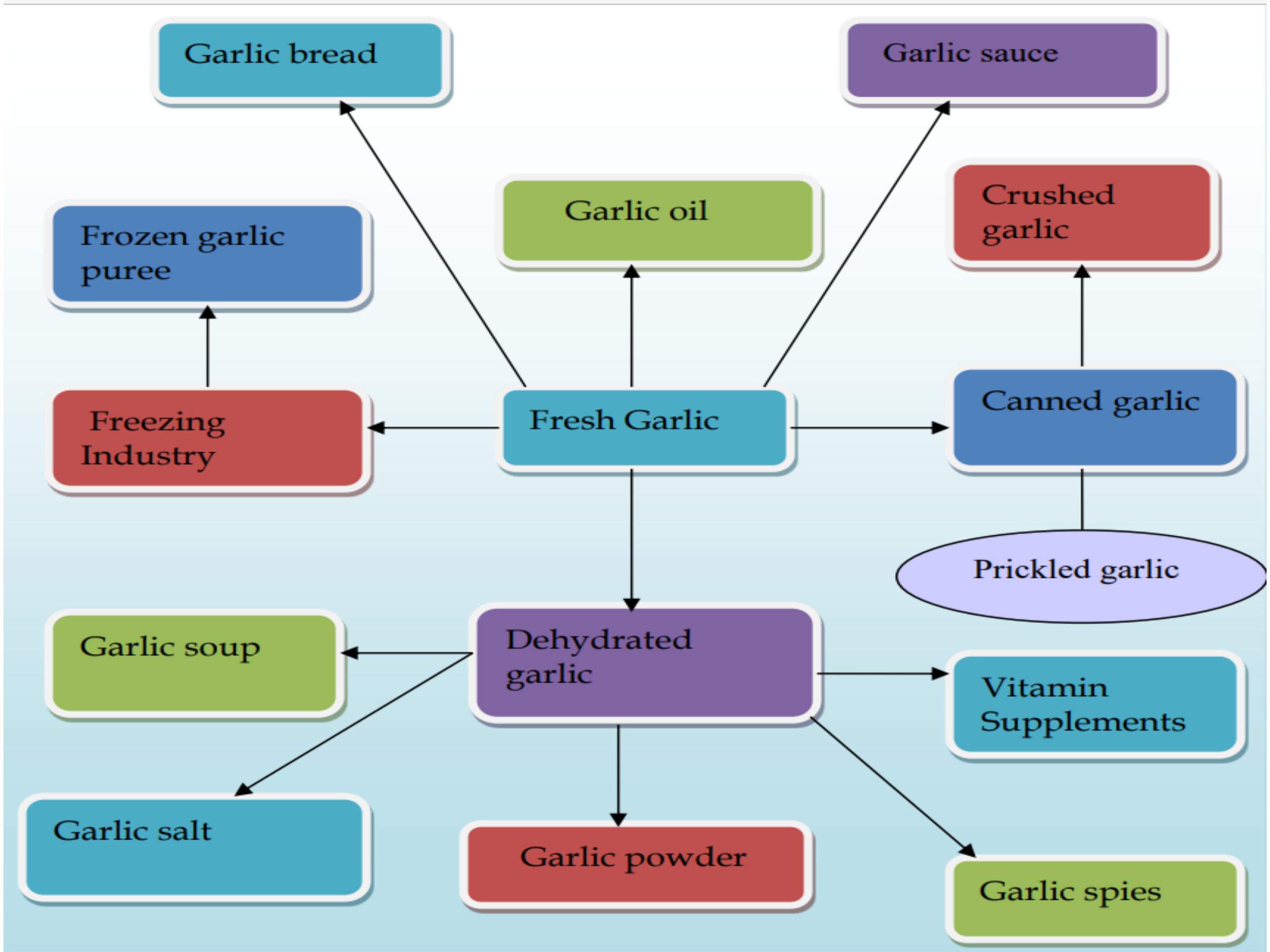

Figure 3. 5.: Garlic value chain tree explaining its uses

Source: DALRRD (2021)

Figure 3. 6.: Market value Chain for Garlic

Source: DALRRD (2021)

The above figure indicates various stages and activities within which the marketing chain of garlic in South Africa is broken. DALRRD (2021) argues that farmers are at the beginning of the garlic value chain since they play a crucial role of combining inputs efficiently and effectively to ensure the yield of garlic. Next are pack house owners, who are responsible for drying, cleaning, grading, and quality control; cold storage and transport facilities, which store and transport garlic on behalf of farmers; garlic traders, who market and sell garlic; garlic processors, who add value by canning, oil extracting, dehydrating, and freezing garlic; and finally, consumers.

3.9. Business opportunities and challenges

3.9.1. Opportunities in the South African garlic market

The use of garlic has shown substantial growth in recent years (FAOSTAT, 2019). Garlic finds its primary applications within the culinary domain, while it also possesses additional utility within the realm of alternative medicine due to its medicinal properties, as well as its efficacy as a pesticide and fungicide. In recent times, notable advancements have emerged in the realm of human medicine pertaining to garlic. Specifically, according to WHO (2019), a component has been found that has the capacity to reduce cholesterol levels. Should these advancements go to the commercial stage, there is the potential for a substantial augmentation in the output of garlic. South Africa remains a significant importer of garlic, hence creating a favorable circumstance for growers to enhance domestic production.

Kindu-Wubet (2022) stated that garlic is regarded as a high-value crop with a stable demand both domestically and internationally. South Africa, being one of the largest garlic importers globally (DALRRD, 2021), has a significant market potential for local producers. Additionally, Farmer’s Weekly (2019) reported that South Africa has favorable climatic conditions, particularly in the cooler regions of the Western Cape and Mpumalanga, which are suitable for garlic cultivation. With the increasing awareness of the health benefits associated with garlic consumption, there is a growing demand for organically grown garlic, which opens up niche market opportunities for farmers looking to differentiate their products. By focusing on organic production, farmers can tap into niche markets and potentially command higher prices for their garlic. This trend aligns with the increasing consumer interest in healthy and sustainable food choices, thereby contributing to the overall profitability of the South African garlic industry.

The stable demand for garlic in South Africa possibly makes the country an attractive market for growers and investors. Garlic has long been a staple ingredient in many South African households and is also widely used by the food processing industry. Furthermore, the country's garlic imports have risen consistently over the years, indicating an unmet demand that local producers can tap into (DALRRD, 2021). This creates opportunities for both small-scale farmers and larger commercial operations to effectively meet the domestic demand and potentially export to other African countries.

FAO (2021) indicated that the demands for garlic in the country has been increasing steadily due to various factors such as population growth, changing food habits, and the growing awareness of the health benefits associated with garlic consumption. Moreover, South Africa's garlic production has been expanding, ensuring a steady supply to meet the rising demand. As a result, exporters can capitalize on this growth by establishing long-term partnerships with South African garlic farmers and suppliers, ensuring a consistent and reliable supply of garlic for international markets.

Although there is a plethora of opportunities in the South African garlic market, exporters need to consider certain factors to maximize their success. Understanding and complying with the country's import regulations and quality standards is crucial to avoid any potential trade barriers (Competition Commission of South Africa, 2023). Additionally, identifying niche markets and developing unique selling propositions can give exporters a competitive edge in the global marketplace. By leveraging the potential of the South African garlic market and implementing effective export strategies, businesses can establish a strong foothold in this lucrative industry.

The South African garlic market presents lucrative opportunities for processing due to the country's suitable agricultural conditions and the growing demand for garlic-based products. With a favorable climate and abundant garlic production, processors can ensure a consistent supply of high-quality raw material for their processing facilities. Additionally, South African consumers' increasing interest in healthy and natural food products creates a receptive market for processed garlic items. By leveraging these factors, entrepreneurs can tap into the South African garlic market to establish successful processing ventures.

3.9.2. Challenges in the South African garlic market

Garlic is a crop that has significant risks and demands substantial labor in order to achieve successful cultivation (DALRRD, 2021). According to Kerr (2019), the cultivation of garlic necessitates strict adherence to a precise time frame for optimal growth. To ensure their survival, it is imperative for every garlic producer to exert efforts in attaining optimal output and quality. Understanding the garlic plant, including its growth cycle and the various factors that influence its growth, output, and quality, is of paramount significance. The marketing of garlic can provide significant challenges for smaller producers. The report by WHO (2020) indicated that there is a current market demand for large, clean, flawless bulbs that are appropriately graded and meticulously wrapped. In addition to contending with inexpensive garlic imports, garlic producers in South Africa face competitive challenges. In 2019, the net imports of garlic in South Africa had a significant increase of 27%. This surge in imports poses a substantial challenge to local producers, who are unable to effectively compete with the low-cost imported garlic that has undergone irradiation.

According to a report by Fresh Plaza (2020), there is a growing need for garlic producers in South Africa to acquire additional space to enhance their market presence and share maximization. The user's preferred outcome entails allocating 50% of the retail shelf space for garlic to South African garlic, accompanied by explicit labeling that clearly identifies it as such. This would provide consumers with a straightforward choice of non-irradiated South African garlic. The elevated costs of garlic serve as a compelling incentive for numerous local farmers to enter the market. However, the production of superior-grade garlic, especially for novice farmers, poses significant challenges.

Amidst the COVID-19 epidemic in 2021, the Competition Commission was inundated with a multitude of grievances from the general populace, asserting that merchants of food products had escalated the prices of garlic. During the second wave, there was an increase in consumer demand which led to a rise in wholesale pricing for the products. However, the commission found that the significant increases in absolute margins observed in certain situations were not deemed reasonable or justifiable. Large-scale shops were subjected to investigation in response to a significant surge in the costs of garlic and ginger throughout the year 2021.

The shop known as Pick ‘n Pay was among the prominent merchants that entered into a memorandum of agreement with the Competition Commission in order to establish a price ceiling on garlic. During the period of January 28 to April 1, 2021, the store has imposed a limit on the gross profit margin for ginger and garlic, which are considered basic food items. Additionally, other stores were encouraged to establish a maximum limit on the prices of garlic.

The production and distribution of garlic in South Africa is currently facing multiple challenges that are hindering its growth and sustainability. The COVID-19 pandemic and the Russia-Ukraine conflict have had a significant impact on the Dehydrated Garlic industry, leading to decreased production and distribution of garlic in the country (WHO, 2021). Additionally, DALRRD (2021) indicated that garlic imports from countries such as China and Spain have been identified as one of the greatest challenges to achieving a sustainable local garlic industry. In response to this issue, Farmer’s Weekly (2019) reported that the Department of Trade and Industry imposed an anti-dumping levy of R19.25/kg on all fresh garlic from China in 2015, but despite these efforts, garlic imports still make up a significant portion of the market in South Africa. These challenges have had a profound effect on the production and distribution of garlic in the country, leading to decreased opportunities for local garlic producers and an increased reliance on imported garlic. It is essential for the government and industry stakeholders to address these challenges comprehensively to achieve a sustainable local garlic industry in South Africa.

The South African garlic industry is currently facing a number of economic challenges that are affecting its competitiveness and sustainability. One of the major challenges highlighted by Fresh Plaza (2020) is the influx of imported garlic that is swamping the local market and making it difficult for local producers to compete on price. Additionally, the COVID-19 pandemic has had a significant impact on the industry, with the country experiencing a precarious situation after a brief period of hope during the lockdowns (Fresh Plaza, 2020). The Dehydrated Garlic Market report provides a strategic analysis of the garlic market in South Africa and identifies key growth and demand drivers, challenges, and main market participants. Furthermore, due to cyclical, structural, and regulatory/policy challenges in the economy, government capital and operational spending has been severely impacted (DTIC, 2023). These economic challenges have resulted in high garlic prices in South Africa, especially as the country imports garlic from Spain and China (DALRRD, 2021). In their report, Competition Commission of South Africa (2023) posited that the skyrocketing prices of lemon, ginger, and garlic, which are believed to help fight COVID-19, have further compounded the economic implications of these challenges for the South African economy as a whole. In light of these challenges, it is imperative that stakeholders in the South African garlic industry work together to find sustainable solutions that support local production and ensure price competitiveness.

3.10. Chapter summary

This chapter discussed a comprehensive discussion of the South African garlic industry. The main focus was on the flow of garlic from the point of production to the point of consumption. Garlic market was thoroughly described, with major production areas in South Africa listed as well. The section also focused on domestic markets and prices for garlic, domestic share analysis, particularly per province, garlic trade (focusing on both the imports and exports), processing and distribution channels, business opportunities and threats and lastly, the chapter concluded by reflecting on contemporary issues pertinent to the markets for garlic in South Africa.

CHAPTER 4: RESEARCH METHODOLOGY

4.1. Introduction

The chapter provides details about the study area, the tools used for data collection, and outlines the analytical techniques employed to address the study's objectives.

4.2. Study area

The study was conducted in South Africa, a country located on the southernmost part of the African continent. It is renowned for its vast natural beauty and cultural diversity, attracting travelers who have made it their favorite destination since the legal dissolution of the apartheid regime in 1994. South Africa, known for its scenic landscapes and rich cultural tapestry, has captured the attention of travelers, especially since the abolition of the apartheid regime in 1994. The term "apartheid" is derived from Afrikaans, translating to "apartness" in English, symbolizing the era of racial segregation that came to an end in the country.

Due to the variation in climate and topography, garlic is not produced anywhere in South Africa, but mainly in the four provinces, namely, Limpopo (particularly, Polokwane Plateau); Northwest; Gauteng; Free State, particularly in the southern, northern and the western parts of this province. Some proportions of garlic are also produced, not mainly though, in some parts of Kwa-Zulu Natal; Western Cape (particularly in the Karoo); and, in some parts of Northern Cape (Douglas in particular). The study conducted by Statistics South Africa (2022) emphasizes that the South African's population is experiencing exponential growth, resulting in an increased demand for agricultural commodities. According to the report, the population rose from 59.31 million in 2020 to 60.14 million in 2021 (StatsSA, 2021). According to Tridge (2020), the South African population mainly uses garlic and herbs in culinary, medicine and farming. Garlic is consumed both in its fresh (unprocessed) and processed forms. DARLRRD (2021) submits that products such as garlic bread, garlic puree, garlic soup, garlic salt, garlic spices, garlic sauce and garlic oil ae typical examples of commodities derived from raw garlic. It is sold directly from the farm, wholesale and retail outlets.

Figure 4. 3.: The South African Map

Source: Google Maps (2023)

4.3. Data Set

Secondary data was gathered from diverse sources, including the University of Limpopo's library, peer-reviewed journals and articles, newspapers, textbooks, and Google Scholar. These sources facilitated the acquisition and in-depth exploration of information related to price transmissions in different agricultural commodities. Secondary time series data, crucial for addressing all the five objectives in this study were sourced from the Department of Trade, Industry, and Competition (DTIC) of South Africa; National Agricultural Marketing Council (NAMC); Joburg Market; and the South African Department of Agriculture, Land Reform and Rural Development (DALRRD. The study used 132 monthly observations of retail, wholesale and farmgate prices for garlic covering

11 years from 2011 January to 2021 December. The monthly data for all prices were measured in rand per kilogram.

4.4. Conceptual framework for analysing price transmission in this study.

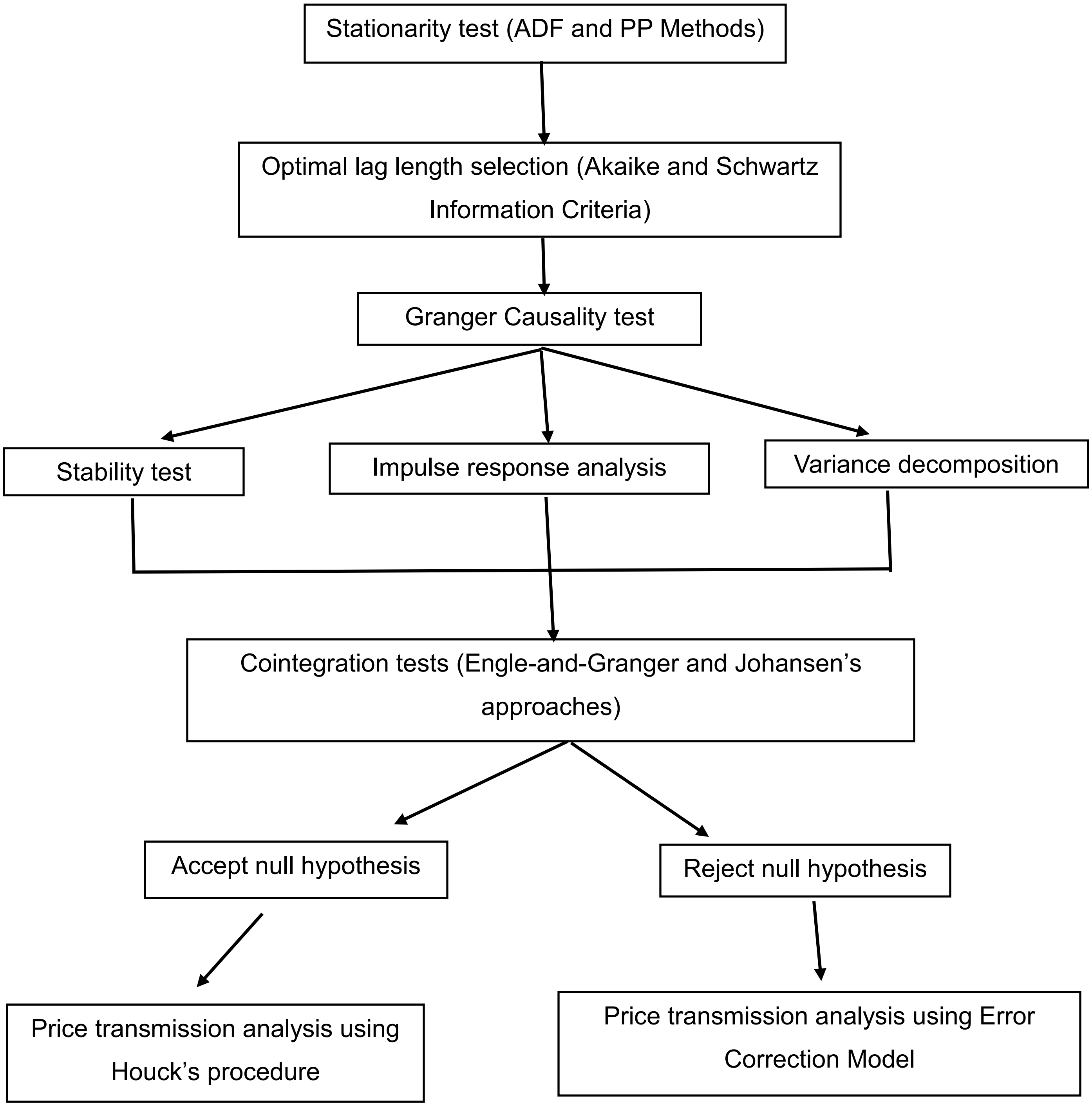

Figure 4. 4.: Conceptual Framework for price transmission analysis

Source: Author's design (2023)

The motivation behind assessing the degree of vertical price transmission typically stems from the recognition of defects within food markets. These faults result in a lack of complete or timely transfer of prices between different stages of the value chain.

Hence, the objective of price transmission analysis in the field of economics is to employ econometric analytical methods in order to obtain findings that either validate or refute these concerns. Similar to other types of analysis based on time series data, before conducting a price transmission analysis, it is essential to initially evaluate the time series features of the data.

This study commenced with an analysis using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to examine the stationarity of the time series data. Subsequently, the determination of the maximum lag length, a crucial step for accurate model specification, was undertaken. Following this, Granger Causality tests were employed to establish the directional influence among the price series under consideration. To validate the results of the Granger Causality tests, stability, impulse response, and variance decomposition tests were conducted. These tests play a vital role in ensuring that the data used in the study yields economically meaningful results.

After confirming stability and analyzing impulse responses and variance decomposition, co-integration tests were performed to assess the time series characteristics of the data. Both the Engle-and-Granger and Johansen's cointegration tests were employed for this purpose, aiming to ensure the validity and reliability of the outcomes. As highlighted by Vavra & Goodwin (2005), these tests contribute to contextualizing the results within the broader research literature and identifying an appropriate model for price transmission.

The investigation into co-integrating relationships followed the two-step approach proposed by Engle & Granger (1987). Initially, a co-integrating relationship between variables was estimated using ordinary least squares (OLS). Subsequently, an Error Correction Model (ECM) was estimated by incorporating lagged residuals from the co-integrating regression as error correction terms.

The choice of employing the Error Correction Model over Houck's procedure was informed by the cointegration test results, which indicated the presence of long-run relationships between the price series. ECM is particularly suitable when cointegrating relationships exist among the variables under investigation. In contrast, Houck's procedure is employed when no cointegrating relationship is found among the variables.

4.5. Techniques for data analysis

To delve into this subject, the study adopted a quantitative research approach. E-Views Student Version 12 was used to facilitate the application of the techniques mentioned in the sub-sequent sections.

4.5.1. Descriptive statistics

The first objective of describing the farmgate, wholesale and retail prices in the South African garlic market, was addressed through the usage of descriptive statistics. Mishra *et al.* (2019) argued that descriptive statistics is one of the branches of statistics that are used to describe the population data, by employing the measures of location (both central and non-central), which include inter alia, mean, median, standard error.

4.5.2. Correlation analysis (Pearson's Product Moment Correlation)

Pearson's Product Moment correlation was used to tackle objective two of this study, which was to determine correlation between farmgate, wholesale and retail prices in the South African garlic market.

4.5.2.1. Pearson's Product Moment Correlation

The Pearson's Product Moment Correlation, often denoted as Pearson's correlation coefficient (represented by "r"), is a widely used measure for assessing the correlation between two variables (Lee Rogers & Nicewander, 1988). Zhi *et al.* (2017) highlight that the Pearson correlation coefficient is a common statistical method employed to evaluate the extent of correlation between two variables. Correlated data indicates a situation where a relationship exists between two variables, meaning a change in the magnitude of one variable corresponds to a corresponding change in the magnitude of another variable. This relationship can either be positive, indicating that the variables move in the same direction, or negative, indicating opposing directions of change (Schober *et al.*, 2018). Furthermore, Schober *et al.* (2018) note that correlation is used to describe a linear association between two continuous variables, quantified by the Pearson product-moment correlation coefficient. According to Mukaka (2012), Pearson coefficient analysis is a straightforward method to calculate and understand, but the author observes a prevalent misuse of this method in many research studies. The author emphasized the importance of interpreting links established through Pearson correlation coefficients as associations rather than causal ties (Mukaka, 2012). According to Asuero *et al.* (2006), the generic model was specified as:

$$r_{xy} = \frac{SS_{xy}}{SS_{xx}} = \frac{\sum x_i \sum y_i - (\sum x_i)(\sum y_i)}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \quad (1)$$

While the operational models are defined as:

$$r_{PB,PA} = \frac{SS_{PB,PA}}{SS_{PB,PB}} = \frac{\sum PB_i \sum PA_i - (\sum PB_i)(\sum PA_i)}{\sqrt{n\sum PB_i^2 - (\sum PB_i)^2}\sqrt{n\sum PA_i^2 - (\sum PA_i)^2}} \quad (2)$$

$$r_{PW,PA} = \frac{SS_{PW,PA}}{SS_{PW,PW}} = \frac{\sum PW_i \sum PA_i - (\sum PW_i)(\sum PA_i)}{\sqrt{n\sum PW_i^2 - (\sum PW_i)^2}\sqrt{n\sum PA_i^2 - (\sum PA_i)^2}} \quad (3)$$

Where:

P_A = Retail price

P_B = Farmgate price

P_W = Wholesale price

n = Denotes number of observations

Σ = Summation

4.5.3. Time series analysis

4.5.3.1. Augmented Dickey-Fuller

Mushtaq (2011) asserts that the assessment of data stationarity holds significant importance in study due to the prevalence of trend or non-stationarity behavior in numerous economic and financial time series. Furthermore, according to Mushtaq (2011), around 30% of the outcomes obtained from the Augmented Dickey-Fuller test are found to yield accurate analytical judgments. The foundational model was initially conceptualized by Dickey & Fuller in 1979, and its representation is as follows:

$$\Delta X_{i,t} = kx_{i,t-1} + \sum_{k=1}^{n} \tilde{\omega}_{i,k} \triangle x_{i,t-k} + U_{k,t} \quad (4)$$

With the null and alternative hypotheses of the model are stated as follows:

H_0: Non-Stationary.

H_1: Stationary.

The practical model is outlined as:

$$\triangle P_{Ai,t} = kP_{Ai,t-1} + \sum^{n}_{k=1} \tilde{\omega}_{i,k} \triangle P_{Ai,t-k} + U_{k,t} \quad (5)$$

$$\triangle P_{Bi,t} = kP_{Bi,t-1} + \sum^{n}_{k=1} \tilde{\omega}_{i,k} \triangle P_{Bi,t-k} + U_{k,t} \quad (6)$$

$$\triangle P_{Wi,t} = kP_{Wi,t-1} + \sum^{n}_{k=1} \tilde{\omega}_{i,k} \triangle P_{Wi,t-k} + U_{k,t} \quad (7)$$

Where:

$\triangle P_{Ai,t}$ = Change in retail price prices over the given time

$\triangle P_{Bi,t}$ = Change in farmgate prices over the given time

$\triangle P_{Wi,t}$ = Change in wholesale prices over given time

$P_{Ai,t-1}$ = Lagged values of retail prices over the given period

$P_{Bi,t-1}$ = Lagged values of farmgate prices over the given period

$P_{Wi,t-1}$ = Lagged values of wholesale prices over the given period k = Coefficient of lagged values for retail, farmgate and retail prices respectively

$U_{k,t}$ = Error term

4.5.3.2. Vector Autoregression model (VAR)

Yayi *et al.* (2021) suggests utilizing the VAR model for constructing a set of theories. This approach enables the examination of impulse response analyses, considering both short-run timing and long-run limitations. Moreover, an information criterion can be applied to determine the optimal lag selection. According to Rossi & Wang (2019), a VAR model involves incorporating lagged values of each variable, along with the current and preceding values of other variables, resulting in a linear model with multiple equations and variables. Rossi & Wang (2019) further note that Vector Autoregressive (VAR) models provide a structured methodology for capturing the intricate dynamics among several time series variables and present a consistent and reliable technique for making predictions. However, in this study, the use of the Vector Autoregression (VAR) model did not rely on interpreting and predicting the computed parameters. Instead, the impulse response function was employed to analyze and understand the interconnectedness of farmgate, wholesale, and retail garlic prices. Frackler & Krieger (1986) introduced the general model of the VAR (p) model.

$$y_t = c_t + A_1 y_{t-1} + A_2 y_{t-2} + A_p y_{\ t-p} + Ut \qquad (8)$$

Which may be rewritten as:

$$\triangle y_t = c_t + \prod y_{t-1} + \sum_{i=1}^{p-1} \prod_i \triangle y_{t-i} + U_t \qquad (9)$$

Where:

$\triangle\ y_t$ = Denotes change retail prices

$\prod$ = Lagged value coefficient

U_t = Residual term

c_t = Deterministic term

4.5.3.3. Cointegration tests

After determining the sequence of integration, it is necessary to examine the cointegration test(s). Granger (1981) developed the concept of cointegration as a theoretical framework for modelling equilibrium, specifically focusing on the long-run relationships between economic variables. Engle & Granger (1987) subsequently conducted an analysis of this idea.

The phenomenon of cointegration between two markets suggests that over an extended period, the price dynamics of both markets tend to align, notwithstanding the possibility of temporary deviations in the short run. The significance of estimating the cointegration connection resides in its ability to uncover long-term associations among non-stationary, integrated variables, hence preventing the occurrence of spurious regression analysis (Gujarati, 2003).

i) Engle and Granger cointegration test

The Engle and Granger test (EG) was introduced in 1987 as a straightforward method for examining the presence of co-integration. This test involves two steps: first, estimating the static cointegration regression using ordinary least squares (OLS), and second, applying the ADF unit-root test to evaluate the null hypothesis of no cointegration.

The estimation of cointegration regression is conducted through the application of ordinary least squares (OLS) method, utilizing equation (10).

$$Y_t^{Producer\ prices} = \alpha + \beta_t X_t^{Wholesale\ prices} + \mu_t \quad (10)$$

Where y_t is the producer price (P_B), x_t is the wholesale price (P_W), and μ_t is the residual/error term. Equation (10) describes the long-run relationship between y_t series and x_t. The null hypothesis suggests that there is an absence of a cointegration relationship between the variables, in contrast to the alternative hypothesis which suggests the presence of cointegration. When the null hypothesis is rejected, it signifies that the alternative hypothesis is accepted, indicating that the variables exhibit cointegration over an extended period.

The test for cointegration is investigated with the ADF test procedure, as indicated by equation (11):

$$\Delta\mu_t = \rho\mu_{t-1} + \Sigma_{i=1}^{n}\lambda_i\Delta\mu_{t-1} + \varepsilon_t \qquad (11)$$

The cointegration test is analogous to the ADF test, which is used to analyze the presence of a unit root in a single data series. However, in the case of cointegration, the test is conducted on the residuals of the cointegration regression. The absolute values of the critical values for the Dickey-Fuller t-test statistic, which is employed to examine cointegration, are higher compared to the critical values used for testing the order of integration.

ii) Johansen cointegration test

The determination of the number of cointegrating vectors in Johansen cointegration is achieved through the utilization of two tests: the Maximum Eigenvalue test and the Trace test (Asari *et al.*, 2011). Additionally, Asari *et al.* (2011) propose that the maximum eigenvalue test is employed to assess the null hypothesis of r cointegrating vectors in comparison to the alternative hypothesis of r+1 cointegrating vectors. Similarly, the trace test is used to examine the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. According to Dwyer (2015), the Johansen cointegration test can be seen as an extension of the extended Augmented Dickey-Fuller test in a multivariate context. The Johansen test provides estimates for all cointegrating vectors, utilizing eigenvalues of data transformations, the least-squares regression equation, and the residuals (the error term) of the regression equation within the framework of unit root analysis (Dwyer, 2015; Rajab, 2011). Johansen (1988) laid out the definition for the generic model:

$$y_t = c_t + A_1 y_{t-1} + A_2 y_{t-2} + A_p y_{t-p} + U_t \qquad (12)$$

Which may be rewritten as:

$$\triangle y_t = c_t + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Pi_i \triangle y_{t-i} + U_t \qquad (13)$$

Johansen introduced two likelihood ratio tests, namely:

Trace test

$$J_{trace} = -T \sum_{i=r+1}^{n} In(1-\lambda_i) \quad (14)$$

Maximum eigenvalue test

$$J_{max} = -TIn(1-\lambda_{r+1}) \quad (15)$$

Where:

T	= Quantity of observations i
$\hat{\lambda}$	= The biggest i^{th} canonical correlation
$\triangle y_t$	= Retail price variations
Ͳ	= Lagged value coefficient
U_t	= Residual term

As per Ojiako's (2021) study, the confirmation of a cointegrating vector is conducted through the deployment of the Trace test statistic and Maximum eigenvalue test statistic. Moreover, Ojiako (2021) noted that the established decision criterion entails rejecting the null hypothesis at a significance level of 5% when the observed Trace statistic exceeds the critical value of 0.05. Conversely, if the observed Maximum eigenvalue statistic exceeds the critical value of 0.05, the null hypothesis is rejected at a 5% level. Otherwise, the null hypothesis is not rejected. The study employed Ojiako's (2021) notion of cointegration as the decision rule.

4.5.3.4. Impulse response functions

In the event of an unforeseen shock impacting the error term, E_t, inside the Vector Error Correction Model (VECM), the dependent variable, Yu, will be influenced. Furthermore, due to potential correlation between the error terms, the remaining equations within the VECM will also be affected. In the given situation, the reactions of the dependent variable, v_t, in the Vector Error Correction Model (VECM) resulting from the initial disturbance to the error term, E_t, are commonly referred to as the 'impulse response'. To enhance clarity, the Impulse Response Function (IRF) is employed visually to illustrate the impact of a shock on the variables of the Vector Autoregression (VAR) model. An impulse response function (IRF) illustrates the dynamic reaction trajectory of a variable resulting from a one-period standard deviation shock to another variable.

The VAR (p) representation of Y_t in equation:

$$Y_t = \mu_0 + \sum_{i=1}^{p} \mu_j Y_{t-j} + \varepsilon_t \tag{16}$$

has a moving average representation of the form:

$$Y_t = r_0 + \sum_{j=0}^{\infty} r_j e_{t-j} + \varepsilon_t \tag{17}$$

Where $r_0 = \beta^{-1}\mu_0$; $r_j = \beta^{-j}\mu$; for j= 1, 2, 3, …; and β is the large operator such that $\beta^{-j}Y_t = Y_{t-j}$. Following Pesaran & Shin (1998), equation (17) can be re-written as:

$$Y_t = \sum_{j=0}^{\infty} Z_j e_t \tag{18}$$

where the matrices, Z_j; for j = 1,2, ..., n are recursively calculated using the relations:

$Z_n = \xi_1 Z_{n-1} + \xi_2 Z_{n-2} + \xi_3 Z_{n-3} + _{\dots} + \xi_p Z_{n-p}$,

$Z_n = 0$ for n < 0,

Z_0= I_p, the p x p identity matrix

$\xi_1 = I - \delta + \phi_1$

$\xi_j = \phi_j - \phi_{j-1}$ for j= 2, 3, …, p

The Generalized Impulse Response Function (GIRF) of Y; relating to a unit (one standard deviation) shock in the i-th variable at time this given as:

$$GIRF_i = \frac{Z_n \Omega \varepsilon_i}{\sqrt{\sigma_i^2}}, \qquad n= 1, 2, 3, \dots \tag{19}$$

Where

$$\Omega = (e_e e_t') = \sigma_{ji}$$

By modifying the equation, the response of Y_{t+i} to a single-unit impulse at time t can be derived. When plotting each element of Z versus j periods, one can observe the response of each variable in the system to the impulse and various structural shocks.

4.5.4. Error Correction Model

To meet the second, third, and fourth objectives, the study employed the von Cramon-Taubadel and Loy Error Correction Model (ECM) derived from the chosen observations. The ECM linked the responses of retail prices (P_A) towards any change in farmgate prices (P_A) and changes in wholesale prices (P_w) and also the error correction term was given by ECT = $P_{A,t} – ß_o – ß_1P_{B,t} – ß_2P_{w,t}$; residuals that were Lagged obtained from predicting the relationship of prices in the long-run. ECT served the purpose of measuring any deviation arising from the long-run equilibrium between the P_A and P_B & $P_{w.}$ So, linking the ECT with ECM enabled P_A to vary with the variation in P_B and P_w, and rectified errors that could have possibly emanated after the establishment of equilibrium in the long run, that stemmed after the past eras. ECT was thus broken into two components which were, negative and positive, ECT^- and ECT^+, respectively (i.e., negative and positive shocks from the long-run equilibrium) for the conduction of a price transmission test. The simultaneous response term was segmented as shown by equation (20) below (Von Cramon-Taubadel & Loy, 1996). This then led to the development of equation (21) shown below, wherein simultaneous and short-run changes to the withdrawals coming from the relation cointegration were not symmetric until the following conditions were met: $β_1^- ≠ β_1^+$ and $β_2^- ≠ β_2^+$ in their respective order. The analysis of price transmission proceeded with the application of the Granger Causality test, determining the direction of price linkage. Time series variables considered were found to be non-stationary integrated of the first order, as determined by the Augmented Dickey-Fuller (ADF) method (Dickey & Fuller, 1979) and Phillips-Perron (PP). This non-stationarity led to a linear integration, resulting in a stationary time series. To confirm this outcome, the Cointegration technique was employed. Engle & Granger (1987) proposed a two-step residual-based test, applied in this study to validate the assertion.

Step 1: This step involved the regression cointegration of price series which were non-stationary, with retail being the response variable and wholesale and farmgate being the predictor variables. Similarly, regression cointegration was performed for non-stationary price series with retail as the dependent variable and farmgate and wholesale as predictors.

$P_{A} = \beta_0 + \beta_1 P_B + \beta_2 P_w + E_t$ …………………………………………………… (20)

Notably, P_A denoted the retail price; P_B denoted farm price; P_w denotes wholesale price and E_t denoted disturbance term.

Step 2: ADF and PP tests were applied to check if residuals from step 1 are non-stationary or otherwise.

$E_t = \beta_0 - \beta_1 P_B - \beta_2 P_w + U_t$ ……………………………………………… (21)

It should be noted that U_t was used to denote the disturbance term.

To ascertain the appropriate number of lags for all the models, two information criteria, namely, the Akaike Information Criterion (AIC) introduced by Akaike (1973), and the Bayesian Information Criterion (SIC) outlined by Schwarz (1978) were utilized. The results of the asymmetry test are presented in the analysis of variance (ANOVA) and summarized in a table for clarity. This table facilitates a comparison between the symmetric and asymmetric models specified in equations (22) and (23), respectively.

$\Delta P_{A,t} = \beta_0 + \beta_1 \Delta P_{B,t} + \beta_2 \Delta P_{w,t} + \beta_3 ECT_{t-1} + \beta_4 \Delta P_{B,\ t-1} + \beta_5 \Delta P_{w,\ t-1} + \beta_6 \Delta P_{A,\ t-1} + \varepsilon$ …………………………………………………………………………… (22)

$\Delta P_{A,t} = \beta_0 + \beta_1^{+} \Delta P_B^{+}{}_{,t} + \beta_1^{-} \Delta P_B^{-}{}_{,\ t} + \beta_2^{+} \Delta P_w^{+}{}_{,t} + \beta_2^{-} \Delta P_w^{-}{}_{,\ t}\ \beta_3 ECT^{+}_{t-1} + \beta_3^{-} ECT^{-}_{t-1} + \beta_3 \Delta P_{B,\ t-1} + \beta_4 \Delta P_{w,\ t-1} + \beta_5 \Delta P_{A,\ t-1} + \varepsilon$ ……………………………………………………………… (23)

Table 4. 2.: Table of variables

	Variable code	Variable name	Unit of measurement
		Dependent	
Y	P_A	Retail price	South African Rands
		Independent	
X_1	P_B	Farm price	South African Rands
X_2	P_W	Wholesale price	South African Rands

X_3	ECT	Error Correction Term	None

Source: Author's computation (2023)

The primary objective of this study was to investigate pricing asymmetry at three distinct levels of the garlic marketing chain: transmission from farmers to retailers, from wholesalers to retailers, and lastly from wholesalers to farmers, as guided by the Granger Causality test outcomes. The following section of this paper outlines the application of the error correction model:

a) Farm-to-retail price transmission

$$\Delta PA_t = \alpha_1 + \sum_{i-1}^{k} \beta_i \, \Delta PA_{t-i} + \sum_{j=0}^{k} \emptyset_j \, \Delta PB_{t-j} + \alpha_2^{+} ECT_{t-1}^{+} + \alpha_2^{-} ECT_{t-1}^{-} \quad (24)$$

b) Wholesale-to-retail price transmission

$$\Delta PA_t = \alpha_1 + \sum_{i-1}^{k} \beta_i \, \Delta PA_{t-i} + \sum_{j=0}^{k} \emptyset_j \, \Delta PW_{t-j} + \alpha_2^{+} ECT_{t-1}^{+} + \alpha_2^{-} ECT_{t-1}^{-} \quad (25)$$

c) Farm-to-wholesale

$$\Delta PW_t = \alpha_1 + \sum_{i-1}^{k} \beta_i \, \Delta PW_{t-i} + \sum_{j=0}^{k} \emptyset_j \, \Delta PB_{t-j} + \alpha_2^{+} ECT_{t-1}^{+} + \alpha_2^{-} ECT_{t-1}^{-} \quad (26)$$

4.6. Forecasting

4.6.1. Introduction

Most data used in statistical analysis is called cross-sectional data, meaning that it is gathered from sample surveys at one point in time. However, the data used in this study was collected over time by secondary sources mentioned in the methodology section of this report. The study used monthly garlic prices which cover a period of 11 years from 2011 until 2021. This type of data is referred to as a time series. For each of the price series used in this study, i.e., farmgate, wholesale and retail garlic prices, an analysis was made to examine trends, identify patterns and prepare forecasts of future values (prices) of the garlic that will be essential to the government, farmers and other stakeholders involved in the garlic value chain for the purposes of budgeting and operational planning. This section, therefore, covers an approach to analyze the afore-mentioned price series so as to inform forecasting. The essence of time series analysis is to identify any recurring patterns in a time series, quantify these patterns through building a statistical model and then use the statistical model to prepare forecasts to estimate future values of the time series (Wegner, 1993).

4.6.2. Decomposition of a Time Series

Time series analysis aims to isolate the influence of each of the four components on the actual time series. The time series model used as the basis for analyzing the influence of these four components assumes a multiplicative relationship between them. The multiplicative time series model is defined algebraically as:

$$Actual\ y = trend \times cyclical \times seasonal \times irregular$$

$$y = T \times C \times S \times I \tag{27}$$

The next sections encapsulate statistical approaches used to quantify trend and seasonal variations only. These two components account for the most significant proportion of an actual value in a time series (Wegner, 1993). By isolating them, most of an actual time series value will be explained.

4.6.2.1. Trend Analysis

The long-term trend in garlic prices being investigated through this project can be isolated by removing the medium- and short-term fluctuations (i.e., cycles, seasonal and random) in the series. This will result in either a smooth curve or a straight line, depending on the method chosen. Two methods for trend isolation were used: the moving average method, which produces a smooth curve regression analysis, which results in a straight-line trend.

Method 1: The Moving Average Method

A moving average removes the short-term fluctuations in a price series by taking successive averages of groups of observations. Each time the monthly actual price is replaced by the average of prices from time periods that surround it. This results in a smoothed time series. Thus, the moving average technique makes time series smooth by removing short-term fluctuations (Wegner, 1993). The number of observations, k, which are summed and averaged in each group, is determined by the number of periods that are believed to span the short-term fluctuations. In this study, a 5-monthly period moving average (5-PMA) was chosen as being ideal since it is assumed by the researcher to be a middle-ground between smoothing out “noise” and detecting changes in the underlying trend. This 5-PMA allows for the smoothing out of most of the random fluctuations in the prices while still allowing quick detection of changes in the trend, making the results more robust. Thus, k = 3.

The following four steps were used to calculate a 5-monthly moving average series.

Step 1: Sum the first five months’ prices and position the total opposite the middle (median) month (i.e., March).

Step 2: Repeat the summing of five-months’ observations by removing the first month’s price (i.e., January) and including the next month’s price (i.e., June). This second moving total (using February, March, April, May and June) is again positioned opposite the middle (median) month, which is April.

Step 3: Continue producing these moving (or running) totals until the end of the time series is reached. This process of positioning each moving total opposite the middle (or median) month of each sum of the five months’ prices is called centering.

Step 4: The moving average series is now calculated by dividing each moving total by k =5 (i.e., the number of prices that are summed in each group). This four-step procedure is applied since the term, k, of our moving average is odd. The calculation of a moving average when k is even will obviously be different since even numbers do not have “visible” centers.

The moving average series is a smooth curve, which has ‘ironed out’ the short-term fluctuations.

A moving average time series is a smoother series than the original time series values. It has removed the effect of short-term fluctuations (i.e., seasonal and irregular fluctuations) from the original observations, y, by averaging over these short-term fluctuations. The moving average value can be seen as reflecting mainly the combined trend and cyclical movements. In symbol terms for the multiplicative model:

$$Moving\ average = \frac{T\times C\times S\times I}{S\times I} = T\ \times\ C \tag{28}$$

As seen from these moving average calculations, its obvious drawback is a loss of information (data values) at both ends of the original time series. Moving averages cannot be found for the first two and last two periods. This is caused by the centering process of moving average values. However, this is not a significant drawback in the case of this study since the time series is long, it has a total of 132 prices for each series. The major benefit of a moving average is the opportunity it affords a policymaker to focus more clearly on the long-term trend (and cyclical) movements in a time series, without the obscuring effect of short-term 'noise' influences.

Method 2: Trendline Using Regression Analysis

A trendline isolates the trend (T) component only. It shows the general direction (upward, downward, constant) in which the series is moving. It is therefore best represented by a straight line. The method of least squares from regression analysis is used to find the trendline of best fit to a time series of numeric data. The dependent variable, y, is the actual time series (i.e., farmgate, wholesale and retail garlic prices) and the independent variable, x, is time. Statistical applications call for the numerical coding of time in order for it to be used as an independent variable in the analysis. Two alternative methods for coding time, namely, zero-sum and sequential numbering systems can be used. The predictions from the employment of any of these two methods will be the same. Therefore, this study chose to use sequential numbering system in the analysis. Any sequential numbering system can be used, but the most common choice of coding is the set of natural numbers (x = 1; 2; 3; 4; 5; …; n, where n = number of time periods in the time series). Each time period (x) of the time series (y) is sequentially assigned an integer value beginning with 1 for the first time period, 2 for the second, 3 for the third, etc.

4.6.3. De-seasonalizing Time Series Values

The removal of seasonal influences, which represent short-term fluctuations in a time series, resulted in a smoother time series that made it easier to identify long-term trend/ cyclical movements. The researcher removed seasonal influences from the three price series used in this study by dividing the actual price for each month by its corresponding seasonal index, following the work of Box (1976):

$$De - seasonalized\ price = \frac{Actual\ price}{Seasonal\ index} \times\ 100 \qquad (29)$$

These de-seasonalized prices, which were measured in the same physical units as the actual prices, reflect the collective influence of the trend and cyclical (and to a lesser extent, irregular) forces only.

5.6.4. Seasonal Analysis

Seasonal analysis isolates the influence of seasonal forces on a time series. The ratio-to-moving-average method was used in this study to measure and quantify these seasonal influences. This method expresses the seasonal influence as an index number. It measures the percentage deviation of the actual values of the time series, y, from a base value that excludes the short-term seasonal influences. These base values of a time series represent the trend/cyclical influences only. The procedure for seasonal analysis employed in this study was inspired by the work of Polwiang (2020) originating from Wegner (1993) which can be summarized as follows:

Ratio-to-Moving-Average

Step 1: Identifying the trend/cyclical movement.

The moving average approach, as described earlier, was used to isolate the combined trend/ cyclical components in the farmgate, wholesale and retail price series. The choice of an appropriate moving average term, k, was determined by the number of periods that span the short-term seasonal fluctuations. In most instances, the term k corresponds to the number of observations that span a one-year period. The resultant smoothed moving average series that reflects the combined trend and cyclical influences represents a base measure of the time series.

Step 2: Finding the seasonal ratios.

A seasonal ratio for each period was found by dividing each actual price series value, y, by its corresponding moving average value (i.e., its base value). Mathematically, this is expressed as:

$$Seasonal\ ratio = \frac{Actual\ price\ series\ value\ (y)}{Moving\ average} \times 100 \quad (30)$$

$$= \frac{T \times C \times S \times I}{\times C} \times 100 = S \times I \times 100 \quad (31)$$

A seasonal ratio by definition is an index that measures the percentage deviation of each actual price, y (which includes seasonal influences) from its moving average (base) value (which represents trend and cyclical influences only). This deviation from the base level (which is the trend/cyclical influence, with index of 100) is a measure of the seasonal impact, and to a lesser extent, irregular forces, on the time series for each time period. The outcomes were long due to the nature of period length used in this study (i.e., a total of 132 observations for each price series).

Step 3: Producing the median seasonal indices.

The study averaged the seasonal ratios across corresponding periods (months) within the years to smooth out the irregular component inherent in the seasonal ratios. Generally, the median is used to find the average seasonal ratios for corresponding periods within the years. The arithmetic mean was not used as it could be influenced by the presence of any outlier seasonal ratios, resulting in unrepresentative seasonal indices. The outcomes are shown in Tables 5.23., 5.24. and 5.25.

Step 4: Computing the adjusted seasonal indices.

Each seasonal index must have a base index of 100. Therefore, the sum of the k median seasonal indices must equal 100 × k, 500 in the case of this study. Since in this study this was not the case, each median seasonal index was adjusted to a base of 100. The adjustment factor was determined using the formula shown below:

$$Adjustment\ factor = \frac{k \times 100}{\sum(\text{Median seasonal indices})} \quad (32)$$

This formula is widely used in time series analysis, but the attribution of its establishment to a specific individual or source remains unclear, however, it was drawn from the work of Wegner (1993).

4.7. Chapter Summary

This chapter encapsulated a comprehensive overview of the methodological approach employed in the study, offering a detailed summary of the research design. It introduces a conceptual framework for investigating vertical price transmission, emphasizing the detailed explanation of the study region, dataset utilization, and the approach adopted for data analysis. Recognizing the importance of assessing the time series characteristics of the data before delving into price transmission research, the justification for selecting the Error Correction Model is grounded in the presence of a co-integration connection, rendering it the most appropriate model for the investigation.

CHAPTER 5: RESULTS AND DISCUSSION

5.1. Introduction

In this chapter, empirical findings of the study are comprehensively discussed. A total of 396 observations on farmgate, wholesale and retail garlic prices in the South African garlic markets were used in the analysis. Of the 396 observations, 132 were monthly prices at farmgate level, 132 at wholesale level and 132 at retail level, from January 2011 to December 2021. EViews was employed to conduct a diverse array of tests related to time series data encompassing both short and long-run equations. These tests comprised Pearson's correlation analysis, the Augmented Dickey-Fuller (ADF) test, determination and validation of the maximum lag order for the VAR model, Engle-and-Granger two-step residual-based cointegration test, Johansen cointegration test, analysis of impulse response function, stability test, Cholesky variance decomposition, Vector Error Correction (VEC) model establishment and parameter estimation, Granger Causality test results, and culminated with diagnostic tests.

5.2. Descriptive Statistics

Table 5. 1.: Descriptive statistics summary for farmgate, wholesale and retail prices for garlic in South Africa

	Farmgate Price	**Wholesale Price**	**Retail Price**
Mean	37.05227	45.59553	89.30848
Median	32.38000	43.95500	84.39500
Maximum	118.0800	120.2300	239.9600
Minimum	14.19000	15.09000	30.40000
Std. Dev.	18.39560	19.65827	41.43140
Skewness	1.650761	0.961659	1.233238
Kurtosis	6.321352	4.207823	4.852446
Jarque-Bera	120.6228	28.36893	52.33284

Probability	0.000000	0.000001	0.000000
Sum	4890.900	6018.610	11788.72
Sum Sq. Dev.	44330.16	50624.62	224869.5
Observations	132	132	132

Source: Author's computation (2023)

From the above Table 5.1, all three price series have 132 observations, indicating the sample size. It can be noted from the above results that average garlic prices per kilogram in the South African garlic market from 2011 to 2021 were approximately R37.06, R45.60 and R89.31 for farmgate, wholesale and retail, respectively. These averages (means) provide a central tendency for each price series and can be compared with historical averages to determine if prices are trending higher or lower. High average retail prices might indicate higher markups in the supply chain. The median (middle) prices of the observed prices from 2011 to 2021 in the South African garlic market are R32.38, R43.95 and R84.40 for farmgate, wholesale and retail, respectively. In other words, when all those prices are arranged from the smallest to the largest in their respective levels (that is to say, farmgate, wholesale and retail), the middle prices are as given above. In a nutshell, approximately half of the farmgate, wholesale and retail prices during the observed period 2011-2021 are smaller than R32.38, R43.95 and R84.40 respectively, and the other half are larger. Comparing the observed means and medians can reveal the presence of outliers (Kaya *et al.*, 2021). Since average prices at each selected marketing chain level (farmgate, wholesale and retail) are significantly more than the middle prices, it suggests that there are some extremely higher prices in the distribution and that the data is skewed to the right. These variations could be linked to various factors, including production and demand trends, transportation expenses, packaging costs, weather conditions, or climatic patterns.

Furthermore, the highest observed prices for farmgate, wholesale and retail are R118.08, R120.23 and R239.96 respectively and the lowest prices are R14.19, R15.09 and R30.40 respectively, for the observed periods 2011 to 2021. These statistics highlight the range of prices within each series. Extreme values can possibly indicate unusual market conditions or events. Farmgate and wholesale standard deviations are approximately 18.40 and 19.66, respectively, signifying moderate variability whereas the retail price has the highest standard deviation at about 41.43, indicating greater price variability (volatility). This higher volatility in retail prices could be due to factors such as demand fluctuations or retailer behavior.

5.3. Correlation analysis

The matrix in Table 5.2 illustrates the intensity and direction of the correlation between farmgate, wholesale, and retail prices in the garlic markets of South Africa. The hypotheses pertinent to these results were stated as follows:

H_0: There is no correlation between farmgate, wholesale and retail prices in the South African garlic markets.

H_1: There is correlation between farmgate, wholesale and retail prices in the South African garlic markets.

Table 5. 2.: Correlation analysis matrices (CAM) between farmgate and wholesale prices as well as farmgate and retail prices

	P_A	P_B
P_A	1.000000	0.7203012
P_B	0.7203012	1.000000

	P_A	P_W
P_A	1.000000	0.814332
P_W	0.814332	1.000000

Source: Author's computation (2023)

Recall: P_A, P_B and P_W represent retail, farmgate and wholesale prices for garlic, respectively

Summarized in the above Table 5.2. are the correlation results generated from eViews student version 12. Correlation coefficients measure the strength and direction of the linear relationship between two variables, with values ranging from -1 to 1. On the basis of the above results, the study rejects the null hypothesis (H_0) stating that there is no correlation between farmgate, wholesale and retail prices in the South African garlic markets. It can be noted that the correlation coefficient between retail price (P_A) and itself (P_A vs P_A) is 1.000000. This is the highest possible correlation coefficient and indicates a perfect positive linear relationship. In simpler terms, when P_A goes up, P_A also goes up in a perfectly predictable manner. This is expected since one variable is being compared to itself. The correlation coefficient between PA and farmgate price (P_B) (P_A vs P_B) is 0.7203012. This value is positive and greater than 0.5, which suggests a moderately strong positive linear relationship between retail prices (P_A) and farmgate prices (P_B) in the South African garlic market. When P_A tends to increase, P_B also tends to increase, but the relationship is not perfect. There may be other factors influencing these prices as well. Similarly, the correlation coefficient between P_B and itself (P_B vs P_B) is 1.000000, as expected when comparing a variable with itself.

The correlation matrix suggests that there is a positive and moderately strong linear relationship between retail prices (P_A) and farmgate prices (P_B) in the South African garlic market, with a correlation coefficient of approximately 0.7203. However, it is important to note that correlation does not imply causation, and other factors may also affect the relationship between these two variables. The relationship between retail and wholesale (P_W) garlic prices is also strong positive with a revealed figure of 0.8143 as shown in the above table 5.2.

5.4. Data Properties

5.4.1. Stationarity Test

A stationary test, often known as a unit root test, is a statistical method employed to ascertain whether a time series dataset is stationary or non-stationary. Stationarity is a crucial concept in time series analysis and plays a pivotal role in various modeling and forecasting techniques. A stationary time series maintains constant statistical properties, such as mean, variance, and autocorrelation, over time. On the contrary, a non-stationary time series displays trends, seasonality, or other patterns that change over time. The stationarity or non-stationarity of a series significantly influences its behavior and characteristics. For instance, non-stationary series exhibit persistent shocks, leading to spurious results in regression models based on such data. Therefore, it is imperative to examine the data generating process of the price series before conducting any analysis. The presence of a unit root in the price data must be investigated, and if detected, appropriate measures should be taken to transform the series into a stationary process. The unit root test was performed using the Augmented Dickey-Fuller procedure, and the results are presented in Tables 5.3 and 5.4 sequentially.

Table 5. 3.: The Augmented Dickey-Fuller (ADF) Unit root test results

Series	ADF test statistics	Test Critical value at 5%	Probability*	ADF statistics	Test Critical value at 5%	Probability*
	Levels			First diff.		
Farmgate Price (P_A)	-4.009402	-3.445590	0.010700	-6.230947	-3.447072	0.000000
Wholesale Price (P_W)	-4.913674	-3.444756	0.000500	-7.411649	-3.446168	0.000000
Retail Price (P_B)	-6.564346	-3.444756	0.000000	-7.209053	-3.446168	0.000000

*MacKinnon (1996) one-sided p-values

Source: Author’s computation (2023)

The confidence level of 95% was used to conduct a stationarity test of the three price series using ADF method and the obtained results are as shown in Table 5.3. The null hypotheses (H_0) for these tests were that the price series are non-stationary and were all rejected. The results reveal that all data series are stationary at both levels and the first difference since the absolute ADF statistics figures are bigger than their corresponding critical values, which were all significant at 5% significance level. This significance level of 5% was chosen so as to align it with the 95% confidence level, because theoretically and practically, significance level and confidence level are collectively exhaustive or rather complementary. In other words, when the two are added together, they give 100%. Hence, the results suggest that the farmgate, wholesale, and retail prices exhibit integration at both levels: levels and first differences. However, the study predominantly favors stationarity at the first difference, considering that the MacKinnon probabilities for all three price series are precisely 0, indicating a high level of significance at first differences. Stationarity at the first difference corresponds to order one, I (1) integration.

Table 5. 4.: The Phillips-Perron (PP) Unit root test results

Series	PP test statistics	Test Critical value at 5%	Probability*	PP test statistics	Test Critical value at 5%	Probability*
		Levels			First diff.	
Farmgate Price (P_A)	-3.039543	-3.444487	0.012560	-7.591621	-3.444756	0.000000
Wholesale Price (P_W)	-8.521920	-3.444487	0.045400	-8.521920	-3.444756	0.000000
Retail Price (P_B)	-5.021775	-3.444487	0.000300	-18.99551	-3.444756	0.000000

*MacKinnon (1996) one-sided p-values

Source: Author's computation (2023)

On the other hand, PP was used to carry out a unit root test using a 95% confidence level. This was done for the purpose of validating results from the ADF test and also for reliability reasons. The null hypotheses (H_0) for these tests were that all the price series under investigation have a unit root, implying non-stationarity and were all rejected. The results reveal that wholesale and retail price series do not have a unit root (that is to say, they are stationary) at levels and are significant at 5% level of significance whereas farmgate shows a presence of unit root (is non-stationary) at levels and insignificant at 5% level of significance. Clear evidence from the results summarized in the above table, in support of this submission is that both wholesale and retail price series exhibit higher absolute PP statistics values opposed to their corresponding critical values, whereas the absolute PP statistics value for farmgate prices is less than its corresponding critical value at levels. This is a partial or minor deviation from the ADF test results. These findings conflict with the ones revealed in the study of Mandizvidza et al. (2013), which found no stationarity in the farmgate, wholesale and retail prices, hence, differencing had to be followed. Vavra and Goodwin (2005) emphasized that economic time series are typically non-stationary, requiring transformation through differencing or de-trending to prevent spurious regressions. Spurious regressions arise when the mean, variance, and covariance of a time series change over time, rendering traditional regression results invalid when applied to non-stationary data.

Moreover, all these three price series prove to exhibit an absence of a unit root at first difference, meaning that they are stationary at first difference. They were all significant at 5% significance level with equivalent probabilities of exactly zero. A significance level of 5% was still chosen so as to make it align with the 95% confidence level, because theoretically and practically, significance level and confidence level add up to 100%. Therefore, according to the PP test results, the farmgate, wholesale and retail prices are integrated at first difference. This now, supports the researcher's decision to mostly prefer stationary at first difference since the MacKinnon probabilities for all the three price series are exactly 0, which indicate high level of significance at first differences, and this is consistent with the findings from the ADF test as shown in table 5.3. Stationarity at first difference alludes to order one, I (1) integration.

5.4.2. Optimal Lag Selection

The subsequent step involved determining the optimal lag order for proper VAR model specification for subsequent Granger Causality tests. The outcomes, indicating the ideal lag lengths for use in the causality tests, are succinctly presented in Table 5.4. In the sample comprising 132 for each price series – farmgate, wholesale, and retail obtained from secondary sources, namely, Joburg Market; National Agricultural Marketing Council; Department of Trade, Industry, and Competition; and the South African Department of

Agriculture Land Reform, and Rural Development databases, the endogenous variables were the prices, namely, farmgate, wholesale, and retail, while the constant C served as the sole exogenous variable. This lag order selection is aimed at ensuring the accurate specification of the VAR model to be employed in the subsequent Granger Causality tests. The optimal lag length results for the causality tests are depicted in Table 5.5, considering the garlic prices in South Africa and the total of 132 observations in each of the three stages of garlic marketing under investigation.

Table 5. 5.: Vector Auto Regressive lag order Selection Criteria (Endogenous variables: P_A, P_B, P_W; Exogenous variable: C)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1600.975	NA	10458247	24.67653	24.74271	24.70342
1	-1396.718	395.9439	518662.3	21.67258	21.93728	21.78014
2	-1364.380	61.19386*	362294.7*	21.31353*	21.77675*	21.50175*

* Indicates lag order selected by the criterion

LR: Sequential modified LR test statistic (each test at 5% significance level)

LPE: Final Prediction Error

SC: Schwarz Information Criterion

AIC: Akaike Information Criterion

HQ: Hannan-Quinn Information Criterion

The outcomes depicted in the table reveal that, across various criteria, such as the sequential modified LR test statistic, Final Prediction Error, Akaike Information Criterion, Schwarz Information Criterion, and Hannan-Quinn Information Criterion, lag 2 is consistently identified as the optimal lag length. This is because, as a rule of thumb, in each of those criteria, the lowest number points to the desirable lag selection. For instance, the AIC has three values which are: 24.67653, 21.93728 and 21.31353. These numbers are in line with lags 0, 1 and 2 respectively. 21.31353 (corresponding with lag 2) is the smallest of the three values in this case and is the one that will be chosen from the SIC as the optimal lag length. Following the same theory, all the criteria shown in the table suggest lag 2 is optimal. Consequently, lag 2 will be selected when conducting the Granger Causality Tests.

Table 5. 6.: Vector Auto Regressive lag order Selection Criteria (Endogenous variables: P_A, P_B; Exogenous variable: C)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1183.228	NA	284509.8	18.23428	18.27839	18.25220
1	-1036.544	286.5976	31678.81	16.03914	16.17149	16.09292
2	-1017.727	36.18735*	25222.77*	15.81118*	16.03176*	15.90081*

* Indicates lag order selected by the criterion

The results shown above show that all the maximum lag selection criteria chose 2 as the lag length between P_A and P_B and lag length of 2 will therefore be used in the Granger Causality test. The lag length for P_A/P_B refers to the amount of time it will take before wholesale markets to respond to price shocks at farm level and vice versa. In this context, it will take a maximum 2 years for wholesales to respond to changes at farm level, and vice versa. Lag 2 was selected because the values in each criterion associated with lag 2 are less than the other values in each criterion column.

Table 5. 7.: Vector Auto Regressive lag order Selection Criteria (Endogenous variables: P_A, P_W; Exogenous variable: C)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1169.263	NA	229505.2	18.01943	18.06355	18.03736
1	-1009.518	312.1171	20902.43	15.62336	15.75571	15.67714
2	-997.9694	22.20947*	18611.64*	15.50722*	15.72780*	15.59685*

* Indicates lag order selected by the criterion

The results shown above show that all the maximum lag selection criteria chose 2 as the lag length between P_A and P_W and 2 will therefore be used in the Granger Causality test.

Lag 2 was also chosen because the values in each criterion associated with lag 2 are less than the other values in each criterion column. This implies that it will still take retailers a maximum of 2 years to respond to the behaviors of retailers and vice versa.

Table 5. 8.: Vector Auto Regressive lag order Selection Criteria (Endogenous variables: P_B, P_W; Exogenous variable: C)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1004.483	NA	18189.41	15.48435	15.52846	15.50227
1	-832.7751	335.4902	1378.146	12.90423	13.03658	12.95801
2	-808.6106	46.47010*	1010.632*	12.59401*	12.81459*	12.68364*

* Indicates lag order selected by the criterion

The results shown above show that all the maximum lag selection criteria chose 2 as the lag length between P_B and P_W and 2 will therefore be used in the Granger Causality test. This lag length of 2 was also chosen due to the fact that the values in each criterion associated with lag 2 are less than the other values in each criterion column. It would still assumably take farmgate prices a maximum of 2 years to respond to the changes in wholesale prices and vice versa. However, in Mosese *et al.* (2020), there were inconsistencies in terms of AIC and SIC. The AIC consistently chose 2 as the maximum lag length for all price pairs, whereas SIC deviated to choosing lag 1 as optimal for farmgate/wholesale. On the other hand, in Mandizvidza *et al.* (2013), all the five criteria consistently chose lag 1 as optimal across all marketing levels under investigation. The current study postulates that the observed variation in these optimal lengths can be attributed to the different commodities used and their nature, including the prices used. Mandizvidza *et al.* (2013) used tomato whereas Mosese *et al.* (2020) focused on potatoes, both of which are highly perishable, hence prices used will be highly variable. The current study is using garlic which is perishable but not highly compared to tomatoes and potatoes.

In consolidating the results presented in the above Tables 5.5., 5.6., 5.7., and 5.8., a maximum lag length of 2 will be used to run Granger Causality tests for P_A, P_B and P_W, using 130 observations in each price series case (i.e., P_A, P_B and P_W). A lag period of 2 was subtracted from a sample of 132 in each of P_A, P_B and P_W, leading to the usage of 130 observations. Recall that this lagged period was determined VAR optimal lag order selection criteria shown in the previous Tables 5.5, 5.6, 5.7, and 5.8.

5.4.3. Granger Causality Test results in the South African garlic market

H_0: There is no direction of price linkage between farmgate, wholesale and retail prices in the South African garlic markets.

H_0: There are directions of price linkage between farmgate, wholesale and retail prices in the South African garlic markets.

Table 5. 9.: Granger Causality test outcomes

Null hypotheses	**Lags**	**Obs.**	**F-stat.**	**Prob.**	**Decision**
P_B does not Granger Cause P_A	2	130	5.6980	0.0043*	Reject
P_A does not Granger Cause P_B	2	130	1.6121	0.2036	Accept
P_W does not Granger Cause P_A	2	130	9.9074	0.0001*	Reject
P_A does not Granger Cause P_W	2	130	0.2622	0.7698	Accept
P_W does not Granger Cause P_B	2	130	8.2649	0.0004*	Reject
P_B does not Granger Cause P_W	2	130	11.8017	0.0002*	Reject

Note: * denotes significance at 1%

Source: Author’s Computation (2023)

The study rejects the null hypothesis stating that there is no direction of price linkage between farmgate, wholesale, and retail prices in the South African garlic markets. Detailed interpretation of the results presented in the above table is as follows:

a) Price causality between farmgate and retail

The p-value of 0.0043 is found to be significant at the 1% level, while the p-value of 0.2036 is deemed insignificant at the 1%, 5%, and 10% levels. Consequently, the hypothesis asserting that price at the producer (farm) level denoted by P_B does not Granger cause the price at the retail level (P_A) can be rejected. However, the hypothesis that the retail price does not Granger cause the farm price cannot be rejected. These results lead to the conclusion that prices exhibit unidirectional flow from the farm level to the retail level. This suggests that farmgate prices possess predictive power over retail prices. The observed market structure of garlic in South Africa indicates a higher concentration at the farm level compared to the retail level, possibly contributing to the direction of price influence from the farm (with more market power) to the retail level.

b) Price causality between wholesale and retail

The p-value of 0.0001 is found to be significant at the 1% level, while the p-value of 0.7698 is considered insignificant at the 1%, 5%, and 10% levels. Consequently, the hypothesis stating that the price at the wholesale level (P_W) does not Granger cause the price at the producer (farm) level can be rejected. However, the hypothesis that the retail price does not Granger cause the wholesale price cannot be rejected. These results suggest unidirectional price flow from the wholesale level to the retail level, indicating that wholesale prices possess predictive power over retail prices. This aligns with economic theory and the principle of rationality in economics, altogether with the propositions of Özalp & Ören (2023) who argued that retailers base their prices on those set at the wholesale level, while wholesalers, in most cases, do not necessarily depend on retailers to determine their prices, *ceteris paribus*. The observed market structure of garlic in South Africa, emphasizing a higher concentration at the farm level than at the retail level, might contribute to the direction of price flow from the wholesale (with more market power) to the retail level.

c) Price causality between farmgate and wholesale

In Table 5.9, the p-values (0.0004 and 0.0002) are found to be statistically significant at the 1% level. Consequently, the null hypotheses suggesting that wholesale prices do not Granger cause farmgate prices and farmgate prices do not Granger cause wholesale prices are rejected. This statistical evidence leads to the conclusion that there exists a bi-directional (or dual) causality at the farmgate and wholesale levels. In other words, farm prices influence wholesale prices, and vice versa. This finding is indicative of a complex interplay of factors, encompassing supply and demand dynamics, information flow, seasonality, transportation costs, government policies, global market conditions, consumer preferences, and competition. A comprehensive understanding and analysis of these factors are essential for market participants and policymakers to make informed decisions within the agricultural sector.

The above Granger Causality results can be represented diagrammatically as follows:

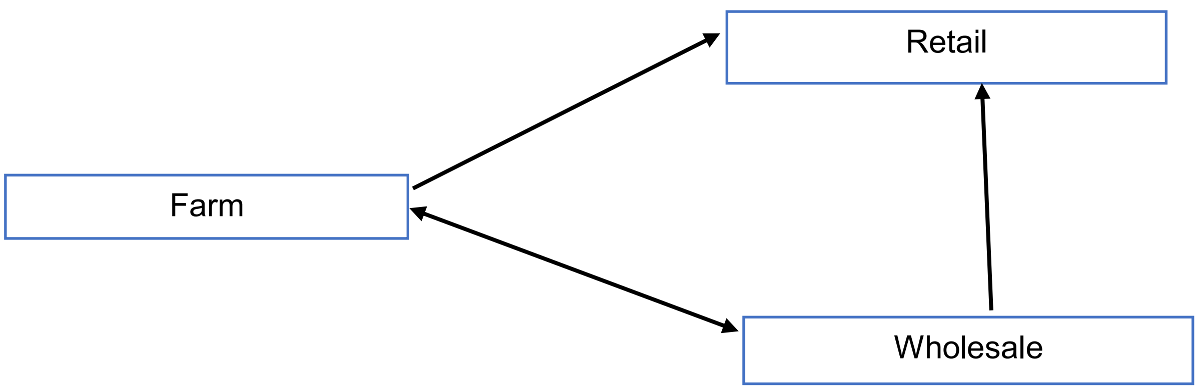

Figure 5. 8.: Causal effects in the price series

Source: Author’s computation (2023)

The above figure shows that there is a bidirectional causality between farmgate and wholesale prices. Meaning that, farmgate prices have affected prices at a wholesale level whereas wholesale price changes also affect the changes in farmgate prices. Furthermore, wholesale prices exert an influence on retail prices and not vice versa. Lastly, farmgate prices influence retail prices whereas retail prices do not affect farmgate prices.

5.4.5. Statistical stability test

In the context of employing a regression model with time series data, it is possible to encounter a structural change in the association between the dependent variable (retail prices in this study) and independent variable(s) (farmgate and wholesale prices). Structural change refers to a situation where the estimated parameter values (*betas*) do not remain constant across the entire duration of the investigation period, which spans from January 2011 to December 2021.

The hypotheses for this test are stated as follows:

H_0: There is a structural change in the price series (P_A, P_B and P_W are not stable)

H_1: There is no structural change in the price series (P_A, P_B and P_W are stable)

This study fails to reject the null hypothesis and detailed explanation is given below this illustration.

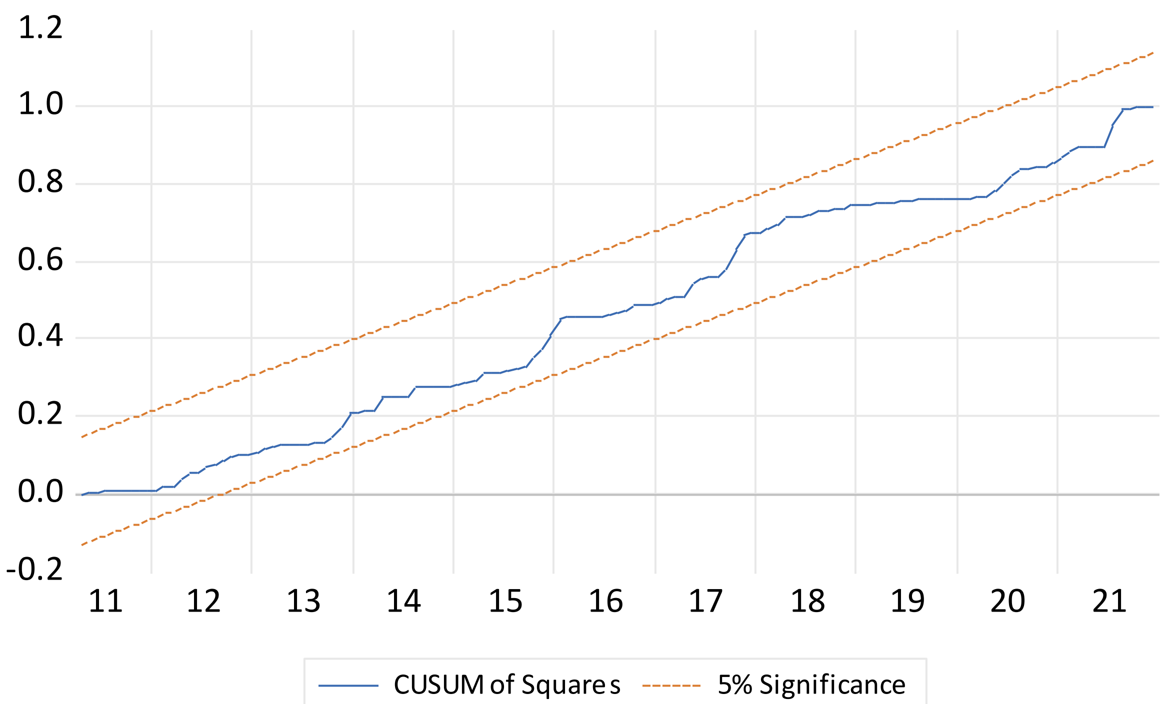

Figure 5. 9.: Stability test results

The graph has two red lines, which indicate the limits of the 5% significance level, which require the studied line (colored blue) to be within in order for stability to be inferred. The blue line as shown in the legend represents the cumulative sum of squares. Since the cumulative sum of squares does not lie outside the significance level (i.e., the blue line lies inside the red lines), the null hypothesis which states that the price series are stable cannot be rejected. Therefore, it can be inferred at a 95% confidence level (which goes with a 5% significance level), that the data series were stable throughout the entire period (2011-January to 2021-December).

5.4.6. Analysis of impulse response functions

This study employed the impulse response function to examine the reactions of retail prices (P_A) to changes in farmgate prices (P_B) and wholesale prices (P_W). The central line in the impulse response function represents the response of the variables, while the two lines flanking it depict the 95% confidence intervals (+2 and -2 S.E), corresponding to a 5% significance level. Figures 5.3 illustrates these responses. It is important to note that the X-axis in the graphs represents the months included in the study, while the Y-axis indicates the percentage variation, reflecting the response rate. A comprehensive explanation of the policy implications derived from the impulse response function is presented in subsection 5.9.1 to complement the VEC findings.

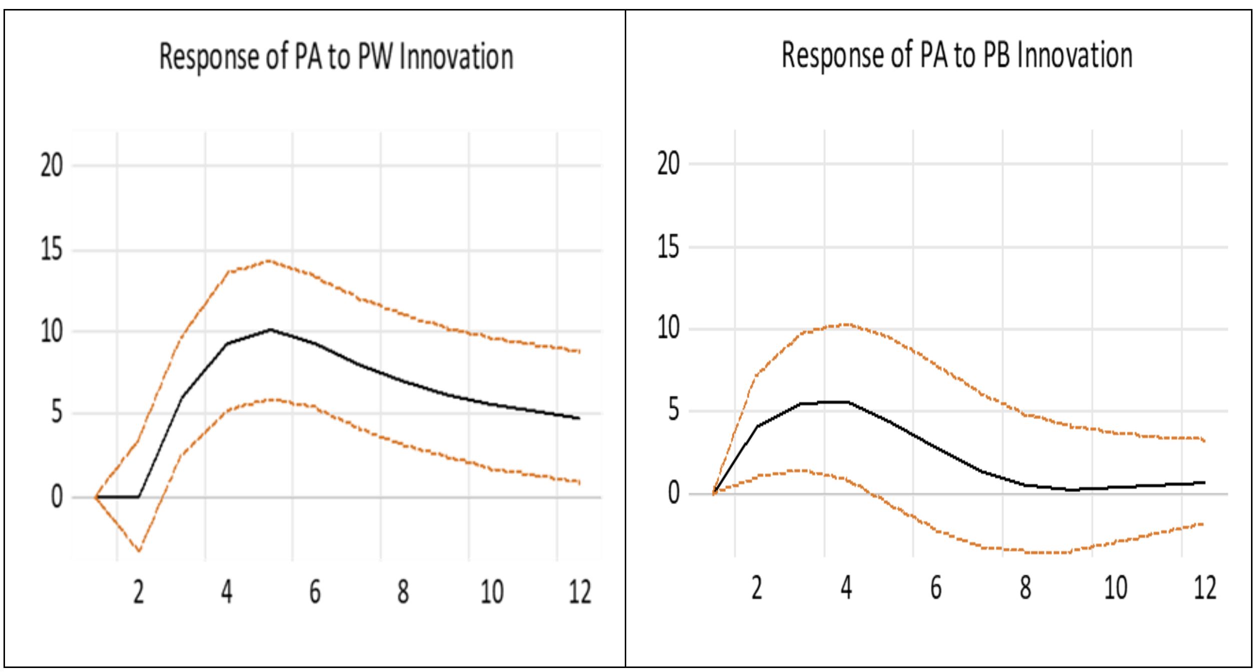

Figure 5. 10.: Impulse response functions

Impulse Response Function (IRF) is used graphically to depict the influence of a shock upon the VAR variables. An IRF shows the dynamic response path of a variable due to a one-period standard deviation shock to another variable. Figure 5.3 presents the accumulated impulse responses presented over 132 months' time horizon. All the shocks are standardized to twenty-percent shocks, and hence, the vertical axes report the approximate percent change in retail prices (P_A) in response to a one-percent shock from farmgate (P_B) and wholesale prices (P_W). As observed from Figure 5.3, the P_A did not respond to P_W shocks from period 1 (January) up to period 2 (February). From period 2 (February), P_A's response to P_W shocks accumulated positively at an increasing rate until late period 5 (late May), but starts to decline at a slow rate thereafter, until period 12 (December). The maximum accumulated response rate of P_A to shocks in P_W was approximately 14%. On the other hand, P_A's response to P_B shocks rapidly increased from period 1 (January) till period 2 (February) at a rate of approximately 4%. This increase continued at a slow rate from period 2 (February) till period 4 (April), wherein a peak response of 6% was reached. Thereafter, P_A's response sharply declined to P_B shocks till period 9 (September). Then the response of P_A to P_B shocks started picking up from late period 9 (September) till period 12 (December). Overall, the response of retail prices is much faster to shocks in both the farmgate and wholesale prices. The responses are all positive in each case as shown in the above graphs.

5.4.7. Variance decomposition

For further analysis of the effects of various shocks on P_A, the researcher conducted the variance decomposition analysis, which provides the information on the percentage contribution of various shocks to the 132-step-ahead forecast errors of respective variables. In this study, variance decomposition elucidates the proportion of forecasting error in retail prices (P_A) over the study period (2011-January to 2021-December) attributable to shocks in farmgate (P_B) and wholesale prices (P_W) in the South African garlic markets. In simpler terms, this analysis assists in gauging the extent to which the variability in retail prices is accountable to its "own shocks" compared to the "shocks in other variables in the system," specifically farmgate and wholesale prices. Similar to the impulse response functions, the Cholesky Decomposition method is applied for ease of identification. The outcomes are succinctly presented in the graph below:

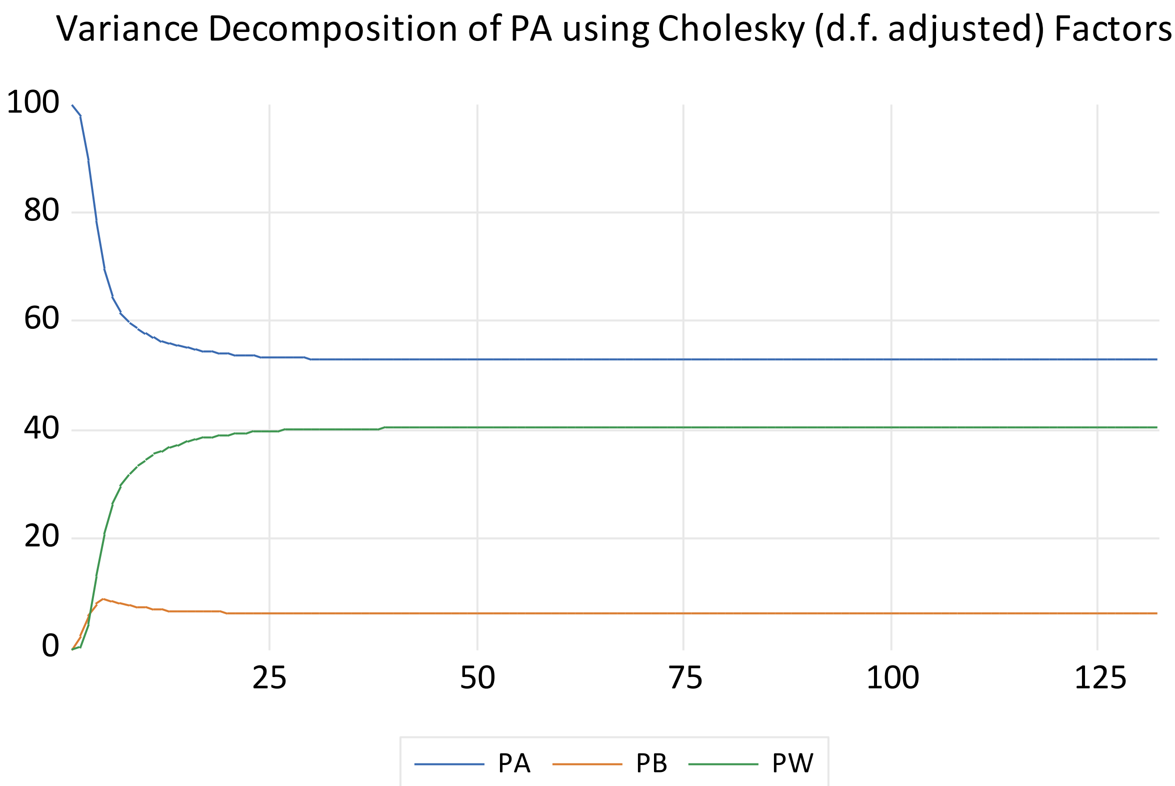

Figure 5. 11.: Impulse response functions

Note: X-axis represents periods (months) and Y-axis shows percentage variation (%)

Figure 5.11 is a graphical representation of the variance decomposition of retail prices (P_A). As observed from these results, both farmgate (P_B) and wholesale (P_W) shocks are important determinants in the P_A variance where P_B accounts for up to 9% in period 6 (6 months), and thereafter 6% till the last period, 132 (11 years). Interestingly, P_W, which precedes P_A in the value chain being investigated, is the most important determinant in the P_A variation compared to P_B as can be seen on the graph. P_W accounts for up to 40% after period 19 (a year and 7 months).

5.4.8. Cointegration Tests

The objective of the cointegration test is to determine the existence of a long-term relationship between the linear combination of farmgate prices (P_W) and wholesale prices

(P_W), farmgate prices and retail prices (P_A), and wholesale prices and retail prices. If producer and wholesale prices move together in the long run, price transmission is symmetrical. When prices do not move together, price transmission is asymmetrical and an in-depth analysis regarding the nature of price adjustments back to equilibrium position becomes imperative. In this study, the Engle & Granger (1987), Johansen (1988) and Gregory Hansen procedures were used to carry out the cointegration tests. Although the Johansen and Gregory & Hansen (1996) tests are seen as superior tests for cointegration, they both rely on sample sizes which are large enough and, in the case of this study, had to be abandoned owing to the data limitations not allowing for any results from which significant inferences and conclusions could be made. For the purpose of this study, the Engle and Granger procedure was thus used for cointegration analysis of the P_B and P_W in the test regression model, including both a constant and trend.

Immediately after ensuring that the series under investigation are integrated of the same order (are stationary), the progress should be made to performing co-integration tests in order to establish the existence of relationships between the variables in the long-run. We have established in through the stationarity tests that data series are integrated of first order, therefore, Engle and Granger residual-based test was used to determine if there is an existence of a linkage between farmgate, wholesale and retail prices of garlic in the long-run. This test postulates that if all variables in the models (i.e., dependent, retail price and independent, wholesale and farmgate prices) are stationary at first difference, spurious regression exists, and results cannot be relied upon. On the contrary, if the variables are integrated at levels, the results are acceptable. The results from Engle and Granger Two-step procedure are shown below:

Step 1: A regression model was run, and the results are summarized in Table 5.10 below:

H_0: Retailers do not respond promptly to changes in farmgate and wholesale prices in the South African garlic markets.

H_1: Retailers respond promptly to changes in farmgate and wholesale prices in the South African garlic markets.

Table 5. 10.: Estimated OLS model for P_A, P_B and P_W

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.587345	5.337664	1.796169	0.0748
PW	2.205426	0.288399	7.647135	0.0000
PB	-0.562353	0.308195	-1.824668	0.0704

R-squared	0.671612	Mean dependent var	89.30848
Adjusted R-squared	0.666521	S.D. dependent var	41.43140
S.E. of regression	23.92567	Akaike info criterion	9.210246
Sum squared resid	73844.46	Schwarz criterion	9.275764
Log likelihood	-604.8762	Hannan-Quinn criter.	9.236870
F-statistic	131.9139	Durbin-Watson stat	0.836309
Prob(F-statistic)	0.000000		

The null hypothesis stating that retailers do not respond promptly to changes in farmgate and wholesale prices in the South African garlic markets is rejected. Based on the above results, the coefficient of determination (R-squared is 0.6716) which implies that approximately 67.16% of the variation in retail prices in the South African garlic market is explained by the variation in wholesale and farm prices. This value (R-squared) is above 0.5 (50%), which means farmgate and wholesale prices predict more than 50% of the changes in retail prices in the garlic markets. Therefore, the above estimated short-run regression model is robust, and the results thereof, can be relied upon. Moreover, since R-squared is less than the Durbin-Watson statistics, accompanied by low t-tests which are also complemented by stationary residuals, there is no possibility of spurious regression. In other words, the results presented above are reliable and have an economic meaning. Just to give a clear interpretation of the short-run relationship between the variables under investigation (P_A against P_B and P_W), the coefficient of P_W (2.2054) is positive, which signifies a positive influence of wholesale prices on retail prices in the South African garlic markets. Simply put, when wholesale prices increase by R1.00, retail prices also increase by R2.21, and vice versa. Wholesale and retail prices are in a positive relationship. On the other hand, the coefficient of P_W (-0.5624) is negative, implying a negative relationship between farmgate and retail prices, that is, farmgate prices have a negative influence on retail prices. When farmgate prices decrease by R1, retail prices increase by R0.56.

The test progressed to steps 2 and 3, wherein the residual or error term of the estimated model was estimated and furthermore unit root test was applied on the error term.

A point of departure in this step was OLS model estimation for intercept and trend in order to check their significance. This was done in order to know exactly what to include in the test equation between "intercept", "intercept and trend" and "none". The findings are shown in the table that follows:

Table 5. 11.: OLS model estimation for intercept and trend

Variable	Coefficient	Std. Error	t-statistic	Prob
Intercept	-10.1430	3.9950	-2.5389	0.0123**
Trend	0.1549	0.0727	2.9373	0.0039*
R-squared	0.6224	**Mean dep. variable**	6.04E-15	
Adjusted R-squared	0.5502	**Standard dev. Dep. variable**	23.7423	
SE regression	3.0799	**Akaike Criterion**	9.1308	
Durbin Watson	2.0089	**Schwarz Criterion**	9.1486	

Note: * Significant at 1% and ** significant at 5%

Source: Author's computation (2023)

From the above table, it can be noted that both the intercept and trend are significant at 5% and 1% respectively. These results are reliable and can be depended upon since the coefficient of determination is above 50% and DW statistics are also highly significant since it is closer to 2. Therefore, when running a unit root test for residual (error term), intercept and trend must be included. The results for unit root tests using both ADF and PP respectively are shown below:

Table 5. 12.: ADF results for error term.

Null Hypothesis: ERROR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on AIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.148459	0.0000
Test critical values:	1% level	-4.030157	
	5% level	-3.444756	
	10% level	-3.147221	

*MacKinnon (1996) one-sided p-values.

Table 5. 13.: PP results for error term

Null Hypothesis: ERROR has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.761932	0.0000
Test critical values:	1% level	-4.029595	
	5% level	-3.444487	
	10% level	-3.147063	

The above results from two different tests (ADF and PP) show the same revelation that the variables in the model are integrated at levels. Since the P-values from both tests are less than 0.05, the null hypothesis stating that the error term has a unit root was rejected. This implies that, the error term is stationary at levels, implying co-integrated between the variables under investigation, which is also a validation that the regression equation estimated earlier was not spurious and the results can be interpreted.

5.4.9. Tests for price asymmetry

Now that the point of price determination and the direction of causality along the primary marketing channel for garlic in South Africa have been estimated, the subsequent focus is on examining price asymmetry. This section aims to determine whether fluctuations in prices at the farm level are transmitted symmetrically to the wholesale and retail stages in the garlic marketing channel in South Africa. The initial step toward this objective involved conducting the Johansen cointegration test, the results of which are detailed in Table 5.8.

Initially, we were able to establish using the ADF and PP that the price series are stationary at levels, specifically level one (that is, integrated of order one). This then allows us to run cointegration test. Performing cointegration test is crucial in the determination of long-run relationships between variables. In other words, we can postulate long-run relation in the model even though the series are drifting apart, or trending either upwards or downwards. The null hypothesis (H_0) of the cointegration test states that there is no cointegration equation whereas the alternative hypothesis (H_1) states that there is a cointegration equation.

Table 5. 14.: Johansen's cointegration test outcomes for P_A, P_B, and P_W.

Series	Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical values	Prob*	Max-Eigen Statistic	0.05 Critical values	Prob*
P_A, P_B and P_W	None *	58.51652	29.79707	0.0000	31.78716	21.13162	0.0011
	At most 1	15.49471	26.72936	0.06711	14.26460	23.45007	0.0711
	At most 2	3.279290	3.841465	0.07021	3.279290	3.841465	0.1702
*Denotes rejection of the hypothesis at the 0.05 level **Mackinnan-Haug-Michelis P values (as reported by EViews) Trace test indicates r co-integrating model (s) at 5% significance level							

Source: Author's Computation, 2023

The Johansen Cointegration test was executed to validate the outcomes derived from the Engle and Granger Two-step procedure for cointegration. As indicated in Table 4.9, the variables P_A, P_B, and P_W exhibit co-integration. The co-integration analysis identified a single co-integrating equation in the examined relationship. The null hypothesis of no co-integration between P_A, P_B, and P_W is rejected, substantiated by the significance of p-values at the 1% level. Consequently, a long-term co-integration relationship is established among the variables, aligning with the findings obtained through the Engle and Granger procedure. This sets the stage for the analysis of price transmission using the VEC model. Since series are cointegrated, that is, they exhibit a long-run relationship, an implication is that they are related and can thus be combined in a linear fashion. Secondly, it means that even if there are shocks in the short-run, which may affect movement in the individual series, they would converge with time (in the long-run). Hence, both the short-run and long-run models must be estimated. Appropriate estimation techniques are the vector autoregressive (VAR) and vector error correction (VEC) models.

5.5. Empirical Results of the Error Correction Model

H_0: There is no price transmission in the South African garlic markets.

H_1: There is price transmission in the South African garlic markets.

Table 5. 15.: Error Correction Model Estimates

Farm to retail price transmission		**Wholesale to retail price transmission**		**Farm to wholesale price transmission**	
Dependent variable: ΔP_A		Dependent variable: ΔP_A		Dependent variable: ΔP_W	
Variables	Coefficient	Variables	Coefficient	Variables	Coefficient
Intercept	0.4601 (0.8048)	Intercept	0.3201 (0.0860)	Intercept	3.9732 (0.086) ***

ΔP_{Bt-1}	-0.6734 (0.0017) *	ΔP_{Wt-1}	0.1210 (0.0213)	ΔP_{Bt-1}	0.8874 (0.0215) **
ΔP_{Bt-2}	-0.3284 (0.0003) *	ΔP_{Wt-2}	-0.2360 (0.0019)	ΔP_{Bt-1}	0.2210 (0.0000) *
ΔP_{At-1}	0.5487 (0.0258) **	ΔP_{At-1}	-0.1049 (0.0159))	ΔP_{Wt-1}	0.3943 (0.2151)
ΔP_{At-2}	-0.0115 (0.9660)	ΔP_{At-2}	0.2507 (0.0047)	ΔP_{Wt-2}	-0.5701 (0.6927)
ECT^{+}	-0.6301 (0.0574) ***	ECT^{+}	-0.4471 (0.0007) *	ECT^{+}	-0.1319 (0.0731) ***
ECT^{-}	-0.1140 (0.001) *	ECT^{-}	-0.2018 (0.000) *	ECT^{-}	-0.0198 (0.0015) *
R-squared= 0.7447 Durbin-Watson stat.= 1.9379		R-squared= 0.7596 Durbin-Watson stat.= 1.9237		R-squared= 0.8929 Durbin-Watson stat.= 2.0108	

Figures in brackets represent probability values.

Note: * significant at 1%, ** significant at 5% and *** significant at 10%

On the basis of the above table, this study confidently rejects the null hypothesis (H_0) stating that there is no price transmission in the South African garlic markets. The outcomes presented in Table 5.15 indicate that garlic prices exhibit asymmetric transmission across all three levels of the marketing chain under examination. In the context of farm-to-retail price transmission, the coefficient for the positive Error Correction Term (ECT^{+}) is not only significant but also higher than the coefficient for the negative Error Correction Term (ECT^{-}). This implies that retail prices for garlic respond more promptly to positive shocks in farmgate prices than they do to negative shocks. Specifically, the retail price adjusts by 63.01% per month toward equilibrium when there are positive price shocks at the producer level, whereas it adjusts by 11.40% when there are negative price shocks. This finding aligns with the results of previous studies by Kinnucan & Forker (1987) and Bor *et al.* (2014). Kinnucan and Forker discovered price asymmetry in the USA milk markets, indicating that retail prices respond more fully and rapidly to producer price increases than to farm price decreases. Similarly, Bor *et al.* (2014) observed that retail milk prices in Turkey adjust more quickly to input price increases than they do to input price decreases. Other studies suggest that retailers might reduce their prices more slowly than the reduction in farmgate prices to avoid stockouts (Reagan and Weitzman, 1982; Balke *et al.*, 1998; Meyer and von Cramon-Taubadel, 2002; Uchezuba, 2010). However, Ward (1982) and Heien (1980) propose alternative factors such as perishability and menu costs that can also contribute to Granger Causality.

Conversely, the findings pertaining to wholesale-to-retail transmission reveal that declines in wholesale prices are transmitted more swiftly and completely to the retail level than increases in wholesale prices. As depicted in Table 5.15, the retail price adjusts by 44.71% per month toward equilibrium in response to positive shocks in wholesale prices, while the rate at which wholesale prices adjust to equilibrium in response to positive farmgate shocks is 13.19%. This indicates the presence of positive asymmetry between wholesale and retail prices. The existence of negative price asymmetry is not unexpected for agricultural commodities like garlic, which is perishable in nature. According to Ward (1982), retailers of non-perishable products may not hesitate to raise prices as upstream prices increase because they know that their products have a long shelf life. Another crucial aspect is the fact that wholesalers precede retailers in the garlic marketing chain. As a result, retailers consistently react to changes in wholesale prices, and in some cases, wholesalers also respond to pricing decisions made at the retail level. This competition between wholesalers and retailers for consumers is influenced by the perishable nature of garlic. Retailers have the advantage of selling garlic in small quantities, which is more convenient for consumers, while wholesalers sell in bulk, and consumers may not always want to purchase larger quantities of garlic.

In the context of farm-to-wholesale price transmission, both the negative and positive Error Correction Terms are statistically significant. This indicates that wholesale garlic prices respond to positive price shocks at the farm level in the short run and are also responsive to negative price shocks at the farm level. This suggests that marketing intermediaries act swiftly in passing wholesale price reductions to the producer to expand their own margins and also transfer wholesale price changes to the producer. These findings align with the results of von Cramon-Taubadel (1998), which reveal that wholesale prices react more rapidly when the margin is squeezed than when it is stretched. Cutts and Kirsten (2006) propose that food value chains are generally less concentrated at the farm level compared to downstream, implying that downstream intermediaries, often structured in an oligopolistic manner, may be better positioned than producers to opportunistically respond to various price shocks. The results in Table 5.15 seem to support this argument, indicating that marketing intermediaries such as wholesalers and retailers have leverage to increase their own margins when involved with producers. For instance, in the case of farm-to-retail price transmission, retail prices are more responsive to positive farmgate price shocks and less responsive to reductions in farmgate price, which represents a margin-stretching action on the part of the retailer. On the other hand, wholesale price increases are partially transferred to the producer price, while the reduction in wholesale price is rapidly and fully transferred to the producer, reflecting a wholesale-margin-stretching and a farmers-share-squeezing phenomenon.

Conclusively, the above results are reliable and there is no evidence of spurious regression since the R-squared value in each of those three scenarios is high (above 0.5), but less than the Durbin-Watson statistics. According to Stock and Watson (2001), the Durbin-Watson statistics measure autocorrelation in the model, and values close to 2 suggest no significant autocorrelation in the model, which is the case in this study since the Durbin-Watson statistics in all the cases of this study (1.9379, 1.9237 and 2.0108) are very close to 2. Therefore, the presented results have an economic meaning, thus the interpretations made thereof can be relied upon as they give a real sense of what is transpiring in the South African garlic as one of the agricultural markets for non-perishable commodities.

5.6. Diagnostic tests

To validate the accuracy of the results obtained in this study, diagnostic tests were conducted, including normality, serial correlation and heteroskedasticity tests, as depicted in Tables 5.16, 5.17, and 5.18, including Figure 5.5. The heteroskedasticity test aimed to assess the variance of errors between the variables, while the serial correlation test was conducted to investigate the presence of error term correlation across different periods of the time series. Additionally, a stability test was performed to ascertain the stability of the observed dataset used in this study, ensuring its reliability as a foundation for decision-making and policy recommendations. The methods employed in these diagnostic tests are outlined in the table below:

Table 5. 16.: Diagnostic test methods

Test	**Method**
Normality	Jarque-Bera Statistic
Serial Correlation	Breusch-Godfrey test
Heteroscedasticity	Breusch-Pagan-Godfrey test

Source: Author’s computation (2023)

5.6.1. Serial correlation

The null and alternative hypotheses were stated as follows to produce the results in Table 5.17.

H_0: There is an absence of serial correlation.

H_1: There is a presence of serial correlation.

Table 5. 17.: Serial correlation results between P_A, P_B and P_W

P_W, P_B and P_W			
F-statistics	0.009364	Prob. F stats	0.8562
Obs* R-squared	0.003981	Prob. Chi-square	0.8391

Source: Author’s compilation (2023)

The study conducted a serial correlation test on P_A, P_B, and P_W using the Breusch-Godfrey test in eViews. The results presented in Table 5.17 indicate that the probability values of the F-statistics and the Chi-square are both insignificant, surpassing the significance level of 0.05. Therefore, the study does not reject the null hypothesis, suggesting the absence of serial correlation. This implies that there is no evidence of serial correlation between P_A, P_B, and P_W. According to Bergmeir *et al.* (2017), ensuring the absence of serial correlation is essential for maintaining the statistical validity, precision, and reliability of data analysis and modeling, particularly in the context of time series data and regression analysis. Failure to account for serial correlation can lead to biased estimates and incorrect conclusions, which can have practical and economic consequences as far as policy recommendations are concerned.

5.6.2 Heteroskedasticity test: ARCH

The null and alternative hypotheses were stated as follows to produce the results in Table 5.18.

H_0: Heteroskedasticity does not exist.

H_1: Heteroskedasticity exists.

Table 5. 18.: Heteroskedasticity results between P_A, P_B and P_W

P_A, P_B and P_W			
F-statistics	1.1352	Prob. F (2.129)	0.3245
Obs* R-squared	2.2830	Prob. Chi-square (2)	0.3193
Scaled explained SS	1.8867	Prob. Chi-square (2)	0.3893

Source: Author’s compilation (2023)

Using the Autoregressive Conditional Heteroskedasticity approach to test for heteroskedasticity, the results in Table 5.18 indicate that the null hypothesis cannot be rejected. The probability values for F-statistics (0.3245) and Chi-squared (0.3193), as well as the probability values for the scaled explained sum of squares for retail prices (P_A), farmgate prices (P_B), and wholesale prices (P_W), are all greater than the default probability of 0.05 (5% significance level). This suggests that there is no evidence of heteroskedasticity. This result is favorable, indicating that the variance (or spread) of the price series used in this study is approximately constant across different levels or groups. In other words, there is no systematic pattern of change in the variability of the price series in the movement along the predictor prices, wholesale, and retail. The findings align with Youness *et al.* (2021), who also found no evidence of serial correlation and heteroskedasticity, supporting the validity of the model.

5.6.3 Normality test

The null and alternative hypotheses were stated as follows to produce the results in figure 5.5. (StataCorp, 2011; Gujarati & Porter, 2009).

H_0: Random error term is normally distributed.

H_1: Random error term is not normally distributed.

Normality test results are presented in the table below:

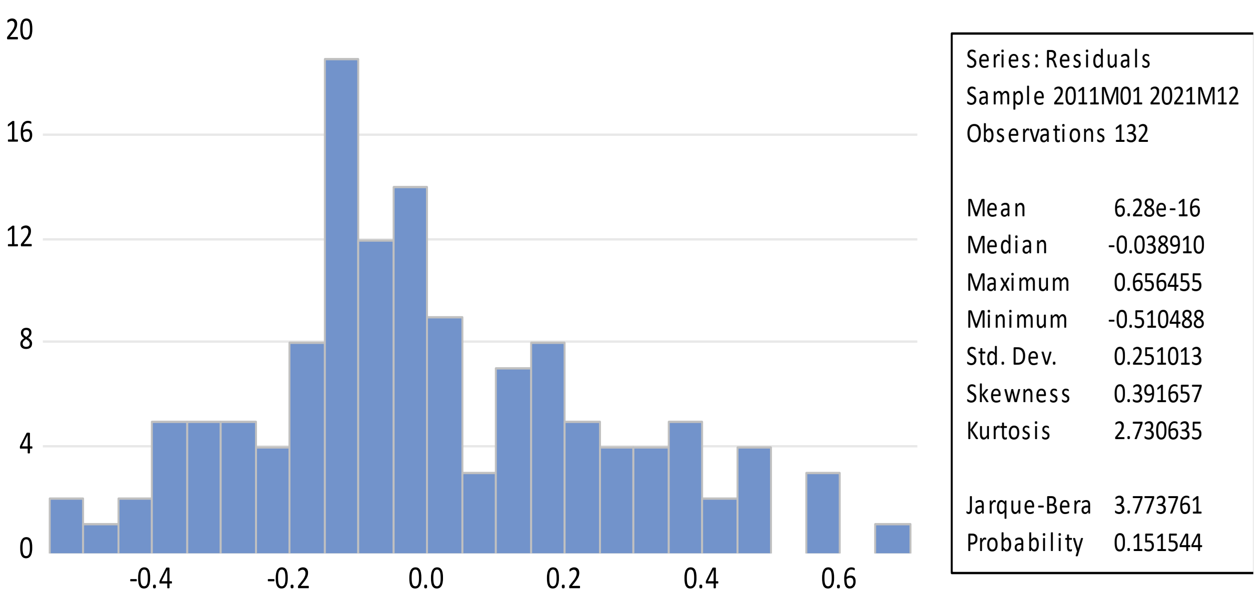

Figure 5. 12.: Normality test results

To test for normality in the price series, the Jarque-Bera statistic was employed. The Jarque-Bera probability, observed to be 0.1515, is above the significance level of 0.05. This implies that the null hypothesis, asserting that the error term of the model is normally distributed, cannot be rejected. The mean and median values, being very close to each other, further support the indication that the data used in this study follows a normal distribution. Additionally, the skewness value of 0.3917, close to 0, and the visual representation of the data through the graph above contribute to the validation of the normal distribution assumption. Hatem *et al.* (2020) argued that a kurtosis value of 3 indicates that the data set is neither heavy-tailed (*leptokurtic*) nor light-tailed (*platykurtic*), thus is normally distributed. In the context of this study, the kurtosis is 2.73 which is very close to 3, further validating normality in this study.

5.7. Forecasting results

5.7.1. Estimated trendline.

The calculation of the trendline using regression for this study is illustrated in appendices 1, 2, 3, 4, 5, 6, 7, 8 and 9. Here follows a summary of the forecasted results for each series:

i) For retail prices

Table 5. 19.: Descriptive statistics for forecasted retail garlic prices.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
Time (x)	0.8608	0.0577	14.9255	0.0000
Constant	32.0669	4.4201	7.2547	0.0000
R-squared	0.6315			
Adjusted R-squared	0.6287			

Durbin-Watson Statistic	0.8144

Source: Author's computation (2023)

From the above results, the trend equation is estimated as follows:

$$T = 32.0669 + 0.8606Time \quad (31)$$

T denotes the trend in retail prices.

The results presented in the above table and equation indicate that time has a positive influence on determination of retail prices in garlic markets. This is reflected by the coefficient of time (0.8608) which is positive and significant at 1% level (probability value is 0.0000). If the time under consideration increases by 1 unit, retail prices also increase by R0.86. The coefficient of determination is 0.6315 (63.15%) which indicates that 63.15% response in retail prices is predicted by every unit change in time whereas the remaining 36.85% cannot be accounted for, however, is captured by the random error term. The following graph further demonstrates the above results.

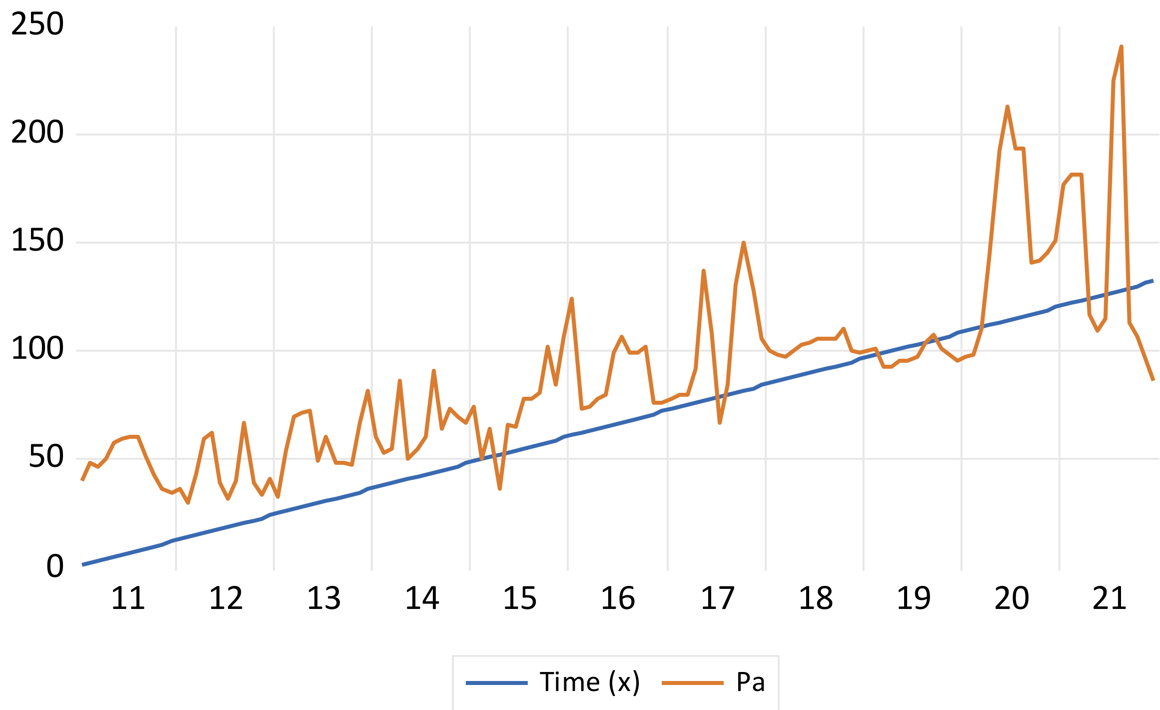

Figure 5. 13.: Trend analysis for forecasted retail garlic prices.

From the above table, retail prices are highly responsive to the change in time. The trend that can also be noted from this graph is that retailers increase their prices exponentially compared to the change in time. The graph also indicates that there have been severe fluctuations of retail prices from 2011 to 2021, with higher prices recorded in 2021 followed by 2020. Irregular price fluctuations can be seen between 2019 and 2021, and these findings could be attributed by the conception and repeated resurgence of COVID-19 between 2019 and 2021. Prices then tend to decline towards the end of 2021. This could possibly be because of the slow rate of COVID-19 infections.

ii) For wholesale prices

Table 5. 20.: Descriptive statistics for forecasted wholesale garlic prices.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
Time (x)	0.2730	0.0347	7.8612	0.0000
Constant	18.8980	2.6616	7.1002	0.0000

R-squared	0.7222
Adjusted R-squared	0.7170
Durbin-Watson Statistic	1.7243

Source: Author's computation (2023)

$$T = 18.8980 + 0.2730Time \quad (32)$$

Similarly, time has a positive influence on wholesale prices. 72,22% of the variation in wholesale prices is explained by the variation in time. When time increases by 1 unit, wholesale prices also increase by R0.27. The Durbin-Watson statistic is close to two and more than R-squared, signifying the absence of serial correlation which is good. The affirmation of these results is also visually illustrated in the below graph:

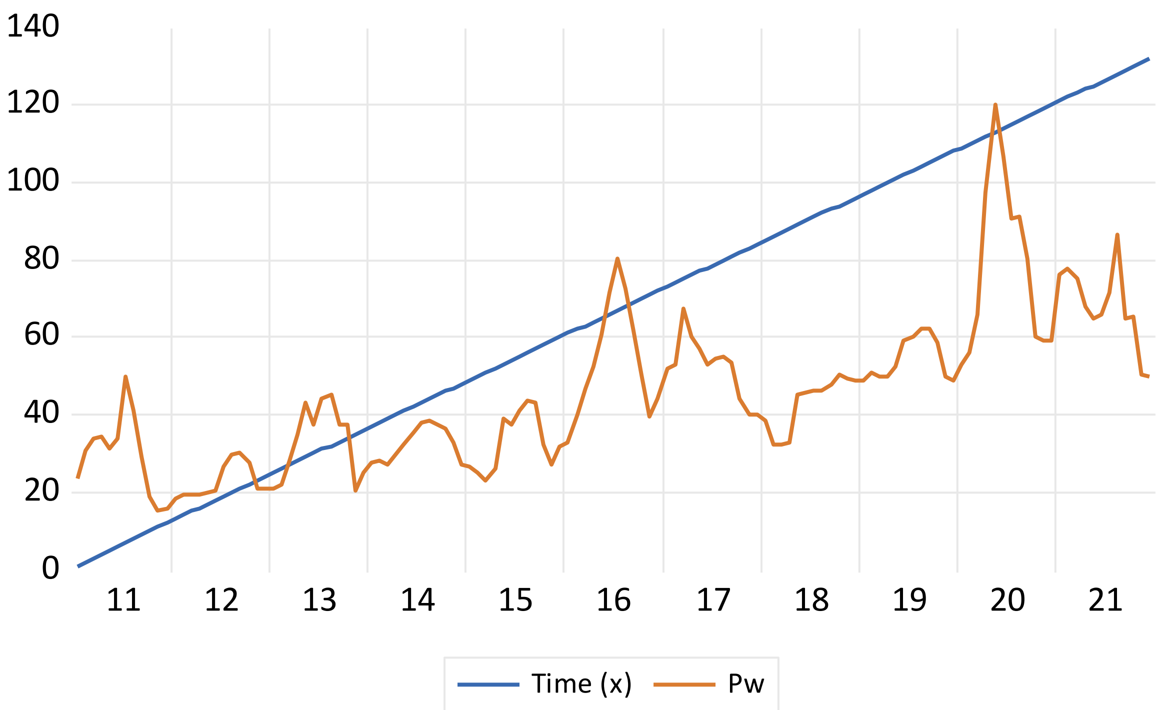

Figure 5. 14.: Trend analysis for forecasted wholesale garlic prices.

The graph visualizes the positive relationship between time and wholesale prices from 2011 to 2021. Interestingly, wholesale prices do not respond the same way as retail prices in the period 2019 to 2021. This further justifies Granger Causality that was established in this study, between wholesalers and retailers. These two graphs prove that there is an immediate response to wholesale price hikes at retail level than there is when wholesale prices drop.

iii) For farmgate prices

Table 5. 21.: Descriptive statistics for forecasted farmgate garlic prices.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
Time (x)	1.4753	0.1113	13.2596	0.0000
Constant	-0.7665	5.5212	-0.1388	0.8898
R-squared	0.8749			
Adjusted R-squared	0.8716			
Durbin-Watson Statistic	1.9331			

Source: Author’s computation (2023)

$$T = -0.7665 + 1.4753Time \tag{33}$$

A unit change in time results in a R1.48 change in farmgate price in the same direction. This is explained by the positive coefficient of time (1.4753), which reflects a positive relationship between changes in time and changes in farmgate prices. Interestingly, 87.49% of the change in farmgate price is predicted by every change in time. The following graph visualizes this relationship:

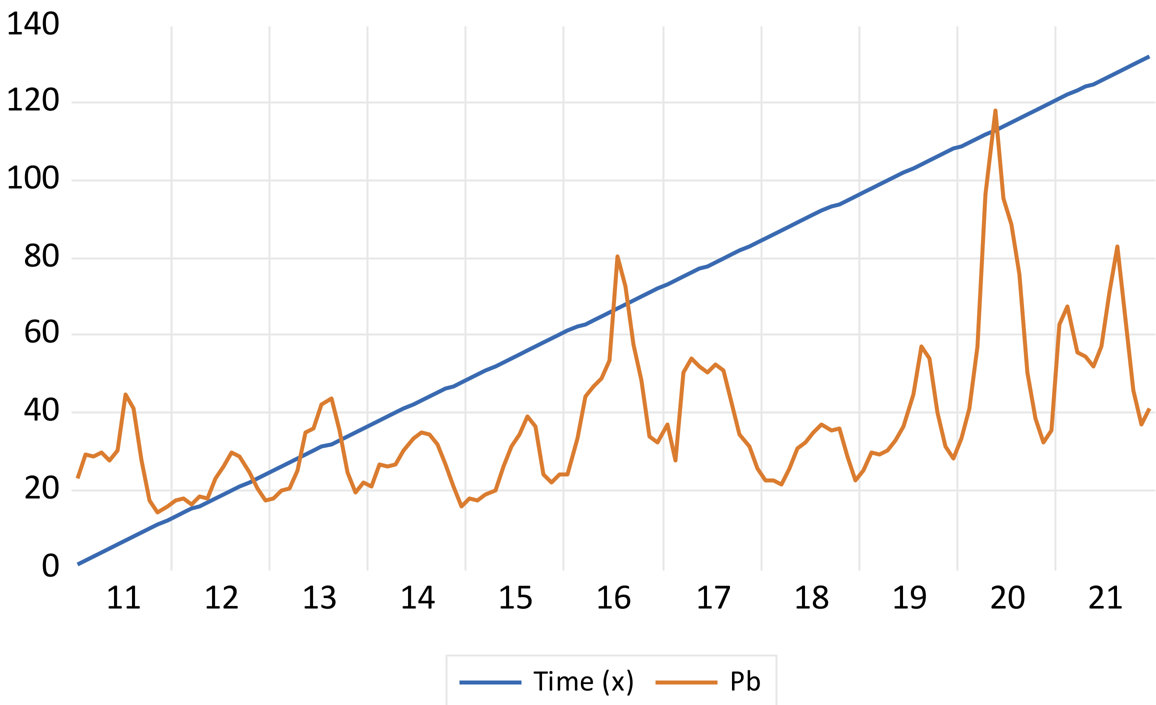

Figure 5. 15.: Trend analysis for forecasted farmgate garlic prices.

Farmgate prices have been fluctuating between 2011 and 2021, with the peak price recorded in 2020, during COVID-19. Perhaps this price hike was influenced by higher demand for garlic both domestically and abroad. As economic theory suggests, *ceteris paribus*, higher demand in the market raises prices. The sensitivity of farmgate price to time is inconsistent with the response of retailers to the change in time. This further justifies the asymmetric transmission of prices between farmers and retailers that was established in this study.

Econometricians argue that the numerical coding scheme used to code time (x) must always be shown together with the trend line, otherwise the trend line coefficients are meaningless. They are determined by the choice of x-values. It also assists in determining the appropriate values of x to substitute into the trend line when trend projections are performed. All these can be seen from our graphs and also on the appendices attached at the end of this project.

An interesting inference that can be drawn from these results is that the regression trend line is 'free' of cyclical, seasonal and irregular influences. The 'other' influences have been removed by trend analysis, leaving only the long-term trend influence. Dagum & Bianconcini (2016) submit that the 'strength' of the trend influence (i.e., growth/decline) can be gauged by the magnitude of the slope coefficient, b_1. A strong (upward/downward) trend is shown by a large positive/negative value of b_1, while values of b_1 close to zero indicate no strong upward/downward pressure on the values of the time series due to trend forces.

5.7.2. Seasonal Analysis

To avoid congesting results and for ease of reference, appendices detailing the seasonal ratios and adjusted prices are attached at the end of this project.

The adjustment factors computed for farmgate, wholesale and retail were found to be 0.4261, 0.4218 and 0.4205, respectively. Each median seasonal index was then multiplied by the adjustment factor to ensure a base of 100 for each index. These adjusted seasonal indices are an (average) measure of the seasonal influences on the actual price series for each given time period (month) within a year.

Each (adjusted) seasonal index measures the average magnitude of the seasonal influence on the actual values of the time series for a given period within the year. By subtracting the base index of 100 (which represents the trend/cyclical component) from each seasonal index, the extent of the influence of seasonal forces was gauged.

Interpretation of seasonal indices for each month of each price series under investigation

Table 5. 22.: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for retail price series.

Month	**Median Seasonal Index**	**Adjustment Factor**	**Adjusted Seasonal Index**
Jan	99.9748	0.4205	42.0394

Feb	94.22526	0.4205	39.62172
Mar	95.88657	0.4205	40.3203
Apr	96.47108	0.4205	40.56609
May	104.9493	0.4205	44.13117
Jun	100.0031	0.4205	42.0513
Jul	103.6307	0.4205	43.57673
Aug	99.69114	0.4205	41.92013
Sep	100.3716	0.4205	42.20626
Oct	99.63983	0.4205	41.89855
Nov	96.76047	0.4205	40.68778
Dec	97.38171	0.4205	40.94901
		Total	499.9684

Source: Author's Computation (2023)

Examining the adjusted seasonal indices for each month allows for a comparison of the impact of the adjustment factor on individual months. From the above Table 5.23, it can be noted that May and July appear to have relatively higher adjusted indices compared to other months, suggesting that the seasonal variation in retail prices for these months is more pronounced after the adjustment. It is also worth noting that the median seasonal indices before adjustment vary from 94.22526 in February to 104.9493 in May. These variations could represent inherent seasonal patterns in retail prices before the application of the adjustment factor. Interestingly, the sum of all adjusted seasonal indices for retail is 499.9684, which is approximately 500 (recall the rule of thumb mentioned in step 4, i.e., k x 100).

Table 5. 23.: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for wholesale price series.

Month	**Median Seasonal index**	**Adjustment Factor**	**Adjusted Seasonal Index**
Jan	100.2943	0.4218	42.30414

Feb	98.11353	0.4218	41.38429
Mar	98.65311	0.4218	41.61188
Apr	97.10975	0.4218	40.96089
May	97.44398	0.4218	41.10187
Jun	99.39083	0.4218	41.92305
Jul	101.7905	0.4218	42.93525
Aug	107.8681	0.4218	45.49878
Sep	102.3616	0.4218	43.17611
Oct	102.9546	0.4218	43.42627
Nov	87.1079	0.4218	36.74211
Dec	92.33245	0.4218	38.94583
		Total	500.0105

Source: Author's Computation (2023)

Based on the adjusted seasonal indices for each month presented in Table 5.24, there is variation in the impact of the adjustment factor. This adjustment factor of 0.4218 indicates a consistent level of adjustment applied to all months in the wholesale price series, reflecting a uniform approach to handling seasonality throughout the year. August appears to have the highest adjusted index (45.49878), suggesting a relatively higher level of seasonal variation compared to other months after the adjustment. The total of the adjusted seasonal indices (500.0105) provides an aggregated measure of the adjusted seasonal variation across all months in the wholesale price series, and it is also good that it qualifies the rule of thumb mentioned earlier in step 4. The median seasonal indices before adjustment vary from 87.1079 in November to 107.8681 in August, indicating inherent seasonal patterns in wholesale prices before the application of the adjustment factor.

Table 5. 24.: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for farmgate price series.

Month	Median Season Index	Adjustment Factor	Adjusted Seasonal Index
Jan	92.6971	0.4261	39.49823
Feb	98.20216	0.4261	41.84394
Mar	94.7963	0.4261	40.3927
Apr	96.64435	0.4261	41.18016
May	99.46237	0.4261	42.38091
Jun	99.19718	0.4261	42.26792
Jul	105.4881	0.4261	44.94849
Aug	115.9717	0.4261	49.41555
Sep	106.3966	0.4261	45.33557
Oct	92.59962	0.4261	39.4567
Nov	84.34424	0.4261	35.93908
Dec	87.57511	0.4261	37.31575
		Total	499.975

Source: Author’s Computation (2023)

Similar to the previous two cases, that is, retail and wholesale index analyses, the total of the adjusted seasonal indices (499.975) is close to 500, which qualifies the rule of thumb, and it also provides an aggregated measure of the adjusted seasonal variation across all months in the farmgate price series. The median seasonal indices before adjustment vary from 84.34424 in November to 115.9717 in August, indicating inherent seasonal patterns in farmgate prices before the application of the adjustment factor.

Summary of the above presented results

The adjusted seasonal indices for all the three price series (farmgate, wholesale and retail) are below 100. This means that, in every month of each year, the seasonal index prices at farmgate, wholesale and retail levels in the marketing chain of garlic in South Africa are depressed by the presence of seasonal forces. For example, an adjusted seasonal index of farmgate prices for August is 49.41555, which means that farmgate prices in August are depressed by the presence of seasonal forces of approximately 51%. Which means that, had seasonal influences not been present, farmgate prices would be 102.37% higher $\left(\frac{50.58445}{49.41555} \times 100\right)$.

The most interesting and puzzling questions one might ask are: "Why is it that none of those indices is above 100? What could be the implication of an index that is higher than 100? How would we interpret an index of close to 100?". In response to the first question of why in the cases of this study an adjusted index of above 100 was not identified, the adjustment factors together with the nature of the prices in each series significantly influenced the indices. It can also be noted that the calculated adjustment factors (farmgate= 0.5261, wholesale= 0.4218 and retail= 0.4205) are less than half, whereas most of the median indices are also not far from 100. Responding to the second question of the implication of an adjusted seasonal index which is greater than 100: An index of more than 100, would suggest that prices are stimulated by the presence of seasonal forces to the extent of approximately a certain proportion. For instance, an adjusted seasonal index of 125.77 for a farmgate price series in January would mean that, on average, every year in January, farmgate prices are stimulated by the presence of seasonal forces to the extent of approximately 26% (i.e., 125 – 100 = 25.77, rounded off to the next whole number integer, it is approximately 26%). Said in a different way, farmgate prices would be about 26% lower, had seasonal influences not been present. Lastly, an interpretation of an index that is close to 100, say for instance, 100.5 adjusted seasonal index for wholesale prices in July would be as follows: Since the index is close to its base of 100, which captures only trend and cyclical variations, seasonal influences are negligible. Seasonal influences account for about 0.5%, which is less than 1% of wholesale prices, average in that particular month (July, in this example).

The adjusted seasonal indices presented for the three cases were further used in the next section to de-seasonalize the farmgate, wholesale and retail price series, so as to facilitate the identification of underlying trends and making more accurate comparisons across different periods.

Why does this study use time series indicators?

Wegner (1993) posits that time series indicators are important planning aids to policymakers, farmers, and other prominent stakeholders in various agricultural markets in two ways. They can be used: to de-seasonalize a time series (i.e., removal of seasonal influences), and so provide a clearer vision of the longer-term trend/cyclical movements emerges. Secondly, time series indicators are used to produce seasonally adjusted trend projections of future values of a time series.

Interpretation of De-seasonalized Time Series Values

The values of a de-seasonalized time series show a time series without the influence of (short-term) seasonal forces, allowing attention to be focused on the long-term trend/ cyclical movements of the time series. If the seasonal index was less than 100 (showing that seasonal forces dampen (or reduce) the level of activity of the time series), the de-seasonalized prices will be inflated (higher) when seasonal influences are removed. Conversely, if the seasonal index was more than 100 (showing that seasonal forces stimulated (or raised) the level of activity of the time series), the de-seasonalized prices will be depressed (lower) when seasonal influences are removed.

Table 5. 25.: De-seasonalized farmgate, wholesale and retail garlic prices

	De-seasonalized prices					
	Farmgate Price		Wholesale Price		Retail Price	
	Actual	Forecasted	Actual	Forecasted	Actual	Forecasted
Mean	37.0523	88.0123	45.5955	109.162	89.3085	214.194
Median	32.3800	77.5440	43.9550	102.898	84.3950	204.570
Maximum	118.080	278.616	120.230	292.517	239.960	572.422
Minimum	14.1900	39.4834	15.0900	41.0570	30.4000	73.8927
Std. Dev.	18.3956	40.8707	19.6583	46.1786	41.4314	98.3828
Skewness	1.65076	1.76793	0.96166	0.97667	1.23324	1.18451
Kurtosis	6.32135	7.24720	4.20782	32.0984	4.85245	4.66849

Jarque-Bera	120.623	167.976	28.3689	14409.4	52.3328	46.1786
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sum	4890.90	11617.6	6018.61	14409.4	11788.7	28273.6
Sum Sq. Dev.	44330.2	218824.1	50624.6	279352	224870	126797.1
Observations	132		132		132	

The above table summarizes descriptive measures of the forecasted farmgate, wholesale and retail prices in the South African garlic market. This is an adjusted version of Table 5.26. presented at the beginning of this chapter. This was done in order to enable a comparison between the initial (unadjusted) and the forecasted (adjusted) prices. The average forecasted prices of farmgate, wholesale and retail garlic prices are R88.01, R109.16 and R214.19, respectively. The median prices, which relate specifically to the farmgate, wholesale and retail prices that separate half of the lower prices and half of the higher prices are, R77.54, R102.90 and R204.57 in their respective manner. It can also be noted that the maximum estimated prices in the value chain order are R278.62, R292.52 and R572.42 whereas minimum prices are predicted to be R39.48, R41.06 and R73.89. The expected aggregate of farmgate, wholesale and retail garlic prices within a period of 11 years in future are forecasted to be R11 617.60, R14 409.40 and R126 797.10. The trend that can be noted between the actual and forecasted prices is that forecasted prices are higher than the actual ones. Detailed trends are found in Figures 5.6, 5.7, and 5.8. These estimations are reasonable since they conform with the economic theories, particularly the time value of money. The concept of time value of money is a fundamental principle in finance that recognizes the idea that money has different values at different points in time. This concept is based on the understanding that receiving a certain amount of money in the future is not equivalent to receiving the same amount of money today. This principle is relevant to the discussion of higher future prices for garlic compared to lower current prices.

When considering the future prices of garlic, the time value of money suggests that higher future prices are expected compared to lower current prices. This is because the purchasing power of money tends to decrease over time due to factors such as inflation and opportunity costs. The time value of money is recognized in Islamic finance, where it is acceptable in trade transactions (Ambrose & Asuhaimi, 2021). By applying the concept of time value of money, it can be inferred that the higher future prices for garlic are a result of factors such as inflation and the expectation of increased demand for garlic in the future.

In agricultural markets, the determination of future prices is influenced by various economic theories. These theories help to understand the factors that impact the prices of agricultural commodities and enable market participants to make informed decisions. One economic theory that links to the determination of future prices in agricultural markets is supply and demand. Supply and demand theory states that the price of a commodity is determined by the interaction of its supply and demand, particularly in a perfectly competitive market structure. This is done through the principle of equilibrium. According to Inoua & Smith (2022) When the demand for agricultural commodities increases, it puts upward pressure on prices. On the other hand, when the supply of agricultural commodities increases, it puts downward pressure on prices, *ceteris paribus*.

Drawing back to the recent notorious pandemic, COVID-19, WHO (2019) noted that lot of people demanded garlic although the supply was low. The higher demand coupled with lower supply led to disequilibrium, which, in economic terms, is referred to as excess demand (or market shortage). As a result, prices had increased in order to adjust the prices and quantities back to equilibrium again. All these actions are influenced by the conflicting interests of the primary market participants, i.e., consumer, whose interest is to maximize the level of utility by buying more of a certain product when the price is low and buying less when the price is high, *ceteris paribus*; and also supplies whose interest is to maximize profit levels by supplying less when markets offer lower prices and supply more when prices are higher, *ceteris paribus* (Dean *et al.,* 2020). With this in mind, the researcher postulates in justifying higher predicted prices by this study, that the present higher demands for agricultural commodities like garlic, which is minimally perishable, will make it more expensive even in future. This is mainly because, recently consumers know more about the benefits of garlic consumption.

Another economic theory that is relevant to the determination of future prices in agricultural markets is the theory of cost of production. The theory of cost of production suggests that the prices of agricultural commodities are influenced by the costs incurred in producing them. Specifically, factors such as input costs, labor costs, and technology advancements can affect the cost of production, which in turn impacts the prices of agricultural commodities.

Additionally, the theory of price expectations plays a role in determining future prices in agricultural markets. According to this theory, market participants form expectations about future prices based on various factors such as past price trends, market forecasts, and economic indicators. These expectations influence their buying and selling decisions, which can in turn impact on the actual prices in the market. One example of an economic theory that links to the determination of future prices in agricultural markets is the theory of market efficiency. This theory states that markets are efficient in reflecting all available information, which includes factors that affect the prices of agricultural commodities. Market efficiency suggests that future price movements in agricultural markets are unpredictable and random, as all relevant information is already incorporated into the current prices. These economic theories provide valuable insights into the determinants of future prices in agricultural markets and help market participants, including the government, make informed decisions.

5.8. Chapter summary

The results presented in this chapter illustrate the presence of indexed price variation, correlation, and causal relationships among retail, farmgate, and wholesale prices in the South African garlic market. Additionally, the impulse response functions were employed to assess the short and long-term effects of the variables. The variance decomposition analysis was utilized to quantify the percentage contributions of various shocks to the 132-step-ahead forecast errors of farmgate and wholesale prices with respect to retail prices. The Vector Error Correction Model (VECM) outcomes underscore the influence of both previous and current periods, signifying a short and long-term association between farmgate, wholesale, and retail prices in the South African garlic markets. This chapter concluded by applying statistical principles to forecast farmgate, wholesale and retail garlic prices.

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1. Introduction

This section encapsulates the key findings and issues discussed in each chapter of the study. It serves as a comprehensive summary, highlighting prominent aspects addressed throughout the research. Additionally, the section presents concluding remarks, policy recommendations, and suggests potential avenues for future research.

6.2. Summary

The principal objective of this study was to investigate price transmission dynamics in the South African garlic markets during the period from 2011 to 2021. The research was guided by five specific objectives, which included providing a comprehensive description of farmgate, wholesale, and retail prices for garlic; assessing the correlation among these price levels; examining the responsiveness of retailers to changes in farmgate and wholesale prices; determining the direction of price linkage across farmgate, wholesale, and retail prices; and analyzing the overall price transmission in the South African garlic markets. The study formulated four hypotheses, each corresponding to the objectives, questioning the existence of correlation, retailer responsiveness, price linkage direction, and price transmission in the garlic market. All the four hypotheses postulated in this study were empirically rejected. The study reviewed the previous literature in the area of price transmission and noted that price asymmetry is a rule rather than an exception. Most of the reviewed papers revealed the existence of price asymmetry between the price series they were examining. It was also noted that garlic is the most important agricultural commodity in South Africa due to the contribution by garlic sector to the gross value of agricultural production, to export earnings, employment creation and economic growth in the country and throughout the SACU region.

The study employed various statistical tests, including the Augmented Dickey-Fuller, Phillips-Perron, Engle and Granger, and Johansen cointegration tests, to assess the time series properties of the data. The findings indicated that the data series were non-stationary at the level but stationary at the first difference. Engle and Granger two-step residual-based tests, as well as Johansen's cointegration test, confirmed the presence of a long-run equilibrium relationship among all analyzed price pairs. This led to the adoption of the Error Correction Model to explore the dynamics of price transmission within the garlic marketing chain.

The Granger Causality test results highlighted the significant influence of the wholesale market on determining garlic prices in South Africa. Specifically, wholesale prices were found to have a substantial impact on both retail and farmgate prices for garlic. Moreover, the Granger Causality test revealed that farmgate prices also exerted influence on wholesale prices, indicating a bidirectional causality between farmgate and wholesale prices.

The findings from the Error Correction Model indicated the presence of price asymmetry in the South African garlic market. Specifically, the results demonstrated that retail prices for garlic exhibit greater responsiveness to positive shocks in farmgate prices compared to negative shocks. This suggests that retailers are more inclined to adjust their prices in response to shocks that compress their profit margins, while being less responsive to shocks that expand them. Furthermore, positive price asymmetry was observed between wholesale and farmgate prices, indicating that producers are more responsive to both negative and positive price shocks at the wholesale level. This implies that producers are quicker to adjust their prices when faced with changes in wholesale prices, regardless of whether those changes are increases or decreases. Lastly, looking at the forecasted farmgate, wholesale and retail prices, it is clear that garlic prices will continue fluctuating, as far as risks and uncertainties amongst other things in agricultural markets are concerned.

6.3. Conclusion

The first hypothesis for this study stated that there is no correlation between farmgate, wholesale and retail prices in the South African garlic markets. This hypothesis is rejected on the basis of the evidence presented in Table 5.2 (Correlation Analysis Matrices).

Positive correlation exists between farmgate, wholesale and retail prices in the South African garlic markets.

Secondly, the study hypothesized that retailers do not respond promptly to a change in farmgate and wholesale garlic prices in South Africa. Table 5.10 which captures the outcomes of an estimated Ordinary Least Squares (OLS) model validates the rejection of this hypothesis. The OLS model reveals that retailers respond positively to changes in wholesale prices and negatively towards changes in farmgate prices.

The third hypothesis made in this study was that there is no direction of price linkage between the farmgate, wholesale, and retail prices of garlic in South Africa. This hypothesis was rejected based on results presented in Table 5.9 which encapsulates Granger Causality results. It is revealed that farmgate prices affect retail prices and not vice versa; wholesale prices also affect retail prices and not vice versa. This means that there is a unidirectional relationship between farmgate prices and retail prices, and also between wholesale and retail prices. A bidirectional relationship exists between farmgate and wholesale prices in the South African garlic market.

Lastly, the study hypothesized that there is no price transmission in the South African garlic market. This hypothesis was rejected based on the outcomes presented in Table 5.15 which revealed that garlic prices exhibit asymmetric transmission across all three price levels of the marketing chain under investigation.

The study's findings imply that retailers and wholesalers promptly adjust to price changes that impact their margins, yet they exhibit delayed responses when faced with margin-stretching shocks, especially concerning their interactions with farmers. This observation may suggest that retailers and wholesalers wield significant market power over producers, influencing their reactions to positive or negative shocks in producer prices. Previous research indicates that such asymmetry can result in consumer welfare losses because upward shifts in farmgate prices swiftly affect consumers, while downward shifts in farmgate prices are not transmitted fully and rapidly to the consumer market. This prompts the question of whether the identified price asymmetry is rooted in a lack of competition or the dominance of market power among retailers and wholesalers.

The existing literature suggests that attributing price asymmetry solely to market power may not be advisable. Various factors, including perishability, government intervention, menu adjustment costs, and search costs, can contribute to price asymmetry. It is important to note that the present study focused on analyzing price transmission and did not delve into identifying the underlying causes of this observed phenomenon.

6.4. Recommendations

Based on the results of this study the following recommendations generated:

1. It is advisable for the government to persist and enhance its endeavors in monitoring food prices across the entire nation. This would enable the formulation of informed food security policies and facilitate the provision of more frequent and comprehensive food price information to relevant stakeholders. It is imperative for the government to contemplate expanding the existing food price monitoring system to encompass the reporting of food prices on a regional and provincial basis. This enhancement would enable the evaluation of price transmission among economically disadvantaged groups along the value chain of agricultural commodities.
2. Furthermore, it is imperative to gather data pertaining to marketing or transaction costs in order to facilitate the inclusion of transaction costs in the analysis of price transmission. This will enable the consideration of many aspects that contribute to price asymmetry. Investigating the structure, conduct, and performance (SCP) of the garlic industry in South Africa is crucial for both the government and the agricultural sector. This inquiry aims to discern whether the observed favorable price asymmetry in garlic markets results from collusive or anticompetitive practices among influential stakeholders. Such an examination can provide valuable insights into market dynamics, help identify potential market power issues, and inform policy decisions to ensure fair and competitive practices within the garlic industry.
3. To overcome the challenges in garlic processing and meet the growing demand, South Africa must invest in the development of modern infrastructure and processing technology. This would help improve efficiency, reduce processing

time, and minimize manual labor. Moreover, implementing training programs and initiatives to address the shortage of skilled workers will be vital for the industry's growth. By prioritizing the advancement of garlic processing techniques, South Africa can strengthen its position in both local and international markets and ensure a sustainable supply of garlic for its consumers.

6.5. Limitations of the study

The study primarily examined vertical price transmission within the South African garlic markets, specifically analyzing how prices move through different stages, namely farms, wholesale markets, and retail outlets. However, it is crucial to acknowledge certain limitations in the study. A significant constraint was the reliance on garlic prices from the Joburg Market as a representative of wholesale prices for the entire country, due to a lack of comprehensive data on average wholesale prices nationwide. Additionally, while the study offered valuable insights into price transmission mechanisms, a more comprehensive understanding of the conduct of various value chain participants could have been achieved with access to reliable data on transaction costs. This data would have allowed for a more thorough examination of delays and disruptions in price pass-through.

6.6. Area for future research

The limitations identified in the study suggest the following five research areas for further investigation:

1. National Wholesale Price Analysis: Given the current study's reliance on prices in the Johannesburg Market as a proxy for national wholesale prices, future research could aim to collect comprehensive and reliable data on average wholesale prices for garlic across the entire country. This would enhance the accuracy of the analysis and provide a more representative picture of price transmission dynamics at the national level.
2. Transaction Costs and Value Chain Conduct: To gain a more thorough understanding of the behavior of value chain players, future research could focus

on gathering reliable data on transaction costs. This information would allow researchers to account for delays and disruptions in the price transmission process. Understanding the conduct of different players in the garlic value chain, including factors influencing transaction costs, could contribute valuable insights into the market dynamics.

3. Geographical Variation in Price Transmission: Investigating how price transmission mechanisms vary across different regions within South Africa could be another direction for research. Different regions may have unique market structures, transportation challenges, and consumer preferences that influence the vertical transmission of garlic prices. A more nuanced analysis by region could provide valuable insights for policymakers and industry stakeholders.
4. Comparative Analysis with Other Countries: To enrich the findings and provide a broader context, future research could compare the vertical price transmission mechanisms observed in the South African garlic market with those in other countries. This comparative analysis could highlight similarities, differences, and potential factors influencing price transmission in various global markets.
5. Qualitative Research on Value Chain Players: Complementing quantitative data with qualitative research, such as interviews or surveys with key stakeholders in the garlic value chain, could offer a deeper understanding of decision-making processes, relationships, and strategies employed by different players. This qualitative insight could provide context to the quantitative findings and offer a more comprehensive view of the market dynamics.

REFERENCES

ACQUAH, H.G., & DADZIE, S.K.N. (2010). An Application of the Von Cramon-Taubadel and Loy Error Correction Models in Analyzing Asymmetric Adjustment between Retail and Wholesale Maize Prices in Ghana. University of Cape Coast, Ghana.

ABDESSALEM, A., LOTA, D. & GERVAIS, J.P. (2011). Do inventories have an impact on price transmission? Evidence from the Canadian chicken industry, Munich: Munich Personal RePEc Archive.

AINI, N, Y. (2020) Estimation Analysis and Mapping the Need for ‘Agen Perisai’ in Expanding the Membership of BP Jamsostek (A Case Study of West Java Province, Indonesia). Available at: https://www.researchgate.net/publication/349002147_Estimation_Analysis_and_Mapping_the_Need_for_'Agen_Perisai'_in_Expanding_the_Membership_of_BP_Jamsostek_A_Case_Study_of_West_Java_Province_Indonesia. (Retrieved: 18 April 2023).

AKAIKE, H. (1973). Information Theory and an Extension of the Maximum Likelihood Principle. B.N. Petrov and F. Csaki (eds.) *2nd International Symposium on Information Theory: Budapest: Akademiai Kiado*: pp. 267-281.

AMBROSE, A.H.A.A. & ASUHAIMI, F.A. (2021). Cash Waqf Risk Management and Perpetuity Restriction Conundrum. Available at: https://journal.inceif.org/index.php/ijif/article/view/385. (Retrieved: 23 July 2022).

AMIKUZUNO, J. & OGUNDARI, K., 2012. The Contribution of Agricultural Economics to Price transmission Analysis and Market Policy in Sub-Sahara Africa. Warwick.

APPEL, V. (1992). Asymmetrie in der Preistransmission. *Agrarwirtschaft Sonderheft. Vol. 135*: pp. 178-213.

ASARI, F.F.A.H., BAHARUDDIN, N.S., JUSOH, N., MOHAMAD, Z., SHAMSUDIN, N., & JUSOFF, K. (2011). A Vector Error Correction Model (VECM) Approach in

Explaining the Relationship between Interest Rate and Inflation towards Exchange Rate Volatility in Malaysia. *World Applied Sciences Journal. Vol. 12(1)*: pp. 49-56.

ASUERO, A.G., SAYAGO, A., & GONZALEZ, A.G. (2006). The Correlation Coefficient: An overview. *Critical Reviews in Analytical Chemistry. Vol. 36(10)*: pp. 41-59.

BAILEY, D. & BRORSEN, B.W. (1989). Price Asymmetry in Spatial Fed Cattle Markets. *Western Journal of Agricultural Economics. Vol.14(2)*: pp. 246-252.

BALKE, N.S., BROWN, S.P.A. & YÜCEL, M.K. (1998). Crude Oil and Gasoline Prices: An asymmetric Relationship? Federal Reserve Bank of Dallas. *Economic Review, First Quarter*. pp. 2-11.

BANERJEE, A., DOLADO, J.J., GALBRAITH, J.W. & HENDRY, D.F. (1993). Co-Integration, Error Correction, and the Econometric Analysis of Non-Stationary Data. Oxford: Oxford University Press.

BARRET, C.B. (2001). Measuring Integration and Efficiency in International Agricultural Market. *Review of Agricultural Economics. Vol. 23*: pp. 19-32.

BLINDER, A.S., CANNETTI, E.R., LEBOW, D.E. & RUDD, J.B. (1998). Asking About Prices: A New Approach to Understanding Price Stickiness. Russel Sage Foundation: New York.

BOR Ö., ISMIHAN, M. & BAYANER, A. (2014). Asymmetry in farm-retail price transmission in Turkish fluid milk market. Atilim University, Ankara, Turkey.

BOX, G.E.P. (1976). Time Series Analysis: Forecasting and Control. *Journal of the American Statistical Association. Vol. 71(356)*: pp. 891-902.

BOYD, M.S. & BRORSEN, B.W. (1988). Price Asymmetry in the U.S. Pork Marketing Channel. *North Central Journal of Agricultural Economics. Vol.10(1)*: pp.103-109.

CHINTAPALLI, V.R., KONDEPU, K., SGAMBELLURI, A., FRANKLIN, A., TAMMA, B R., CASTOLDI, P.Y. & VALCARENGHI, L. (2020). Orchestrating Edge- and Cloud-based Predictive Analytics Services. In Proceedings of the 2020 European Conference on Networks and Communications (EuCNC). Available at: https://earchivo.uc3m.es/bitstream/handle/10016/31341/orchestrating_EuCNC_2020_ps.pdf;jsessionid=029FB3D59678DC62886690FFD0EEF0E2?sequence=1. (Retrieved: 03 April 2023).

CUTTS, M. and KIRSTEN J. (2006). Granger Causality and Market Concentration: An Investigation into Four South African Agro-Food Industries. *South African Journal of Economics. Vol 74(2)*: pp. 323-333.

COLMAN, D. (1995). Problems of Measuring Price Distortion and Price Transmission: A Framework for Analysis. Oxford Agrarian Studies.

DAGUM, E. B., & BIANCONCINI, S. (2016). Seasonal adjustment methods and real time trend-cycle estimation. Berlin/Heidelberg, Germany: Springer International Publishing.

DEAN, E., ELARDO, J., GREEN, M., WILSON, B., & BERGER, S. (2020). Demand, Supply, and Equilibrium in Markets for Goods and Services. *Principles of Economics: Scarcity and Social Provisioning (2nd Ed.)*.

DEATON, A. & LAROQUE, G. (1992). On the Behaviour of Commodity Prices. *Review of Economic Studies. Vol. 59*: pp. 1-23.

DEPARTMENT OF AGRICULTURE, LAND REFORM & RURAL DEVELOPMENT (DALRRD). (2021). Annual Report. Pretoria, South Africa.

DHALL, R.K., CAVAGNARO, P.F., SINGH, H. AND MANDAL, S. (2023). History, evolution and domestication of garlic: a review. *Plant Systematics and Evolution*. *Vol. 309*(5): pp.33.

DICKEY, D.A. & FULLER, W.A. (1979). Distribution of the Estimators for Autoregressive Time Series with Unit Root. *Journal of American Statistics Association. Vol. 74*: pp. 427-431.

DWYER, G.P. (2015). The Johansen Tests for Cointegration. Accessed at http://jerrydwyer.com/pdf/Clemson/Cointegration.pdf on the 07 August 2021

ENGLE, R.F. & GRANGER, C.W.J. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. *Economics. Vol. 55*: pp. 251-276.

ENKE, S. (1951). Equilibrium among Spatially Separated Markets: Solution by Electric Analogue. *Econometrica*. *Vol. 19*(1): pp. 40–47. Available at: https://doi.org/10.2307/1907907. (Retrieved: 10 January 2023).

FAJAR, M. (2019) An Application of Hybrid Forecasting Singular Spectrum Analysis – Extreme Learning Machine Method in Foreign Tourists Forecasting. Available at: https://mpra.ub.uni-muenchen.de/105044/. (Retrieved: 16 October 2023).

FARMER'S WEEKLY. (2019). Growing Garlic: A Golden Opportunity for SA Farmers. Farmer's Weekly. Available at: https://www.farmersweekly.co.za/crops/field-crops/growing-garlic-opportunity-for-sa-farmers/. (Retrieved: 10 December 2023).

FRACKLER, J.S., & KRIEGER, S.C. (1986). An Application of Vector Time Series Techniques to Macroeconomics Forecasting. *Journal of Business and Economic Statistics. Vol. 4(1)*: pp. 71-78.

FOOD AND AGRICULTURE STATISTICS (FAOSTAT). (2019). Food and Agriculture Organization of the United Nations. Production: Crops. Available at: https://faostat.fao.org. (Retrieved: 03 May 2022).

GARDNER, B. (1975). The Farm-Retail Price Spread in a Competitive Food Industry. *American Journal of Agricultural Economics. Vol. 57*: pp. 383-406.

GOLETTI, F. & BABU, S. (1994). Market liberalization and market integration of maize markets in Malawi. *Agricultural Economics. Vol. 11*: pp. 311-324.

GOODWIN, B.K. & HOLT, M.T. (1999). Price Transmission and Asymmetric Adjustment in the U.S. Pork Sector. *Journal of Agricultural and Applied Economics. Vol. 81*: pp. 630-637.

GRANGER, C. (1981). Some properties in time series data and their use in econometric model specification. *Journal of Econometrics. Vol. 16(1)*: pp. 121-130.

GREGORY, A. & HANSEN, B. (1996). Residual based tests for cointegration in models with regime shifts. *Journal of Econometrics. Vol. 70*: pp. 99-126.

GUJARATI, D. (2003). Basic econometrics. Boston: McGraw-Hill Higher Education.

GUJARATI, D.N. & PORTER, D.C. (2009). Basic Econometrics. Fifth edition. The McGraw-Hill Series Economics, 557-758. New York, USA.

HAHN, W. F. (1990). Price transmission asymmetry in pork and beef markets. *The Journal of Agricultural Economics Research. Vol. 42(4)*: pp. 21-30.

HANSMIRE, M.R. & SCHERTZ-WILLET, L. (1992). Price Transmission Processes: A Study of Price Lags and Asymmetric Price Response Behavior for New York Red Delicious and Mcintosch Apples, Cornell University.

HATEM, G., ZEIDAN, J., GOOSSENS, M. AND MOREIRA, C. (2022). Normality testing methods and the importance of skewness and kurtosis in statistical analysis. *BAU Journal-Science and Technology*. *Vol. 3(2)*: pp.7.

HEIEN, D.M. (1980). Markup pricing in a dynamic model of the food industry. *American Journal of Agricultural Economics. Vol. 62(1)*: pp. 10-18.

HOUCK, J.P. (1977). An Approach to Specifying and Estimating Non-reversible Functions. *American Journal of Agricultural Economics. Vol. 59*: pp. 570-572.

INOUA, S. M., & SMITH, V. L. (2022). Neoclassical supply and demand, experiments, and the classical theory of price formation. *History of Political Economy*. *Vol. 54(1)*: pp. 37-73.

INTERNATIONAL TRADE CENTRE (ITC). (2020). Trade Map. International Trade Centre (ITC). Available at: https://www.trademap.org/. (Retrieved: 13 November 2023).

JAMES E. (1952). Samuelson (Paul A.) - Economics: An Introductory Analysis. *Revue Économique, Programme National Persée. Vol. 3(6)*: pp. 875-877.

JESSICA-ELIZABETH, D.L.T., GASSARA, F., KOUASSI, A.P., BRAR, S.K., BELKACEMI, K., EL-SAYED, S.M., YOUSSEF, A.M. & OGORI, A.F., (2019). Spices and Herbs for Home and Market Spices and Herbs for Home and Market. *Heliyon. Vol. 5(1).*

JOHANSEN, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Econometric Dynamics and Control. Vol. 12(2)*: pp. 231-254.

KARANTININIS, K., KATRAKYLIDIS, K., & PERSSON, M. (2011). Price Transmission in the Swedish Pork Chain: Asymmetric Non-Linear ARDL. Zurich, Switzerland: Paper prepared for presentation at the *EAAE 2011 Congress Change and Uncertainty Challenges for Agriculture, Food and Natural Resources*.

KAYA, A., GÜMÜŞ, R. & AYDIN, Ö. (2021). Time Series Outlier Analysis for Model, Data and Human-induced Risks in Covid-19 Symptoms Detection. Available at: https://dergipark.org.tr/en/pub/mejs/issue/67381/970510. (Retrieved: 19 July 2022).

KEKANA, M. R., LUSEBA, D., & MUYU, M. C. (2021). Effects of garlic supplementation on in vitro nutrient digestibility, rumen fermentation, and gas production. *South African Journal of Animal Science*. Vol. 51(2): pp. 271-279.

KERR, B. (2019). Growing garlic: Part 1. Farmer's Weekly, 2019(19049), pp.58-58.

KINDU-WUBET, G. (2022). Value chain analysis of garlic in LiboKemkem district: In the Era of COVID-19, South Gondar Zone Amhara Region, Ethiopia. *Cogent Business & Management*. Vol. 9(1): pp. 2076298.

KINNUCAN, H.W. & FORKER, O.D. (1987). Asymmetry in the Farm-Retail Price Transmission for Major Dairy Products. *American Journal of Agricultural Economics. Vol. 69*: pp. 285-292.

KOHLS, R.L. & UHL, J.N. (2002). Marketing of Agricultural Products, 9th edition. Upper Saddle River, USA: Prentice Hall.

KWESINDZEBAH-DADZIE, S. & DE GRAFT-ACQUAH, H. (2010). An Application of the von Cramon-Taubadel and Loy Error Correction Models in Analyzing Asymmetric Adjustment Between Retail and Wholesale Maize Prices in "An Application of the von Cramon-Taubadel and Loy Error Correction Models in Analyzing Asymmetric Adjustment between Retail and Wholesale Maize Prices in Ghana. Available at: https://www.academicjournals.org/JDAE (Retrieved: 18 April 2022).

LEE RODGERS, J., & NICEWANDER, W.A. (1988). Thirteen ways to look at the Correlation Coefficient. *The American Statistician. Vol. 42(1)*: pp. 59-66.

LLOYD, T., MCCORRISTON, S., MORGAN, C.W. & RAYNER, A.J. (2003). The Impact of Food Scares on Price Transmission in Interrelated Markets. Paper Presented to the *25th IAAE Conference* in Durban, South Africa.

LLOYD, T.A., MCCORRISTON, S., MORGAN, C.W., & RAYNER, A.J. (2006). Food Scares, Market Power and Price Transmission: The UK BSE Crisis. *European Review of Agricultural Economics. Vol. 33(2)*: pp. 119-147.

LOMBARD, H.L. (2015). Price transmission in the beef value chain: the case of Bloemfontein, South Africa. Department of Agricultural Economics. University of the Free State, South Africa.

LOUW, M., MEYER, F., & KIRSTEN, J. (2017). Vertical price transmission and its inflationary implications in South African food chains. *Agrekon, Vol. 56(2)*: pp.110-122.

MACKINNON, J.G. (1996). Numerical Distribution Functions for Unit Root and Cointegration Tests. *Journal of Applied Econometrics. Vol. 11*: pp. 601-618. Available at: https://dx.doi.org/10.1002/(SICI)1099-1255(199611)11:6%3C601::AID-JAE417%3E3.0.CO;2-T. (Retrieved: 17 October 2023).

MAJHI, K.S. (2023). Food price index prediction using time series models: A Study of Cereals, Millets and Pulses. Available at: https://ouci.dntb.gov.ua/en/works/4EVJaQKl/. (Retrieved: 19 November 2023).

MANDIZVIDZA, K., MUCHOPA L.C. & CHAMINUKA, P. (2013). Price Transmission in Tomato Markets of Limpopo Province, South Africa. Department of Agricultural Economics and Animal Production. University of Limpopo, South Africa.

MCCORRISTON, S., MORGAN, C.W. & RAYNER A.J. (2001). Price Transmission: The Interaction Between Market Power and Returns to Scale. *European Review of Agricultural Economics. Vol. 28*: pp. 143-159.

MCCORRISTON, S. (2002). Why Should Imperfect Competition Matter to Agricultural economists? *European Review of Agricultural Economics. Vol. 29(3)*: pp. 349-371.

MEYER, J.P., & VON CRAMON-TAUBADEL, S. (2000). Granger Causality: A Survey. Göttingen, Germany: Department of Agricultural Economics.

MEYER, J.P., STANLEY, D.J., HERSCOVITCH L., & TOPOLNYSKY, L. (2002). Affective, Continuance, and Normative Commitment to the Organization: A Meta-Analysis of Antecedents, Correlates, and Consequences. *Journal of Vocational Behavioral. Vol. 6*: pp. 20-52. Available at: https://dx.doi.org/10.1006/jvbe.2001.1842. (Retrieved: 23 June 2022).

MEYER, J.P. & VON CRAMON-TAUBADEL, S. (2002). Granger Causality: A Survey. Zaragosa (Spain).

MEYER, J.P. & VON CRAMON-TAUBADEL, S. (2004). Granger Causality: A Survey. *Journal of Agricultural Economics. Vol. 55(3)*: pp. 581-593.

MILLER, D.J. & HAYENGA, M.L. (2001). Price Cycles and Granger Causality in the US Pork Market. *American Journal of Agricultural Economics. Vol. 83(3)*: pp. 551-562.

MISHRA, P., PANDEY, C.M., SINGH, U., GUPTA, A., SAHU, C. & KESHRI, A. (2019) Descriptive statistics and normality tests for statistical data. *Ann Card Anaesth*. *Vol. 22*: pp. 67-72.

MOSESE, D.M., HLONGWANE, J.J. & GIDI, L.S. (2020). Analysis of Vertical Price Transmission in the South African Potato Markets. Department of Agricultural Economics and Animal Production. University of Limpopo, South Africa.

MUKAKA, M.M. (2012). Statistics corner: A guide to appropriate use of Correlation coefficient in medical research. *Malawi Medical Journal. Vol 24(3)*: pp. 69-70.

MUSHTAQ, R. (2011). Augmented Dickey-Fuller Test. Available at https://dx.doi.org/10.2139/ssrn.1911068. (Retrieved: 17 October 2023).

OJIAKO, I. A. (2021). Dynamic Linkage between Monetary Policy and Stock Performance in Nigeria: Cointegration and ECM Techniques. *South Asian Journal of Social Studies and Economics. Vol 10(3)*: pp. 1-26.

ÖZALP, B. & ÖREN, M.N. (2023). Political economy of input–output markets of groundnut: A case from the groundnut value chain of Turkey. *Journal of Agrarian Change*: pp. e12568.

PELTZMAN, S. (2000). Prices Rise Faster Than They Fall. *Journal of Political Economics. Vol. 108(3)*: pp. 466-502.

PESARAN, M.H. & SHIN, Y. (1998) An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis. *Econometric Society Monographs*. *Vol. 31*: pp. 371-413.

PHILLIPS, P.C.B. & PERRON, P. (1988). Testing for a Unit Root in Time Series Regression. *Biometrika. Vol. 75*: pp. 335-346.

PICK, D.H., KARRENBROCK, J.D. & CARMAN, H.F. (1990). Price Asymmetry and Marketing Margin Behavior: An Example for California - Arizona Citrus. *Agribusiness.Vol. 6(1)*: pp. 75-84.

POLWIANG, S. (2020). The Time Series Seasonal Patterns of Dengue Fever and Associated Weather Variables in Bangkok (2003-2017). *BMC infectious diseases*: *Vol. 20(1):* pp. 1-10.

RAPSOMANIKIS, G., HALLAM, D. & CONFORTI, P. (2003). Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and Application. *Commodity Market Review*: pp. 1-55

REAGAN, P.B. & WEITZMAN, M.L. (1982). Asymmetries in Price and Quantity Adjustments by the Competitive Firm. *Journal of Political Economy. Vol. 27*: pp. 410-420.

REVERODO, C.L., NADOLYAK, D.A. & FLETCHER, S.M. (2004). Explaining Price Transmission Asymmetry in the US Peanut Marketing Chain. [Online] Available at:

https://agecon.lib.umn.edu/cgi-bin/pdfview.pl?paperid=14494&ftype=.pdf. (Retrieved: 25 December 2022).

REZITIS, A.N. & TSIONAS, E.G. (2019). Modelling Granger Causality in the European food market. *Vols. 216–230.* Available at: https://10.1016/j.econmod.2018.08.004. (Retrieved: 13 June 2022).

RICCI, E.C., PERI, M. & BALDI, L. (2019). The Effects of Agricultural Price Instability on Vertical Price Transmission: A Study of the Wheat Chain in Italy. Vol. 36. Multidisciplinary Digital Publishing Institute. Available at: https://10.3390/agriculture9020036. (Retrieved: 20 May 2022).

ROSE, H., PAPARAS, D., TREMMA, O. & DE AGUIAR, L. (2019). Price Transmission: The Case of the UK and the USA Broiler Markets. *International Journal of Agricultural Resources, Governance and Ecology, Inderscience Enterprises Ltd. Vol. 15(4)*: pp. 281-306.

ROSSI, B., AND WANG, Y. (2019). Vector Autoregressive-Based Granger Causality Test in the Presence of Instabilities. *The Stata Journal. Vol. 9(4)*: pp. 883-899.

SAMUELSON, P.A. (1952). Economic Theory and Mathematics: An Appraisal. *The American Economic Review*. *Vol. 42(2): pp. 56-66*.

SCHEEPERS, S.V. (2018). Vertical Coordination and Integration, Market Power and Price Transmission in the Value Chain of the South African Macadamia Industry. Department of Agricultural Economics and Extension. University of North-West, South Africa.

SCHNEPF, R. (2006). Price determination in agricultural commodity markets: A primer. National Agricultural Law Centre, USA.

SCHOBER, P., BOER, C., & SCHWARTE, L.A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia and Analgesia. Vol. 126(15)*: pp. 1763- 1768.

SCHWARZ, G. (1978). Estimating the Dimension of a Model. *Annals Statistics. Vol. 6(2)*: pp. 461-464. Available at: https://dx.doi.org/10.1214/aos/1176344136. (Retrieved: 05 September 2023).

SHINDE, A., DOND, S., DIWATE, V., PAWAR, S., KATKAR, R. AND DARANDALE, S. (2021). Historical approach of garlic (Allium sativum) in food, spices and it's phytochemicals and therapeutic uses in medicine: A review. *World Journal of Pharmaceutical Research*, *10*(1): pp. 737-744.

SIMS, D. (2012). Correlation Analysis- Market Research. Available at: https://www.djsresearch.co.uk/. (Retrieved: 22 March 2023).

SISODIYA, P., & SHARMA, G. (2018). The Impact of Marketing Mix Model/Elements on Consumer Buying Behaviour: A Study of FMCG Products in Jaipur City. *International Journal of Technical Research & Science*. Available at https://doi.org/10.30780/ijtrs.v3.i1.2018.016. (Retrieved: 09 August 2023).

STATACORP. (2011). Stata Time Series Reference Manual Release 12. Stata Press, 418-754.

STATISTICS SOUTH AFRICA. (2011). Mid-year Estimates. Accessed at: www.statssa.gov.za. (Retrieved: 19 August 2023).

STOCK, H.J. & WATSON, M.W. (2001). Vector Autoregression, Massachusetts: National Bureau of Economic Research.

TAKAYAMA, T. & JUDGE, G.G. (1972). Spatial and Temporal Price and Allocation Models.

TWEENTEN, L.G. & QUANCE, C.L. (1969). Positivistic Measures of Aggregate Supply Elasticities: Some new Approaches. *American Journal of Agricultural Economics. Vol. 51*: pp. 342-352.

TYERS, R, & ANDERSON, K. (1992). Disarray in World Food Markets: A Quantitative Assessment, Cambridge University Press.

UCHEZUBA, I.D., JOOSTE, A. & WILLEMSE, J. (2010). Measuring Asymmetric Price and Volatility Spillover in the South African Broiler Market. *2010 AAAE Third*

Conference/AEASA 48th Conference, *September 19-23, 2010*. Cape Town, South Africa 96434, *African Association of Agricultural Economists (AAAE).*

UNITED NATIONS CONFERENCE ON TRADE & DEVELOPMENT. (2019). Trade and Development Report: Financing a Global Green New Deal. UNCTAD. Accessed on: https://unctad.org/system/files/official-document/tdr2019_en.pdf. (Retrieved: 28 October 2023).

VAVRA, P. & GOODWIN, B. (2005). Analysis of Price Transmission along the Food Chain. *OECD Food, Agricultural and Fisheries Working Papers. Issue 3*: pp. 3-8.

VON CRAMON-TAUBADEL, S., LOY, J.P., & MUSFELDT, E. (1995). Empirical Method to Analyze Market Integration. *Vol. 31: pp. 119-137*.

VON CRAMON-TAUBADEL, S. & LOY, J.P. (1996). Price Asymmetry in the International Wheat Market: *Canadian Journal of Agricultural Economics. Vol. 44*: pp. 311-317.

VON CRAMON-TAUBADEL, S., & FAHLBUSCH, S. (1998). Estimating Granger Causality with Error Correction Representation: An Application to the German Pork Market. Kiel, Germany: University of Kiel, Department of Agricultural Economics.

WARD, R.W. (1982). Asymmetry in Retail, Wholesale and Shipping Point Pricing for Fresh Vegetable. *American Journal of Agricultural Economics Vol. 64*: pp. 205-212.

WOLFRAM, R. (1971). Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches – Some Critical Notes. *American Journal of Agricultural Economics. Vol. 53*: pp. 356-359.

WORLD HEALTH ORGANISATION (2011): World Health Organization Statistics. Available at: https/www.who.int/whosis/whostat/2011/en/index.html (Retrieved: 10 April 2022).

WORLD HEALTH ORGANIZATION. (2020). Novel Coronavirus (2019-nCoV): Situation Report, 19. *World Health Organization*. Available at: https://apps.who.int/iris/handle/10665/330988. (Retrieved: 25 April 2022).

WEAVER, R.D., CHATTIN, P. & BANERJEE, A. (1989). Market Structure and the Dynamics of Retail Food Prices. *Northeastern Journal of Agricultural Resource Economics. Vol.18*: pp. 160-170.

WEITZMAN, M. & REAGAN, P. (1982). Asymmetries in Price and Quantity Adjustments by the Competitive Industry. *Journal of Economic Theory*. Available at: https://scholar.harvard.edu/weitzman/publications/asymmetries-price-and-quantity-adjustments-competitive-industry. (Retrieved: 13 November 2023).

WEGNER, T. (1993). *Applied Business Statistics*.

YAYI, Y., JITI, G., & BIN, P. (2021). On Time-Varying VAR Models: Estimation, Testing and Impulse Response Analysis. Available at: https://ssrn.com/abstract=3953608 (Retrieved: 19 September 2022).

YOUNESS, E.A., BOUHADI, A.E, AND BENALI, M. (2021). Exchange Rate Passthrough in Morocco: A Structural VAR Approach. *European Journal of Economic and Financial Research. Vol 5(3)*: pp. 1179-1180.

ZHANG, P., FLETCHER, S. & CARLEY, D. (1995). Peanut Price Transmission Asymmetry in Peanut Butter. *Agribusiness. Vol. 11(1)*: pp.13-20.

ZHI, X., YUEXIN, S., JIN, M., LUJIE, Z., & ZIJIAN, D. (2017). Research on the Pearson Correlation Coefficient Evaluation Method of Analog Signal in the Process of Unit Peak Load Regulation. *International Conference on Electronic Measurement & Instruments*. Available at: https://ieeexplore.ieee.org/abstract/document/8265997 (Retrieved: 27 November 2023).

APPENDICES

Appendix 1: Farmgate price series moving averages and de-seasonalized prices.

Period	Farmgate prices (Rands)	5-PMA	Seasonal Ratio	% Seasonal Ratio	Adjusted Seasonal index	De-seasonalized index	De-seasonalized farmgate prices
2011-01	23.05	N/A	N/A	N/A	39.49823	0.58357	58.35704
2011-02	28.94	N/A	N/A	N/A	41.84394	0.691617	69.16175
2011-03	28.72	27.642	1.038999	103.8999	40.3927	0.711019	71.10195
2011-04	29.75	29.052	1.024026	102.4026	41.18016	0.722435	72.24353
2011-05	27.75	32.204	0.861694	86.16942	42.38091	0.654776	65.47759
2011-06	30.1	34.656	0.868536	86.85365	42.26792	0.712124	71.2124
2011-07	44.7	34.276	1.30412	130.412	44.94849	0.994472	99.44717
2011-08	40.98	32.202	1.272592	127.2592	49.41555	0.829294	82.92937
2011-09	27.85	29.02	0.959683	95.9683	45.33557	0.614308	61.43079
2011-10	17.38	23.23	0.74817	74.81705	39.4567	0.440483	44.04829
2011-11	14.19	18.446	0.769272	76.92725	35.93908	0.394835	39.48348
2011-12	15.75	16.414	0.959547	95.95467	37.31575	0.422074	42.20737
2012-01	17.06	16.184	1.054128	105.4128	39.49823	0.431918	43.1918
2012-02	17.69	16.986	1.041446	104.1446	41.84394	0.422761	42.27613
2012-03	16.23	17.43	0.931153	93.11532	40.3927	0.401805	40.18052
2012-04	18.2	18.656	0.975557	97.55575	41.18016	0.44196	44.19604
2012-05	17.97	20.35	0.883047	88.30467	42.38091	0.424012	42.40116
2012-06	23.19	23.004	1.008086	100.8086	42.26792	0.548643	54.8643
2012-07	26.16	25.142	1.04049	104.049	44.94849	0.582	58.19995
2012-08	29.5	26.462	1.114806	111.4806	49.41555	0.596978	59.69781
2012-09	28.89	25.952	1.113209	111.3209	45.33557	0.637248	63.72479
2012-10	24.57	24.132	1.01815	101.815	39.4567	0.622708	62.2708
2012-11	20.64	21.76	0.948529	94.85294	35.93908	0.574305	57.43052
2012-12	17.06	19.968	0.854367	85.4367	37.31575	0.45718	45.71796
2013-01	17.64	19.106	0.92327	92.32702	39.49823	0.446602	44.66022
2013-02	19.93	20.026	0.995206	99.52062	41.84394	0.476294	47.62936
2013-03	20.26	23.556	0.860078	86.00781	40.3927	0.501576	50.15757
2013-04	25.24	27.244	0.926443	92.64425	41.18016	0.612917	61.29166
2013-05	34.71	31.716	1.0944	109.44	42.38091	0.819001	81.90007
2013-06	36.08	36.372	0.991972	99.19718	42.26792	0.853602	85.36024
2013-07	42.29	38.352	1.10268	110.268	44.94849	0.940855	94.08547
2013-08	43.54	36.31	1.199119	119.9119	49.41555	0.881099	88.10992
2013-09	35.14	32.936	1.066918	106.6918	45.33557	0.775109	77.51087

2013-10	24.5	28.872	0.848573	84.8573	39.4567	0.620934	62.09339
2013-11	19.21	24.35	0.788912	78.89117	35.93908	0.534516	53.45156
2013-12	21.97	22.616	0.971436	97.14362	37.31575	0.588759	58.87594
2014-01	20.93	22.902	0.913894	91.3894	39.49823	0.529897	52.98971
2014-02	26.47	24.404	1.084658	108.4658	41.84394	0.632589	63.25886
2014-03	25.93	26.004	0.997154	99.71543	40.3927	0.641948	64.19476
2014-04	26.72	28.432	0.939786	93.97862	41.18016	0.648856	64.88562
2014-05	29.97	30.132	0.994624	99.46237	42.38091	0.707158	70.71579
2014-06	33.07	31.854	1.038174	103.8174	42.26792	0.78239	78.239
2014-07	34.97	32.844	1.06473	106.473	44.94849	0.778002	77.80017
2014-08	34.54	32.146	1.074473	107.4473	49.41555	0.69897	69.89703
2014-09	31.67	29.766	1.063966	106.3966	45.33557	0.698568	69.85684
2014-10	26.48	25.944	1.02066	102.066	39.4567	0.671115	67.11155
2014-11	21.17	22.64	0.935071	93.50707	35.93908	0.589052	58.90523
2014-12	15.86	19.788	0.801496	80.14959	37.31575	0.425022	42.50216
2015-01	18.02	18.22	0.989023	98.90231	39.49823	0.456223	45.62229
2015-02	17.41	17.97	0.968837	96.8837	41.84394	0.41607	41.60698
2015-03	18.64	20.066	0.928935	92.89345	40.3927	0.461469	46.14695
2015-04	19.92	22.73	0.876375	87.63748	41.18016	0.483728	48.37281
2015-05	26.34	26.166	1.00665	100.665	42.38091	0.621506	62.15062
2015-06	31.34	30.222	1.036993	103.6993	42.26792	0.741461	74.14607
2015-07	34.59	33.488	1.032907	103.2907	44.94849	0.769548	76.95475
2015-08	38.92	33.028	1.178394	117.8394	49.41555	0.787606	78.76064
2015-09	36.25	31.168	1.163052	116.3052	45.33557	0.799593	79.95928
2015-10	24.04	29.038	0.827881	82.78807	39.4567	0.609276	60.92755
2015-11	22.04	26.024	0.846911	84.69105	35.93908	0.61326	61.326
2015-12	23.94	25.406	0.942297	94.22971	37.31575	0.641552	64.15521
2016-01	23.85	29.39	0.811501	81.15005	39.49823	0.603824	60.38245
2016-02	33.16	34.342	0.965582	96.55815	41.84394	0.792468	79.24684
2016-03	43.96	39.324	1.117892	111.7892	40.3927	1.088315	108.8315
2016-04	46.8	45.294	1.033249	103.3249	41.18016	1.13647	113.647
2016-05	48.85	54.704	0.892988	89.29877	42.38091	1.152641	115.2641
2016-06	53.7	60.408	0.888955	88.89551	42.26792	1.270467	127.0467
2016-07	80.21	62.606	1.281187	128.1187	44.94849	1.784487	178.4487
2016-08	72.48	62.498	1.159717	115.9717	49.41555	1.466745	146.6745
2016-09	57.79	58.528	0.987391	98.73907	45.33557	1.274716	127.4716
2016-10	48.31	48.912	0.987692	98.76922	39.4567	1.22438	122.438
2016-11	33.85	41.842	0.808996	80.89957	35.93908	0.941872	94.18716
2016-12	32.13	35.814	0.897135	89.71352	37.31575	0.86103	86.10304
2017-01	37.13	36.24	1.024558	102.4558	39.49823	0.940042	94.0042
2017-02	27.65	40.246	0.687025	68.70248	41.84394	0.660789	66.07886

2017-03	50.44	44.18	1.141693	114.1693	40.3927	1.24874	124.874
2017-04	53.88	46.782	1.151725	115.1725	41.18016	1.308397	130.8397
2017-05	51.8	51.716	1.001624	100.1624	42.38091	1.222248	122.2248
2017-06	50.14	51.844	0.967132	96.71322	42.26792	1.186242	118.6242
2017-07	52.32	49.598	1.054881	105.4881	44.94849	1.163999	116.3999
2017-08	51.08	46.07	1.108748	110.8748	49.41555	1.033683	103.3683
2017-09	42.65	42.276	1.008847	100.8847	45.33557	0.940762	94.07623
2017-10	34.16	36.89	0.925996	92.59962	39.4567	0.865759	86.57592
2017-11	31.17	31.2	0.999038	99.90385	35.93908	0.867301	86.73009
2017-12	25.39	27.144	0.935382	93.53817	37.31575	0.68041	68.04097
2018-01	22.63	24.646	0.918202	91.82017	39.49823	0.572937	57.2937
2018-02	22.37	23.55	0.949894	94.98938	41.84394	0.534605	53.46055
2018-03	21.67	24.656	0.878894	87.88936	40.3927	0.536483	53.6483
2018-04	25.69	26.582	0.966443	96.64435	41.18016	0.623844	62.38442
2018-05	30.92	29.094	1.062762	106.2762	42.38091	0.729574	72.95737
2018-06	32.26	32.136	1.003859	100.3859	42.26792	0.763227	76.32266
2018-07	34.93	34.032	1.026387	102.6387	44.94849	0.777112	77.71118
2018-08	36.88	35.06	1.051911	105.1911	49.41555	0.746324	74.63238
2018-09	35.17	34.326	1.024588	102.4588	45.33557	0.77577	77.57705
2018-10	36.06	31.856	1.131969	113.1969	39.4567	0.913913	91.39133
2018-11	28.59	29.506	0.968955	96.89555	35.93908	0.795513	79.55128
2018-12	22.58	28.402	0.795014	79.50144	37.31575	0.605106	60.51064
2019-01	25.13	27.002	0.930672	93.06718	39.49823	0.636231	63.6231
2019-02	29.65	27.286	1.086638	108.6638	41.84394	0.708585	70.85853
2019-03	29.06	29.364	0.989647	98.96472	40.3927	0.719437	71.94368
2019-04	30.01	31.642	0.948423	94.8423	41.18016	0.728749	72.87491
2019-05	32.97	34.622	0.952285	95.22847	42.38091	0.777945	77.79445
2019-06	36.52	40.24	0.907555	90.75547	42.26792	0.864012	86.40122
2019-07	44.55	45.076	0.988331	98.83308	44.94849	0.991135	99.11345
2019-08	57.15	46.466	1.229932	122.9932	49.41555	1.156519	115.6519
2019-09	54.19	45.444	1.192457	119.2457	45.33557	1.195309	119.5309
2019-10	39.92	42.144	0.947229	94.72285	39.4567	1.011742	101.1742
2019-11	31.41	37.394	0.839974	83.99743	35.93908	0.873979	87.39789
2019-12	28.05	34.754	0.807101	80.71013	37.31575	0.751693	75.16932
2020-01	33.4	38.22	0.873888	87.3888	39.49823	0.845607	84.56074
2020-02	40.99	51.196	0.800648	80.06485	41.84394	0.979592	97.95923
2020-03	57.25	69.202	0.827288	82.72882	40.3927	1.417335	141.7335
2020-04	96.29	81.634	1.179533	117.9533	41.18016	2.338262	233.8262
2020-05	118.08	91.17	1.295163	129.5163	42.38091	2.78616	278.616
2020-06	95.56	94.892	1.00704	100.704	42.26792	2.260816	226.0816
2020-07	88.67	85.74	1.034173	103.4173	44.94849	1.972703	197.2703

2020-08	75.86	69.776	1.087193	108.7193	49.41555	1.535144	153.5144
2020-09	50.53	57.164	0.883948	88.39479	45.33557	1.114577	111.4577
2020-10	38.26	46.53	0.822265	82.22652	39.4567	0.969671	96.96706
2020-11	32.5	43.94	0.739645	73.9645	35.93908	0.904308	90.4308
2020-12	35.5	47.274	0.750941	75.09413	37.31575	0.951341	95.13408
2021-01	62.91	50.698	1.240877	124.0877	39.49823	1.592729	159.2729
2021-02	67.2	55.138	1.21876	121.876	41.84394	1.605967	160.5967
2021-03	55.38	58.42	0.947963	94.7963	40.3927	1.37104	137.104
2021-04	54.7	57.232	0.955759	95.5759	41.18016	1.32831	132.831
2021-05	51.91	57.954	0.89571	89.57104	42.38091	1.224844	122.4844
2021-06	56.97	63.448	0.897901	89.79006	42.26792	1.347831	134.7831
2021-07	70.81	65.368	1.083252	108.3252	44.94849	1.575359	157.5359
2021-08	82.85	64.1	1.292512	129.2512	49.41555	1.676598	167.6598
2021-09	64.3	60.112	1.06967	106.967	45.33557	1.418312	141.8312
2021-10	45.57	54.162	0.841365	84.13648	39.4567	1.154937	115.4937
2021-11	37.03	N/A	N/A	N/A	35.93908	1.030355	103.0355
2021-12	41.06	N/A	N/A	N/A	37.31575	1.10034	110.034

Appendix 2: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for farmgate price series.

Month	Median Season Index	Adjustment Factor	Adjusted Seasonal Index
Jan	92.6971	0.4261	39.49823
Feb	98.20216	0.4261	41.84394
Mar	94.7963	0.4261	40.3927
Apr	96.64435	0.4261	41.18016
May	99.46237	0.4261	42.38091
Jun	99.19718	0.4261	42.26792
Jul	105.4881	0.4261	44.94849
Aug	115.9717	0.4261	49.41555
Sep	106.3966	0.4261	45.33557
Oct	92.59962	0.4261	39.4567
Nov	84.34424	0.4261	35.93908
Dec	87.57511	0.4261	37.31575
		Total	499.975

Appendix 3: Moving averages and seasonal median (unadjusted) indices for farmgate price series.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	N/A	N/A	103.8999	102.4026	86.16942	86.85365	130.412	127.2592	95.9683	74.81705	76.92725	95.95467	
2012	105.4128	104.1446	93.11532	97.55575	88.30467	100.8086	104.049	111.4806	111.3209	101.815	94.85294	85.4367	
2013	92.32702	99.52062	86.00781	92.64425	109.44	99.19718	110.268	119.9119	106.6918	84.8573	78.89117	97.14362	
2014	91.3894	108.4658	99.71543	93.97862	99.46237	103.8174	106.473	107.4473	106.3966	102.066	93.50707	80.14959	
2015	98.90231	96.8837	92.89345	87.63748	100.665	103.6993	103.2907	117.8394	116.3052	82.78807	84.69105	94.22971	
2016	81.15005	96.55815	111.7892	103.3249	89.29877	88.89551	128.1187	115.9717	98.73907	98.76922	80.89957	89.71352	
2017	102.4558	68.70248	114.1693	115.1725	100.1624	96.71322	105.4881	110.8748	100.8847	92.59962	99.90385	93.53817	
2018	91.82017	94.98938	87.88936	96.64435	106.2762	100.3859	102.6387	105.1911	102.4588	113.1969	96.89555	79.50144	
2019	93.06718	108.6638	98.96472	94.8423	95.22847	90.75547	98.83308	122.9932	119.2457	94.72285	83.99743	80.71013	
2020	87.3888	80.06485	82.72882	117.9533	129.5163	100.704	103.4173	108.7193	88.39479	82.22652	73.9645	75.09413	
2021	124.0877	121.876	94.7963	95.5759	89.57104	89.79006	108.3252	129.2512	106.967	84.13648	N/A	N/A	
Median	92.6971	98.20216	94.7963	96.64435	99.46237	99.19718	105.4881	115.9717	106.3966	92.59962	84.34424	87.57511	1173.375

Appendix 4: Wholesale price series moving averages and de-seasonalized prices.

Period	Wholesale prices	5-PMA	Seasonal Ratio	% Seasonal Ratio	Adjusted Seasonal index	De-seasonalized Wholesale index	De-seasonalized wholesale price (Rands)
2011-01	23.38	N/A	N/A	N/A	42.30414	0.552665	55.26646
2011-02	30.74	N/A	N/A	N/A	41.38429	0.742794	74.2794
2011-03	34.02	30.748	1.106413	110.6413	41.61188	0.817555	81.7555
2011-04	34.44	32.846	1.04853	104.853	40.96089	0.840802	84.0802
2011-05	31.16	36.642	0.85039	85.03903	41.10187	0.758116	75.81163
2011-06	33.87	38.042	0.890332	89.03317	41.92305	0.807909	80.79087
2011-07	49.72	36.998	1.343856	134.3856	42.93525	1.158023	115.8023
2011-08	41.02	34.496	1.189123	118.9123	45.49878	0.901563	90.15627
2011-09	29.22	30.74	0.950553	95.0553	43.17611	0.676763	67.67632
2011-10	18.65	23.994	0.777278	77.72777	43.42627	0.429464	42.94636
2011-11	15.09	19.448	0.775915	77.59153	36.74211	0.4107	41.07004
2011-12	15.99	17.47	0.915283	91.52833	38.94583	0.41057	41.05703
2012-01	18.29	17.586	1.040032	104.0032	42.30414	0.432345	43.23454
2012-02	19.33	18.414	1.049745	104.9745	41.38429	0.467085	46.70855
2012-03	19.23	19.24	0.99948	99.94802	41.61188	0.462128	46.21276
2012-04	19.23	19.698	0.976241	97.62412	40.96089	0.469472	46.94722
2012-05	20.12	21.168	0.950491	95.04913	41.10187	0.489515	48.95154
2012-06	20.58	23.256	0.884933	88.49329	41.92305	0.490899	49.08994
2012-07	26.68	25.454	1.048165	104.8165	42.93525	0.621401	62.14008
2012-08	29.67	27.008	1.098563	109.8563	45.49878	0.652105	65.21054
2012-09	30.22	27.046	1.117356	111.7356	43.17611	0.699924	69.99242
2012-10	27.89	25.87	1.078083	107.8083	43.42627	0.642238	64.2238
2012-11	20.77	24.1	0.861826	86.18257	36.74211	0.565291	56.52914
2012-12	20.8	22.472	0.925596	92.55963	38.94583	0.534075	53.40752
2013-01	20.82	22.49	0.925745	92.57448	42.30414	0.49215	49.21504
2013-02	22.08	25.29	0.873072	87.30724	41.38429	0.533536	53.35358
2013-03	27.98	29.736	0.940947	94.0947	41.61188	0.672404	67.24041
2013-04	34.77	33.048	1.052106	105.2106	40.96089	0.848858	84.88585
2013-05	43.03	37.46	1.148692	114.8692	41.10187	1.046911	104.6911
2013-06	37.38	40.902	0.913892	91.38917	41.92305	0.891634	89.16336
2013-07	44.14	41.452	1.064846	106.4846	42.93525	1.02806	102.806
2013-08	45.19	40.29	1.121618	112.1618	45.49878	0.993213	99.32135
2013-09	37.52	36.864	1.017795	101.7795	43.17611	0.868999	86.89992
2013-10	37.22	33.006	1.127674	112.7674	43.42627	0.857085	85.7085
2013-11	20.25	29.466	0.687233	68.72327	36.74211	0.551139	55.11387
2013-12	24.85	27.558	0.901735	90.17345	38.94583	0.638066	63.80658
2014-01	27.49	25.54	1.076351	107.6351	42.30414	0.649818	64.98182

2014-02	27.98	27.39	1.021541	102.1541	41.38429	0.676102	67.6102
2014-03	27.13	28.85	0.940381	94.03813	41.61188	0.651977	65.19773
2014-04	29.5	30.378	0.971098	97.10975	40.96089	0.720199	72.01991
2014-05	32.15	32.33	0.994432	99.44324	41.10187	0.782203	78.22028
2014-06	35.13	34.56	1.016493	101.6493	41.92305	0.837964	83.79638
2014-07	37.74	36.15	1.043983	104.3983	42.93525	0.878998	87.8998
2014-08	38.28	37.016	1.034147	103.4147	45.49878	0.841341	84.13413
2014-09	37.45	36.586	1.023616	102.3616	43.17611	0.867378	86.73779
2014-10	36.48	34.478	1.058066	105.8066	43.42627	0.840045	84.00446
2014-11	32.98	32.164	1.02537	102.537	36.74211	0.897608	89.76077
2014-12	27.2	29.698	0.915887	91.58866	38.94583	0.698406	69.8406
2015-01	26.71	27.042	0.987723	98.77228	42.30414	0.63138	63.13803
2015-02	25.12	25.63	0.980101	98.01014	41.38429	0.606994	60.69937
2015-03	23.2	27.982	0.829104	82.91044	41.61188	0.557533	55.75331
2015-04	25.92	30.08	0.861702	86.17021	40.96089	0.632799	63.27987
2015-05	38.96	33.314	1.169478	116.9478	41.10187	0.947889	94.78887
2015-06	37.2	37.428	0.993908	99.39083	41.92305	0.88734	88.734
2015-07	41.29	40.888	1.009832	100.9832	42.93525	0.961681	96.16807
2015-08	43.77	39.566	1.106253	110.6253	45.49878	0.962004	96.20038
2015-09	43.22	37.54	1.151305	115.1305	43.17611	1.001017	100.1017
2015-10	32.35	35.586	0.909065	90.90654	43.42627	0.744941	74.49409
2015-11	27.07	33.372	0.811159	81.11591	36.74211	0.736757	73.67568
2015-12	31.52	32.726	0.963149	96.31486	38.94583	0.809329	80.93294
2016-01	32.7	35.658	0.917045	91.70453	42.30414	0.772974	77.2974
2016-02	39.99	40.716	0.982169	98.21692	41.38429	0.966309	96.63088
2016-03	47.01	46.584	1.009145	100.9145	41.61188	1.129725	112.9725
2016-04	52.36	54.398	0.962535	96.25354	40.96089	1.278292	127.8292
2016-05	60.86	62.512	0.973573	97.35731	41.10187	1.480711	148.0711
2016-06	71.77	67.664	1.060682	106.0682	41.92305	1.711946	171.1946
2016-07	80.56	69.52	1.158803	115.8803	42.93525	1.876314	187.6314
2016-08	72.77	67.462	1.078681	107.8681	45.49878	1.599384	159.9384
2016-09	61.64	60.988	1.010691	101.0691	43.17611	1.427641	142.7641
2016-10	50.57	53.754	0.940767	94.07672	43.42627	1.164503	116.4503
2016-11	39.4	49.618	0.794067	79.40667	36.74211	1.072339	107.2339
2016-12	44.39	47.846	0.927768	92.77683	38.94583	1.139788	113.9788
2017-01	52.09	51.226	1.016866	101.6866	42.30414	1.231322	123.1322
2017-02	52.78	55.434	0.952123	95.21232	41.38429	1.275363	127.5363
2017-03	67.47	57.932	1.164641	116.4641	41.61188	1.621412	162.1412
2017-04	60.44	58.056	1.041064	104.1064	40.96089	1.475554	147.5554
2017-05	56.88	58.372	0.97444	97.44398	41.10187	1.383879	138.3879
2017-06	52.71	55.918	0.94263	94.26303	41.92305	1.257303	125.7303

2017-07	54.36	54.51	0.997248	99.72482	42.93525	1.266093	126.6093
2017-08	55.2	51.994	1.061661	106.1661	45.49878	1.213219	121.3219
2017-09	53.4	49.49	1.079006	107.9006	43.17611	1.236795	123.6795
2017-10	44.3	46.64	0.949828	94.98285	43.42627	1.02012	102.012
2017-11	40.19	43.29	0.92839	92.83899	36.74211	1.09384	109.384
2017-12	40.11	39.062	1.026829	102.6829	38.94583	1.029892	102.9892
2018-01	38.45	36.642	1.049342	104.9342	42.30414	0.908894	90.88945
2018-02	32.26	35.158	0.917572	91.75721	41.38429	0.779523	77.95229
2018-03	32.2	36.198	0.889552	88.95519	41.61188	0.773817	77.38175
2018-04	32.77	37.632	0.870801	87.08014	40.96089	0.800031	80.00314
2018-05	45.31	40.408	1.121313	112.1313	41.10187	1.102383	110.2383
2018-06	45.62	43.206	1.055872	105.5872	41.92305	1.088184	108.8184
2018-07	46.14	46.224	0.998183	99.81828	42.93525	1.074641	107.4641
2018-08	46.19	47.206	0.978477	97.84773	45.49878	1.015192	101.5192
2018-09	47.86	47.95	0.998123	99.8123	43.17611	1.108483	110.8483
2018-10	50.22	48.518	1.03508	103.508	43.42627	1.156443	115.6443
2018-11	49.34	49.08	1.005297	100.5297	36.74211	1.342873	134.2873
2018-12	48.98	49.656	0.986386	98.63863	38.94583	1.257644	125.7644
2019-01	49	49.544	0.98902	98.90199	42.30414	1.158279	115.8279
2019-02	50.74	49.672	1.021501	102.1501	41.38429	1.226069	122.6069
2019-03	49.66	50.338	0.986531	98.65311	41.61188	1.193409	119.3409
2019-04	49.98	52.382	0.954145	95.41446	40.96089	1.220188	122.0188
2019-05	52.31	54.286	0.9636	96.36002	41.10187	1.272691	127.2691
2019-06	59.22	56.778	1.04301	104.301	41.92305	1.412588	141.2588
2019-07	60.26	59.2	1.017905	101.7905	42.93525	1.403509	140.3509
2019-08	62.12	60.432	1.027932	102.7932	45.49878	1.365311	136.5311
2019-09	62.09	58.578	1.059954	105.9954	43.17611	1.438064	143.8064
2019-10	58.47	56.326	1.038064	103.8064	43.42627	1.34642	134.642
2019-11	49.95	54.444	0.917456	91.74565	36.74211	1.359476	135.9476
2019-12	49	53.2	0.921053	92.10526	38.94583	1.258158	125.8158
2020-01	52.71	54.69	0.963796	96.37959	42.30414	1.245977	124.5977
2020-02	55.87	64.2	0.870249	87.02492	41.38429	1.350029	135.0029
2020-03	65.92	78.446	0.840323	84.03233	41.61188	1.584163	158.4163
2020-04	97.5	89.2	1.093049	109.3049	40.96089	2.380319	238.0319
2020-05	120.23	96.114	1.25091	125.091	41.10187	2.925171	292.5171
2020-06	106.48	101.178	1.052403	105.2403	41.92305	2.539891	253.9891
2020-07	90.44	97.702	0.925672	92.56719	42.93525	2.106428	210.6428
2020-08	91.24	85.676	1.064942	106.4942	45.49878	2.005329	200.5329
2020-09	80.12	76.168	1.051885	105.1885	43.17611	1.855656	185.5656
2020-10	60.1	69.934	0.859382	85.93817	43.42627	1.383955	138.3955
2020-11	58.94	66.952	0.880332	88.03322	36.74211	1.604154	160.4154

2020-12	59.27	66.488	0.891439	89.14391	38.94583	1.521858	152.1858
2021-01	76.33	69.532	1.097768	109.7768	42.30414	1.804315	180.4315
2021-02	77.8	71.32	1.090858	109.0858	41.38429	1.879941	187.9941
2021-03	75.32	72.446	1.039671	103.9671	41.61188	1.81006	181.006
2021-04	67.88	70.336	0.965082	96.50819	40.96089	1.65719	165.719
2021-05	64.9	69.12	0.938947	93.89468	41.10187	1.579004	157.9004
2021-06	65.78	71.314	0.9224	92.23995	41.92305	1.569065	156.9065
2021-07	71.72	70.738	1.013882	101.3882	42.93525	1.670422	167.0422
2021-08	86.29	70.804	1.218716	121.8716	45.49878	1.896534	189.6534
2021-09	65	67.742	0.959523	95.95229	43.17611	1.505462	150.5462
2021-10	65.23	63.358	1.029546	102.9546	43.42627	1.502086	150.2086
2021-11	50.47	N/A	N/A	N/A	36.74211	1.373628	137.3628
2021-12	49.8	N/A	N/A	N/A	38.94583	1.278699	127.8699

Appendix 5: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for wholesale price series.

Month	**Median Seasonal index**	**Adjustment Factor**	**Adjusted Seasonal Index**
Jan	100.2943	0.4218	42.30414
Feb	98.11353	0.4218	41.38429
Mar	98.65311	0.4218	41.61188
Apr	97.10975	0.4218	40.96089
May	97.44398	0.4218	41.10187
Jun	99.39083	0.4218	41.92305
Jul	101.7905	0.4218	42.93525
Aug	107.8681	0.4218	45.49878
Sep	102.3616	0.4218	43.17611
Oct	102.9546	0.4218	43.42627
Nov	87.1079	0.4218	36.74211
Dec	92.33245	0.4218	38.94583
		Total	500.0105

Appendix 6: Moving averages and seasonal median (unadjusted) indices for wholesale price series.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	N/A	N/A	110.6413	104.853	85.03903	89.03317	134.3856	118.9123	95.0553	77.72777	77.59153	91.52833	
2012	104.0032	104.9745	99.94802	97.62412	95.04913	88.49329	104.8165	109.8563	111.7356	107.8083	86.18257	92.55963	
2013	92.57448	87.30724	94.0947	105.2106	114.8692	91.38917	106.4846	112.1618	101.7795	112.7674	68.72327	90.17345	
2014	107.6351	102.1541	94.03813	97.10975	99.44324	101.6493	104.3983	103.4147	102.3616	105.8066	102.537	91.58866	
2015	98.77228	98.01014	82.91044	86.17021	116.9478	99.39083	100.9832	110.6253	115.1305	90.90654	81.11591	96.31486	
2016	91.70453	98.21692	100.9145	96.25354	97.35731	106.0682	115.8803	107.8681	101.0691	94.07672	79.40667	92.77683	
2017	101.6866	95.21232	116.4641	104.1064	97.44398	94.26303	99.72482	106.1661	107.9006	94.98285	92.83899	102.6829	
2018	104.9342	91.75721	88.95519	87.08014	112.1313	105.5872	99.81828	97.84773	99.8123	103.508	100.5297	98.63863	
2019	98.90199	102.1501	98.65311	95.41446	96.36002	104.301	101.7905	102.7932	105.9954	103.8064	91.74565	92.10526	
2020	96.37959	87.02492	84.03233	109.3049	125.091	105.2403	92.56719	106.4942	105.1885	85.93817	88.03322	89.14391	
2021	109.7768	109.0858	103.9671	96.50819	93.89468	92.23995	101.3882	121.8716	95.95229	102.9546	N/A	N/A	
Median	100.2943	98.11353	98.65311	97.10975	97.44398	99.39083	101.7905	107.8681	102.3616	102.9546	87.1079	92.33245	1185.421

Appendix 7: Retail price series moving averages and de-seasonalized prices.

Period	Wholesale prices	5-PMA	Seasonal Ratio	% Seasonal Ratio	Adjusted Seasonal index	De-seasonalized Wholesale index	De-seasonalized wholesale price (Rands)
2011-01	40	N/A	N/A	N/A	42.0394	0.951488	95.14883
2011-02	48.26	N/A	N/A	N/A	39.62172	1.218019	121.8019
2011-03	46.65	48.624	0.959403	95.94028	40.3203	1.156985	115.6985
2011-04	50.49	52.55	0.960799	96.07992	40.56609	1.244636	124.4636
2011-05	57.72	54.998	1.049493	104.9493	44.13117	1.307919	130.7919
2011-06	59.63	57.668	1.034022	103.4022	42.0513	1.41803	141.803
2011-07	60.5	57.788	1.04693	104.693	43.57673	1.388356	138.8356
2011-08	60	54.8	1.094891	109.4891	41.92013	1.431293	143.1293
2011-09	51.09	50.08	1.020168	102.0168	42.20626	1.210484	121.0484
2011-10	42.78	44.83	0.954272	95.42717	41.89855	1.021038	102.1038
2011-11	36.03	40.03	0.900075	90.00749	40.68778	0.885524	88.55239
2011-12	34.25	35.892	0.954252	95.42516	40.94901	0.836406	83.64061
2012-01	36	35.996	1.000111	100.0111	42.0394	0.856339	85.63394
2012-02	30.4	40.63	0.748216	74.82156	39.62172	0.767256	76.72559
2012-03	43.3	46.26	0.936014	93.60138	40.3203	1.073901	107.3901
2012-04	59.2	46.98	1.260111	126.0111	40.56609	1.459347	145.9347
2012-05	62.4	47.34	1.318124	131.8124	44.13117	1.413967	141.3967
2012-06	39.6	46.674	0.848438	84.84381	42.0513	0.941707	94.17069
2012-07	32.2	48.274	0.667026	66.70257	43.57673	0.738926	73.89265
2012-08	39.97	43.578	0.917206	91.72059	41.92013	0.95348	95.348

2012-09	67.2	42.312	1.588202	158.8202	42.20626	1.592181	159.2181
2012-10	38.92	43.992	0.884706	88.47063	41.89855	0.92891	92.89104
2012-11	33.27	42.584	0.781279	78.12794	40.68778	0.81769	81.76902
2012-12	40.6	39.882	1.018003	101.8003	40.94901	0.991477	99.1477
2013-01	32.93	46.018	0.71559	71.55896	42.0394	0.783313	78.33127
2013-02	53.69	53.656	1.000634	100.0634	39.62172	1.355065	135.5065
2013-03	69.6	59.936	1.161239	116.1239	40.3203	1.726178	172.6178
2013-04	71.46	63.228	1.130195	113.0195	40.56609	1.76157	176.157
2013-05	72	64.658	1.113551	111.3551	44.13117	1.6315	163.15
2013-06	49.39	60.458	0.816931	81.69308	42.0513	1.174518	117.4518
2013-07	60.84	55.762	1.091066	109.1066	43.57673	1.396158	139.6158
2013-08	48.6	50.946	0.953951	95.39512	41.92013	1.159348	115.9348
2013-09	47.98	54.402	0.881953	88.19529	42.20626	1.136798	113.6798
2013-10	47.92	58.554	0.81839	81.83899	41.89855	1.143715	114.3715
2013-11	66.67	60.878	1.095141	109.5141	40.68778	1.638576	163.8576
2013-12	81.6	61.842	1.319492	131.9492	40.94901	1.992722	199.2722
2014-01	60.22	63.298	0.951373	95.13729	42.0394	1.432466	143.2466
2014-02	52.8	67.244	0.7852	78.52002	39.62172	1.332602	133.2602
2014-03	55.2	61.044	0.904266	90.42658	40.3203	1.369037	136.9037
2014-04	86.4	60.04	1.439041	143.9041	40.56609	2.129858	212.9858
2014-05	50.6	61.624	0.821109	82.11087	44.13117	1.146582	114.6582
2014-06	55.2	68.824	0.802046	80.20458	42.0513	1.312682	131.2682
2014-07	60.72	64.424	0.942506	94.25059	43.57673	1.393404	139.3404

2014-08	91.2	68.97	1.322314	132.2314	41.92013	2.175566	217.5566
2014-09	64.4	71.788	0.897086	89.70859	42.20626	1.52584	152.584
2014-10	73.33	73.106	1.003064	100.3064	41.89855	1.75018	175.018
2014-11	69.29	69.798	0.992722	99.27219	40.68778	1.702968	170.2968
2014-12	67.31	67.038	1.004057	100.4057	40.94901	1.643752	164.3752
2015-01	74.66	65.252	1.144179	114.4179	42.0394	1.775953	177.5953
2015-02	50.6	58.75	0.861277	86.12766	39.62172	1.277077	127.7077
2015-03	64.4	58.488	1.101081	110.1081	40.3203	1.59721	159.721
2015-04	36.78	56.478	0.651227	65.1227	40.56609	0.906669	90.66686
2015-05	66	61.954	1.065307	106.5307	44.13117	1.495542	149.5542
2015-06	64.61	64.608	1.000031	100.0031	42.0513	1.536457	153.6457
2015-07	77.98	73.318	1.063586	106.3586	43.57673	1.789487	178.9487
2015-08	77.67	80.524	0.964557	96.45572	41.92013	1.852809	185.2809
2015-09	80.33	84.484	0.950831	95.08309	42.20626	1.903272	190.3272
2015-10	102.03	90.272	1.130251	113.0251	41.89855	2.435168	243.5168
2015-11	84.41	99.626	0.847269	84.72688	40.68778	2.074579	207.4579
2015-12	106.92	98.288	1.087824	108.7824	40.94901	2.611052	261.1052
2016-01	124.44	92.69	1.34254	134.254	42.0394	2.96008	296.008
2016-02	73.64	91.434	0.80539	80.53897	39.62172	1.858576	185.8576
2016-03	74.04	86.078	0.86015	86.01501	40.3203	1.836296	183.6296
2016-04	78.13	80.988	0.964711	96.47108	40.56609	1.925993	192.5993
2016-05	80.14	87.51	0.915781	91.57811	44.13117	1.81595	181.595
2016-06	98.99	92.546	1.06963	106.963	42.0513	2.354029	235.4029

2016-07	106.25	96.754	1.098146	109.8146	43.57673	2.438228	243.8228
2016-08	99.22	101.194	0.980493	98.04929	41.92013	2.366882	236.6882
2016-09	99.17	96.596	1.026647	102.6647	42.20626	2.349651	234.9651
2016-10	102.34	90.558	1.130104	113.0104	41.89855	2.442567	244.2567
2016-11	76	86.312	0.880526	88.05265	40.68778	1.867883	186.7883
2016-12	76.06	82.46	0.922387	92.23866	40.94901	1.857432	185.7432
2017-01	77.99	78.038	0.999385	99.93849	42.0394	1.855164	185.5164
2017-02	79.91	81.274	0.983217	98.32173	39.62172	2.016823	201.6823
2017-03	80.23	93.404	0.858957	85.89568	40.3203	1.989816	198.9816
2017-04	92.18	99.448	0.926917	92.69166	40.56609	2.272341	227.2341
2017-05	136.71	96.858	1.411448	141.1448	44.13117	3.097811	309.7811
2017-06	108.21	97.688	1.10771	110.771	42.0513	2.573285	257.3285
2017-07	66.96	105.364	0.635511	63.55112	43.57673	1.5366	153.66
2017-08	84.38	108.06	0.780862	78.08625	41.92013	2.012876	201.2876
2017-09	130.56	111.906	1.166693	116.6693	42.20626	3.09338	309.338
2017-10	150.19	119.564	1.256147	125.6147	41.89855	3.584611	358.4611
2017-11	127.44	122.688	1.038732	103.8732	40.68778	3.132144	313.2144
2017-12	105.25	116.31	0.904909	90.49093	40.94901	2.57027	257.027
2018-01	100	105.726	0.945841	94.58411	42.0394	2.378721	237.8721
2018-02	98.67	100.186	0.984868	98.48681	39.62172	2.490301	249.0301
2018-03	97.27	99.688	0.975744	97.57443	40.3203	2.412432	241.2432
2018-04	99.74	100.398	0.993446	99.34461	40.56609	2.458704	245.8704
2018-05	102.76	101.724	1.010184	101.0184	44.13117	2.328513	232.8513

2018-06	103.55	103.444	1.001025	100.1025	42.0513	2.462468	246.2468
2018-07	105.3	104.672	1.006	100.6	43.57673	2.416427	241.6427
2018-08	105.87	106.198	0.996911	99.69114	41.92013	2.525517	252.5517
2018-09	105.88	105.488	1.003716	100.3716	42.20626	2.508633	250.8633
2018-10	110.39	104.342	1.057963	105.7963	41.89855	2.634697	263.4697
2018-11	100	103.17	0.969274	96.9274	40.68778	2.45774	245.774
2018-12	99.57	102.136	0.974877	97.48766	40.94901	2.431561	243.1561
2019-01	100.01	98.52	1.015124	101.5124	42.0394	2.378959	237.8959
2019-02	100.71	97.12	1.036965	103.6965	39.62172	2.541788	254.1788
2019-03	92.31	96.27	0.958866	95.88657	40.3203	2.289417	228.9417
2019-04	93	95.346	0.975395	97.53949	40.56609	2.292555	229.2555
2019-05	95.32	94.662	1.006951	100.6951	44.13117	2.159925	215.9925
2019-06	95.39	96.872	0.984701	98.47015	42.0513	2.26842	226.842
2019-07	97.29	99.714	0.97569	97.56905	43.57673	2.232614	223.2614
2019-08	103.36	100.79	1.025499	102.5499	41.92013	2.465641	246.5641
2019-09	107.21	101.44	1.056881	105.6881	42.20626	2.540144	254.0144
2019-10	100.7	101.064	0.996398	99.63983	41.89855	2.403424	240.3424
2019-11	98.64	99.846	0.987921	98.79214	40.68778	2.424315	242.4315
2019-12	95.41	98.082	0.972757	97.27575	40.94901	2.329971	232.9971
2020-01	97.27	99.964	0.97305	97.30503	42.0394	2.313782	231.3782
2020-02	98.39	109.166	0.901288	90.12879	39.62172	2.483234	248.3234
2020-03	110.11	128.55	0.856554	85.65539	40.3203	2.730882	273.0882
2020-04	144.65	151.634	0.953942	95.39417	40.56609	3.565786	356.5786

2020-05	192.33	170.614	1.127281	112.7281	44.13117	4.358144	435.8144
2020-06	212.69	187.316	1.135461	113.5461	42.0513	5.05787	505.787
2020-07	193.29	186.518	1.036307	103.6307	43.57673	4.435624	443.5624
2020-08	193.62	176.3	1.098242	109.8242	41.92013	4.618784	461.8784
2020-09	140.66	162.912	0.863411	86.34109	42.20626	3.332681	333.2681
2020-10	141.24	154.348	0.915075	91.5075	41.89855	3.371	337.1
2020-11	145.75	150.89	0.965935	96.59354	40.68778	3.582157	358.2157
2020-12	150.47	158.932	0.946757	94.67571	40.94901	3.67457	367.457
2021-01	176.33	166.882	1.056615	105.6615	42.0394	4.194398	419.4398
2021-02	180.87	161.084	1.12283	112.283	39.62172	4.56492	456.492
2021-03	180.99	152.828	1.184273	118.4273	40.3203	4.488806	448.8806
2021-04	116.76	140.496	0.831056	83.10557	40.56609	2.878266	287.8266
2021-05	109.19	149.198	0.731846	73.18463	44.13117	2.474215	247.4215
2021-06	114.67	160.992	0.712271	71.22714	42.0513	2.726907	272.6907
2021-07	224.38	160.168	1.400904	140.0904	43.57673	5.149078	514.9078
2021-08	239.96	159.706	1.502511	150.2511	41.92013	5.724219	572.4219
2021-09	112.64	156.014	0.721986	72.19865	42.20626	2.668798	266.8798
2021-10	106.88	128.416	0.832295	83.2295	41.89855	2.550924	255.0924
2021-11	96.21	N/A	N/A	N/A	40.68778	2.364592	236.4592
2021-12	86.39	N/A	N/A	N/A	40.94901	2.109697	210.9697

Appendix 8: Median (unadjusted) seasonal indices, adjustment factor and adjusted seasonal indices for retail price series.

Month	**Median Seasonal Index**	**Adjustment Factor**	**Adjusted Seasonal Index**
Jan	99.9748	0.4205	42.0394
Feb	94.22526	0.4205	39.62172
Mar	95.88657	0.4205	40.3203
Apr	96.47108	0.4205	40.56609
May	104.9493	0.4205	44.13117
Jun	100.0031	0.4205	42.0513
Jul	103.6307	0.4205	43.57673
Aug	99.69114	0.4205	41.92013
Sep	100.3716	0.4205	42.20626
Oct	99.63983	0.4205	41.89855
Nov	96.76047	0.4205	40.68778
Dec	97.38171	0.4205	40.94901
		Total	499.9684

Appendix 9: Moving averages and seasonal median (unadjusted) indices for retail price series.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	N/A	N/A	95.94028	96.07992	104.9493	103.4022	104.693	109.4891	102.0168	95.42717	90.00749	95.42516	
2012	100.0111	74.82156	93.60138	126.0111	131.8124	84.84381	66.70257	91.72059	158.8202	88.47063	78.12794	101.8003	
2013	71.55896	100.0634	116.1239	113.0195	111.3551	81.69308	109.1066	95.39512	88.19529	81.83899	109.5141	131.9492	
2014	95.13729	78.52002	90.42658	143.9041	82.11087	80.20458	94.25059	132.2314	89.70859	100.3064	99.27219	100.4057	
2015	114.4179	86.12766	110.1081	65.1227	106.5307	100.0031	106.3586	96.45572	95.08309	113.0251	84.72688	108.7824	
2016	134.254	80.53897	86.01501	96.47108	91.57811	106.963	109.8146	98.04929	102.6647	113.0104	88.05265	92.23866	
2017	99.93849	98.32173	85.89568	92.69166	141.1448	110.771	63.55112	78.08625	116.6693	125.6147	103.8732	90.49093	
2018	94.58411	98.48681	97.57443	99.34461	101.0184	100.1025	100.6	99.69114	100.3716	105.7963	96.9274	97.48766	
2019	101.5124	103.6965	95.88657	97.53949	100.6951	98.47015	97.56905	102.5499	105.6881	99.63983	98.79214	97.27575	
2020	97.30503	90.12879	85.65539	95.39417	112.7281	113.5461	103.6307	109.8242	86.34109	91.5075	96.59354	94.67571	
2021	105.6615	112.283	118.4273	83.10557	73.18463	71.22714	140.0904	150.2511	72.19865	83.2295	N/A	N/A	
Median	99.9748	94.22526	95.88657	96.47108	104.9493	100.0031	103.6307	99.69114	100.3716	99.63983	96.76047	97.38171	1188.986