ANALYSIS OF FARM TO RETAIL PRICE TRANSMISSION FOR SELECTED AGRICULTURAL COMMODITIES DURING COVID-19 PANDEMIC IN SOUTH AFRICA

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ANALYSIS OF FARM TO RETAIL PRICE TRANSMISSION FOR SELECTED AGRICULTURAL COMMODITIES DURING COVID-19 PANDEMIC IN SOUTH AFRICA

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DECLARATION 1

I, Mkasi Felicity Ntombikayiso, declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (Agricultural Economics) has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

	21/05/2025
Signature	Date

DECLARATION 2 – PUBLICATIONS

Mkasi, F.N., Lefophane, M.H., and Belete, A. *Farm-to-Retail Price Transmission Analysis for Selected Agricultural Commodities in South Africa During the COVID-19 Pandemic.* This paper will be extracted from this mini-dissertation for review and publication in the *International Journal of Emerging Markets*.

DEDICATION

Dedicated

To

My late grandfather, Mr MJ Mkasi

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I am deeply grateful to Almighty God for granting me the strength and understanding throughout this study. I would like to express my sincere gratitude to my supervisor, Dr. M.H. Lefophane, and co-supervisor, Prof. A. Belete. Thank you for your support, motivation, and insightful critiques. Your encouragement and extensive input greatly improved my work and helped me to organise my thoughts. Completing this study would have been difficult without your invaluable guidance.

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ABSTRACT

This study aims to analyse farm-to-retail price transmission for selected agricultural commodities (ginger, garlic, and lemon) during the COVID-19 pandemic in South Africa. To achieve this, the Mark-Up Pricing model was used to estimate farm-to-retail price transmission elasticities, addressing the first objective of the study. The Houck model was employed to determine whether there is symmetric or asymmetric farm-to-retail price transmission, fulfilling the second objective. The Error Correction Model (ECM) was applied to examine the long-run relationship between farm and retail prices, achieving the third objective. Monthly data from March 2020 to December 2022 were used, with farm price data sourced from the Joburg Market and retail price data from Statistics South Africa.

The Mark-Up Pricing model revealed that farm price changes were largely passed on to retail prices, indicating limited market power by intermediaries. However, the Houck model highlighted asymmetry in this process, with retailers more responsive to rising farm prices than to decreases. The ECM results showed that the ginger market had the fastest adjustment to deviations, the garlic market adjusted moderately, and the lemon market was the slowest, indicating varying responsiveness to long-run equilibrium. Despite the asymmetry, the market eventually adjusted, with retail prices fully reflecting farm price changes. The ECM also confirmed more than complete pass-through in the long run for all commodities, supporting the asymmetry detected by the Houck model.

Therefore, stricter regulations should be implemented to monitor and prevent anti-competitive practices in the supply chain to promote fair competition. Additionally, the South African government should continue monitoring food prices, expand reporting to the regional level, introduce measures to stabilise farm prices, and establish price forecasting mechanisms to reduce uncertainty and support long-term planning for farmers and retailers.

Keywords: Farm-to-retail price transmission, selected agricultural commodities, COVID-19 pandemic

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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

The Coronavirus-2019 (COVID-19) pandemic had significant economic impacts across the world, affecting both developed and developing countries (Jinjarak et al., 2020; Mohan and Nambia, 2020; Ramsey et al., 2021). The disease was first identified in Wuhan, China, in early December 2019 (Mohan and Nambia, 2020). It quickly spread across the globe, causing a range of health complications, including sore throats, cold sores, fever or chills, dry cough, shortness of breath, loss of taste or smell, and more (Mayo Clinic, 2022). In response, health specialists recommended the use of ginger, garlic, and lemon, due to their medicinal properties believed to help reduce the effects of COVID-19 (ImmuneSchein, 2022). This led to a sudden and unexpected surge in demand for these commodities, driven by their perceived health benefits. Consequently, the prices of ginger, garlic, and lemon increased sharply (Lodolo and Muller, 2021).

It is important to demonstrate that there were significant price increases for ginger, garlic, and lemon during the COVID-19 pandemic across both developed and developing countries. For instance, in South Africa, pre-COVID-19, the prices of ginger, garlic, and lemon ranged from R90/kg to R100/kg, R50/kg to R70/kg, and R12/kg to R15/kg, respectively. Comparatively, during the pandemic, these prices surged to R360/kg to R400/kg for ginger, R100/kg to R120/kg for garlic, and R25/kg to R30/kg for lemon (Philips, 2020; Wamucii, 2021), representing increases of 300%, 100%, and 83.3%, respectively.

In Australia, the prices of ginger, garlic, and lemon prior to COVID-19 were $27/kg, $31/kg, and $14/kg, respectively. However, during the pandemic, these prices soared to $100/kg for ginger, $67/kg for garlic, and $32/kg for lemon (Nicholas, 2021; Sinclair, 2021), marking price increases of 270%, 116.13%, and 128.57%, respectively. In China, pre-COVID-19, the prices of ginger, garlic, and lemon were Rs295, Rs230, and Rs125, respectively. During the pandemic, these prices rose to Rs400 for ginger, Rs355 for garlic, and Rs311 for lemon (Khan, 2020), reflecting price increases of 35.59%, 54.35%, and 148.8%, respectively. The observed price surges for ginger, garlic, and lemon across different global markets during the COVID-19 pandemic underline the necessity for a price transmission analysis, which is the central focus of this study.

Price transmission refers to the extent to which price changes in one location influence or correlate with price changes in another location (Colman, 1995). Farm-to-retail price transmission can be either symmetric or asymmetric, depending on the magnitude and speed of these price changes. Symmetric transmission occurs when price changes at the farm level are fully passed on to the retail level. For example, when farm prices rise, retail prices increase proportionally, and vice versa. These changes are then transmitted to the final consumer (Mkhabela and Nyhodo, 2011). Previous studies by Louw et al. (2017) and Ramsey et al. (2021) provided evidence of symmetric price transmission in South African food chains and the U.S. meat market, respectively. Their findings showed that changes in farm prices were consistently reflected in retail prices, indicating that price increases were quickly passed on to final consumers.

Conversely, asymmetric price transmission occurs when farm prices increase, but retail prices decrease or remain unchanged. In such cases, the price changes at the farm level are not fully transmitted to consumers. Studies by Billa et al. (2022), Erol and Saghaian (2022), and Odiase and Saghaian (2022) identified asymmetric price transmission in the Nigerian cattle market, the U.S. beef market, and the U.S. fresh banana market, respectively. These studies highlighted that asymmetric transmission is often due to imperfect market conditions, where market power inhibits farm-level price reductions from being passed through the supply chain to consumers.

There are contrasting findings in the literature regarding the nature of price transmission during the COVID-19 pandemic. For instance, Ramsey et al. (2021) found evidence of symmetric price transmission in the U.S. meat market. In contrast, studies by Billa et al. (2022), Erol and Saghaian (2022), and Odiase and Saghaian (2022) reported asymmetric price transmission in the Nigerian cattle market, the U.S. beef market, and the U.S. fresh banana market, respectively. However, there is a lack of empirical evidence on the nature of price transmission for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa, particularly regarding whether it was symmetric or asymmetric for these selected agricultural commodities. In other words, existing studies on price transmission during COVID-19 do not offer insights into the dynamics of price transmission for South African ginger, garlic, and lemon, as they were conducted in other countries and focused on different commodities. The rationale for conducting this study is to address the literature gap by providing empirical evidence on the nature of price transmission, whether symmetric or asymmetric, for ginger, garlic, and lemon in South Africa during the COVID-19 pandemic, as existing studies have focused on different commodities and countries.

1.2 Problem statement

Agricultural commodities (ginger, garlic, and lemon) are associated with various medicinal benefits, including soothing sore throats, alleviating cold sores, and improving the respiratory system (ImmuneSchein, 2022). For instance, and according to Vats (2020), garlic has antibacterial properties that can help fight infections, while ginger is known to treat sore throats and colds due to its antioxidant, antibacterial, and anti-inflammatory properties. Lemon, rich in vitamin C, aids in boosting the immune system and reducing the severity of colds and sore throats (Vats, 2020).

The outbreak of the COVID-19 pandemic led to a sudden and unexpected surge in demand for ginger, garlic, and lemon, driven by the perceived medicinal benefits of these commodities (Lodolo and Muller, 2021). As a result of the increased demand, prices for these commodities rose sharply (Lodolo and Muller, 2021). This price increase was influenced by a low supply of ginger, garlic, and lemon, as farmers and producers had not anticipated the surge in demand (Spiller, 2021). To balance supply and demand, some retail food stores increased the prices of these commodities (Lodolo and Muller, 2021). For example, in South Africa, the prices of ginger, garlic, and lemon increased by 300%, 100%, and 83.3%, respectively, during the COVID-19 pandemic.

While the prices of ginger, garlic, and lemon increased during the COVID-19 pandemic in South Africa (Duma, 2021), the nature of the price transmission, specifically, whether farm-to-retail price transmission was symmetric or asymmetric, remains unknown. An analysis of price transmission is important, as farmers and retailers often experience unequal price changes. For instance, when farm prices decrease, retail prices may take time to adjust (Mkhabela and Nyhodo, 2011). Such delays in price adjustments can lead to issues such as market power, market failure, and marketing inefficiencies (Hosseini et al., 2012).

Given that the surge in demand and price increases for ginger, garlic, and lemon were unexpected, no studies have analysed symmetric or asymmetric price transmission for these commodities during the COVID-19 pandemic in South Africa. To support this, previous scholars such as Cutts and Kirsten (2006), Mkhabela and Nyhodo (2011), Lombard (2015), and Louw et al. (2017) have focused on price transmission in agro-food industries, poultry, beef, and food value chains, respectively, prior to the COVID-19 pandemic. Understanding whether price transmission was symmetric or asymmetric during this period is essential for assessing market efficiency and informing future policy interventions under crisis conditions. Therefore, this study aims to fill this research gap by analysing the nature of price transmission for these selected commodities during the COVID-19 pandemic in South Africa.

1.3 Aim and objectives

1.3.1 Aim of the study

To analyse farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa.

1.3.2 Objectives of the study

i. To estimate farm-to-retail price transmission elasticities for selected agricultural commodities during the COVID-19 pandemic in South Africa.

ii. To determine the nature of farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa.

iii. To determine long-run relationship between farm prices and retail prices for selected agricultural commodities during the COVID-19 pandemic in South Africa.

1.3.3 Hypotheses of the study

i. There are no significant farm-to-retail price transmission elasticities for the selected agricultural commodities during the COVID-19 pandemic in South Africa.

ii. There is no symmetric farm-to-retail price transmission for the selected agricultural commodities during the COVID-19 pandemic in South Africa.

iii. There is no long-run relationship between farm prices and retail prices for the selected agricultural commodities during the COVID-19 pandemic in South Africa.

1.4 Rationale

The rationale of this study is based on the need to understand how price transmission for selected agricultural commodities (ginger, garlic, and lemon) functioned during the COVID-19 pandemic in South Africa. Price transmission analysis is essential for understanding how prices are determined and transmitted along the agricultural value chain, especially during periods of food price crises (Timmer, 2009; Mkhabela and Nyhodo, 2011). In times of market disruption, such as the COVID-19 pandemic, understanding how farm prices affect retail prices and the resulting price transmission mechanisms becomes even more critical. Price transmission is a key determinant of market efficiency and equity, particularly in times of economic shocks (von Cramon-Taubadel and Goodwin, 2021).

During the pandemic, the prices of ginger, garlic, and lemon experienced significant increases, driven by a surge in demand and constrained supply (Barman et al., 2021; Lodolo and Muller, 2021). The pandemic-induced changes in consumer behaviour, supply chain disruptions, and logistical challenges contributed to this price volatility (Kunyanga et al., 2023). Given this context, it is crucial to analyse the price transmission mechanisms for these commodities during the pandemic to identify how retail prices responded to changes in farm prices and to assess the market's ability to absorb supply-side shocks.

To address this, price transmission elasticities for ginger, garlic, and lemon during the pandemic were estimated. The results provide insights into how changes in retail prices compared to farm prices have affected the marketing margins for these commodities. By understanding the price transmission elasticities, policymakers and market actors can assess the magnitude of price changes and develop strategies to regulate price fluctuations more effectively (Gutierrez et al., 2022).

Another important aspect of the study is determining whether farm-to-retail price transmission for these commodities is symmetric or asymmetric. If price transmission is symmetric, it suggests that price changes at the farm level were transmitted to retail prices in both directions (Mkhabela and Nyhodo, 2011). However, if the transmission is asymmetric, it implies that price changes were passed on more quickly in one direction than the other, potentially indicating market power among retailers (Falkowski, 2010). Identifying the nature of price transmission can help policymakers formulate interventions to address any imbalances in market power and ensure that price changes are equitably distributed along the value chain (Li, 2020).

Finally, the study examines the long-run relationship between farm prices and retail prices for ginger, garlic, and lemon during the pandemic. The results offer an understanding of whether these price relationships were temporary or long-lasting, providing insights into the stability of the market. If farm and retail prices are co-integrated, it indicates a long-term equilibrium relationship between the two, which is critical for predicting future market behaviour and informing policy decisions related to price regulation and market support (Yu and Gould, 2019; Erol and Saghaian, 2022). Understanding the long-term dynamics of price transmission helps policymakers predict how agricultural markets will respond to future shocks and design more effective interventions that enhance market resilience (Sharma et al., 2025). Overall, this study's findings contribute to a broader understanding of agricultural price dynamics during periods of economic disruption and assist policymakers in designing effective market interventions to enhance food security and market stability (Barman et al., 2021; Gutierrez et al., 2022).

1.5 Organisation of the study

Chapter One covered the background of the study, the problem statement, the aim and objectives, and the motivation. Chapter Two entails the definition of basic concepts and a literature review of national and international studies on farm-to-retail price transmission for selected agricultural commodities or products. Chapter Three presents the research methodology, including the study area, data sources, and the analytical tools, namely, unit root tests, the Mark-Up Pricing model, the Houck model, the Error Correction Model (ECM), and diagnostic tests. Chapter Four provides an overview of the South African ginger, garlic, and lemon markets, including production and consumption, challenges faced by farmers, government support, trade, and the market value chain. Chapter Five presents a discussion of the results for the unit root tests, Mark-Up Pricing, Houck and ECM models, and diagnostic test results. Chapter Six provides a summary of the study's findings, conclusions, and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The literature review section covers key concepts and previous studies related to price transmission, focusing on the dynamics between farm and retail prices for agricultural commodities. It begins by defining price transmission, highlighting both symmetric and asymmetric transmission. The review includes international studies examining price transmission across various markets, such as poultry, rice, and cattle, identifying instances of asymmetric transmission linked to market power and inefficiencies. It then shifts to national literature, examining price transmission in South Africa's agro-food industries, with a focus on poultry, beef, wheat, and maize chains. Lastly, the chapter identifies key gaps in the literature, noting the lack of empirical research on price transmission for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa, and the absence of evidence on whether the observed price increases for these commodities were temporary or long-lasting.

2.1.1 Definition of key concepts

2.1.1.1 Price transmission

According to Colman (1995), price transmission refers to the extent to which price changes in one location cause or correlate with price changes in another location. In the context of farm-to-retail price transmission, it can be either symmetric or asymmetric, depending on the magnitude and speed at which prices are transmitted. Symmetric price transmission occurs when price changes at the farm level are fully and proportionately passed on to the retail level. This means that if farm prices rise, retail prices also increase, and if farm prices fall, the retail prices decrease accordingly. In this case, the changes are transmitted all the way to the final consumer (Mkhabela and Nyhodo, 2011). For example, previous studies by Louw et al. (2017) and Ramsey et al. (2021) found symmetric price transmission in the South African food supply chain and the U.S. meat market, respectively. Their results indicated that changes in farm prices led to corresponding changes in retail prices, implying that price increases were promptly passed on to consumers.

In contrast, asymmetric price transmission occurs when price changes at the farm level are not fully reflected at the retail level. For instance, an increase in farm prices may not be matched by a corresponding increase in retail prices, or a price reduction at the farm level may not lead to a price decrease for consumers. This suggests imperfect transmission along the supply chain. Studies by Billa et al. (2022), Erol and Saghaian (2022), and Odiase and Saghaian (2022) found evidence of asymmetric price transmission in the Nigerian cattle market, the U.S. beef market, and the U.S. fresh banana market, respectively. These studies indicated that market power often led to asymmetric transmission, as price reductions at the farm level were not fully passed on to the retail level.

In the context of this study, price transmission refers to the effects of price changes for ginger, garlic, and lemon from the farm level to the retail level. There are two possible outcomes for price transmission, depending on the magnitude and speed of transmission: symmetric and asymmetric price transmission. In this study, symmetric price transmission refers to equal and proportional changes in the prices of ginger, garlic, and lemon from the farm to the retail level. Conversely, asymmetric price transmission refers to unequal changes in these prices between the farm and retail levels.

2.1.1.2 COVID-19 pandemic

The COVID-19 pandemic is caused by a virus that was discovered in Wuhan, China, in early December 2019 (Mohan and Nambia, 2020). It rapidly spread across the globe, causing health complications such as sore throats, cold sores, fever or chills, dry cough, shortness of breath, and loss of taste or smell, among others (Mayo Clinic, 2022). In Africa, the first confirmed case was reported on February 14, 2020, in Egypt, followed by Nigeria later that month. South Africa recorded its first case on March 5, 2020. Within three months, the virus had spread across the entire continent, with Lesotho being the last African country to report a case on May 13, 2020 (Lone and Ahmad, 2020).

In response, the South African government implemented several non-pharmaceutical measures to limit the spread of the virus. These included lockdown restrictions (ranging from Alert Level 5 to Alert Level 1), social distancing of at least 1.5 meters, mandatory mask-wearing in public places, and the use of sanitisers (South African Government, 2020; South African Government, 2024). To mitigate the effects of COVID-19, ginger, garlic, and lemon were recommended for their medicinal properties, leading to a significant increase in demand and a corresponding spike in prices (Lodolo and Muller, 2021). The sharp rise in the prices of these commodities during the pandemic highlights the need for a price transmission analysis, which is the focus of this study.

2.2 Review of related literature

2.2.1 International literature review

Hosseini et al. (2012) analysed price transmission in the Iranian chicken market from October 2002 to March 2006, using the Houck, Error Correction, and Threshold Models. The results revealed that price transmission was symmetric in the long run but asymmetric in the short run. This means that, in the short run, the market behaves in a way that favours retailers when farm prices fall, leading to slower price reductions for consumers. However, in the long run, the market adjusts, and both price increases and decreases at the farm level are eventually reflected in retail prices.

Fiamohe et al. (2013) examined price transmission between paired producer and consumer markets for local rice in Benin and Mali using the Threshold Model (Enders and Siklos) for the period 2000 to 2010. In Benin, price increases in surplus zone markets were transmitted faster to the consumer market than price decreases. In contrast, Mali exhibited symmetric price transmission, indicating lower transaction costs in the market.

De and Koemle (2015) studied price transmission between hog prices and feed prices (domestic maize and international soybean) in China from January 2000 to April 2014 using the Vector Error Correction Model (VECM). Their findings showed asymmetric price transmission, with inefficiencies in price transmission across hog, maize, and soya markets. The hog market demonstrated market power, limiting the transmission of price changes, and indicating a long-term relationship between farm and retail prices, where price increases persisted over time.

Kharin (2018) investigated vertical price transmission along the Russian milk supply chain from 2002 to 2014 using a Vector Autoregression Model (VAR). The study found that farm price responses to retail price changes were greater and longer-lasting than retail price responses to farm price changes, due to retailers holding more market power. This resulted in asymmetric price transmission, where price reductions at the farm level were only partially and slowly passed through the supply chain.

Ramsey et al. (2021) analysed the impact of COVID-19 on price transmission in the US meat markets using Linear and Threshold Autoregressive Models and the VECM for the period 2010 to 2015. The results showed that COVID-19 caused supply and demand shocks, leading to high retail prices. Overall, the study found symmetric price transmission, with price changes at the farm level being transmitted to consumers.

Billa et al. (2022) examined price transmission in the Nigerian cattle market from 2002 to 2017 using the Threshold Vector Error Correction Model (TVECM). The results indicated asymmetric price transmission due to inefficiencies and lack of competition, where farm price decreases were not reflected in retail prices, suggesting that price changes were not transmitted to consumers.

Erol and Saghaian (2022) explored the impact of COVID-19 on vertical price transmission in the US beef industry, analysing monthly farm, wholesale, and retail prices from 1970 to 2021. The results showed asymmetric price adjustments, with wholesale prices adjusting faster than farm and retail prices. The study concluded that consumers and farmers bore the brunt of the pandemic, paying higher prices while receiving lower incomes, although the market returned to pre-shock conditions within four to six months.

Odiase and Saghaian (2022) investigated the effect of COVID-19 on price transmission in the US fresh banana market from January 2001 to December 2020, using the VECM. They found that price adjustments were asymmetric, with import prices recovering faster than retail prices, resulting in increased price margins. The study attributed this asymmetry to market power, where price reductions at the farm level were slowly transmitted, benefiting those with greater market control.

2.2.2 Literature review from a South African perspective

Cutts and Kirsten (2006) analysed asymmetric price transmission and market concentration in South Africa's agro-food industries using the Error Correction Model on data from January 2000 to December 2003. The results revealed asymmetric price transmission, where farmers were receiving low prices while consumers were paying higher amounts. This indicates that price changes were not evenly transmitted through the value chain, suggesting market inefficiencies.

Mkhabela and Nyhodo (2011) examined farm-to-retail price transmission in the South African poultry industry using Houck and Error Correction models with data from 1993 to 2010. The results showed elastic price transmission, meaning that retail prices responded strongly to changes in farm prices, with more than a one-to-one relationship. This implies that a unit change in the farm price of chicken led to a greater change in the retail price, resulting in increased marketing margins for chicken in South Africa. Additionally, the study found symmetry in price transmission, where changes in farm prices were fully transmitted to retail prices and then to consumers. The long-run relationship between farm and retail prices suggested that these price changes would persist over time.

Lombard (2015) investigated price transmission in the South African beef value chain using the Vector Error Correction Model (VECM) using data from 2012 to 2014. The study found asymmetric price transmission, attributed to market power within the beef sector. This means that price reductions at the farm level were slowly and incompletely passed through the supply chain, allowing those with market power to maintain higher profit margins.

Louw et al. (2017) studied vertical price transmission and its inflationary effects in South Africa's food chains using the VECM for data spanning from January 2000 to September 2016. The findings showed symmetry in price transmission for the wheat-to-bread and maize-to-maize meal chains, meaning that changes in farm prices were fully reflected at the retail level and passed on to consumers.

2.2.3 Discussion of main findings

Overall, both international and national studies exhibit common findings related to market power and price transmission asymmetry. For instance, several studies noted that market power plays a crucial role in price transmission asymmetry. In essence, market power held by retailers or intermediaries often results in slower price decreases reaching consumers, even when farm prices fall (De and Koemle, 2015; Lombard, 2015; Kharin, 2018; Odiase and Saghaian, 2022). This suggests that retailers and intermediaries, due to their dominant positions, delay passing price reductions to consumers while quickly responding to price increases.

Studies in both international (e.g., Billa et al., 2022; De and Koemle, 2015) and national settings (e.g., Cutts and Kirsten, 2006; Lombard, 2015) found evidence of asymmetric price transmission. This is often attributed to market inefficiencies or power dynamics, where price decreases at the farm level are not fully transmitted to retail prices. In other words, this underlines market inefficiencies and power imbalances that could disadvantage consumers by keeping prices unnaturally high, even when farm prices fall. While many studies found asymmetric price transmission, Ramsey et al. (2021) and Louw et al. (2017) reported symmetric transmission in some markets, such as the US meat market and the South African wheat-to-bread and maize-to-maize meal chains. In these cases, price changes at the farm level were fully reflected at the retail level and transmitted to consumers.

In addition to market power and symmetric/asymmetric price transmission findings, studies by Ramsey et al. (2021) and Erol and Saghaian (2022) in the US highlighted the disruptions caused by COVID-19 on price transmission. These studies found that the pandemic led to price asymmetries and supply chain shocks, with price changes often favouring retailers or intermediaries. Specifically, these studies show how supply chain shocks can exacerbate price transmission asymmetries, particularly affecting vulnerable actors in the market.

There are also varying findings, especially in terms of market efficiency and responsiveness to price changes, across both the international and national studies. For example, Mkhabela and Nyhodo (2011) found elastic price transmission in the South African poultry market, where retail prices responded more than proportionally to changes in farm prices. In contrast, studies like Billa et al. (2022) found evidence of inelastic transmission in the Nigerian cattle market, where price reductions were not fully passed on to consumers.

2.2.4 Discussion of literature gaps

From the reviewed literature, both internationally and nationally, three key gaps were identified. First, there is no empirical evidence on price transmission elasticities for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa. For example, the study by Mkhabela and Nyhodo (2011) focused on poultry price transmission, not on ginger, garlic, or lemon, and was conducted outside the COVID-19 context.

Second, no empirical research has explored symmetric or asymmetric price transmission for ginger, garlic, and lemon during the pandemic in South Africa. Previous studies concentrated on agro-food industries, food value chains, rice, milk, meat, and banana markets (Cutts and Kirsten, 2006; Fiamohe et al., 2013; Louw et al., 2017; Kharin, 2018; Erol and Saghaian, 2022; Odiase and Saghaian, 2022). Therefore, these studies do not offer insight into whether farm-to-retail price transmission for these specific commodities during the pandemic was symmetric or asymmetric.

Third, there is no evidence on whether the observed price increases for ginger, garlic, and lemon during the COVID-19 pandemic were temporary or long-lasting. While Mkhabela and Nyhodo (2011) examined the co-integration relationship between farm and retail prices for poultry in South Africa, and De and Koemle (2015) did the same for hog and feed prices in China, these studies cannot provide insights into the price dynamics of ginger, garlic, and lemon during the pandemic.

This study addresses these gaps and contributes to the literature in three ways, in line with the three objectives of the study. Firstly, it focuses on estimating farm-to-retail price transmission elasticities for selected commodities during COVID-19 pandemic in South Africa. By so doing, this study contributes to literature by providing empirical evidence on farm-to-retail price transmission elasticities for ginger, garlic, and lemon during COVID-19 in South Africa, addressing a gap by showing how price increases impacted marketing margins.

Secondly, it is focused on determining whether there is symmetric or asymmetric farm-to-retail price transmission for selected agricultural commodities during COVID-19 pandemic in South Africa. In so doing, this study contributes to literature by exploring whether price transmission for these commodities is symmetric or asymmetric, filling a gap in understanding how market power affects price changes during the pandemic.

Lastly, it focuses on examining long-run relationship between retail prices and farm prices for selected agricultural commodities during COVID-19 pandemic in South Africa. By so doing, this study contribute to literature by offering insights into whether the price increases for these commodities during COVID-19 were temporary or long-lasting.

2.3 Chapter summary

The literature review section covered key concepts and previous studies related to price transmission, focusing on the dynamics between farm and retail prices for agricultural commodities. It began by defining price transmission, highlighting both symmetric and asymmetric transmission. The review included international studies that examined price transmission across various markets, such as poultry, rice, and cattle, and identified instances of asymmetric transmission linked to market power and inefficiencies. It then shifted to national literature, examining price transmission in South Africa's agro-food industries, with a focus on poultry, beef, wheat, and maize chains. Lastly, the chapter identified key gaps in the literature, noting the lack of empirical research on price transmission for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa, and the absence of evidence on whether the observed price increases for these commodities were temporary or long-lasting.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The chapter provides a description of the study area and data sources. The chapter also covers the analytical techniques, which are categorised into three sections. The first section entails the pre-testing methods, specifically unit-root testing, which is done to check for stationarity, using the Augmented Dickey-Fuller test and the Phillips-Perron test. The second section involves a description of econometric modelling methods, namely, the Mark-Up Pricing Model, which was used to address the first objective, the Houck Model, which was used to address the second objective, and finally, the Error Correction Model, which was used to address the third objective. The last section entails a description of validation tests meant to validate the econometric model results using diagnostic tests.

3.2 Study area

The study was conducted in South Africa, a country located on the southernmost part of the African continent, known for its stunning natural beauty and cultural diversity, which have captured the attention of travellers (Bundy, 2022). South Africa has a diversified, market-oriented agricultural economy, producing a wide range of products, including major grains (except rice), ginger, oilseeds, sugar, citrus, and garlic. The country is divided into nine provinces, with the main producers of ginger, garlic, and lemon being Mpumalanga, Gauteng, and Limpopo Provinces, respectively. Figure 3.1 illustrates the map of South Africa, highlighting the provinces that are the primary producers of ginger, garlic, and lemon.

Figure 3.1: South African map

Source: Nations Online Project (2023)

At the onset of the COVID-19 pandemic, there was a sudden and unanticipated spike in demand for ginger, garlic, and lemon, driven by the perceived medicinal benefits of these commodities. However, farmers were unable to foresee this surge in demand, resulting in a limited supply and a consequent rise in retail prices (Vats, 2020; Lodolo and Muller, 2021). These observed price increases highlight the need for this study to analyse price transmission for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa.

3.3. Data collection

3.3.1 Data sources

The study used secondary time-series data. A time series is a sequence of data points typically measured at consecutive, equally spaced intervals (week, month, year, etc.) (Vavra and Goodwin, 2005). Thus, secondary time-series data for farm and retail prices from March 2020 to December 2022 were used to analyse farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa. The period March 2020 to December 2022 was chosen because COVID-19 was first detected in South Africa in March 2020, and the related regulations were lifted in 2022 (South African Government, 2022). Farm price data were sourced from Joburg Market, while retail price data were sourced from Statistics South Africa (Stats SA) and the price monitoring reports of the National Agricultural Marketing Council (NAMC). Retail price data from the NAMC were used to supplement missing data points in the Stats SA dataset.

3.3.2 Data set

In this study, monthly data from March 2020 to December 2022 were used to analyse farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa. Specifically, the data include monthly farm and retail prices for ginger, garlic, and lemon over this period, as presented in Table 3.1.

Table 3.1: Description of variables

Variable type	**Variable name**	**Description**
Dependent	Retail Prices (Ginger, Garlic, Lemon)	Monthly retail prices for ginger, garlic, and lemon from March 2020 to December 2022
Independent	Farm Prices (Ginger, Garlic, Lemon)	Monthly farm prices for ginger, garlic, and lemon from March 2020 to December 2022

Therefore, the total observations for each commodity (ginger, garlic, and lemon) is 34, and the overall total observations for the study, combining all three commodities, is 102. The overall observations for the study and for each commodity meets the recommended minimum of 30 to 50 observations for reliable time-series modelling, ensuring sufficient statistical power and robustness in the analysis (Gujarati and Porter, 2009).

3.4 Analytical techniques

3.4.1 Unit root testing

The Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test were used to check whether farm prices and retail prices are integrated of the same order or different orders. In line with previous studies, both the ADF and PP tests were applied, with the ADF test conducted first, followed by the PP test, to provide a more comprehensive analysis of stationarity and ensure robustness against heteroskedasticity and autocorrelation (Acquah and Owusu, 2012; Joiya and Shahzad, 2013; Halagundegowda et al., 2021).

The Augmented Dickey-Fuller (ADF) test is an extended version of the Dickey-Fuller test and is used for larger and more complex time-series data. The ADF test accounts for the possibility of serial correlation in the errors by adding lagged values of the dependent variable. It tests the null hypothesis that a unit root is present (i.e., the series is non-stationary) against the alternative hypothesis that the series is stationary. The ADF test involves estimating the following regression (Hamilton, 1994):

$$\triangle Y_t = \alpha + \beta_t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \triangle Y_{t-1} + \varepsilon_t \quad (1)$$

Where: ΔY_t represents the first difference of the time series ($Y_t - Y_{t-1}$), α is the constant (intercept) term, β_t is the trend component (optional, depending on the test), γ is the coefficient of the lagged level of the time series, δ_i represents coefficients of the lagged differences of the time series, p is the number of lags included to account for serial correlation, and ε_t is the error term.

On the other hand, the Phillips-Perron (PP) test is known to better correct for heteroskedasticity and serial correlation in the error terms compared to other unit root tests. Additionally, the PP test has the advantage of capturing structural breaks and the short-run behaviour of the data (Joiya and Shahzad, 2013). The PP test addresses the limitations of the ADF test (which only accounts for autocorrelation in the first differences of a series by estimating additional parameters) by using non-parametric statistical methods to handle serial correlation in the error terms without including lagged difference terms (Gujarati and Porter, 2009). Therefore, it is important in this study to complement the ADF test with the PP test. The PP test estimates the following equation (Enders, 2014):

$$\triangle Y_t = \alpha + \beta_t + \gamma y_{t-1} + \varepsilon_t \quad (2)$$

Where: $\Delta yt = y_t - y_{t-1}$ is the first difference of the series at time t, α is a constant (drift term), βt is the deterministic trend term, y_{t-1} is the lagged level of the series, γ is the coefficient of the lagged level, which is tested for stationarity, and ε_t is the error term.

The key difference between the ADF and PP tests is that, while the ADF test includes lagged differences to handle autocorrelation, the PP test uses a correction factor to adjust for autocorrelation and heteroskedasticity. However, like the ADF test, if the null hypothesis of a unit root is rejected, it indicates that the series is stationary (Enders, 2014; Greene, 2018).

In this study, conducting unit root tests is necessary to ensure that farm and retail price data are either stationary or co-integrated, given the three models used to achieve the study's objectives. Specifically, the first objective involves estimating farm-to-retail price elasticities. Non-stationary farm and retail price data can lead to spurious results, making unit root testing essential to determine whether the data need to be differenced to ensure stationarity, which is crucial for valid elasticity estimation.

The second objective requires determining the nature of price transmission between farm and retail prices. Therefore, unit root testing is essential to ensure that the data are stationary or co-integrated to ensure proper modelling of short-run asymmetries. The third objective involves co-integration analysis, which typically requires both farm and retail prices to be integrated of the same order (either I(0) or I(1)) to test for a long-run relationship. Thus, unit root testing is critical to verify the integration order of farm and retail prices before conducting farm-to-retail price transmission analysis.

3.4.2 Empirical models

3.4.2.1 Mark-Up Pricing model

The Mark-Up Pricing Model was used to address the first objective, which is to estimate farm-to-retail price transmission elasticities for selected agricultural commodities during the COVID-19 pandemic in South Africa. The Mark-Up Pricing Model has been widely used in previous studies to estimate price transmission elasticities (Kinnucan and Forker, 1987; Goodwin and Holt, 1999; Mkhabela and Nyhodo, 2011). An alternative to the Mark-Up Pricing Model is the Price Spread

Specification Model, which has been shown to outperform the Mark-Up Pricing Model (Gardner, 1975; Wohlgenant and Mullen, 1987). Although the Price Spread Specification Model is generally regarded as superior, the Mark-Up Pricing Model has proven to be more effective than the Price Spread Specification Model in producing more reliable price transmission elasticity estimates (Mkhabela and Nyhodo, 2011). The Mark-Up Pricing Model is as follows:

$$\mathrm{MM_t} = \mathrm{c} + \beta_1 \mathrm{P_{rt-1}} + \beta_2 \mathrm{P_{ft-1}} \quad (3)$$

Where $\mathrm{MM_t}$ is the retail price ($\mathrm{P_{rt}}$) less farm price ($\mathrm{P_{ft}}$) in month t (R/kg), $\mathrm{P_{rt}}$ is retail prices and $\mathrm{P_{ft}}$ is farm prices of the agricultural commodities (R/kg).

Equation (3) can be estimated using either an ordinary least squares (OLS) or generalised least squares (GLS) model. According to the rule of thumb, generalised least squares is used if serial correlation is present, while ordinary least squares is applied if serial correlation is absent (Mkhabela and Nyhodo, 2011). The advantage of the Mark-Up Pricing Model is its ability to produce price transmission elasticities for agricultural commodities (e.g., ginger, garlic, and lemon) over a time series of particular interest. The formula for the elasticity of price transmission is as follows:

$$\mathrm{EPT_t} = \frac{1}{(1-\beta_1)} * \frac{\mathrm{P_{rt}}}{\mathrm{P_{ft}}} \quad (4)$$

3.4.2.2 Houck model

The second objective, which is to determine whether there is symmetric or asymmetric farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa, was addressed using the Houck Model. According to Capps and Sherwell (2007), Houck's (1977) model is the most appropriate for analysing whether price transmission is symmetric or asymmetric for agricultural commodities, as confirmed by previous scholars (Kinnucan and Forker, 1987; Boyd and Brorsen, 1998; Peltzman, 2000; Aguiar and Santana, 2002; Mkhabela and Nyhodo, 2011).

Wolfram's (1971) technique first introduced the variable-splitting method to estimate asymmetry in price transmission. Houck (1977) adapted Wolfram's approach by excluding the initial observations. While Wolfram's method involves a recurring sum of all positive and negative changes, the Houck Model focuses on the relationship where retail prices are a function of farm prices, and vice versa. The Houck Model can be expressed as:

$$\Delta\, P_{rt} = \alpha_0 + \alpha_1 \Delta P_{ft}^{+} + \alpha_2 \Delta P_{ft}^{-} + \epsilon_t \quad (5)$$

Where P_{ft} is farm price of agricultural commodities (R/kg), t = 1, 2,..., Δ is the first difference operator, ΔP_{ft}^{+} is cumulative of $P_{ft} - P_{ft-1}$, if $P_{ft} > P_{ft-1}$ and 0 otherwise, and ΔP_{ft}^{-} is cumulative of $P_{ft} - P_{ft-1}$, if $P_{ft} < P_{ft-1}$ and 0 otherwise.

Modification of Equation (5) can be done by including a time lag, which can be estimated through generalised or ordinary least squares and thus be written as:

$$\Delta\, P_{rt} = \alpha_0 + \sum_{i=0}^{M_1} \alpha_1 \Delta P_{ft}^{+} + \sum_{i=0}^{M_2} \Delta P_{ft}^{-} + \epsilon_t \quad (6)$$

Where M_1 and M_2 are the length of the lags, and other variables are as described in Equation (5).

Asymmetry hypothesis formal test (shown by Equation 7) can be conducted using a t-test or F-test, which follows Gardner (1975) specification, as follows.

$$H_0: \sum_{i=0}^{M_1} \alpha_{1i} = \sum_{i=0}^{M_2} \alpha_{2i} \quad (7)$$

The lag lengths were determined using the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). Both criteria are commonly used for selecting the most appropriate model, which helps in avoiding misspecified and over-parametrised models (Ludden et al., 1994).

3.4.2.3 Error Correction Model (ECM)

Equation (7) can further be determined using the Error Correction Model (ECM). In other words, the third objective, which is to examine long-run relationship between farm prices and retail prices for selected agricultural commodities during the COVID-19 pandemic in South Africa, was addressed using the ECM. The ECM is specifically designed to analyse both the short-run and long-run relationships between variables. Since the Houck model captures the short-run nature of price transmission, in this study, the ECM focuses only on the long-run adjustments to avoid redundancy, while still providing a comprehensive understanding of how quickly and to what extent deviations from the long-run equilibrium are corrected. Therefore, the ECM is used in this study to assess how farm and retail prices for selected agricultural commodities adjust to deviations from their long-run equilibrium during the COVID-19 pandemic in South Africa. It helps to identify both the long-term co-integration relationship and the speed of adjustment in the short run. The residuals of the ECM can be included in the Engle-Granger Theorem, and the price transmission process equation is given as:

$$\Delta P_{rt} = \alpha_0 + \alpha_1 \Delta P_{ft} + \alpha_2 ECT_{t-1} + \sum_{i=1}^{M_1} \alpha_{3i} \Delta P_{rt-i}^{+} + \sum_{i=1}^{M_2} \alpha_{4i} \Delta P_{ft-1} + \epsilon_t \quad (8)$$

Where ECT is the residuals resulting from the co-integrating relationship between P_{rt} and P_{ft} and other variables are defined above.

Granger and Lee (1989) modified Equation (8), resulting in the splitting of the Error Correction Term (ECT) into two components (positive and negative). Von Cramon-Taubadel and Loy (1999) made further developments, allowing the integration of ΔP_{ft} results into an asymmetric Error Correction Model. The model is expressed as follows:

$$\Delta P_{rt} = \alpha_0 + \sum_{i=1}^{M_1} \alpha_{1i} P_{rt-i} + \sum_{i=0}^{M_2} \alpha_{2i}^{-} \Delta P_{ft-i}^{-} + \alpha_{3i}^{+} ECT_{t-1}^{+} + \alpha_{3}^{-} ECT_{t-1}^{-} + \epsilon_t \quad (9)$$

Equation (9) yields the long-run or cumulative effect of farm-to-retail price transmission (i.e., for both increasing and decreasing price transmission). The long-run effect of the increasing and decreasing farm-to-retail price transmission model is given as:

$$\Delta P_{rt} = \alpha_0 + \sum_{i=1}^{M_1} \alpha_{1i} \Delta P_{rt-i} + \alpha_{2i} \Delta P_{ft-i}^{+} \sum_{i=0}^{M_2} \alpha_{3i}^{+} \Delta P_{ft-i}^{+} + \alpha_{4i}^{-} \Delta P_{ft-i}^{-} + \sum_{i=0}^{M_3} \alpha_{5i}^{-} \Delta P_{ft-i}^{-} + \alpha_{6}^{+} ECT_{t-1}^{+} + \alpha_{7}^{-} ECT_{t-1}^{-} \epsilon_t \quad (10)$$

The Error Correction Model approach is superior to the Houck approach, as the coefficients α_{1i}, α_{6}^{+}, and α_{7}^{-} are statistically different from zero when Equation (10) is estimated through generalised or ordinary least squares estimation. Since the price transmission for agricultural commodities (ginger, garlic, and lemon) can be either symmetrical or asymmetrical, a t-test or F-test can be conducted using the hypothesis outlined below:

$$H_0: \alpha_{2i}^{+} = \alpha_{4i}^{-} \text{ or } \sum_{i=0}^{M_2} \alpha_{3i}^{+} = \sum_{i=0}^{M_3} \alpha_{5i}^{-} \quad (11)$$

Price transmission elasticities for the short-run and long-run can be derived from Equation (10) and are written as follows:

Short-run price transmission elasticities:

Increasing farm prices:

$\varepsilon_{sr}^{-}=\alpha_{2i}^{+} * P_{ft}/P_{rt}$ (12)

Decreasing farm prices:

$\varepsilon_{sr}^{+}=\alpha_{4i}^{-} * P_{ft}/P_{rt}$ (13)

Long-run price transmission elasticities:

Increasing farm prices:

$\varepsilon_{LR}^{+}=\sum_{i=0}^{M_2} \alpha_{3i}^{+} * P_{ft}/P_{rt}$ (14)

Decreasing farm prices:

$\varepsilon_{LR}^{-}= \sum_{i=0}^{M_3} \alpha_{5i}^{-} * P_{ft}/P_{rt}$ (15)

3.4.3 Validation of the results

The diagnostic tests were conducted to ensure the validity, reliability, and robustness of the results for the ECM. Various diagnostic tests were conducted to evaluate the assumptions of normality, heteroskedasticity, and serial correlation in the residuals of the ginger, garlic, and lemon price series. Diagnostic tests were chosen because they are effective tools for validating the results for the ECM, as demonstrated by previous scholars such as Sanjuan and Gil (2001), De and Koemle (2015), and Kharin (2018).

The Jarque-Bera test was used to examine whether the error terms are normally distributed, while the heteroskedasticity test was employed to determine if the variance of the residuals is constant. Additionally, Breusch-Godfrey Test (also known as the Lagrange multiplier (LM) test) was performed to assess the presence of serial correlation. These diagnostic tests are crucial in econometrics, as they help identify any violations of assumptions that could affect the efficiency, consistency, and unbiasedness of the estimated ECM parameters (Gujarati and Porter, 2009; Sekar, 2010; Wooldridge, 2016, Greene, 2018).

3.5 Chapter summary

The chapter provided a description of the study area and data sources. It also covered the analytical techniques, which were divided into three sections. The first section outlined the pre-testing methods, specifically unit-root testing, which was conducted to check for stationarity using the Augmented Dickey-Fuller test and the Phillips-Perron test. The second section described the econometric modelling methods, including the Mark-Up Pricing Model, which addressed the first objective, the Houck Model, which addressed the second objective, and the ECM, which addressed the third objective. The final section detailed the validation tests used to ensure the accuracy of the econometric model results through diagnostic testing.

CHAPTER FOUR: OVERVIEW OF THE SOUTH AFRICAN GINGER, GARLIC AND LEMON MARKETS

4.1 Introduction

This chapter provides a detailed overview of the South African ginger, garlic and lemon markets. Specifically, it focuses on production and consumption of these commodities in South Africa, challenges faced by farmers and government support, trade, as well as the market value chain.

4.2 Production and consumption of ginger, garlic and lemon in South Africa

4.2.1 Production and consumption of ginger

There are various ginger cultivars produced in South Africa, including Yellow ginger, White ginger, and Galangal ginger (Brodie, 2023). Each cultivar offers different flavours, sizes, and levels of pungency, allowing consumers to choose based on their preferences. Ginger production has been increasing both in South Africa and internationally. The average production was approximately 4,720 tons pre-COVID-19 and 4,970 tons during the pandemic (DALRRD, 2021). This slight increase in production was insufficient to meet the surge in demand during COVID-19, leading to higher prices.

The main ginger-producing provinces in South Africa are Mpumalanga, Limpopo, and KwaZulu-Natal. In Mpumalanga, ginger is typically grown in Nelspruit, White River, and Hazyview. Limpopo's ginger production occurs in areas like Tzaneen, Modjadjiskloof, and Letsitele. In KwaZulu-Natal, ginger is produced in Tongaat, KwaDukuza (Ballito), and Pietermaritzburg. Ginger is propagated through rhizomes, which are sections of the plant's underground stem. The rhizomes are planted shallowly, about 2 to 5 centimeters (0.8 to 2 inches) deep, with the buds facing upwards. They are usually planted during spring or early summer, and the crop takes about 8 to 10 months to reach maturity, depending on the variety and growing conditions.

Ginger thrives in warm, humid climates, with well-drained soil and adequate water availability (Jansen, 2021). Optimal temperatures for ginger cultivation range between 20°C (68°F) and 35°C (95°F). The plant requires moderate rainfall, especially during the summer months of December, January, and February, to maintain sufficient moisture levels (Botha, 2020). Ginger grows best in sandy loam and loamy soils.

Additionally, the altitude for ginger cultivation ranges from 200 meters to 1,000 meters above sea level. Harvesting typically occurs when the leaves start to yellow and dry out (Brodie, 2023). Careful digging is necessary to avoid damaging the rhizomes. After harvesting, the ginger undergoes cleaning, sorting, and preparation for market. Proper handling is important to prevent bruising or breaking the rhizomes, as this affects their quality and shelf life.

In South Africa, ginger is primarily used for cooking and food preparation, as well as for its medicinal properties. It is believed to have various health benefits and is often used as a natural remedy for digestive issues, colds, flu-like symptoms, and more. Ginger consumption in South Africa has been increasing in recent years, with a significant spike during the COVID-19 pandemic due to its perceived medicinal benefits in reducing the effects of the virus (Botha, 2020).

Before the pandemic, ginger consumption was driven by its availability, accessibility, and affordability. Ginger was readily available in South African markets and grocery stores (e.g., Shoprite, Spar, Boxer), making it easily accessible to consumers (Wamucii, 2020). Its affordability and versatility contributed to its widespread use in cooking, food preparation, and for medicinal purposes.

Ginger production plays an important role in South Africa's agricultural economy by creating employment opportunities and generating revenue across farming, processing, and distribution sectors (DALRRD, 2020). The country produces enough ginger to meet domestic demand, reducing the need for imports, and exports ginger to neighbouring countries, making it an attractive crop for farmers seeking profitable ventures (Botha, 2020).

4.2.2 Production areas and consumption of garlic in South Africa

There are various garlic cultivars produced in South Africa, including Creole, Italian, Early Purple, and Chinese garlic (Graceland, 2022). Each cultivar offers different flavours, sizes, and levels of pungency, allowing consumers to choose based on their preferences. Garlic production in South Africa has been steadily growing in recent years. For example, the average garlic production increased from approximately 4,500 tons pre-COVID-19 to 5,600 tons during the pandemic (DALRRD, 2021). This increase, although slight, indicates that despite the rise in production, demand outstripped supply, leading to higher prices.

The major garlic-producing provinces in South Africa are Limpopo, Mpumalanga, and the Western Cape. In Mpumalanga, garlic is typically grown in the Drakensberg escarpment area, which includes towns such as Sabie, Graskop, Lydenburg, Nelspruit, and Barberton. In Limpopo, garlic is produced in areas such as Bela-Bela, Modimolle, Tzaneen, Mookgophong, and Polokwane. In the Western Cape, garlic production is concentrated in the Swartland, Overberg, and Cape Winelands regions (Graceland, 2022).

Garlic cultivation generally takes place during the summer, with rhizomes planted 5 to 10 cm deep and spaced 20 to 30 cm apart, buds facing upward, and then covered with soil, gently pressed down. South Africa's favourable climate and soil conditions make it an ideal location for garlic cultivation (Caxton Magazines, 2017). The Mediterranean-like climate, characterised by hot, dry summers and cool, wet winters, provides optimal conditions for garlic growth (Bezuidenhout, 2020). Garlic thrives in cooler climates with distinct seasons, requiring a period of cold temperatures (4°C to 8°C) for bulb development. It grows best in well-draining, sandy loam or loamy soils with a pH level between 6.0 and 7.0. The suitable altitude for garlic cultivation ranges from 1,000 m to 2,000 m above sea level (DALRRD, 2020).

Garlic is typically ready for harvest 8 to 10 months after planting, when the lower leaves turn yellow and dry out, indicating the bulbs have matured. During harvest, the bulbs must be carefully dug up to avoid damage, then dried in a well-ventilated area, protected from direct sunlight, for about two to three weeks (Brodie, 2023). After drying, any excess soil is removed, and the roots and stems are trimmed. Garlic is then stored in a cool, dry, and well-ventilated area. Properly cured garlic can be stored for several months.

Garlic has gained popularity worldwide due to its culinary uses, health benefits, and traditional medicinal properties. During the COVID-19 pandemic, there was a significant increase in garlic consumption, driven by its perceived medicinal benefits, such as boosting the immune system to help prevent colds and flu. The production of garlic contributes to South Africa's agricultural economy, providing income opportunities for farmers (DALRRD, 2020). It also supports employment in the farming, processing, and distribution sectors. The country produces enough garlic to meet domestic demand, reducing the need for imports, and also exports garlic to neighbouring countries, making it an attractive crop for farmers seeking profitable ventures (Bezuidenhout, 2020).

4.2.3 Production and consumption of lemon in South Africa

South Africa produces various lemon cultivars, including Eureka, Lisbon, and Villafranca (Citrus Industry, 2023). Each variety has its own characteristics in terms of fruit size, flavour, and suitability for different market preferences. Lemon trees require well-drained soil and full sun exposure. They are typically propagated through budding or grafting onto rootstocks. Farmers provide regular irrigation, fertilisation, and pest management to ensure healthy tree growth and fruit production.

Lemon production mainly occurs in Limpopo, Mpumalanga, the Eastern Cape, and the Western Cape (Citrus Industry, 2023). In Limpopo, lemons are primarily produced in the Tzaneen and Letsitele regions. Mpumalanga’s lemon production is concentrated in Nkomazi. In the Eastern Cape Province, lemons are mostly grown in the Sundays River Valley. In the Western Cape Province, production is centred on Citrusdal and Clanwilliam.

South Africa is renowned for its significant lemon production and is one of the leading lemon producers in the Southern Hemisphere (DALRRD, 2020). Before COVID-19, average lemon production was approximately 1,700,000 tons, while during the pandemic, production dropped to 168,000 tons (DALRRD, 2020). This reduction in production during COVID-19 indicates that demand outstripped supply, leading to a rise in lemon prices.

Several factors must be considered before cultivating lemons. For optimal growth, lemons require warm to hot temperatures, ranging from 15°C (59°F) to 30°C (86°F). The annual rainfall needed for lemon cultivation is generally between 600mm (24 inches) and 1,200mm (47 inches) (Citrus Industry, 2023). However, lemons can tolerate drier conditions with adequate irrigation. Additionally, lemons are typically cultivated at altitudes between 0 and 1,000 meters (0 to 3,280 feet) above sea level.

Lemon consumption rapidly increased during the COVID-19 pandemic due to its medicinal properties, such as soothing sore throats and alleviating common cold symptoms. The growing consumer awareness of the health benefits of lemons contributed to the rising demand for fresh lemons and value-added lemon products in South Africa. Lemon production plays a vital role in the country's agricultural economy, providing employment opportunities, generating revenue, and contributing to export earnings (DALRRD, 2020). Profitability and market availability also drive lemon production.

Lemons in South Africa are in demand year-round, both locally and internationally. Supermarkets, grocery stores, farmers' markets, and street vendors distribute lemons to consumers, selling them in bulk, loose, or pre-packaged in bags or nets, in small quantities or individually (Brodie, 2023). In addition, South Africa exports a substantial portion of its lemon production to various international markets due to the high demand driven by the quality, taste, and preference for South African lemons in these markets (Citrus Industry, 2023).

Overall, given the increasing demand for ginger, garlic and lemon and the role they play in both domestic consumption and exports, analysing farm-to-retail price transmission is essential. Understanding the dynamics of price changes for these agricultural commodities across the supply chain helps in identifying the extent to which price increases at the farm level are passed on to consumers. This analysis is especially critical during periods of high demand, such as the COVID-19 pandemic, where supply constraints and increased consumer demand led to significant price fluctuations. By examining these price transmission mechanisms, policymakers and stakeholders can better manage supply chains, stabilise prices, and ensure that both farmers and consumers benefit fairly from the production and sale of ginger, garlic, and lemon.

4.2.4 Challenges faced by producers and government support in South Africa

Ginger, garlic, and lemon producers in South Africa have faced several challenges over the years. For instance, cultivation requires significant investments in inputs such as seeds, land, labour, irrigation, and fertilisers, which are costly for farmers. Additionally, rising production costs, including energy and labour expenses, negatively impact profitability. Farmers are also subjected to competition from imported products, particularly from countries with lower production costs (The Africa Report, 2023). Imported products like ginger and garlic are often sold at lower prices, making it difficult for local farmers to compete in the market. As a result, local farmers face challenges related to market demand and price fluctuations, as consumers tend to opt for cheaper imported products (Sihlobo, 2023).

Furthermore, the COVID-19 pandemic had a significant impact on the food supply chain due to lockdown restrictions that were imposed, such as trade restrictions, logistical limitations, and reduced labour in agricultural firms. These restrictions contributed to the challenges faced by farmers. A slight increase in the average production of ginger was observed, rising from 4,720 tons pre-COVID-19 to 4,970 tons during the pandemic (DALRRD, 2021). Similarly, garlic production increased slightly from 4,500 tons pre-COVID-19 to 5,600 tons during the pandemic (DALRRD, 2021). However, lemon production saw a major decline, dropping from an average of 1,700,000 tons pre-COVID-19 to 168,000 tons during the pandemic (DALRRD, 2020).

Due to these lockdown restrictions, there was a limited supply of ginger, garlic, and lemons, causing demand to exceed supply, which led to significant price increases. For example, during the pandemic, the prices of ginger, garlic, and lemons in South Africa increased by 300%, 100%, and 83.3%, respectively. These price increases were a direct result of the supply chain disruptions caused by COVID-19 restrictions.

Moreover, the lockdown restrictions led to the temporary closure of many South African businesses, resulting in job losses and decreased profitability. Disruptions in production, caused by labour shortages, logistical issues, and trade restrictions, affected both national and international supply chains (South African Government, 2023). Despite the changes in consumption patterns and increased demand for ginger, garlic, and lemons during the pandemic, farmers struggled to reach consumers and supply their products due to the lockdown regulations. This mismatch between high demand and low supply led to sharp price increases.

In response to the significant economic impact of the COVID-19 pandemic, the South African government implemented several strategies to assist farmers. These included providing access to agricultural inputs such as seeds, fertilisers, and pesticides by ensuring their availability during lockdown periods (South African Government, 2023). Special measures, such as deploying extension officers and making information available to farmers, were put in place to facilitate the smooth movement and distribution of essential agricultural inputs.

Additionally, the government introduced financial relief programmes to support farmers affected by the pandemic, including relief funds, grants, and loan schemes aimed at alleviating financial hardships. The government also made efforts to maintain market access and support trade by ensuring the smooth functioning of logistics and supply chains, allowing farmers to continue marketing and selling their produce. These interventions helped mitigate the disruptions caused by the pandemic and ensured farmers could access both domestic and international markets.

Given the challenges faced by ginger, garlic, and lemon producers in South Africa, especially during the COVID-19 pandemic, conducting a farm-to-retail price analysis is crucial. Understanding how price changes at the farm level are transmitted to retail prices can help identify inefficiencies and disparities within the supply chain. The sharp increases in prices during the pandemic, coupled with disruptions in production and supply, highlight the importance of studying price transmission mechanisms; hence, this study.

4.3 Trade for ginger, garlic and lemon markets

4.3.1 South African ginger exports

There is a slight oversupply of ginger in the global market, which is driving down prices despite reasonably stable demand overall (Wamucii, 2021). The health benefits of ginger have contributed to its increased popularity, especially in the wake of the pandemic, a trend observed in the global market. Figure 4.3 below illustrates South Africa's ginger exports, 2011 to 2020.

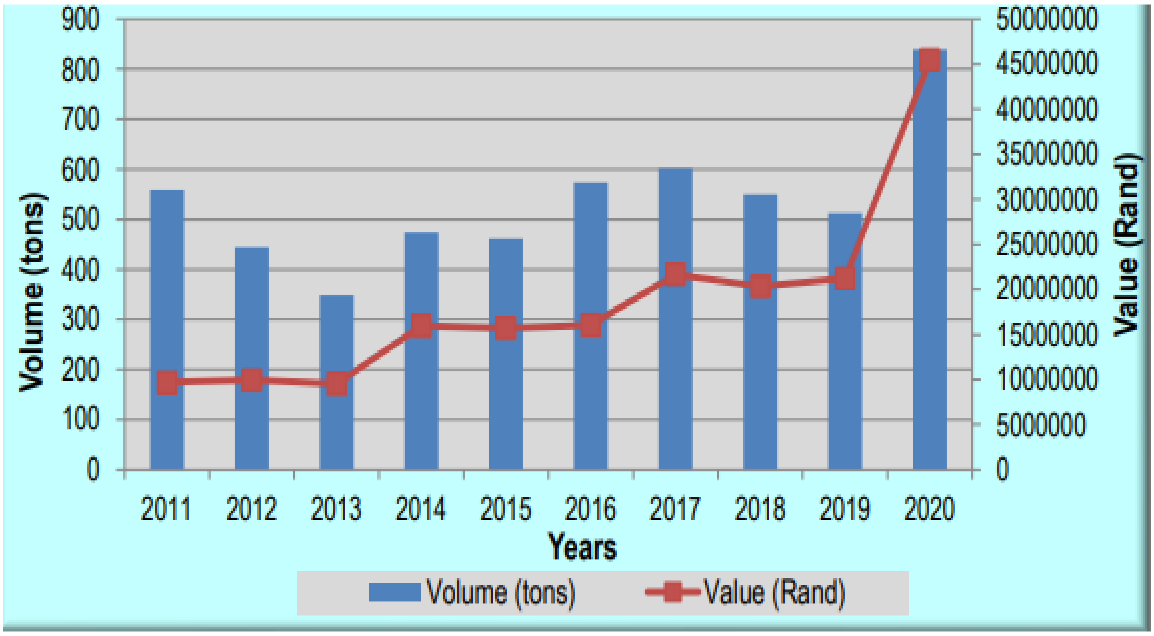

Figure 4.3: South African ginger exports

Source: Quantec EasyData (2023)

In 2012, ginger exports fell by 20.4% compared to 2011. In 2013, there was a further drop of 21.4% in ginger exports compared to the 2012 export volume. However, in 2014, ginger export volume increased by 35.6% compared to the previous year (2013). In 2015, there was a decrease of 2.5% in ginger exports, while the export value dropped by 1.6%. Exporting ginger was relatively more profitable in 2007, 2009, and from 2012 to 2015. This was because, during these years, supply exceeded demand, leading to lower prices in the South African market, and thus, more profit was accumulated through the export of ginger.

In 2016, South Africa's ginger exports increased by 24%, making it more profitable to export ginger compared to 2015. In 2017, ginger exports grew by 5% relative to 2016, and it remained more profitable to export ginger than in the previous year (2016). By 2018, South Africa's ginger exports grew modestly by 8.5%, and exporting ginger was more profitable than in 2017.

In 2019, ginger exports declined slightly by 6.8%, and exporting ginger in 2018 was more profitable than in 2019. However, compared to 2019, South Africa's ginger exports surged by 63.7% in 2020. As a result, it was substantially more profitable to export ginger in 2020 than in 2019, due to the global increase in ginger demand driven by the COVID-19 pandemic.

4.3.2 South African ginger imports

During the COVID-19 pandemic in South Africa, there was a significant surge in demand for ginger, which exceeded the available supply, leading to the necessity of importing ginger. A detailed representation of South Africa's ginger import data from 2011 to 2020 is provided in Figure 4.2 below.

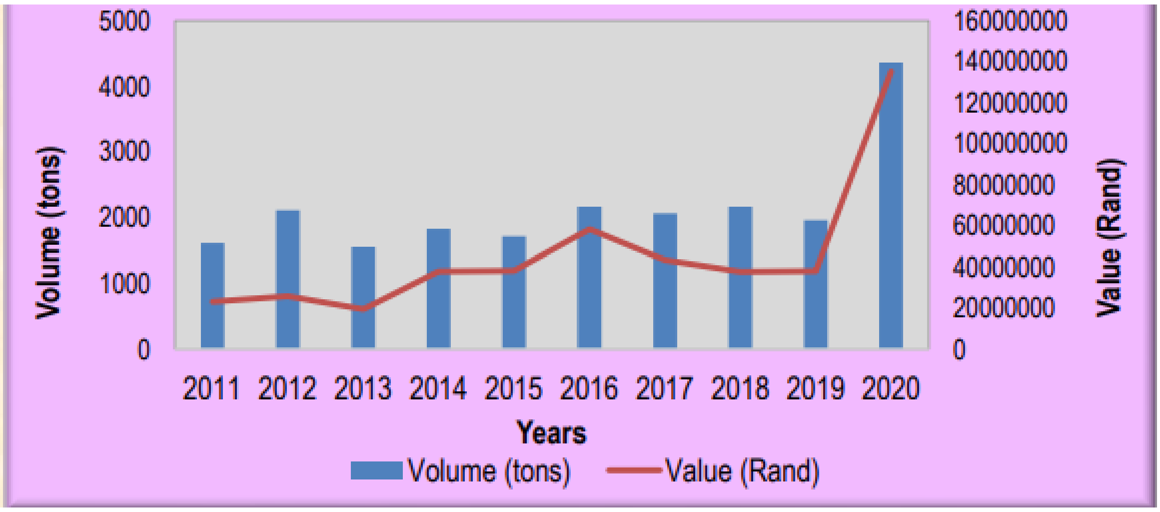

Figure 4.2: South African ginger imports

Source: Quantec EasyData (2023)

Figure 4.2 shows that in 2011, South Africa imported approximately 1,611 tons of ginger. In 2012, ginger imports rose to just over 2,000 tons. However, in 2013, there was a 26% decline in imports, followed by a slight increase to 1,828 tons in 2014. The figure also illustrates that in 2015, import volumes slightly decreased by 6.6% compared to 2014, making it slightly more expensive for South Africa to import ginger compared to the previous year.

In 2016, South Africa imported 26% more ginger, and the cost of importing ginger was higher than in 2015. This increase in cost could be attributed to factors such as market conditions, trade agreements, and government policies. In 2017, ginger imports decreased by 4.7%, and it became cheaper to import compared to 2016. By 2018, imports grew slightly by another 4.7%, and it remained more affordable to import ginger compared to 2017. In 2019, ginger imports dropped by 9.2%, and the cost of importing ginger was lower than in 2018.

In 2020, South Africa's ginger imports surged significantly, and it became relatively more expensive to import compared to 2019. This price increase was driven by the high consumption of ginger, as many consumers turned to ginger for its perceived medicinal benefits in alleviating COVID-19 symptoms.

4.3.3 South African garlic exports

The global surge in demand for garlic positioned South Africa as one of the exporters to its neighbouring countries. A detailed graphical representation and explanation of South Africa's garlic exports are provided in Figure 4.3 below.

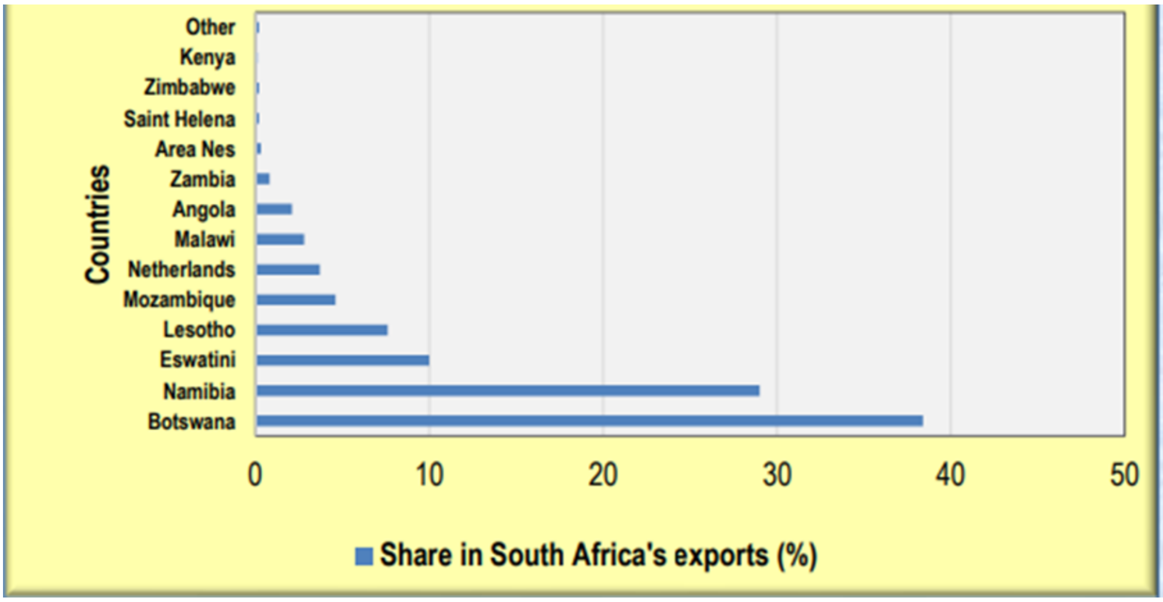

Figure 4.3: South African garlic exports

Source: Trade Map (ITC) (2023)

Based on Figure 4.3 above, South Africa was not a major exporter of garlic during the COVID-19 pandemic. South Africa contributed only about 0.1% to the global garlic exports. The country lost its competitiveness in the global garlic market, ranking 26th in the world for garlic exports in 2019. During the pandemic in 2020, South Africa primarily exported garlic to Namibia, Zambia, Eswatini, Canada, Lesotho, Mozambique, the Netherlands, Malawi, Angola, and Zambia. In 2020, the largest portion of South Africa's garlic exports went to Botswana (38.4%), followed by Namibia (29%) and Eswatini (10%). Lesotho imported approximately 7.6% of South Africa's garlic production that year. On the global scale, China ranked as the top garlic exporter, being the largest garlic producer in the world, followed by Spain, Argentina, the Netherlands, France, Italy, Chile, and Egypt (DALRRD, 2021).

4.3.4 South African garlic imports

Although South Africa was one of the garlic exporters, the demand during the COVID-19 pandemic exceeded supply, leading to a deficit. As a result, the country had to import garlic to balance demand and supply. The data on South African garlic imports from 2011 to 2020 is shown in Figure 4.4 below.

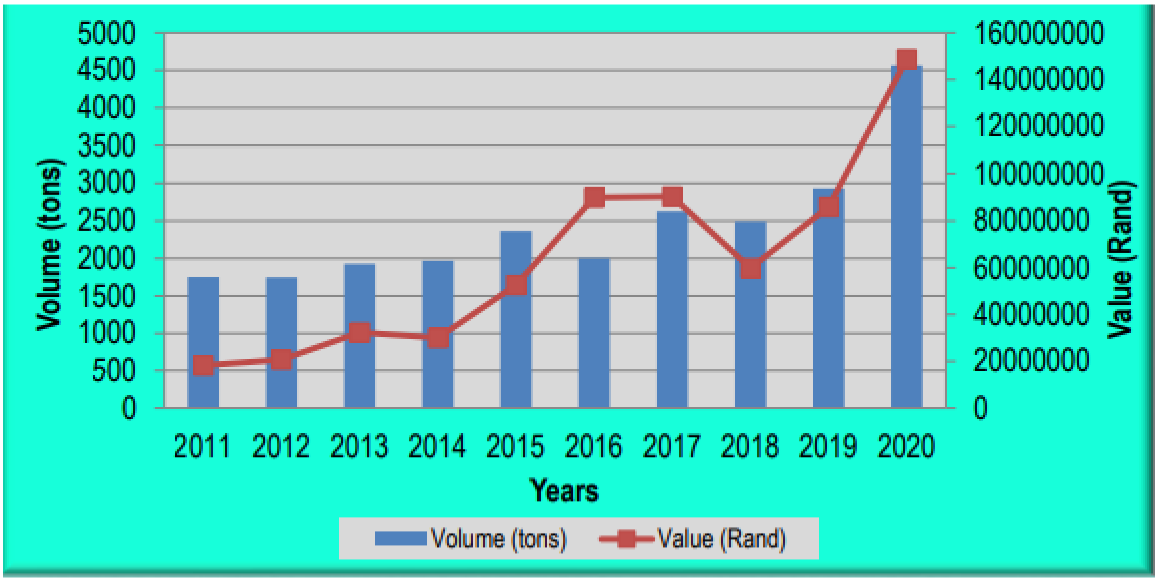

Figure 4.4: South African garlic imports

Source: Quantec EasyData (2023)

Figure 4.3.4 illustrates South Africa’s garlic imports from 2011 to 2020. In 2011, South Africa imported approximately 1,750 tons of garlic. In 2012, garlic imports increased slightly by 0.3%, largely due to low global demand. By 2013, garlic imports rose by 10.3% compared to 2012, and it became more expensive to import garlic that year. In 2015, imports increased by 19%, with higher costs of importation compared to 2014.

However, in 2016, South Africa experienced a 15% decline in garlic imports, making it more expensive to import compared to previous years. In 2017, garlic imports increased by 31% relative to 2016, and importing garlic became cheaper, compared to the previous year. By 2018, South Africa’s garlic imports decreased by 5%, and it remained relatively cheaper to import garlic compared to 2017.

In 2019, garlic imports increased by 17.7%, and it was more expensive to import garlic than in 2018. Garlic imports surged by 56% in 2020, making it more costly to import garlic compared to the 2019 period. The figure clearly shows that during the COVID-19 pandemic, South Africa imported significantly more garlic than in the pre-pandemic period. This surge in demand was due to many consumers relying on garlic as a home remedy to alleviate the effects of the virus. As a result, South Africa had to import large quantities of garlic to meet the rising demand and balance supply.

4.3.5 South African lemon export

South Africa is recognised as one of the major exporters of citrus fruits, including lemons, on a global scale. Despite the abnormal surge in global demand for lemons due to the COVID-19 pandemic, South Africa continued to excel as one of the prominent exporters. Figure 4.5 below presents South Africa's lemon exports against various countries.

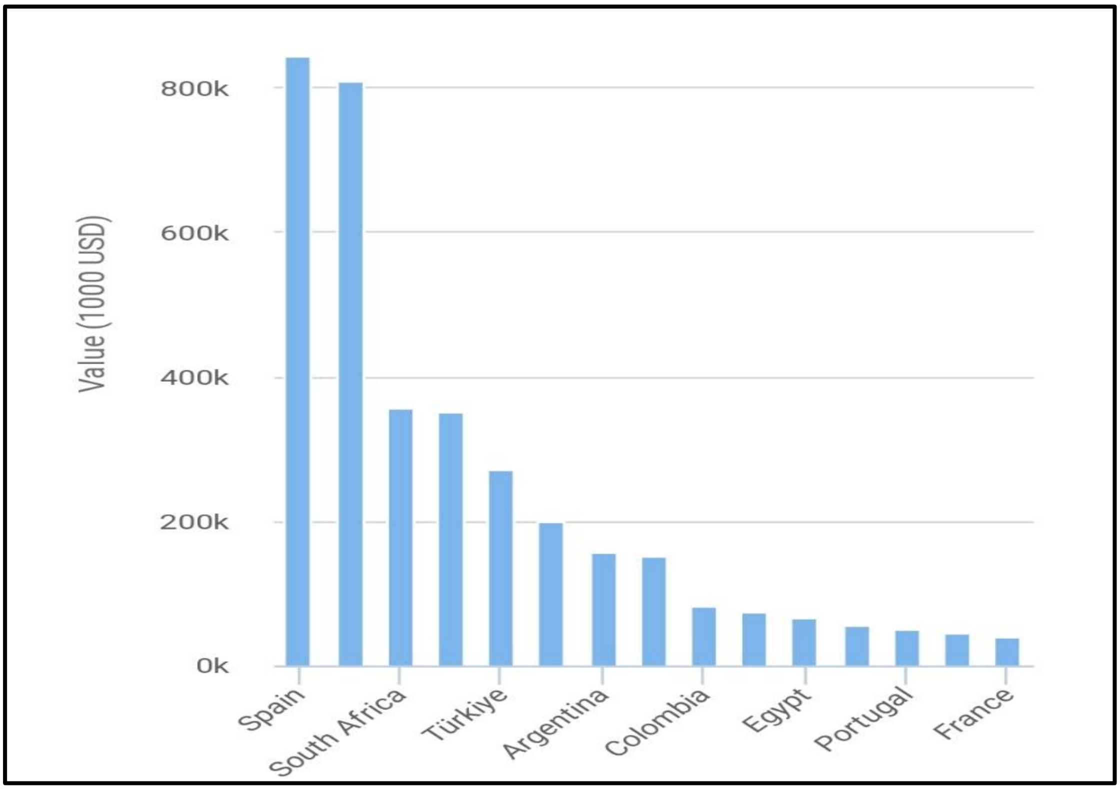

Figure 4.5: South African lemon exports

Source: Trade Map (ITC) (2023)

Based on the figure above, it is clear that South Africa was one of the leading global exporters of lemons, ranking second after Spain in 2019. Spain exported approximately USD 830,000 worth of lemons, followed by South Africa with USD 805,000, and Turkey in third place with a net export value of USD 385,000. During the COVID-19 pandemic, global lemon exports increased significantly compared to pre-pandemic levels. This surge was driven by the heightened global demand and consumption, as lemons were widely sought after for their medicinal benefits, which played a crucial role in alleviating the effects of COVID-19. As a result, demand exceeded supply, leading to an increase in lemon prices.

4.4 Market value chain

A market value chain refers to a series of consecutive steps involved in the creation of a finished product, from its initial design to its delivery to the final consumer (Tardi, 2023). For a market value chain to function effectively, efficiency, coordination, collaboration, and communication are essential at each stage. The market value chain typically consists of several stages. Figure 4.4 below illustrates a typical market value chain for ginger, garlic, and lemon in South Africa.

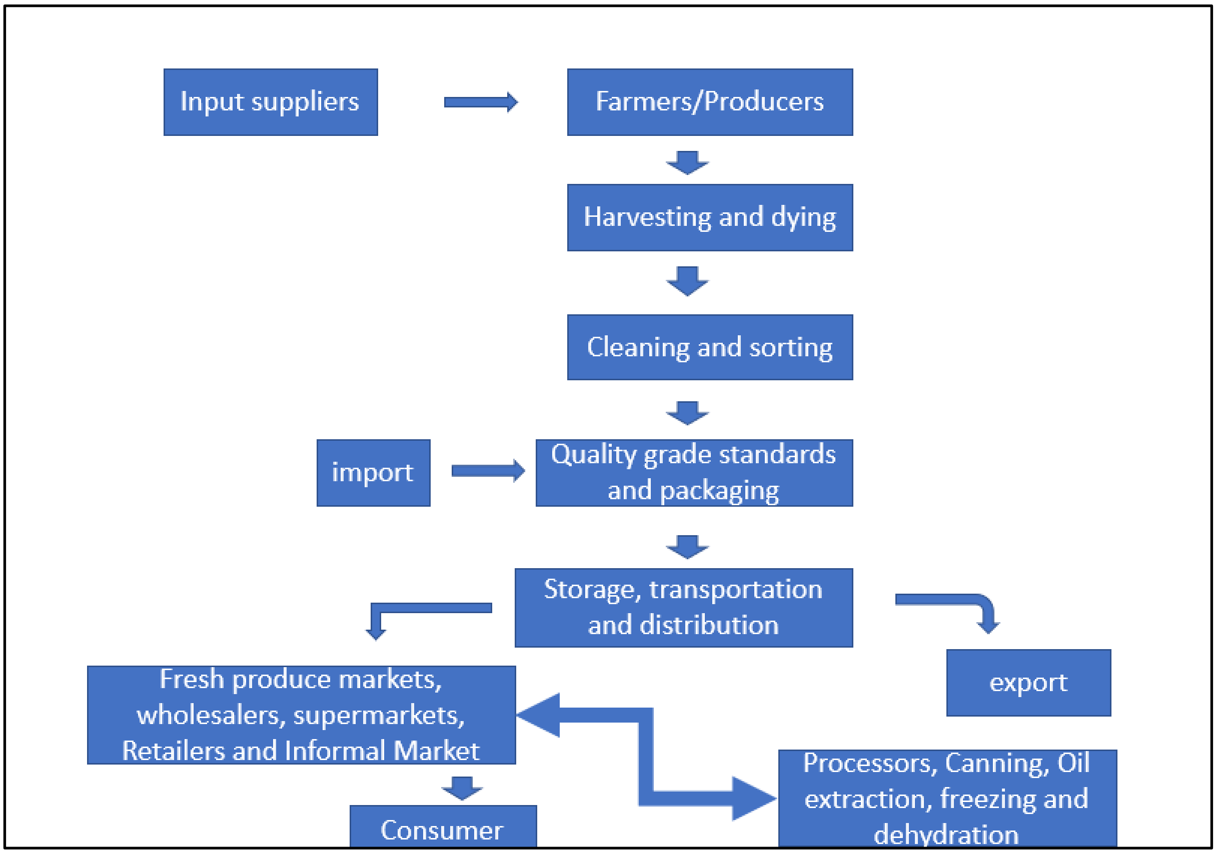

Figure 4.4: Market value chain for ginger, garlic and lemon

Initially, the process begins with input suppliers, who are responsible for providing raw materials, components, or services essential for the production of ginger, garlic, and lemon (Banton, 2023). These suppliers may include agricultural producers, manufacturers, packaging suppliers, and others providing goods and services required for production. The next stage is the producers or farmers' stage, where raw materials (i.e., seeds for ginger, garlic, and lemon) supplied by input providers are transformed into finished products (MacInnis, 2016). At this stage, farmers utilize the inputs to grow and harvest the crops using various production processes.

The cleaning and washing stage follows, where the harvested ginger, garlic, and lemon are cleaned to remove dirt or contaminants (Hadad, 2019). This step is crucial for ensuring food safety and maintaining product quality. Next, the quality grading and sorting stage ensures the products meet predetermined standards for size, colour, ripeness, or other required characteristics (Armor, 2019). Quality control methods, including visual inspections and laboratory tests, guarantee that only the highest-quality products reach the market.

In the packaging and labeling stage, processors package the ginger, garlic, and lemon into suitable containers, ensuring proper labeling that includes product information, nutritional details, expiration dates, and regulatory information (Akram, 2020). Packaging and labeling are vital for product identification, marketing, and compliance with industry standards. The handling and transportation stage involves safely handling the packaged products to prevent damage or spoilage during transportation. Proper storage and packing are essential to maintain product freshness.

The storage and distribution stage involves storing ginger, garlic, and lemon under optimal conditions to preserve their quality. Afterward, the products move to the processing stage, where value-added processing activities, such as extending shelf life or meeting specific consumer preferences, occur (Law Insider, 2016). The importing stage focuses on bringing goods like ginger and garlic into South Africa to meet local demand, while the exporting stage involves selling surplus products to international markets. This enables revenue generation, market expansion, and job creation (Segal, 2021; Segal, 2022).

The distribution or wholesale stage involves distributors purchasing products in bulk from farmers and transporting them to retailers (B2B Ecommerce, 2018). Retailers, acting as intermediaries, sell the products to consumers through various channels, including physical stores and online platforms (Hudson, 2020). Finally, consumers purchase and consume the ginger, garlic, and lemon for personal or business use.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the results of the analysis. EViews 12 was employed to conduct several tests. These tests included the Augmented Dickey-Fuller (ADF) and Phillips-Perron tests for stationarity, the Mark-Up Pricing model for determining elasticities, the Houck model for price transmission analysis, and the Error Correction Model (ECM) for identifying the long-run relationship between farm prices and retail prices. Finally, diagnostic tests were applied to validate the econometric results.

5.2 Descriptive results

Before presenting the results of these analyses, descriptive statistics were calculated to summarise the key features of the farm and retail prices of ginger, garlic, and lemon. These descriptive results provide an initial overview of the data to offer insights into price dynamics at both the farm and retail levels by exploring measures such as the mean, median, minimum, and maximum values, and standard deviation. The descriptive statistics for ginger, garlic and lemon are presented in Table 5.1 below.

Table 5.1: Descriptive statistics for ginger, garlic and lemon

	Ginger		**Garlic**		**Lemon**	
	Farm price	**Retail price**	**Farm price**	**Retail price**	**Farm price**	**Retail price**
Mean	39.0365	92.2542	37.2584	89.2444	34.5428	85.6044
Median	35.2845	86.2884	31.6848	84.6841	86.2684	80.6971
Maximum	126.8548	245.2844	114.5985	192.9841	109.8449	164.5895
Minimum	17.5512	36.5844	15.1578	24.5574	10.5878	18.0581
Standard deviation	21.8984	44.6841	17.5417	40.6847	13.4871	36.9851

Source: Author's compilation (2024)

The mean farm prices per kilogram for ginger, garlic, and lemon were R39.04, R37.26, and R34.54, respectively. Conversely, the mean retail prices per kilogram for ginger, garlic, and lemon were R92.25, R89.24, and R85.60, respectively, during the COVID-19 pandemic in South Africa. Among the three commodities, ginger had the highest average farm and retail prices, garlic had moderate prices, and lemon had the lowest prices at both the farm and retail levels.

This suggests that farm-to-retail price transmission exhibits a consistent pattern across these commodities, with ginger having the highest mark-up and lemon the lowest. The significant mark-up from farm to retail for all three commodities indicates potential inefficiencies or costs added along the supply chain, such as transportation, handling, storage, or retailer pricing strategies. Higher mark-ups on ginger, for example, could reflect either stronger retail demand for ginger during COVID-19 pandemic or greater costs associated with bringing the product to market compared to garlic and lemon.

The observed median farm prices for ginger, garlic, and lemon during the COVID-19 pandemic in the South African markets were R35.2845, R31.6848, and R86.2684, respectively. In contrast, the retail prices during the same period were R86.2884, R84.6841, and R80.6971 for ginger, garlic, and lemon, respectively.

The maximum observed farm prices were R126.85, R114.60, and R109.74 for ginger, garlic, and lemon, respectively. Meanwhile, the maximum retail prices were R245.28, R192.98, and R164.59 for ginger, garlic, and lemon, respectively, during the COVID-19 pandemic in South Africa. The minimum observed farm prices were R17.55, R15.16, and R10.59 for ginger, garlic, and lemon, respectively. On the other hand, the minimum retail prices for ginger, garlic, and lemon were R36.58, R24.56, and R18.06, respectively, during the COVID-19 pandemic in South Africa.

This shows that, like the average prices, the maximum and minimum prices follow a similar pattern where ginger consistently has the highest prices, garlic has the moderate prices, and lemon has the lowest prices. In other words, ginger not only had the highest average prices but also the most extreme maximum prices, suggesting it was the most affected by the price surges during the COVID-19 pandemic. In contrast, lemon had the lowest prices (i.e. averages, maximum and minimum values). There is also a significant gap between the maximum and minimum, which indicates high volatility during the pandemic, both at the farm and retail levels. Additionally, retail prices had higher maxima compared to farm prices, which suggests that retailers might have been able to pass on increased costs to consumers during periods of high demand or limited supply.

The standard deviations of farm prices for ginger, garlic, and lemon were approximately 21.90, 17.54, and 13.49, respectively, indicating moderate variability.

Specifically, the farm prices for ginger, garlic, and lemon show moderate variability, with ginger exhibiting the highest standard deviation (21.90) and lemon the lowest (13.49). This suggests that while there were fluctuations in farm prices, they were relatively stable compared to retail prices. In contrast, the standard deviations of retail prices for ginger, garlic, and lemon were approximately 44.68, 40.68, and 36.99, respectively, indicating higher volatility. This shows that there is much larger standard deviations for retail prices, particularly for ginger (44.68), suggesting that prices at the retail level were more volatile. This higher volatility at the retail level means that retailers may have adjusted their prices more frequently in response to a surge in demand and supply chain disruptions during COVID-19 pandemic.

5.3 Unit root testing results

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were performed for all series used in the analysis. These tests assist the researcher in determining the order of integration of the data before applying regression techniques. Each commodity (ginger, garlic, and lemon) was analysed individually. The null hypothesis for both tests posits that the time series data for each commodity is non-stationary, whereas the alternative hypothesis suggests that the time series data is stationary. The rule of thumb is that the probability value (p-value) of the PP test or the ADF test must be less than or equal to 5% (0.05) to reject the null hypothesis, thus concluding that the data is stationary. The ADF test results for the data in their levels is presented in Table 5.2. The table shows the ADF test statistics, the 5% critical values, and the p-values (probability).

Table 5.2: ADF unit root test results

Series	ADF test statistics	Test Critical value at 5%	Probability*	ADF test statistics	Test Critical value at 5%	Probability*
	Levels			**First difference**		
Ginger						
Farm Price (P_A)	-4.6822	-3.9954	0.0058***	-7.8820	-3.9972	0.0000***
Retail price (P_B)	-7.5852	-3.9928	0.0000***	-8.2681	-3.9988	0.0000***
Garlic						

Farm price (P_A)	-4.1052	-3.1054	0.0058***	-6.2841	-3.1045	0.0000***
Retail price (P_B)	-7.0288	-3.1012	0.0000***	-8.0684	-3.1025	0.0000***
Lemon						
Farm price (P_A)	-3.5765	-2.8752	0.0020***	-5.9257	-2.8759	0.0000***
Retail price (P_B)	-6.6585	-2.8728	0.0000***	-6.6574	-2.8755	0.0000***

Source: Author's computation (2024); Note: *** Significant at 1%.

The ADF test results are presented for both the levels and first differences of the series (farm and retail prices) for ginger, garlic, and lemon. Both the farm price (with ADF statistic of -4.6822 and p-value of 0.0058) and the retail price (with ADF statistic of 7.5852 and p-value of 0.0000) for the ginger series were stationary at levels. Equally, the farm price (with ADF statistic of -4.1052 and p-value of 0.0058) and the retail price (with ADF statistic of -7.0288 and p-value of 0.0000) for garlic were stationary at levels. Additionally, both the farm price (with ADF statistic of -3.5765 and p-value of 0.0020) and retail price (with ADF statistic of -6.6585 and p-value of 0.0000) for lemon were stationary at levels as well.

Overall, the time series data for ginger, garlic, and lemon (both farm and retail prices) were all stationary at levels, as indicated by the ADF test statistic values, which are less than the critical values and the p-values being less than 0.05. This means both the farm and retail prices for these commodities do not exhibit a unit root at levels and no differencing is needed. In other words, this ensures robustness, but differencing is not required since stationarity was achieved at levels (Hamilton, 1994; Dougherty, 2016).

After first differencing, the farm price and the retail price for ginger remained stationary. Equally, both farm price and retail price were stationary after differencing. Similarly, the farm price and the retail price were stationary. This implies that, even though the series were already stationary at levels, the ADF results at first differences also confirmed stationarity. In conclusion, both farm and retail prices for all commodities (ginger, garlic, and lemon) were stationary at levels, meaning there was no need to transform or difference the data to perform regression analysis. Additionally, since both farm and retail price series were stationary in their levels, they did not require co-integration testing. As such, standard co-integration tests were not conducted in this study. This is because co-integration tests are typically used when the individual time series are non-stationary but might share a long-run equilibrium relationship (Enders, 2014; Greene, 2018).

The PP test results were employed to validate the reliability of the ADF test results for ginger, garlic, and lemon prices at the 95% confidence level. Specifically, the PP results were compared with those of the ADF test to confirm the order of integration of the series. Table 5.3 shows the PP unit root test results with corresponding PP test statistics, the 5% critical values, and the p-values (probability).

Table 5.3: 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 difference**		
Ginger						
Farm Price (P_A)	-4.6127	-3.9972	0.0069***	-7.6255	-3.9999	0.0000***
Retail price (P_B)	-7.0089	-3.9972	0.0000***	-8.0179	-3.9999	0.0000***
Garlic						
Farm price (P_A)	-3.965	-3.1044	0.0004***	-6.1074	-3.1017	0.0000***
Retail price (P_B)	-7.0096	-3.1044	0.0000***	-8.0009	-3.1017	0.0000***
Lemon						
Farm price (P_A)	-2.9765	-2.8757	0.0032***	-5.1436	-2.8740	0.0000***
Retail price (P_B)	-6.1285	-2.8757	0.0000***	-6.3058	-2.8740	0.0000***

Source: Author’s computation (2024); Note: *** Significant at 1%.

Overall, the PP test confirmed the ADF results that both the farm and retail prices for ginger, garlic, and lemon were stationary at levels (I(0)), as the PP test statistic values were less than the critical values, with p-values of less than 0.05. Thus, both tests confirmed that the farm and retail price series for ginger, garlic, and lemon were stationary at levels, meaning that these price series were integrated of order zero, I(0).

In conclusion, the results from the PP test are consistent with those of the ADF test. The consistency between the two tests ensures the robustness and reliability of the results. Therefore, no differencing is needed, and the data can be used directly for further regression analysis. Ultimately, the null hypotheses (H_0) for ginger, garlic, and lemon, which stated that the price series are non-stationary, were all rejected. Since the series are stationary at levels, the price transmission analyses were conducted without concerns of non-stationarity. Hence, the next section presents the results of the Mark-Up Pricing model, which was used to determine the farm-to-retail price elasticities.

5.4 Empirical results

5.4.1 Mark-Up Pricing model results

Before conducting the Mark-Up Pricing model analysis, the Kendall's rank correlation test was performed to determine whether there are significant positive correlations between farm prices, mark-up prices, and retail prices for ginger, garlic, and lemon. For each commodity (ginger, garlic, and lemon), the null hypothesis states that there is no significant rank correlation between farm prices, mark-up prices, and retail prices for ginger, garlic, and lemon. This implies that changes in farm prices are not consistently associated with changes in mark-up prices and retail prices, suggesting that there is no relationship in price transmission. The alternative hypothesis states that there is a significant rank correlation between farm prices, mark-up prices, and retail prices for ginger, garlic, and lemon. This means that changes in farm prices are consistently associated with changes in mark-up prices and retail prices, indicating a relationship in price transmission.

If Kendall's tau (τ) value is greater than 0.5 and statistically significant (based on the p-value), it indicates a strong positive correlation, and we reject the null hypothesis in favour of the alternative hypothesis. Additionally, tau values between 0.3 and 0.5 indicate a moderate correlation, while values below 0.3 show a weak correlation (Cohen, 1988; Hollander et al., 2013). Kendall's rank correlation test results are shown in Table 5.4 below.

Table 5.4: Kendall's rank correlation test results

Variable	Farm price	Mark-up price	Retail price
Ginger			
Farm price	1.0000		
Mark-up price	0.7924	1.0000	
Retail price	0.8886	0.9624	1.0000
Garlic			
Farm price	1.0000		
Mark-up price	0.7152	1.0000	
Retail price	0.8093	0.8332	1.0000
Lemon			
Farm price	1.0000		
Mark-up price	0.6881	1.0000	
Retail price	0.7990	0.8080	1.0000

Source: Author's computation (2024)

For all three commodities (ginger, garlic, and lemon), the correlation coefficients between farm prices, mark-up prices, and retail prices are above 0.5. In terms of ginger, the correlation coefficients are 0.8886 (farm price vs. retail price) and 0.9624 (mark-up price vs. retail price). This shows that there is a strong positive correlation between farm price, mark-up price and retail price for ginger. For garlic, the correlation coefficients are 0.8093 (farm price vs. retail price) and 0.8332 (mark-up price vs. retail price). Similarly, this shows that there is a strong positive correlation between farm price, mark-up price and retail price for garlic. In terms of lemon, the correlation coefficients are 0.7990 (farm price vs. retail price) and 0.8080 (mark-up price vs. retail price). As with ginger and garlic, this shows that there is a strong positive correlation between farm price, mark-up price and retail price for lemon.

In conclusion, there is a significant and strong positive rank correlation between farm prices, mark-up prices, and retail prices for ginger, garlic, and lemon. This means that changes in farm prices were consistently associated with changes in mark-up prices and retail prices, indicating effective price transmission from the farm level to the retail level. In other words, when farm prices increase or decrease, retail prices tend to follow a similar trend, suggesting that price changes at the farm level are being passed through to the retail market. Thus, across all commodities, there was limited market power being exercised by intermediaries or retailers since farm price changes were effectively passed on to retail prices. This implies that retailers were not significantly manipulating prices to their advantage but rather reflecting changes that occur at the farm level.

Comparatively, ginger displayed the strongest correlation, indicating that changes in farm prices were transmitted more consistently and proportionally to retail prices, with the mark-up price accurately reflecting changes in marketing costs, suggesting an efficient price transmission process. Garlic showed a moderately strong correlation, suggesting some variability in the marketing margin and potential inefficiencies or market frictions that may cause delays or inconsistencies in passing farm price changes to the retail market. Lemon exhibited the lowest strong correlation, indicating that the marketing margin is more variable, with possible factors such as higher transaction costs, supply chain inefficiencies, or market power contributing to delays or fluctuations in how farm price changes are transmitted to the retail market.

These results, along with the observed correlations, provide a solid foundation for analysing how changes in farm prices were transmitted to consumers in the retail market. This analysis was conducted by calculating the price transmission elasticities, which indicate the proportion of farm price changes reflected in retail prices using the Houck model. The price transmission elasticities were estimated using the GLS method, as shown in Equation (3), to capture the degree of price transmission from farm prices to retail prices. The results presented in Table 5.5 include the estimated coefficients, standard errors, and model statistics for the Mark-Up Pricing model applied to ginger, garlic, and lemon, using retail price, lagged retail price, and producer price as independent variables. The dependent variable is the mark-up price, defined as the difference between retail and farm prices. The significance levels (*, **, and ***) are based on the t-statistic values, which are given by the coefficients divided by their standard errors.

Table 5.5: Mark-Up Pricing model results

Commodity	**Ginger**		**Garlic**		**Lemon**	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Dependent variable: Mark-up price						
Intercept	-3.1110	0.6101	-3.5118	0.6011	-2.1023	0.5015
Retail price $(\mathbf{P_{rt}})$	0.7115	0.5247	0.7569	0.4508	0.5661	0.3878
Retail price _lagged $(\mathbf{P_{rt-1}})$	0.8999	0.0581***	0.9106	0.0610***	0.8101	0.0577***
Producer price	0.9512	0.6574	0.7658	0.6200	0.7230	0.50032

Adjusted R-squared	0.8741		0.8088		0.7882	
Akaike info criterion	0.5887		0.5417		0.4552	
Schwarz criterion	0.6498		0.5997		0.5241	
Durbin-Watson statistics	2.5425		2.1985		2.1854	

Source: Author's computation (2024); *** shows 1% significance level.

The adjusted R-squared values indicated that the model explains about 87.41% of the variation in the mark-up price for ginger (0.8741), 80.88% for garlic (0.8088), and 78.82% for lemon (0.7882). This demonstrates that the model is a very good fit for ginger and provides good fits for garlic and lemon, respectively. Ginger (0.8741) had the best model fit, followed by garlic (0.8088), and lemon (0.7882), suggesting that the Mark-Up Pricing model is most effective in explaining the variability in ginger's mark-up price.

The AIC and SC were used to measure goodness of fit of the Mark-Up Pricing model, with lower values indicating a better fit relative to model complexity. The AIC values are 0.5887 for ginger, 0.5417 for garlic, and 0.4552 for lemon, while the SC values are 0.6498 for ginger, 0.5997 for garlic, and 0.5241 for lemon. Both criteria indicated that the model for lemon has the most efficient fit, followed by garlic and then ginger, making the lemon model the most effective in capturing the relationship between retail and farm prices while maintaining simplicity. However, this does not invalidate the results for either ginger or garlic but rather suggest that the lemon model is more appropriately balanced in terms of fit and complexity compared to ginger.

The Durbin-Watson statistic values are 2.5425 for ginger, 2.1985 for garlic, and 2.1854 for lemon, all of which are close to 2, suggesting no significant autocorrelation issues across all commodities. Therefore, the results are valid, and the Durbin-Watson statistic values do not raise any serious concerns about autocorrelation in any of the commodities.

For all three commodities, the coefficients for the current Retail Price (Prt) are 0.7115, 0.7569, and 0.5661, respectively, and are statistically insignificant. The insignificance of the coefficients suggest that the current retail prices are not strong determinants of the mark-up price for ginger, garlic and lemon. This indicates that other factors, such as past retail prices, may play a more prominent role in influencing their mark-up prices.

Across all three commodities, the coefficients for the producer price are 0.9512 for ginger, 0.7658 for garlic, and 0.7230 for lemon, and these coefficients are also statistically insignificant. The insignificance of these coefficients suggests that the producer price is not a strong determinant of the mark-up price for ginger, garlic, and lemon. This implies that, similar to the retail price, other factors, such as past retail prices, may have a more substantial impact on determining the mark-up prices for these commodities.

The coefficients for Retail Price Lagged (P_ (rt-1)) are statistically significant at the 1% level for all three commodities, with values of 0.8999 for ginger, 0.9106 for garlic, and 0.8101 for lemon. This indicates that that a 1-unit increase in the previous period's retail price leads to an increase in the current mark-up price by 0.8999, 0.9106, and 0.8101, respectively. In all three cases, the statistically significant coefficients for the lagged retail price indicate that the previous period's retail price plays a crucial role in determining the current mark-up price for ginger, garlic, and lemon. Thus, the Mark-Up Pricing for ginger, garlic and lemon heavily depend on the retail price trend from the previous period.

Overall, the results showed that the mark-up prices for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa were significantly influenced by past retail prices, indicating a lagged effect in how retail price changes impact the mark-up prices. Ginger exhibited the highest explanatory power, implying a more consistent price transmission process. Overall, the results imply that, despite some lag in price adjustments, the market power exerted by retailers or intermediaries is limited, with farm price changes ultimately being passed on to the retail market for ginger, garlic, and lemon. These results provide a static view of how farm prices were transmitted to retail prices but do not capture the nature of price transmission, specifically whether it is symmetric or asymmetric. Therefore, the Houck model was employed to analyse the farm-to-retail price transmission. The next step involves using the Houck model to examine how retail prices respond to both rising and falling farm prices for these commodities, thereby capturing the nature of the farm-to-retail price transmission.

5.4.2 Houck model results

The preceding discussion provided an overview of the behaviour of retail prices for ginger, garlic, and lemon in response to changing farm prices. To gain a deeper understanding of how retail prices respond to rising and falling farm prices for these commodities, the Houck approach was utilised. This approach offers insights into the behaviour of retail prices for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa in relation to changes (both increases and decreases) in farm prices. The Houck approach is represented by Equation (6), and the results are presented in Table 5.6 below.

Table 5.6: Parameter estimates of the Houck model

Commodity	**Ginger**		**Garlic**		**Lemon**	
Parameter	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Intercept	-0.4809	0.7552	-0.0057	0.5841	-0.3068	0.5841
$\Delta \mathbf{P}_{\mathbf{ft}}^{+}$	-0.5648	0.4824	-0.3229	0.2135	-0.3995	0.2135
$\Delta \mathbf{P}_{\mathbf{ft-1}}^{+}$	-0.4452	0.5100	-0.5597	0.1587	-0.5289	0.1587
$\sum \Delta \mathbf{P}_{\mathbf{ft}}^{+}$	1.3685	0.2831	3.4446	0.4486	1.3354	0.4486
$\Delta \mathbf{P}_{\mathbf{ft}}^{-}$	-0.8742	0.5549	-0.4012	0.2682	-0.6221	0.2682
$\Delta \mathbf{P}_{\mathbf{ft-1}}^{-}$	-0.4687	0.4555	0.6991	0.2372	-0.3039	0.2372
$\sum \Delta \mathbf{P}_{\mathbf{ft}}^{-}$	1.4755	0.2524	2.4223	0.1884	1.2008	0.1884
AR (1)	0.8350	0.042***	0.3010	0.048***	0.6852	0.048***
R-square	0.9102		0.8766		0.8203	
Akaike Info Criterion	1.8697		1.7822		1.6523	
Schwarz Info Criterion	1.9967		1.8999		1.5471	
Durbin-Watson statistics	2.1325		2.3221		2.1153	

Source: Author's computation (2024); *** shows 1% significance level

The adjusted R-squared values indicate that the Houck model explains about 91.02% of the variation in retail prices for ginger, 87.66% for garlic, and 82.03% for lemon. This demonstrates that the model is a very good fit for ginger and provides good fits for garlic and lemon, respectively. Ginger had the best model fit, followed by garlic, and lemon, suggesting that the model for ginger has the highest explanatory power.

The Durbin-Watson statistic values are 2.1325 for ginger, 2.3221 for garlic, and 2.1153 for lemon, all of which are close to 2. This indicates that there is no significant autocorrelation in the residuals for any of the models. Therefore, the results for all three commodities are valid.

The AIC values are 1.8697 for ginger, 1.7822 for garlic, and 1.6523 for lemon, while the while the SC values are 1.9967 for ginger,1.8999 for garlic, and 1.5471 for lemon. Thus, lemon has the lowest AIC value, indicating that, despite its R-squared being comparatively lower. This means that the Houck model for lemon is the most efficient in terms of balancing goodness-of-fit and model complexity among the three commodities. Similar to the AIC, the SC is also lowest for lemon, further confirming that the lemon model is the most efficient model.

For ginger, garlic, and lemon, the coefficients for positive changes ($\Delta\mathbf{P}_{\mathbf{ft}}^{+}$ and $\Delta\mathbf{P}_{\mathbf{ft}}^{-}$) were negative. This means that increases in farm prices were not fully passed on to retail prices or were partially absorbed by the supply chain. The cumulative effect ($\sum \Delta \mathrm{P}_{\mathrm{ft}}^{+}$) showed that garlic had the highest response to positive farm price changes (3.4446) compared to ginger (1.3685) and lemon (1.3354). This implies that retail prices for garlic were more responsive to rising farm prices over time.

The coefficients for negative changes ($\Delta\mathbf{P}_{\mathbf{ft}}^{-}$ **and** $\Delta\mathbf{P}_{\mathbf{ft-1}}^{-}$) indicated varied responses to falling farm prices. For ginger, the coefficients were -0.8742 and -0.4687, respectively. This suggests that decreases in farm prices were only partially passed on to retail prices, and not proportionally. Similarly, for lemon, the coefficients were -0.6221 and -0.3039. This means that, in both cases, changes in farm prices for ginger and lemon were not fully transmitted to the retail level, indicating asymmetric farm-to-retail price transmission. Specifically, when farm prices decreased, the reductions were not passed through proportionally to retail prices, meaning that consumers did not experience the full benefit of lower farm prices.

For garlic, the coefficient for $\Delta\mathbf{P}_{\mathbf{ft}}^{-}$ was -0.4012, but the coefficient for $\Delta\mathbf{P}_{\mathbf{ft-1}}^{-}$ was 0.6991, indicating mixed responses. The positive lagged coefficient suggested that retail prices were somewhat resistant to fully passing on farm price declines, potentially due to delayed or sticky price adjustments by retailers. In other words, when farm prices went down, retail prices did not drop as quickly or as much as expected, possibly because retailers were slow to adjust their prices or chose to keep them higher despite reduced costs.

The cumulative effect ($\sum \Delta \mathbf{P}_{\mathbf{ft}}^{-}$) showed that garlic (2.4223) had the highest overall response to declining farm prices compared to ginger (1.4755) and lemon (1.2008). This implies that retail prices for garlic were more responsive to falling farm prices over time than the other commodities.

Overall, the results indicated asymmetric farm-to-retail price transmission for all three commodities. The tendency to pass on farm price increases more readily while resisting decreases pointed to profit-maximising behaviour and a less competitive market structure, giving retailers greater influence over retail prices. This was most evident in garlic, where retailers were more resistant to passing on farm price declines than increases, suggesting that they had some degree of market power. These findings necessitated a deeper analysis of the speed and extent of farm-to-retail price transmission. As such, the ECM model analysis was conducted, and the results are presented in the next section.

5.4.3 Error Correction Model results

The ECM was used to examine the long-run relationship between farm prices and retail prices, as well as the short-run dynamics of price adjustments. This approach helped determine whether farm and retail prices moved together in the long run, even if they deviated in the short run, by indicating how quickly deviations from the long-run equilibrium were corrected (Engle and Granger, 1987; Hamilton, 1994).

Following the estimation of parameters using the Houck approach, an additional co-integration test was conducted on the relationship between farm and retail prices, utilising the ECM as specified in Equation 10. In this context, the ECM incorporates the co-integration relationship by using the ECT derived from the long-run equilibrium between farm and retail prices to analyse both short-run and long-run dynamics. Therefore, co-integration is embedded in the ECM, allowing it to serve as a model to explore the co-integration relationship between farm prices and retail prices for ginger, garlic, and lemon (Engle and Granger, 1987; Hamilton, 1994).

Since the Houck model captured the short-run nature of price transmission, the reporting of the ECM results focuses only on the long-run adjustments to avoid redundancy, while still providing a comprehensive understanding of how quickly and to what extent deviations from the long-run equilibrium are corrected. By concentrating on the long-run adjustment results, valuable insights into the equilibrium relationship between farm and retail prices are provided, which complement the short-run findings from the Houck model. The parameter estimates of the ECM are as shown in Table 5.7 below.

Table 5.7: Parameter estimates of the ECM

Commodity	**Ginger**		**Garlic**		**Lemon**	
Parameter	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Intercept	-0.0068	0.1159	-0.0057	0.1102	-0.0042	0.1055
ECT_{t-1}^{+}	0.4410	0.0296***	0.3018	0.0240***	0.198	0.0100***
ECT_{t-1}^{-}	-0.4998	0.0305***	-0.4478	0.0256***	-0.2995	0.0977***
R-square	0.7056		0.8766		0.8465	
Akaike Info Criterion	1.8381		1.7822		1.5246	
Schwarz Info Criterion	1.9100		1.8999		1.6225	
Durbin-Watson statistics	2.3415		2.3221		2.2995	

Source: Author's computation (2024); *** shows 1% significance level

The model fit indicators confirm that all three commodities have DW statistics near 2, implying that the residuals from the ECM models for ginger, garlic, and lemon do not exhibit substantial autocorrelation. This enhances the reliability of the estimated coefficients for the Error Correction Terms (ECTs). Additionally, the ECMs for garlic and lemon have strong explanatory power, with garlic having the best R-squared value and lemon showing the best fit based on AIC and SIC criteria. These results highlight the efficiency and effectiveness of price transmission from farm to retail prices over time, particularly for ginger, which adjusts more quickly to long-run equilibrium compared to garlic and lemon.

The results also capture the Error Correction Terms (ECTs), where ECT_{t-1}^{+} and ECT_{t-1}^{-} represent the adjustments for positive and negative deviations from the long-run equilibrium, respectively. The coefficients ECT_{t-1}^{+} and ECT_{t-1}^{-} indicate the speed and direction at which farm-to-retail price deviations from the long-run equilibrium are corrected in the ECM. The results for positive deviations showed that the coefficient for ginger is 0.4410, suggesting that 44.10% of positive deviations from the long-run equilibrium are corrected in the next period, indicating a moderate adjustment speed. The coefficient for ginger is 0.3010, indicating that 30.10% of positive deviations are adjusted in the next period, representing a slower adjustment compared to ginger. For lemon, the coefficient is 0.1988, meaning only 19.88% of positive deviations are corrected in the following period, showing the slowest adjustment among the three commodities.

The results for negative deviations showed that the coefficient for ginger is -0.4998, showing that 49.98% of negative deviations are corrected in the subsequent period, representing a relatively fast adjustment to the long-run equilibrium. For garlic, the coefficient is -0.4478, indicating that 44.78% of negative deviations are adjusted in the next period, showing a considerable correction rate. The coefficient for lemon is -0.2995, suggesting that 29.95% of negative deviations are corrected in the following period, indicating the slowest adjustment for negative deviations among the three commodities. Overall, ginger demonstrated the quickest adjustment for both positive and negative deviations, indicating a strong return to equilibrium. Garlic adjusts moderately, while lemon has the slowest correction speed, suggesting less responsiveness to both positive and negative deviations from the long-run equilibrium.

Following the earlier analysis of price adjustments using the Error Correction Model (ECM), this section presents the estimates of short-run and long-run elasticities of farm-to-retail price transmission for ginger, garlic, and lemon. Table 5.8 shows both short-run and long-run price transmission elasticities for rising and falling farm prices. The results offer insights into how changes in farm prices were transmitted to retail prices for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa, both in the short run and the long run.

Table 5.8: Estimates of short-run and long-run elasticities of farm-to-retail price transmission

Method	Short-run elasticity of price transmission		Long-run elasticity of price transmission	
	Rising farm prices	**Falling farm prices**	**Rising farm prices**	**Falling farm prices**
		Ginger		
ECM	0.5520	0.3187	1.3988	1.4334
		Garlic		
ECM	0.4812	0.3005	1.1248	1.2369
		Lemon		
ECM	1.2491	1.1052	2.9356	1.0034

Source: Author's computation (2024)

The results for short-run price transmission showed that, for rising farm prices, lemon exhibited the highest short-run elasticity at 1.2491. This means that a 1% increase in farm prices led to a 1.2491% increase in retail prices, indicating more than complete pass-through. Ginger and garlic had lower elasticities at 0.5520 and 0.4812, respectively. This means that a 1% increase in farm prices led to 0.5520% and 0.4812% increases in retail prices for ginger and garlic, respectively. This suggests moderate transmission, where retail prices rose less than proportionally to farm prices.

The results for falling farm prices showed that lemon still had the highest short-run elasticity at 1.1052, indicating that a 1% decrease in farm prices led to a 1.1052% decrease in retail prices. This demonstrates an almost complete pass-through. In contrast, ginger and garlic had lower elasticities at 0.3187 and 0.3005, respectively, meaning that a 1% decrease in farm prices led to only a 0.3187% and 0.3005% decrease in retail prices for ginger and garlic, respectively. This indicates that retail prices adjusted less in response to falling farm prices.

Overall, in the short run, lemon exhibited the highest elasticity for both rising and falling farm prices, indicating a strong and almost immediate response, with retail prices adjusting more than proportionally to farm price changes. Ginger and garlic showed moderate short-run adjustments, particularly in response to rising farm prices, and even less responsiveness to falling prices.

The results for long-run price transmission showed that, for rising farm prices, lemon again exhibited the highest long-run elasticity at 2.9356. This means that a 1% increase in farm prices led to a 2.9356% increase in retail prices, indicating a very strong and more than complete pass-through. Ginger and garlic had lower elasticities at 1.3988 and 1.1248, respectively, meaning that a 1% increase in farm prices led to a 1.3988% and 1.1248% increase in retail prices for ginger and garlic, respectively. This suggests more than complete transmission, but the response was less evident compared to lemon.

For falling farm prices, ginger showed the highest long-run elasticity at 1.4334, indicating that a 1% decrease in farm prices led to a 1.4334% decrease in retail prices. This demonstrates more than complete pass-through. Garlic and lemon had lower elasticities at 1.2369 and 1.0034, respectively, meaning that a 1% decrease in farm prices led to a 1.2369% and 1.0034% decrease in retail prices for garlic and lemon, respectively. This suggests that while all three commodities exhibited more than complete transmission in the long run, ginger was the most responsive to falling farm prices, followed by garlic and lemon.

Overall, in the long run, lemon continued to demonstrate the highest elasticity for rising farm prices, while ginger was the most responsive to falling farm prices. All three commodities showed more than complete transmission in the long run, but the degree of adjustment varied, with ginger, garlic, and lemon all eventually aligning with farm price movements. These findings suggest that while price transmission from farm to retail was asymmetric in the short run, with lemon reacting more strongly, the long-run adjustments were more comprehensive across all commodities. This indicates that retail prices eventually reflected changes in farm prices, though at different rates and intensities.

5.4.4 Discussion of the results

The results from the Mark-Up Pricing Model, Houck Model, and the ECM are compared and contrasted with findings from the reviewed international and national literature as follows:

a) Comparison of asymmetric and symmetric price transmission

This study revealed asymmetric price transmission in the short run, with lemon responding more strongly to rising farm prices and ginger more responsive to falling prices. In the long run, all commodities demonstrated more than complete transmission, eventually aligning with farm price movements. This is similar to the findings of Hosseini et al. (2012), who also observed asymmetric transmission in the short run for the Iranian chicken market, with farm price decreases being transmitted more slowly to retail prices. However, symmetric transmission was observed in the long run, reflecting this study's long-run findings, where all commodities eventually reflected changes in farm prices.

In contrast, Fiamohe et al. (2013) found asymmetric transmission for local rice in Benin but symmetric transmission in Mali. This suggests market inefficiencies in Benin, where price increases were passed on faster than decreases, similar to what this study found for lemon. However, Mali's symmetry contrasts with the short-run results in this study, where lemon, ginger, and garlic all displayed asymmetric transmission.

b) Market power and asymmetry

The findings of asymmetry, especially for garlic, where retailers were more resistant to passing on price declines, align with other studies that highlight market power as a key factor driving price asymmetry. For example, De and Koemle (2015) found asymmetric price transmission in the Chinese hog market, attributing it to market inefficiencies and the power of retailers to limit transmission. Similarly, Kharin (2018) noted that market power in the Russian milk supply chain led to price reductions being transmitted slowly through the supply chain. These findings are consistent with this study's conclusion that retailers tend to resist price decreases, maintaining higher retail prices.

However, Ramsey et al. (2021) found symmetric transmission in the US meat market despite the disruptions caused by COVID-19, which contrasts with this study, where lemon, ginger, and garlic demonstrated asymmetry. This difference suggests that the degree of market power and supply chain inefficiencies can vary by commodity and market context.

c) Supply chain shocks and asymmetric transmission

The literature also highlighted the impact of external shocks, such as COVID-19, on price transmission. Erol and Saghaian (2022) and Odiase and Saghaian (2022) both found asymmetric price adjustments in the US beef and fresh banana markets, where retail prices adjusted more slowly than farm prices due to market power and supply chain disruptions. Similarly, this study found that the long-run adjustments for lemon, ginger, and garlic were more complete, but the short-run responses were asymmetric. This suggests that supply chain factors during the pandemic may have exacerbated asymmetries in the lemon, ginger, and garlic markets, a pattern also observed in the international studies.

d) National studies and price transmission in South Africa

In South Africa, studies like Cutts and Kirsten (2006) and Lombard (2015) also found evidence of asymmetric price transmission, largely due to market concentration and inefficiencies. These findings align with this study's results, where asymmetry was present in the short run. In contrast, Mkhabela and Nyhodo (2011) observed elastic and symmetric price transmission in the South African poultry market, where retail prices responded strongly to changes in farm prices. This contrasts with this study's findings for lemon, ginger, and garlic, where responses varied across commodities and were not always symmetric.

Additionally, Louw et al. (2017) found symmetric price transmission for wheat-to-bread and maize-to-maize meal chains in South Africa, indicating that price changes were fully reflected at the retail level. This symmetric behaviour contrasts with the findings of short-run asymmetry but supports the long-run adjustments observed in this study, where retail prices for all commodities eventually aligned with farm prices.

e) Elasticity and market efficiency

This study found that lemon exhibited the highest elasticity for rising farm prices, while ginger was most responsive to falling prices. In contrast, the literature presents mixed results regarding market efficiency. For instance, Mkhabela and Nyhodo (2011) found elastic price transmission in the South African poultry market, where retail prices responded more than proportionally to changes in farm prices, similar to the high elasticity observed in the lemon market in this study. However, Billa et al. (2022) found inelastic transmission in the Nigerian cattle market, where price reductions were not fully passed on to consumers, which contrasts with the more responsive transmission found for ginger in this study.

In summary, this study's findings on price transmission dynamics for lemon, ginger, and garlic align with much of the international and national literature regarding asymmetric transmission in the short run and the influence of market power on price behaviour. However, the degree of elasticity and the presence of symmetric transmission in the long run reflect mixed outcomes across the literature, indicating that market context, commodity type, and external shocks (such as COVID-19) play crucial roles in shaping price transmission patterns.

5.5 Validation of the results

The diagnostic tests were conducted to ensure the validity, reliability, and robustness of the results for the ECM. Various diagnostic tests were conducted to evaluate the assumptions of normality, heteroskedasticity, and serial correlation in the residuals of the ginger, garlic, and lemon price series. The Jarque-Bera test was used to examine whether the error terms are normally distributed, while the Autoregressive Conditional Heteroscedastic (ARCH) test was employed to determine if the variance of the residuals is constant. Additionally, Breusch-Godfrey Test (also known as the Lagrange multiplier (LM) test) was performed to assess the presence of serial correlation. These diagnostic tests are crucial in econometrics, as they help identify any violations of assumptions that could affect the efficiency, consistency, and unbiasedness of the estimated parameters. The results for each test are presented below.

5.5.1 Normality test results

Table 5.9 below shows the normality test results for the residuals of ginger, garlic, and lemon price series during the sample period. The statistics include measures of central tendency (mean, median), dispersion (standard deviation), skewness, kurtosis, the Jarque-Bera test statistic, and its corresponding p-value. The null and alternative hypotheses for normality assumption were stated as follows:

- Null hypothesis (H_0): The random error term is normally distributed.
- Alternative hypothesis (H_1): The random error term is not normally distributed.

Table 5.9: Normality Results for Ginger, Garlic, and Lemon

Series: Residuals			
Sample 2020M03 - 2022M12			
	Ginger	**Garlic**	**Lemon**
Mean	6.59e-18	6.33e-15	6.20e-09
Median	-0.065471	-0.04168	-0.00125

Maximum	0.96248	0.66930	0.32963
Minimum **Std. Dev**	-0.46425	-0.21212	-0.11967
Skewness	0.24698	0.35733	0.19857
Kurtosis	2.90087	2.41097	2.61097
Jarque-Bera	3.96326	3.66654	3.22179
Probability	0.26858	0.12178	0.35488

Source: Author's computation (2024)

The decision rule for testing the null hypothesis of normality is that if the p-value from the test is greater than the chosen significance level (e.g., 0.05), we fail to reject the null hypothesis. This means that the residuals are normally distributed. Conversely, if the p-value is less than 0.05, we reject the null hypothesis. This means that the residuals are not normally distributed. In this case, the Jarque-Bera test yielded statistic values of 3.96326 for ginger, 3.66654 for garlic, and 3.22179 for lemon, with p-values greater than 0.05 in all instances. Therefore, we fail to reject the null hypothesis of normality, indicating that the residuals for the ginger, garlic, and lemon price series are normally distributed.

According to Hatem et al. (2020), a kurtosis value of 3 indicates that the dataset has a mesokurtic distribution, meaning it is neither heavy-tailed (leptokurtic) nor light-tailed (platykurtic) and, therefore, follows a normal distribution. For ginger, the skewness (0.24698) is close to zero, and the kurtosis (2.90087) is very close to 3, indicating that the distribution of error terms is approximately normal and mesokurtic. For garlic, the skewness (0.35733) suggests a slight asymmetry, and the kurtosis (2.41097) is less than 3, indicating a distribution that is flatter than a normal (platykurtic) distribution.

For lemon, the skewness (0.19857) is close to zero, and the kurtosis (2.61097) is slightly below 3, suggesting a nearly normal distribution but with a slightly flatter peak than a perfectly normal distribution. In conclusion, ginger shows a normal distribution of error terms, lemon demonstrates a nearly normal distribution, and garlic shows a somewhat flatter than normal distribution, but none of the variables exhibit extreme deviations from normality. This is validated by the Jarque-Bera statistic results, which were discussed earlier.

5.5.2 Heteroskedasticity test results

The table 5.10 below presents the heteroskedasticity test results for ginger, garlic, and lemon. The test statistics include the F-statistic, Obs*R-squared, and the Scaled Explained Sum of Squares, along with their corresponding p-values. The null and alternative hypotheses for testing the assumption of constant variance of error terms (homoscedasticity) are as follows:

- Null hypothesis (H_0): Heteroskedasticity does not exist (Homoscedasticity – the variance of the errors is constant).
- Alternative hypothesis (H_1): Heteroskedasticity exists (the variance of the errors is not constant, i.e., non-homoscedastic).

Table 5.10: Heteroskedasticity Results for Ginger, Garlic, and Lemon

Test Statistic	Ginger	Garlic	Lemon
F-statistic	1.1582	1.1398	1.0287
Prob. F (2,223)	0.3936	0.3204	0.3027
Obs*R-squared	2.7614	2.2840	2.1325
Prob. Chi-square (2)	0.3612	0.3199	0.3001
Scaled explained SS	1.9953	1.8196	1.4377
Prob. Chi-square (2)	0.3992	0.3888	0.3257

Source: Author's compilation (2024)

The decision rule for heteroskedasticity assumption is that if the p-value from the test is greater than a chosen significance level (i.e., 0.05), we fail to reject the null hypothesis of homoscedasticity. This means that there is no evidence of heteroskedasticity, and the variance of the errors is constant. Conversely, if the p-value is less than 0.05, we reject the null hypothesis. This means that heteroskedasticity exists, meaning the variance of the errors is not constant.

The F-statistic values are 1.1582, 1.1398, and 1.0287 for ginger, garlic, and lemon, respectively, with p-values greater than 0.05 across these commodities. Therefore, we fail to reject the null hypothesis in each case. This indicates that there is no evidence of heteroskedasticity, and the variance of the errors is constant (i.e., the residuals are homoscedastic). Additionally, the p-values for both the Obs*R-squared and Scaled Explained Sum of Squares statistics are greater than 0.05 in all cases, which further confirms the absence of heteroskedasticity.

5.5.3 Serial correlation test results

The table 5.11 below presents the results of serial correlation tests for ginger, garlic, and lemon. The table reports the F-statistic, Observed R-squared, and their associated p-values. The null and alternative hypotheses for testing the assumption of no presence of serial correlation are as follows:

- Null hypothesis (H_0): There is no serial correlation (the residuals are uncorrelated over time).
- Alternative hypothesis (H_1): There is serial correlation (the residuals are correlated over time).

Table 5.11: Serial Correlation Results for Ginger, Garlic, and Lemon

Test Statistic	Ginger	Garlic	Lemon
F-statistic	0.001065	0.009522	0.006748
Prob. F-statistic	0.8964	0.8521	0.6135
Observed R-squared	0.004928	0.003883	0.002961
Prob. Chi-square	0.8620	0.8339	0.5958

Source: Author's compilation (2024)

The decision rule for serial correlation assumption is that if the p-value is greater than a chosen significance level (i.e, 0.05), we fail to reject the null hypothesis, indicating an absence of serial correlation. Conversely, if the p-value is less than 0.05, the null hypothesis is rejected, indicating the presence of serial correlation.

The F-statistic values are 0.001065, 0.009522, and 0.003883 for ginger, garlic, and lemon, respectively, with p-values greater than 0.05 across these commodities. Therefore, we fail to reject the null hypothesis in each case. This indicates that there is no evidence of serial correlation, and the residuals are uncorrelated over time. Additionally, the p-values for Observed R-squared are greater than 0.05 in all cases, which further confirms the absence of serial correlation.

Overall, normality test results showed that the residuals for ginger, garlic, and lemon price series are either normally or nearly normally distributed, as confirmed by the Jarque-Bera test and the skewness and kurtosis values. This supports the reliability and robustness of the model estimations. The ARCH test results indicated that the error terms for ginger, garlic, and lemon exhibit no evidence of heteroskedasticity , as the p-values for the F-statistic, Obs*R-squared, and Scaled Explained Sum of Squares are all greater than 0.05. Furthermore, results of the serial correlation tests showed that there is no evidence of serial correlation in any of the commodities, as the F-statistic and Observed R-squared p-values were also greater than 0.05. Overall, these findings confirm that the residuals are homoscedastic, uncorrelated, and nearly normally distributed, thereby validating the reliability and robustness of the ECM used in this analysis.

5.6 Chapter summary

This chapter presented the findings from the ADF and PP tests, as well as the econometric modelling methods, namely the Mark-Up Pricing model, which was used to address the first objective, the Houck model for the second objective, and the Error Correction Model for the third objective. Finally, the Jarque-Bera, ARCH test, and LM test were conducted to ensure the validity, reliability, and robustness of the ECM results.

CHAPTER SIX: RESEARCH SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter comprises the key findings and issues discussed in each chapter of the study. By doing so, it serves as a comprehensive summary that highlights important aspects addressed throughout the research. Additionally, it presents concluding remarks, policy recommendations, and suggestions for future research.

6.2 Summary

This study analysed farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa, using secondary time-series data from March 2020 to December 2022. Farm prices were sourced from Joburg Market, while retail prices were obtained from the Stats SA and supplemented with data from NAMC to address any missing points. Both the ADF and PP tests were conducted to check whether farm and retail price series data were stationary, ensuring robustness against heteroskedasticity and autocorrelation. The results confirmed that the farm and retail price series for ginger, garlic, and lemon were stationary at levels (I(0)), with test statistic values less than the critical values and p-values below 0.05. Thus, no transformation or differencing was needed for farm-to-retail price transmission analysis, and co-integration testing was unnecessary, as it applies to non-stationary series with potential long-run equilibrium relationships.

The first objective involved estimating farm-to-retail price transmission elasticities for ginger, garlic, and lemon using the Mark-Up Pricing model. Kendall's rank correlation test confirmed significant positive correlations between farm, mark-up, and retail prices, indicating effective price transmission for all commodities. Ginger showed the strongest correlation, suggesting efficient transmission, while garlic exhibited moderate transmission. Lemon showed the lowest, indicating potential inefficiencies or variability due to transaction costs or supply chain issues. The Mark-Up Pricing model revealed that retail prices were significantly influenced by past prices, suggesting that, despite some lag in price adjustments, farm price changes were largely passed on to retail prices, indicating limited market power by intermediaries.

However, this model provided only a static view and did not capture whether price transmission was symmetric or asymmetric.

To address this limitation, the Houck model was employed for the second objective to analyse the nature of farm-to-retail price transmission, specifically whether it was symmetric or asymmetric. The Houck model results revealed asymmetric transmission for all three commodities, as retail prices did not adjust proportionally to rising and falling farm prices. This means that retailers passed on farm price increases more readily while resisting decreases, indicating profit-maximising behaviour and a less competitive market structure, especially for garlic, where resistance to price declines suggested market power. In other words, while the Mark-Up Pricing model showed that farm prices influenced retail prices, the Houck model results highlighted the asymmetry in this process, with retailers taking advantage of rising farm prices but less willing to reduce retail prices when farm prices fell.

Building on the findings of the Houck model, the ECM was used to further analyse the speed and extent of farm-to-retail price transmission, achieving objective three. The ECM results showed that ginger had the fastest adjustment for both positive and negative deviations, indicating a strong return to equilibrium, while garlic adjusted moderately, and lemon had the slowest correction speed, suggesting less responsiveness to deviations from the long-run equilibrium. This confirmed that, although asymmetric price transmission was present, the market eventually adjusted, with retail prices becoming fully responsive to farm price changes over time. Additionally, the ECM confirmed that more than complete pass-through occurred in the long run for all commodities, verifying the asymmetric transmission detected by the Houck model.

Together, the three models provided a comprehensive analysis of farm-to-retail price transmission, achieving the objectives of the study. The Mark-Up Pricing model established the influence of past retail prices on mark-up prices, the Houck model identified asymmetric transmission behaviour, and the ECM demonstrated the speed and extent of adjustment to equilibrium. Diagnostic tests, including the Jarque-Bera test, ARCH test, and Breusch-Godfrey test, confirmed the validity, reliability, and robustness of the ECM. This ensures that the results are reliable and accurately capture the dynamics of farm-to-retail price transmission for ginger, garlic, and lemon during the COVID-19 pandemic in South Africa.

6.3 Conclusion

The first hypothesis stated that there are no significant farm-to-retail price transmission elasticities for the selected agricultural commodities during the COVID-19 pandemic in South Africa, for the objective of estimating farm-to-retail price transmission elasticities for selected agricultural commodities during the COVID-19 pandemic in South Africa. However, based on the obtained results, the study rejects this hypothesis, as significant elastic price transmission elasticities were found for all the selected agricultural commodities (ginger, garlic, and lemon) during the COVID-19 pandemic in South Africa.

The second hypothesis stated that there is no symmetric farm-to-retail price transmission for the selected agricultural commodities during the COVID-19 pandemic in South Africa, for the objective of determining whether there is symmetric or asymmetric farm-to-retail price transmission for selected agricultural commodities during the COVID-19 pandemic in South Africa. The study rejects this hypothesis as well since the results revealed asymmetric farm-to-retail price transmission for all selected commodities (ginger, garlic, and lemon), confirming that price adjustments differed for rising and falling farm prices.

The final hypothesis stated that there is no long-run relationship between farm prices and retail prices for the selected agricultural commodities during the COVID-19 pandemic in South Africa, for the objective of examining the long-run relationship between farm prices and retail prices for selected agricultural commodities during the COVID-19 pandemic in South Africa. According to the results, the study rejects this hypothesis, as it found a significant long-run relationship between farm and retail prices for all selected agricultural commodities (ginger, garlic, and lemon) during the COVID-19 pandemic in South Africa.

6.4 Recommendations

Based on the findings from the Mark-Up Pricing model, the Houck model, and the ECM, several policy strategies are recommended to address the issue of asymmetric price transmission and ensure a more competitive market structure for garlic, ginger, and lemon:

6.4.1 Regulatory Oversight on Retail Pricing

The Competition Commission, Department of Trade, Industry, and Competition (DTIC), and National Consumer Commission should implement and enforce regulations to monitor and limit price asymmetry, ensuring that retailers pass on both farm price increases and decreases to consumers proportionately. This would lead to reduction in price manipulation by retailers and intermediaries, leading to fairer retail prices for consumers, which are more reflective of farm price changes.

6.4.2 Market Competition Enhancement

The Competition Commission, Department of Small Business Development (DSBD), and National Treasury should support and promote smaller retailers and intermediaries through financial incentives and grants to enhance competition and reduce market concentration that leads to asymmetric price behaviour. This would results in increased competition in the market, limiting the power of dominant retailers, and promoting fairer pricing behaviour, especially for garlic, ginger, and lemon.

6.4.3 Price Monitoring Systems

The National Agricultural Marketing Council (NAMC), Statistics South Africa (Stats SA), Department of Agriculture, Land Reform, and Rural Development (DALRRD) should establish a comprehensive farm-to-retail price monitoring system to track price movements, ensuring that farm price changes are reflected in retail prices promptly and fairly. This would lead to improved transparency in the price-setting process, with farm price changes being more accurately and quickly passed on to retail prices, ensuring consumer protection and fair competition.

6.4.4 Consumer Protection Policies

The National Consumer Commission, Department of Trade, Industry, and Competition (DTIC), and Consumer Goods Council of South Africa (CGCSA) should strengthen consumer protection laws to prevent price exploitation, particularly during market volatility. This includes ensuring transparent pricing practices and fair price adjustments by retailers. This would lead to enhanced consumer protection, reducing the likelihood of price exploitation, and fostering trust in the market for garlic, ginger, and lemon.

6.4.5 Subsidies for Key Commodities

The Department of Agriculture, Land Reform, and Rural Development (DALRRD) should provide targeted subsidies or support programmes for essential commodities (such as garlic) prone to price manipulation, stabilising retail prices and reducing the market power of dominant retailers. This would result in stabilised retail prices for key commodities, reducing market volatility and ensuring that price adjustments at the farm level are not manipulated by retailers.

Overall, the proposed policy strategies are aimed at addressing the challenges identified in the price transmission process and fostering a more equitable, competitive, and transparent market for the selected agricultural commodities. By implementing these strategies, relevant stakeholders, including farmers, retailers, and consumers, would benefit from fairer pricing practices, improved market efficiency, and greater protection against price manipulation.

6.5 Delimitations and areas for future research

This study has several delimitations, which also serve as potential areas for further analysis. The focus was on estimating farm-to-retail price transmission elasticities for selected agricultural commodities during the COVID-19 pandemic in South Africa. This scope limits insights into how price transmission elasticities might differ outside a pandemic context. Future research should examine these elasticities over a broader time frame, including pre-pandemic, pandemic, and post-pandemic periods, to assess the long-term effects of such events on price transmission.

Additionally, the study did not perform Granger causality tests, which limits understanding of the causal relationship between farm and retail prices. Future research should incorporate Granger causality analysis to determine whether changes in farm prices lead to changes in retail prices or vice versa. This would provide deeper insights into the lead-lag dynamics of price transmission.

Since both farm and retail price series were stationary at levels (I(0)), standard co-integration tests were excluded, as they apply to non-stationary series with potential long-run equilibrium relationships (Enders, 2014; Greene, 2018). While this decision was justified, future studies involving non-stationary price series (I(1)) should include co-integration testing, such as the Johansen test or the Engle-Granger approach, to assess long-run equilibrium relationships between farm and retail prices. This would offer a more comprehensive understanding of long-term price transmission dynamics.

Furthermore, the study examined long-run relationships using the Error Correction Model (ECM), which limited the analysis of short-term fluctuations or seasonal effects. Future studies should integrate models that account for seasonal variations and short-term dynamics to provide a more detailed understanding of price adjustments over different time intervals.

Lastly, this study focused on selected commodities during the pandemic, potentially limiting the generalisability of the findings to other agricultural products. Therefore, future research should expand the analysis to include a broader range of commodities to determine whether the observed price transmission patterns are consistent across different agricultural goods.

In summary, these delimitations highlight opportunities for future research to expand and refine the understanding of price transmission within the agricultural sector, ensuring a more comprehensive analysis across varying contexts and periods.

REFERENCES

Acquah, HD., Owusu, R. (2012) ‘Spatial Market Integration and Price Transmission of selected plantain markets in Ghana’, *Journal of Sustainable Development in Africa,* vol 14, no.5, pp. 24-28.

Aguiar, D., Santana, JA. (2002) ‘Asymmetry in farm to retail price transmission: Evidence for Brazil’, *Agribusiness*, vol 18, no.2, pp. 37-48.

Akram, G. (2020) Packaging and labelling, Accessed 10 June 2023, https://en.m.wikipedia.org/wiki/Packaging_and_labeling#

Ali, A., Ur Rehman, H. (2015) ‘Macroeconomic instability and its impact on Gross Domestic Product: An Empirical Analysis of Pakistan’, *Munich Personal RePEc Archieve*, pp. 285-316, Accessed 01 August 2022, htpps://mpra.ub.uni-muenchen.de/71037/

Armor, Q. (2019) Grades and standards, Accessed 11 June 2023, https://en.m.wikipedia.org/wiki/Grades_and_standards

Banton, C. (2019) Raw Materials: Definition, Accounting, and Direct vs. Indirect, Accessed 11 June 2023, https://www.investopedia.com/terms/r/rawmaterials.asp

Barman, A., Das, R., De, PK. (2021) ‘Impact of COVID-19 in food supply chain: Disruptions and recovery strategy’ *Current Research in Behavioural Sciences*, vol. 2, pp.100017

Billa, Y., Ojo, CO., Bulama, YM. (2022) ‘Analysing price transmission in the Nigerian cattle market’, *International Journal of Economic Policy*, vol. 2, no.1, pp. 1-55.

Bernard, JC., Willett, LS. (1996) ‘Asymmetry price relationship in the U.S. broiler industry’, *Journal of Agricultural and Applied Economics*, vol. 28, no.1 pp. 279-289.

Bezuidenhout, C. (2020) Imports crowd South African garlic out of the marketplace, Accessed 9 June 2023, https://www.freshplaza.com/africa/article/9264313/imports-crowd-south-african-garlic-out-of-the-marketplace/

Botha, L. (2020) Ginger: a challenging crop, but well worth the effort, Accessed 9 June 2023 https://www.farmersweekly.co.za/crops/field-crops/ginger-a-challenging-crop-but-well-worth-the-effort/#:~:text=The%20current%20average%20yield%20is,the%20soil%20without%20breaking%20it.

Boyd, SM., Brorsen, BW. (1998) 'Price asymmetry in U.S. pork marketing channel', *North Central Journal of Agricultural Economics*, vol. 10, no.2, pp.103-110.

Brodie, L. (2023) Garlic vegetable farming in South Africa, Accessed 12 June 2023, https://southafrica.co.za/garlic.html

Brodie, L. (2023) Lemons in South Africa: Fruit farming in South Africa, Accessed 12 June 2023, https://southafrica.co.za/lemons-south-africa.html

Bundy, CJ. (2022) 'South Africa', *Britannica*, Accessed 10 September 2022, https://www.britannica.com/South-Africa/

B2B Ecommerce. (2018) Manufacturers vs. Distributors vs. Wholesalers: What You Need to Know, Accessed 11 June 2023, https://www.bigcommerce.com/articles/b2b-ecommerce/manufacturer-vs-distributor/

Capps, O., Sherwell, P. (2007) 'Alternative approaches in detecting asymmetry in farm to retail price transmission in fluid milk', Agribusiness: *An International Journal*, vol. 23, no .3, pp. 313- 331.

Caxton Magazines. (2017) Some tips for growing garlic, Accessed 12 June 2023, https://www.farmersweekly.co.za/farming-basics/how-to-crop/tips-growing-garlic/

Citrus Industry. (2023) South Africa Lemons/Limes to Hit Historic High production and price, Accessed 10 June 2022 https://citrusindustry.net/2023/01/19/south-africa-lemon-lime-crop-to-hit-historic-high/#:~:text=The%20Eastern%20Cape%20province%20is,representing%2075%25%20of%20total%20area.

Cohen, J. (1988) *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.), Lawrence Erlbaum Associates.

Cutts, M., Kirsten, J. (2006) ‘Asymmetric price transmission and market concentration: an investigation into four South African agro-food industries’, *South African Journal of Economics*, vol. 74, no. 2, pp. 323-333.

De, Z. Koemle, D. (2015) ‘Price transmission in hog and feed markets of China’, *Journal of Integrative Agriculture* 2015, vol. 14, no.6, pp. 1122-1129.

DALRRD. (2021) A profile of the South African garlic market value chain, Accessed 12 June 2023, https://webapps1.daff.gov.za/AmisAdmin/upload/Garlic%20Market%Value%20Chain%20Profile

DALRRD. (2021) Garlic Market Value Chain, Accessed 9 June 2023, http://webapps1.daff.gov.za/AmisAdmin/upload/Herb%20and%20Spice%20Market%20Value%20Chain%20Profile%202021.pdf

DALRRD. (2021) Herb and Spice Market Value Chain, Accessed 9 June 2023, http://webapps.daff.gov.za/AmisAdmin/upload/Herb%20and%20Spice%20Market%20Value%20Chain%20Profile%202019F.pdf

Dougherty, C. (2016) *Introduction to Econometrics*, Oxford University Press.

Duma, N. (2021) No evidence ginger, lemon, garlic combo prevents covid-19 infections experts, Accessed 19 June 2022, https://ewn.co.za/2021/01/28/no-evidence-ginger-lemon-garlic-combo-prevents-combo-prevents-covid-19-infections-experts/

Enders, W. (2014) *Applied Econometric Time Series* (4th ed.), Wiley.

Engle, R. F. and Granger, C. W. J. (1987) 'Co-integration and Error Correction: Representation, Estimation, and Testing.' *Econometrica*, vol. 55, no. 2, pp. 251-276.

Falkowski, J. (2010) ‘Price transmission and market power in a transition context: evidence from the Polish fluid milk sector’, *Post-Communist economies*, vol. 22, pp. 513-529.

Fiamohe, R., Seck, PA., Didier, YA., Diagne, A. (2013) ‘Price transmission analysis using threshold models: An application to local rice markets in Benin and Mali’, *Food Security*, vol.5, no. 8, pp. 427–438.

Gardner, BL. (1975) 'The Farm-retail price spread in a competitive food industry', *American of Agricultural Economics*, vol. 57, no.3, pp. 399-409.

Goodwin, BK., Holt, MT. (1999) 'Price transmission and asymmetric adjustment in the US beef sector', *American Journal of Agricultural Economics*, vol. 81, no.3, pp. 630-637.

Graceland. (2022) How to grow garlic https://gracelandgarlicseed.com/how-to-grow-garlic/#:~:text=Planting%20time%20for%20garlic%20is,winter%20to%20produce%20sizable%20bulbs.

Granger, CWJ., Lee, TH. (1989) 'Investigation of production, sales, and inventory relationships using multi cointegration and Non-Symmetric Error Correction Models', *Journal of Applied Economics*, vol.4, no.4, pp. 145-159.

Greene, W. H. (2018) *Econometric Analysis* (8^{th} ed.), Pearson.

Gujarati, DN., Porter, DC. (2009) Basic Economics (5^{th} Ed.), New York: McGrraw-Hill.

Gutierrez, P., Gandara-Marti, T., Abreu, Y., Nieto-Rufino, CD. (2022) 'Probiotic improves symptomatic and viral clearance in Covid19 outpatients: a randomized, quadruple-blinded, placebo-controlled trial' *Gut Microbes,* vol.14, no.1, pp. 2018899

Hadad, R. (2019) Cleaning Small-Farm Produce Wash Equipment, Accessed 11 June 2023, https://www.food-safety.com/articles/6418-cleaning-small-farm-produce-wash-equipment

Halagundegowda, GR., Kumaresan, P., Kantharaju, BM., Pallavi, J. (2021) 'Modelling of price transmissions: Evidence from Indian silk market', *Journal of Entomology and Zoology Studies,* vol. 9, no. 2, pp. 427-434.

Hamilton, J. D. (1994) *Time Series Analysis*, Princeton University Press.

Hayes, A. (2023) Perfect Competition: Examples and How It Works, Accessed 11 June 2023, https://www.investopedia.com/terms/p/perfectcompetition.asp

Hollander, M., Wolfe, D. A., and Chicken, E. (2013) *Nonparametric Statistical Methods* (3^{rd} ed.), Wiley.

Houck, PJ. (1977) 'An approach to specifying and estimating non-reversible functions', *American Journal of Agricultural Economics,* vol. 59, no. 1, pp. 570-572.

Hosseini, SS., Nikoukar, A., Dourandish, A. (2012) 'Price Transmission Analysis in Iran Chicken Market', *International Journal of Agricultural Management and Development*, vol. 2, no. 4, pp. 243-253.

Hudson, M. (2020) What Is a Retailer?, Accessed 11 June 2023, https://www.thebalancemoney.com/what-is-a-retailer-2890386

ImmuneSchein. (2022) ImmuneSchein Ginger Elixirs & Teas, Accessed 19 June 2022, https://immune-schein.com/blogs/news/base-lemon-ginger-and-garlic

Jansen, C. (2021) South African ginger market is white-hot, Accessed 12 June 2023, https://www.freshplaza.com/africa/article/9286911/south-african-ginger-market-is-white-hot/

Jinjarak, Y., Ahmed, R., Nair-Desai, S., Xin, W., Aizenman, J. (2020) Pandemic shocks and fiscal-monetary policies in the Eurozone: Covid-19 dominance during January-June 2020, Accessed 19 February 2023, https: //doi.org/10.3386/w27451

Joiya, SA., Shahzad, AA. (2013) 'Determinants of high prices: The case of Pakistan', *Pakistan Economic and Social Review*, vol. 51, no.1, pp. 93-107.

Khan, AS. (2020) Prices of Chinese ginger, garlic go up in view of coronavirus threat, Accessed 21 February 2023, https://www.dawn.com/news/1531891/prices-of-chinese-ginger-garlic-go-up-in-view-of-coronavirus-threat

Kharin, S. (2018) 'Price Transmission Analysis: The Case of Milk Producers in Russia', *AGRIS on-line papers in Economics and Informatics*, vol.10, no.1, pp.15-23.

Khurana, A. (2021) South Africa's ginger prices skyrocket in 2021 as COVID-19 induced demand continues, Accessed 19 June 2022, https://www.tridge.com/stories/south-africas-ginger-prices-skyrocket-in 2021-as-COVID-19-induced-demand-continues-to/

Kinnucan, HW., Forker, OD. (1987) ‘Asymmetry in farm-retail price transmission for major dairy products’, *American Journal of Agricultural Economics,* vol. 69, no.2, pp. 285-292.

Kunyanga, CN., Byskov, MF., Hyams, K., Mburu, S., Werikhe, G., Bett, R. (2023) ‘Influence of COVID-19 pandemic on food market in Nairobi, Kenya’, *Sustainability*, vol.15, no.2, pp.1304.

Law Insider. (2016) Storage and distribution definition, Accessed 11 June 2023, https://www.lawinsider.com/dictionary/storage-and-distribution

Li, S. (2020) A quick introduction on Granger Causality testing for time series analysis, *Towards Data Science,* Accessed 18 July 2022, https://towardsdatascience.com/a-quick-introduction-on-granger-causality-testing-for-time-series-analysis-7113dc9420d2/

Lodolo, G., Muller, J. (2021) High ginger, garlic and lemon prices have left a sour taste in mouths of South Africans, Accessed 20 May 2022, https://wwwafricanantitrust.com/2021/02/05/healthy-foods-price-gouging-during-pandemic/

Lombard, HL. (2015) ‘Price transmission in the beef value chain: The case of Bloemfontein, South Africa’ *University of Free State*, vol. 10, no. 1.

Lone, SA., Ahmad, A. (2020) 'COVID-19 pandemic–an African perspective.' *Emerging Microbes & Infections*, vol. 9, no. 1, pp. 1300-1308.

Louw, M., Meyer, F., Kirsten, J. (2017) ‘Vertical price transmission and its inflationary implications in South African food chains’, *Agrekon*, vol. 56, no. 2, pp. 110-122.

Ludden, TM., Beal, SL., Sheiner, LB. (1994) ‘Comparison of the Akaike Information Criterion, the Schwarz criterion and the F test as guides to model selection’, *Journal of Pharmacokinetics and Biopharmacy*, vol.22, no.5, pp. 431-445.

Maclnnis, T. (2016) Producer agriculture, Accessed 11 June 2023, https://en.m.wikipedia.org/wiki/Producer_(agriculture)

Mayo Clinic. (2022) Coronavirus disease 2019 (COVID-19), Accessed 21 February 2023, https://clinmedjournals.org/articles/jidejournal-of-infectious-diseases-andepidemology-jide-6-146.phpid=jide

Mkhabela, T., Nyhodo, B. (2011) 'Farm and Retail Prices in the South African Poultry Industry: Do the Twain Meet?', *International Food and Agribusiness Management Association*, vol. 14, no. 3, pp.11-20.

Mohan, BS., Nambia, V. (2020) 'COVID-19: An Insight into SARS-CoV-2 Pandemic Originated at Wuhan City in Hubei Province of China', *Journal of Infectious Diseases and Epidemiology,* vol.6, no.4.

Nicholas, J. (2021) Ginger prices skyrocket to record highs amid worldwide shortage, Accessed 21 February 2023, https://www.abc.net.au/news/rural/2021-02-07/covid-19-ginger-shortage-drives-prices-to-record-highs/13124794

Peltzman, S. (2000) 'Prices Rise Faster than They Fall', *Journal of Political Economy*, vol.108, no.2, pp 466-502.

Philips, L. (2020) South African consumers to pay much more for garlic, Accessed 21 May 2022, https://www.farmersweekly.co.za/agri-news/south-africa/south-african-consumers-to-pay-much-more-for-garlic/

Ramsey, AF., Barry, BK., Hahn, WF., Holt, MT. (2021) 'Impacts of COVID-19 and Price Transmission in U.S. Meat Markets' *The Journal of the International Association of Agricultural Economists*, vol.52, no.2, pp.441-458.

Sanjuan, AI., Gil, JM. (2001) 'Price transmission analysis: a flexible methodological approach applied to European pork and lamb markets', *Applied Economics,* vol. 33, no. 1, pp.123-131.

Segal, T. (2021) Import: Definition, Examples, and Pros and Cons, Accessed 11 June 2023, https://www.investopedia.com/terms/i/import.asp#:~:text=our%20editorial%20policies-,What%20Is%20an%20Import%3F,known%20as%20a%20trade%20deficit

Segal, T. (2022) What Are Exports? Definition, Benefits, and Examples, Accessed 11 June 2023, https://www.investopedia.com/terms/e/export.asp

Sekar, P. (2010) 'Diagnostic checking of time series models', *Indian Journal of Science and Technology,* vol. 9, no.3, pp. 101-185.

Sharma, M., Antony, R., Sharma, A., Daim, T. (2025) 'Can smart supply chain bring agility and resilience for enhanced sustainable business performance?' *The International Journal of Logistics Management,* vol. 36, no.2, pp.501-555

Sihlobo, W. (2023) Farming in South Africa: 6 things that need urgent attention in 2023 Accessed 12 June 2023, https://phys.org/news/2023-01-farming-south-africa-urgent-attention.html

Sinclair. A. (2021) '$60 a kilo?' Woolworths shopper's disbelief over new price of popular produce item, Accessed 02 March 2023, https://7news.com.au/lifestyle/food/60-a-kilo-woolworths-shoppers-disbelief-over-new-price-of-popular-produce-item-c-2046736

South African Government. (2020) *About alert system*, Accessed 28 March 2024, https://www.gov.za/covid-19/about/about-alert-system.

South African Government. (2022) *Disaster Management Act: Termination of national state of disaster*, Accessed 5 August 2024, https://www.gov.za/documents/notices/disaster-management-act-termination-national-state-disaster-04-apr-2022

South African Government. (2023) Land and Agriculture, Accessed 12 June 2023, https://www.gov.za/issues/govt-programmes-economic-opportunities/land-agriculture#:~:text=Land%20Redistribution%20for%20Agricultural%20Development,-This%20programme%20provides&text=Applicants%20who%20want%20to%20farm,Individuals%20or%20groups%20may%20apply.6

South African Government. (2024) *Regulations and Guidelines - Coronavirus COVID-19*, Accessed 28 March 2024, https://www.gov.za/covid-19/resources/regulations-and-guidelines-coronavirus-covid-19.

Tardi, C. (2023) Value Chain: Definition, Model, Analysis and Example, Accessed 01 June 2020, https://www.investopedia.com/terms/v/valuechain.asp#What%20Is%20A%20Value%20Chain?

The Africa Report (2023) South Africa: 10 challenges facing multibillion-dollar agriculture sector, Accessed 12 June 2023, https://www.theafricareport.com/282106/south-africa-10-challenges-facing-multibillion-dollar-agriculture-sector/

Timmer, CP. (2009) 'Behavioural dimensions of food security' *Proceedings of the National Academy of Sciences,* vol. 109, no.31, pp.12315-12320.

Van der Walt, J. (2021) Seven retailers identified for ginger, garlic price gouging, Accessed 20 May 2022, https://www.farmersweekly.co.za/agri-news/south-africa/seven-retailer-identified-for-ginger-price-gouging/

Vats, V. (2020) Home remedies for sore throat: Try this simple ginger-garlic drink for quick relief, Accessed 17 May 2022, https://www.ndtv.com/health/health/home-remedies-for-sore-throat-try-this-simple-ginger-garlic-drink-for-quick-relief-224800/amp/1

Vavra, P., Goodwin, B. (2005) 'Analysis of Price Transmission Along the Food Chain', *OECD Food, Agriculture and Fisheries Papers* vol. 10, no. 3, pp.75-99.

Verma, E. (2023) Market Structure: Definition, Types, Features and Fluctuations, Accessed 11 June 2023, https://www.simplilearn.com/market-structures-rar188-article#:~:text=Market%20structure%20refers%20to%20the,monopolistic%20markets%2C%20and%20monopolistic%20competition.

Von Cramon-Taubadel, S., Loy, JP. (1996) 'Price Asymmetry in the International Wheat Market: Comment', *Canadian Journal of Agricultural Economics*, vol. 44, no.1, pp. 311-317.

Von Cramon-Taubadel, S., Goodwin, BK. (2021) 'Price transmission in agricultural markets) *Annual Review of Resources Economics,* vol. 13, no.1, pp.65-84.

Wamucii, S. (2020) South Africa Ginger Market Insights, Accessed 12 June 2023, https://www.selinawamucii.com/insights/market/south-africa/ginger/

Wamucii, S. (2021) South Africa lemon prices, Accessed 17 May 2022, https://www.selinawamucii.com/insights/prices/south-africa/lemon/

Wooldridge, J. M. (2016). *Introductory Econometrics: A Modern Approach* (6th ed.). Cengage Learning.

Wohlgenant, M., Mullen, J. (1987) 'Modelling the farm-retail price spread for beef', *Western Journal of Agricultural Economics*, vol. 64, pp. 205-212.

Yu, C., Gould, BW. (2019) 'Market power and farm-retail price transmission: The case of US fluid milk markets' *Agribusiness,* vol. 35, no. 4, pp. 537-555.