

Swapi, Asemahle; Akande, Joseph Olorunfemi; Hosu, Yiseyon Sunday

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Article

Wheat Value Chains and Vertical Price Transmission in South Africa: A Nonlinear Autoregressive Diagnostic Lag Bound Approach

Asemahle Swapi ¹, Joseph Akande ² and Yiseyon Sunday Hosu ^{1,3,*}

¹ Department of Business Management and Economics, Faculty of Economics and Financial Sciences, Walter Sisulu University, P.B X1, Mthatha 5117, South Africa; aseswapi@gmail.com

² Department of Accounting Science, Faculty of Economics and Financial Sciences, Walter Sisulu University, P.B X1, Mthatha 5117, South Africa; jakande@wsu.ac.za

³ Small Scale Agri-Business Rural Nonfarm Enterprises Research Niche, Faculty of Economics and Financial Sciences, Walter Sisulu University, P.B X1, Mthatha 5117, South Africa

* Correspondence: yhosu@wsu.ac.za

Abstract: This study examined the vertical transmission of wheat price among the main value chain, looking at the pricing behaviour of certain role players in the wheat production/supply and the distribution of bread, which is a major staple food consumed in South Africa. A nonlinear autoregressive distributed lag (NARDL) model was used to analyse the yearly time series data for the period of 2000 to 2022. The results of the stationarity test showed that all variables were of order one, I (1). The study used two pairs, namely farmgate price and retail price, and farmgate price and wholesale price, to examine the existence of asymmetry between these prices, with rainfall and temperature as control variables. The results indicate the existence of a positive long-run asymmetry of 35.9% between the farmgate price of wheat and retail price of bread, and 3.49% asymmetry between the farmgate price and wholesale price of wheat. To develop informed policies on food security, this study suggests that the government should enhance regular access to data and sustain its monitoring and communication of food price information across the whole country. For farmers, a policy on price transparency can help them to establish a public platform to share market prices, ensuring that they receive fair prices. This paper also recommends the provision of subsidies for wheat farmers to help the wheat industry, reduce the cost of bread production, and make bread more affordable and accessible for consumers.

Keywords: vertical price transmission; farmgate price; wholesale price; retail price; price asymmetry



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1. Introduction

The ability of markets to communicate price signals horizontally and vertically is an essential aspect of many current economic trends (Deb et al. 2020). Due to ongoing changes in the market, producers of agricultural commodities are becoming more interested in price transmission (Rose and Paparas 2023). The exchange of price shocks between manufacturers and retailers illustrates vertical price transmission, one way of assessing the upstream and downstream implications of the linkages in a supply chain (Rose and Paparas 2023). To better understand how prices, interact at different levels of a marketing chain, research on vertical price transmission processes must be done (Tifaoui and Von Cramon-Taubadel 2017).

Wheat was introduced to South Africa in the middle of the 17th century, and by 1684, wheat production was well established in the Cape. According to Kriel (2023), 75% of wheat in South Africa is produced under dryland conditions and 25% under irrigation. The Free State (21%), Northern Cape (17%), and Western Cape (42%) produce most of South Africa's wheat. The remaining provinces produce less. South Africa is still the second-largest

sub-Saharan wheat supplier behind Ethiopia by exporting to nearby countries and acting as a passage for cereals brought in from beyond the region. It continues to import more wheat than it grows because it requires 40 to 50 percent of its own requirements in imports.

The annual yields of wheat in South Africa range between 1.5 million and 3 million metric tons, with 2–2.5 tons/ha under dryland but not less than 5 tons/ha under irrigation. Research from a variety of fields, including plant breeding, agronomy, crop physiology, and crop protection, has contributed to the rise in wheat production's efficiency, productivity, and quality over time. However, production has also been affected by climate change, such as excessive or lack of rainfall and high temperatures, which can lead to droughts over the years. According to Pachauri et al. (2014), rising temperatures, as well as rainfall, are projected to lower the production of crops such as wheat, which will have a significant negative impact on the country's food security. It is estimated that the wheat business contributes around ZAR 5 billion annually to the gross value of agricultural produce (Mphateng 2022).

Studies have been carried out to examine price relationships between farm, wholesale, and retail markets in South Africa. A study by Mosese (2020) aimed to determine the nature of price transmission in the South African potato market. A study by Mandizvidza (2013) attempted to fill the knowledge gap on the performance of Limpopo Province's tomato markets by examining vertical price linkages amongst successive marketing levels. Mphateng (2022) analysed the transmission of world wheat prices to the domestic wheat market in South Africa in which they focused on world prices; they suggested that a study on the vertical price transmission of wheat in South Africa should be conducted. This study aims to fill the gap, as suggested by Mphateng (2022); by focusing on domestic prices to examine the price transmission in the wheat-to-bread value chain and it will use a nonlinear autoregressive diagnostic lag (NARDL) model.

Statistics provided by the Department of Agriculture, Land Reform and Rural Development in 2020 revealed that the total annual production of wheat is generally less than the domestic consumption requirements. The observation provided a general indication that wheat production volumes are on the decline while consumption is continually increasing. During the marketing year 2018, the wheat production volume was about 1.80 million tons while the consumption amounted to about 3.23 million tons. This has left a deficit of about 1.43 million tons of wheat. During 2018, wheat production increased by 19% compared to the previous year, 2017. Over the same period, the local wheat utilization/consumption slightly increased by 1.3% from 3.19 million tons to 3.23 million tons. On average, South Africa produced only 56% of the country's consumption requirements over the past ten-year period (2009–2018), and the balance came from imports.

The purpose of this study is to examine the vertical price transition of wheat in South Africa, looking at the transmission of wheat farmgate prices to wheat wholesale prices to retail prices of bread from the period 2000 to 2022. The availability of data was taken into consideration when deciding the period that the study used. With a few studies performed by other authors regarding the price transmission of agricultural commodities, the vertical price transmission of wheat in South Africa was not yet performed; this led to a decision to perform this research. The objectives of this paper include analysing the long-run relationship between the wheat farm price and the wholesale wheat price and retail price, examining the asymmetry between the farmgate price and retail price, and examining the asymmetry between the farmgate price and wholesale price. The hypotheses of this paper are as follows:

- H1.** *There is no long-run relationship between wheat farmgate, wholesale, and retail prices.*
- H2.** *There is no existence of price asymmetry between the farmgate price and retail price.*
- H3.** *There is no existence of price asymmetry between the wholesale price and farmgate price.*

The objectives of this research were achieved under the section of estimation techniques. The first objective was achieved by performing a nonlinear bounds test to check the existence of a long-run relationship between the three prices (farmgate price, wholesale price, and retail price). The second objective of this paper can be found in the results for the estimates of the long-run coefficients for the farmgate price of wheat and the retail price of bread. The last objective was attained from the estimates of the long-run coefficients for the farmgate price and wholesale price of wheat.

2. Literature Review

2.1. Theoretical Literature

2.1.1. Market Power Theory

According to the market power theory, companies merge to reduce output or work together to increase their capacity to determine product prices. Among the arguments that have been provided to account for asymmetric price movements, the most cited is the presence of market power in retail and processing industries (Bakucs et al. 2013). Generally, it is expected that downstream food enterprises, able to exert market power, transmit price movements that threaten their marketing margin faster than price movements that improve it (Bakucs et al. 2013). More specifically, market power in downstream sectors may affect price transmission by depressing purchasing prices in upstream sectors below the level of a perfectly functioning market and deterring entry or fostering exit. Firms with market power can set prices higher than in a market with greater competition (Vaidya 2023). Consumer prices may increase as a result, and this may spread across the supply chain. On the other hand, firms can also use their bargaining power to negotiate lower prices for inputs, resulting in lower prices for producers, and this can be passed on throughout the supply chain (Conforti 2004).

2.1.2. Theory of Asymmetric Information

The economic theory of asymmetric information was developed by three economists, namely Akerlof, Spence, and Stiglitz, in the 1970s and 1980s as a plausible explanation for market failures (Ross 2022). The theory proposes that an imbalance of information between buyers and sellers can lead to market failure (Ross 2022). Asymmetry in information has a big impact on agricultural commodity prices. Businesses may have asymmetric knowledge about future period prices, harvest, or other pertinent variables in a lot of agricultural markets (Perloff and Rausser 1993). This informational inequality may result in market power and the capacity to set prices, which may have an impact on distribution and welfare. Businesses that own market power in processing or exporting industries, for instance, are probably more knowledgeable than other agents, and they can utilise this knowledge to boost their market power in subsequent transactions. When price information was given to farmers in the context of agricultural transactions, like the sale of crops from farmers to traders, average margins earned by traders did not change, suggesting that there was information asymmetry about prices present in these transactions (Mitra et al. 2012).

2.2. Empirical Literature

This section presents the analysis of empirical literature by other scholars using different methodologies in different countries with the objective of identifying gaps that exist and other potential variables.

A study by Rezitis (2019) investigated price transmission in the Finnish dairy sector and a nonlinear ARDL model was applied to monthly price data to analyse vertical price transmission among farm and retail markets for a variety of dairy products in Finland. Hillen (2021) used detailed price data on farm gate, wholesale, export, and retail levels, and they applied asymmetric vector autoregression and vector error correction models to study vertical price transmission in Swiss dairy and cheese chains. A study by Arida et al. (2023) empirically measured and analysed the long-run relationship and asymmetric price transmission of the rice market in Aceh Province, Indonesia. The study used a series of

econometric techniques comprising cointegration, causality, and the Error Correction Model (ECM) to investigate the research objectives. The results of all of the studies mentioned present the existence of a positive long-run asymmetry between prices.

A few studies regarding price transmission have been conducted in South Africa. In a study by [Ramoshaba \(2019\)](#), a price transmission mechanism is described with an agricultural product within the dairy industry, which is pasteurised liquid milk. The VECM results showed asymmetric price transmission, implying that retailers and processors react quicker to price increases than to price decrease. Price monitoring policy is suggested to protect the consumers from unfair prices passed on by the retailers. A study by [Mosese \(2020\)](#) aimed to determine the nature of price transmission in the South African potato market. The study made use of the Error Correction Model and the Granger Causality test. The Empirical results reveal the existence of price asymmetry in the South African potato value chain. Furthermore, the results show that retail prices are more responsive to producer price increases than they are to producer price declines.

[Mphateng \(2022\)](#) used the average weekly wheat prices for the months of January 2010 through December 2019 to evaluate how changes in global wheat prices affected South Africa's domestic wheat market. The goals of the study are to apply the Error Correction Model to determine how far the transmission of global wheat prices to domestic prices in South Africa takes place and to establish the extent of the cointegration—long-term relationship—between the two variables. The findings verified that, over time, South Africa's domestic market eventually receives a transmission of global wheat prices. The results also show that domestic wheat prices were found to have a relatively low rate of corrections or modifications towards equilibrium conditions. More research is advised by the study, with a focus on the vertical price transmission from wheat to wheat-flour and other wheat-based items including cereals and bread.

2.3. Wheat-to-Bread Value Chain in South Africa

South Africa's wheat industry plays a vital role in the nation's agricultural economy and contributes significantly to food security. Wheat is grown primarily in the western parts of South Africa, while farmers in the northern regions experience a competitive disadvantage due to pricing based on the Randfontein grain market in Gauteng ([Midgley 2016](#)). Even though wheat is one of South Africa's top crops, the country remains a net importer, with imports fluctuating around 1.4 million to 1.8 million tonnes annually ([Matohlang Mohlatsane et al. 2018](#)). After wheat is harvested, activities that are done to it involve milling and producing wheat flour, bran, and meal. Bakery products account for a substantial share of the retail price of bread following the deregulation of the wheat industry ([Abdelaziz et al. 2022](#)). The wheat-to-bread value chain is illustrated in Figure 1.

Figure 1 above shows the process of how wheat is transferred from farmgate to retail/consumer. There are several types of storage facilities for wheat, all of which also store imported wheat. Subsequently, the wheat is taken to milling firms where it is converted to wheat flour. This flour is then used in baking, such as for bread, rolls, frozen dough, and other wheat-based goods like cereals, pasta, and biscuits. A tiny proportion of low-quality wheat is used to make animal feed ([Midgley 2016](#)). The milling, baking, and retail industries are the key players in the value chain.

There are some challenges that are faced by the wheat-to-bread value chain in South Africa. The first one is climate risks where farmers are increasingly exposed to climate variability and change, putting them at risk financially without adequate support or partnerships with institutions and government ([Midgley 2016](#)). The second one is the shift towards import dependence, as with local production unable to meet demand, there is a growing trend toward increased wheat imports, potentially leading to higher costs for both producers and consumers ([Midgley 2016](#)). Consumers have felt the effects in the form of higher pricing for basic wheat-based commodities like bread. The retailer may receive a significant portion of the miller-to-retail margin. Retailers appear to respond faster to

shocks that stretch their market margins than to those that squeeze them, which is linked to the food market chain's anti-competitive nature.

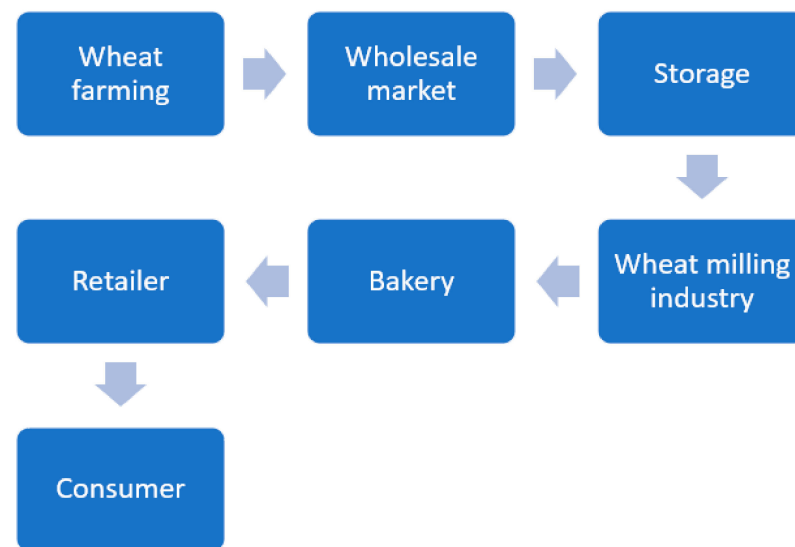


Figure 1. Wheat-to-bread value chain. Source: Author's own drawing.

2.4. Wheat and Bread Prices in South Africa

Farmgate pricing is determined only after a crop has been harvested and the agricultural producer has sold their excess. The average transport difference and handling expenses are subtracted from the SAFEX spot price to arrive at the producer price of wheat in South Africa. Drought and a harsh winter can harm crops, which lowers output and drives up costs (Pettinger 2022). The wholesale price is the market price for the commodity that includes the demand and supply as well as the expected demand and supply of the commodity. Since it includes additional expenses like transportation, marketing, storage, and the profit margin of the participating companies, the market price is often greater than the farmgate price. For South Africa, wheat imports result in the fluctuation of local prices because of effects such as global wheat price movements and changes in the value of the South African currency, which is a rand, as well as the variations in transportation costs. This is one reason why there might be price changes for wheat products in the domestic economy. A sizable portion of South Africa's population is living in poverty and rapidly urbanizing. The consumption of ready-to-eat food increases as cities grow. The majority (70–80%) of the wheat flour produced in South Africa is used to make bread, making it the most significant product in the baking industry (Mphateng 2022). According to estimates from the Department of Agriculture, Land Reform and Rural Development (2020), the nation consumes 2.8 billion loaves of bread annually, or 62 loaves per person. The cost of wheat, manufacturing costs, and transportation costs are only a few of the variables that might affect bread prices in South Africa.

Figure 2 provides the fluctuation of wheat prices (at farmgate and wholesale) and bread prices (at retail level) in South Africa, from the period of 2000 to 2022.

Wheat prices at the farmgate level increased from 55.9% in 2000 to 78.2% in 2002. From 2003 to 2005, the producer price of wheat decreased from 74.6% to 55%, respectively. According to Theunissen (2005), in 2002 and 2003, the profit margin of wheat was high, after which it dropped in 2004 and 2005. Although the price per ton had dropped in 2005, the biggest reason for the loss in profitability was the fact that there was a lower yield due to the drought. In 2007, the prices then rose by 149.9% but fell by 93.1% to a paltry 93.1 percent two years later. It was 10% better based on the wheat production calculation against an increase of 10% relative to the five-year average of 1.91 million tons (2002/2003 to 2006/2007 seasons), which was indicative that this season's final harvest was higher

than what has been harvested recently—in the preceding season—which means there will be more cereal that year than the previous ([Winter Cereal Trust 2007](#)).

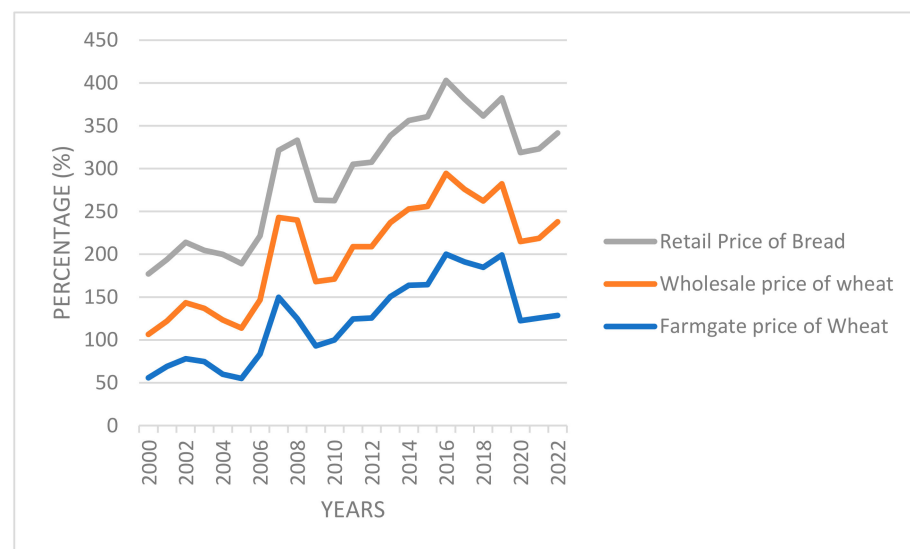


Figure 2. Farmgate price of wheat, wholesale price of wheat, and retail price of bread in South Africa from 2000 to 2022. Source: Author's own drawing.

In 2009, farmgate wheat prices were 93.1%; then, they showed an increasing trend up until 2016, when they were the highest at 200.1%. In 2015–2016, there were droughts in South Africa, and high poverty levels could have impacted the increase in wheat prices. There was a drastic decrease in farmgate prices from being 199.2% in 2019 to 122.42% in 2020. This was caused by a decline in planted areas, and with less than 2 million tons annually, South Africa's wheat production fell by about 50%. With 1.5 million tons harvested, the wheat crop for 2019–20 is the smallest since deregulation in 1997. Wheat prices then increased between 2020 and 2022, from 122.4% to 128.57%, respectively; this is because wheat production in South Africa increased by approximately 2.3 million metric tons compared to 2020.

The market wheat prices in 2000 were 50.59% and they increased to 65.22% in 2002. In 2006, the percentage of wheat prices were 63.23% and they increased to 115.23% in 2008 and then decreased to 71.2% in 2010. The total production of wheat in 2008 was not sufficient to meet the domestic requirements; therefore, South Africa had to import the remainder to meet the domestic consumption, and this resulted in an increase in wheat prices. Except for 2010, when 2.9 million tons were used overall, wheat consumption has always been above 3 million tons annually ([Mphateng 2022](#)). The percentage of wheat prices was 84.39% in 2011 which further increased to 94.29% in 2016. From 2018 to 2022, the percentage wheat prices increased from 77.47% to 109.4%, respectively. The increase in wheat prices between 2019 and 2020 was caused by an increase in the local demand for wheat. Since then, the wheat price has shown an increasing trend; this is because of wheat prices in South Africa reaching a record high due to price trends in the international market and domestic exchange rate movements ([Omarjee 2022](#)).

Bread price percentage decreased from 70.71% in 2000 to 67.78% in 2003. In 2006, the percentage of bread prices rose from 74.92% to 95.13% in 2009. According to an article by [Reliefweb \(2007\)](#), in importing poor nations, like South Africa, the combination of increased export prices and skyrocketing freight rates in 2007 drove up domestic prices of bread and other staple goods. The year-on-year consumer price index for food in 2008 increased. The percentage of the retail price of bread was 95.13% in 2009, and it decreased to 91.57% in 2010. South Africa has been consuming more than 3 million tons of wheat annually, but in 2010 it was recorded at 2.9 million tons; this decrease in the consumption of wheat means that there was a decrease in the production of bread. After this decrease, the percentage in

bread prices started increasing up to 108.56% in 2016, then decreased to 99.17% in 2018 and then increased up to 103.58% in 2022. According to data, South Africa's average annual increase in consumer food prices for the first 11 months of 2021 was 6.5%, up from 4.6% in 2020. The increase in the headline consumer food price inflation has been mostly supported by items from the category of food inflation, such as "bread and cereals". When the price of wheat and wheat products (such as bread) increased, the South African government was unable to take the same action to mitigate the effects of rising costs on its population as they did in 2022 in response to rising oil prices.

3. Research Methodology

3.1. Methodological Design

This paper applied a positivist research philosophy, which means that the study is limited to objective data collection and interpretation. The findings under this research philosophy are typically measured and observable. Put in another way, positivist philosophy maintains that problems can be solved through accurate measurement and data analysis, particularly regarding numerical data (Jansen 2023). The time series research design which the study followed was the explanatory analysis, which attempts to understand the data and the relationships within it, as well as cause and effect. This paper used a quantitative research approach, which involves gathering and analysing numerical data to explain, forecast, or regulate relevant occurrences.

As this paper focused on the wheat-to-bread value chain in South Africa, it used yearly data from the period 2000 to 2022 and the reason for the choice of this period is that the data for one of the variables, which is the farm price of wheat, is only available from 2000 (available at South Africa: producer price index of wheat 2000–2019 (Statista, published by Cowling (2023))). Data for farmgate prices (wheat producer price) were collected from Statista. Data for wholesale prices (wheat market prices) and retail prices (white bread price) were sourced from the South African Grain Information Service (SAGIS); this is because SAGIS is a government-run platform, ensuring that data comes directly from sources, reducing the risk of bias and manipulation. Data for the national average rainfall and temperature (minimum and maximum) were sourced from South African Weather Services (SAWS).

3.2. The Estimated Model

This paper uses nonlinear autoregressive distributed lag (NARDL) to estimate the model. NARDL proposes an expanded nonlinear version of the linear ARDL model. Ben Abdallah et al. (2020) indicates in their study the advantages of using NARDL such as that every variable does not need to have the same integration order. Even with tiny samples, the NARDL model allows for assessing asymmetries and cointegration dynamics. The NARDL model allows for the simultaneous determination of both short- and long-nonlinear interactions, which is necessary to achieve the goals of the study.

This model was used by Ben Abdallah et al. (2020) in their study to find the effects of food price on macroeconomic variables and test the hypothesis of asymmetric price transmission between farmers and retailers, where their explicative variable was the farmgate price of raw milk and the independent variables were different prices of milk products. They first developed a long-run equation, given as follows:

$$\ln y_t = \alpha_0 + \alpha^+ \ln x_t^+ + \alpha_2^- \ln x_t^- + \varepsilon_t \quad (1)$$

where $\ln y_t$ refers to the natural logarithm of the dairy products to be analysed, and $\alpha = (\alpha_0, \alpha_1^+, \alpha_2^-)$ is a cointegrating vector or vector of long-run parameters to be estimated. Equation (1) was then adjusted to apply to this research and to achieve the first objective of the study.

$$RP_t = a_0 + a^+ FP_t^+ + a_2^- FP_t^- + a_3^+ WSP_t^+ + a_4^- WSP_t^- + \varepsilon_t \quad (2)$$

Comparing Equations (1) and (2), $\ln y_t$ is replaced with RP_t because the dependent variable for this equation is retail price, and the dependent variables are farmgate price (FP_t) and wholesale price (WSP_t).

In the following Equations (3) and (4), $\ln x_t^+$ and $\ln x_t^-$ are partial sums of positive and negative changes in $\ln x_t$ which designs the logarithm of the independent variable (x).

$$\ln x_t^+ = \sum_{i=1}^t \Delta \ln x_t^+ = \sum_{i=1}^t \max(\Delta \ln x_t, 0) \quad (3)$$

$$\ln x_t^- = \sum_{i=1}^t \Delta \ln x_t^- = \sum_{i=1}^t \min(\Delta \ln x_t, 0) \quad (4)$$

Their NARDL model was expressed as follows:

$$\ln y_t = \beta_0 + \beta_1 \ln y_{t-1} + \beta_2^+ \ln PPRM_{t-1}^+ + \beta_3^- \ln PPRM_{t-1}^- + \sum_{i=1}^p \omega 1i \Delta y_{t-1} + \sum_{i=0}^q \omega 2i \Delta \ln PPRM_t^+ + \sum_{i=0}^m \omega 3i \Delta \ln PPRM_t^- + \varepsilon_t \quad (5)$$

where $\beta_2^+ = -\beta_1/a_1^+$ and $\beta_2^- = -\beta_1/a_2^+$. p , q , and m are lag orders of dependent and independent variables, ε_t is the error correction term of the NARDL model; $\sum_{i=1}^p \omega 1i$, $\sum_{i=0}^q \omega 2i$, and $\sum_{i=0}^m \omega 3i$ are the coefficients of short-run asymmetric cointegration models; $\sum_{i=0}^q \omega 2i$, and $\sum_{i=0}^m \omega 3i$ are the positive and negative coefficients, respectively, of the exogenous variable; and $\sum_{i=1}^p \omega 1i$ are coefficients of lagged dependent variables.

Farmgate-to-wholesale and farmgate-to-retail price transmission are the two levels at which this study examined price asymmetry. The section that follows presents the NARDL model that was used in this investigation.

(i) Farmgate-to-retail price transmission

Equation (5) is then adjusted to apply to this research, and the new equation for farm-to-wheat price transmission is given as follows:

$$\ln RP_t = \beta_0 + \beta_1 \ln RP_{t-1} + \beta_2^+ \ln FP_{t-1}^+ + \beta_3^- \ln FP_{t-1}^- + \sum_{i=1}^p \omega 1i \Delta RP_{t-1} + \sum_{i=0}^q \omega 2i \Delta \ln FP_t^+ + \sum_{i=0}^m \omega 3i \Delta \ln FP_t^- + \varepsilon_t \quad (6)$$

Comparing Equations (5) and (6), y_t is replaced with RP_t because the dependent variable for this equation is retail price (RP); $PPRM$ (the producer price of raw milk) is removed; and FP (farmgate price) is added as an independent variable.

(ii) Farmgate-to-wholesale price transmission

$$\ln FP_t = \beta_0 + \beta_1 \ln FP_{t-1} + \beta_2^+ \ln WSP_{t-1}^+ + \beta_3^- \ln WSP_{t-1}^- + \sum_{i=1}^p \omega 1i \Delta FP_{t-1} + \sum_{i=0}^q \omega 2i \Delta \ln WSP_t^+ + \sum_{i=0}^m \omega 3i \Delta \ln WSP_t^- + \varepsilon_t \quad (7)$$

For this equation, FP (farmgate price) is the dependent variable and WSP (whole-sale price) is the independent variable.

3.3. Variable Description

Each variable is described below, and the expectation of their relationships is mentioned for each equation/model.

FP_t refers to the farmgate price of wheat during period (t). The farmgate price of wheat refers to the price that farmers receive for their wheat crops. This price can vary depending on factors such as location, supply and demand, and government policies.

WSP_t refers to the wholesale price of wheat. The wholesale price of wheat refers to the price at which wheat is sold in bulk to retailers, processors, and other buyers. This price can vary depending on factors such as location, supply and demand, and the quality of the wheat.

RP_t refers to the retail price of bread. Retail prices are the prices that customers pay for a product when purchasing it at a retail store and these prices are set by the retailer and are usually higher than the wholesale price.

The study had control variables that assisted with findings of the studies, and these variables include the following:

$Rainfall_t$, which is the average national rainfall data, was added to all the models as a control variable. Rainfall has a significant impact on wheat production, and the effects can vary depending on the amount, timing, and distribution of rainfall.

$Temp_t$, which is the temperature (average), was added to all the models as a control variable. The effects of temperature on wheat production can be both positive and negative, depending on the specific conditions and growth stages of the plant. According to [Wollenweber et al. \(2003\)](#), wheat reacts to extreme heat exceptionally during all the growth phases; however, this response is more pronounced at the time of the formation and ripening of grains, rather than throughout the entire cycle.

4. Results and Discussion

4.1. Descriptive Statistics

Table 1 shows the summary of statistics for all of the variables used in this investigation.

Table 1. Descriptive statistics.

	FP	WSP	RP	Rainfall	Temp
Mean	4.73	4.35	4.49	3.91	6.05
Median	4.82	4.42	4.56	3.91	6.04
Maximum	5.29	4.74	4.68	4.24	6.09
Minimum	4.01	3.92	4.21	3.51	6.01
Std. Dev	0.41	0.21	0.16	0.16	0.02
Skewness	−0.34	−0.33	−0.55	−0.32	0.24
Kurtosis	1.93	2.31	1.64	3.52	1.94
Jarque-Bera	1.55	0.89	2.95	0.66	1.29
Probability	0.46	0.64	0.22	0.71	0.52
Sum	108.86	100.27	103.49	90.01	139.17
Sum Sq Dev	3.78	1.06	0.57	0.59	0.013
Observations	23	23	23	23	23

Source: Author's own computation.

In the descriptive statistics table, we look at the skewness and the kurtosis. Skewness is a statistical measure that describes the asymmetry of a distribution. It may be zero (symmetrical), positive (right-skewed), or negative (left-skewed). The right side of the tail is longer when the skewness is positive, and the left side is longer when the skewness is negative. A symmetric distribution has zero skewness. FP, WSP, RP, and Rainfall are negatively skewed, which means that they have a long-left tail. On the other hand, Temp is positively skewed, meaning that it has a long right tail.

A statistical metric called kurtosis is used to characterise how much a score clusters in the frequency distribution's tails or peak. Mesokurtic or normal, leptokurtic or more than normal, and platykurtic or less than usual, are the three types of kurtoses. The kurtosis of FP, WSP, RP, and Temp is less than three, which means that they are platykurtic relative to normal distribution. Platykurtic variables may indicate that the data has outliers, which can affect the interpretation of the results, as the relationship between variables may be more complex and nonlinear. The kurtosis of rainfall is greater than three, which means it is leptokurtic relative to normal distribution.

4.2. Correlation

The correlation between every variable considered in this study is illustrated in Table 2.

Table 2. Correlation.

	LFP	LWSP	LRP	LRAINFALL	LTEMP
LFP	1.000000				
LWSP	0.783628	1.000000			
LRP	0.833059	0.798545	1.000000		
LRAINFALL	−0.247238	−0.141706	−0.061806	1.00000	
LTEMP	0.275730	0.168679	0.135791	−0.614888	1.000000

Source: Author's own computation.

LFP and LWSP have a correlation of 0.78, which is close to one, meaning that LFP and LWSP have a strong positive correlation, and if one increases, the other one will also increase; the same results are expected when there is a decrease. LFP and LRP have a correlation of 0.83, which is close to one, meaning that LFP and LRP have a strong positive correlation and if one increases the other will also increase; the same results are expected when there is a decrease. LFP and LRAINFALL have a correlation of -0.24 , which is not close to -1 , meaning that the correlation is not strongly negative and if one increases the other one will decrease, and vice versa. LFP and LTEMP have a correlation of 0.28, which is not close to one, meaning that the correlation of LFP and LTEMP is not strongly positive.

LWSP and LRP have a correlation of 0.79, which is close to one, meaning that LWSP and LRP have a strong positive correlation, and if one increases the other one will also increase; the same results are expected when there is a decrease. LWSP and LRAINFALL have a correlation of -0.14 , which is not close to negative one, meaning that the correlation is not strongly negative and if one increases the other one will decrease, and vice versa. LWSP and LTEMP have a correlation of 0.17, which is not close to one, meaning that the correlation between LWSP and LTEMP is not strongly positive. LRP and LRAINFALL have a correlation of -0.62 , which is not close to -1 , meaning that the correlation is not strongly negative, and if one increases, the other one will decrease, and vice versa. LRP and LTEMP have a correlation of 0.14, which is not close to one, meaning that the correlation of LWSP and LTEMP is not strongly positive. The following section presents the unit root testing of variables used in this study.

4.3. Unit Root Testing

In NARDL, the most used test to check for stationarity is the Augmented Dickey-Fuller (ADF) test. This test has wide popularity due to its resilience against non-linear relationships among variables (Allen and McAleer 2021). The Phillips Perron test modifies the ADF test by correcting for autocorrelation and heteroscedasticity in the errors (Prabhakaran 2019). The ADF test serves as a foundation for the PP test. This is illustrated in Table 3 below.

Table 3. Formal stationarity test.

Series	Model	ADF			PP		
		Lags	p-Value	Decision	Lags	p-Value	Decision
FP	Trend and Intercept	4	0.264	Non-stationary	2	0.564	Non-stationary
ΔFP	Trend and Intercept	4	0.001	Stationary	2	0.000	Stationary
WSP	Trend and Intercept	4	0.032	Stationary	2	0.250	Non-stationary
ΔWSP	Trend and Intercept	4	0.002	Stationary	2	0.000	Stationary
RP	Trend and Intercept	4	0.838	Non-stationary	2	0.863	Non-stationary
ΔRP	Trend and Intercept	4	0.001	Stationary	2	0.000	Stationary
Rainfall	Trend and Intercept	4	0.021	Stationary	2	0.021	Stationary
ΔRainfall	Trend and Intercept	4	0.001	Stationary	2	0.000	Stationary
Temp	Trend and Intercept	4	0.001	Stationary	2	0.000	Stationary
ΔTemp	Trend and Intercept	4	0.000	Stationary	2	0.000	Stationary

Source: Author's own computation using E-views 10.

All of the variables demonstrate stationarity at the first difference $I(1)$, meaning that the factors are integrated into order one. The results presented by the stationarity test allow the use of the nonlinear autoregressive distributed model to check the relationship and the asymmetry of prices. The next section presents the testing of cointegration, for which the bounds test is used.

4.4. Autoregressive Diagnostic Lag Model (ARDL)

The ARDL method uses the bound test to test for cointegration. In the bound test, the value of f -statistics determines whether there is cointegration, based on the results of the lower and upper limit. Table 4 below presents the ARDL bounds test.

Table 4. Bounds test results.

Test Statistics	Values	K = 5
F-statistics	2.23	
	Critical values for the lower bound limit $I(0)$	Critical values for the upper bound limit $I(1)$
Critical Values		
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Source: Author's own computation.

According to the data in Table 4, the f -statistic of 2.23 is less than 2.86 at the lower bound and 4.01 at the upper bound at a 5% significance level. These findings do not support the existence of a long-term relationship between farm price, wholesale price, and retail price. Because the results indicate no long-run relationship between variables, it is generally recommended not to proceed with estimating the ARDL. The following section therefore focuses on NARDL.

4.5. Test for Cointegration

The bounds test, which may also be used to look for long-term correlations between several variables, is utilized by the NARDL method to test for cointegration. Based on the findings of the lower and upper bounds, the bounds test's f -statistics value establishes if cointegration exists. To determine whether there is a long-term link between the three prices (farmgate, wholesale, and retail), Table 5 shows the results of the boundaries test.

Table 5. Bounds test results: farmgate price, wholesale price, and retail price.

Test Statistics	Values	K = 5
F-statistics	4.88	
	Critical values for the lower bound limit $I(0)$	Critical values for the upper bound limit $I(1)$
Critical Values		
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Source: Author's own computation.

According to the data in Table 5, the f -statistic of 4.88 is more than 2.86 at the lower bound and greater than 4.01 at the upper bound at a 5% significance level. These findings support the existence of a long-term relationship between the retail price of bread in South Africa, the wholesale price of wheat, and the farmgate price of wheat, as well as

providing evidence of nonlinear cointegration among the variables. These findings support the primary goal of the study, which was to determine whether there was a long-term relationship between the three prices (farmgate, wholesale, and retail). As shown in Table 5, the first null hypothesis—that there is no long-term association between the retail price of bread, the wholesale price of wheat, and the wheat farmgate price—is rejected.

Even with delays or asymmetries, changes in farmgate pricing are likely to be followed by changes in the wholesale price of wheat and then the retail price of bread. These prices are connected by underlying market forces, such as supply and demand, production costs, and market power (Nguyen and Mobsby 2016). The theory that these results relate to is the cost pass-through theory because changes in farmgate prices affect wholesale and retail prices.

Table 6a,b below present the bounds testing for nonlinear cointegration, which will be looking at two different pairs, farmgate price and retail price and wholesale price and farmgate price.

Table 6. (a) Bounds test results: farm price and retail price. (b) Bounds test results: wholesale price and farm price.

(a)		
Test Statistics	Values	K = 5
F-statistics	6.78	
	Critical values for the lower bound limit I(0)	Critical values for the upper bound limit I(1)
Critical Values		
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68
(b)		
Test Statistics	Values	K = 5
F-statistics	3.24	
	Critical values for the lower bound limit I(0)	Critical values for the upper bound limit I(1)
Critical Values		
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source: (a) Author's own computation using E-views 10. (b) Author's own computation.

Table 6a presents the results of the bounds test for nonlinear cointegration, looking at the pair of farmgate price and retail price with added control variables, which are rainfall and temperature. At a 5% significance level, the f-statistic of 6.78 is greater than 2.62 at the lower bound and greater than 3.79 at the upper bound. These findings support the notion that there is a nonlinear cointegration between the variables. A study by Ben Abdallah et al. (2020) confirms that if cointegration exists, the NARDL model is appropriate for estimating the model.

At a 5% significance level, the f-statistic of 3.24 is greater than 2.62 at the lower bound and is also less than 3.79 at the upper bound, meaning that the results are inconclusive. The following section presents the results of NARDL long-run and short-run estimates, which check if there is price asymmetry between the different prices.

4.6. The Nonlinear Autoregressive Distribution Lag (NARDL) Estimation

The NARDL estimation performs the long-run and short-run results of the variables, looking at the first pair of farmgate price and retail price, and the second one, which is wholesale price and farmgate price. Table 7a,b below shows the outcomes of the long-run equation and how they are interpreted using the coefficient and probability.

Table 7. (a) Unrestricted long-run equation: farmgate price and retail price. (b) Unrestricted long-run equation: farmgate price and wholesale price.

(a)				
Variables	Coefficient	St. Error	T-Statistic	Probability
LFP_POS	0.35	0.05	6.17 ***	0.01
LFP_NEG	0.10	0.08	1.20	0.27
LRAINFALL_POS	0.21	0.19	1.10	0.31
LRAINFALL_NEG	0.40	0.23	1.67	0.14
LTEMP	−0.68	1.04	−0.65	0.53
(b)				
Variables	Coefficient	St. Error	T-Statistic	Probability
LWSP_POS	−3.49	5.55	−0.62	0.57
LWSP_NEG	−10.98	13.08	−0.83	0.46
LRAINFALL_POS	−4.80	4.66	−1.02	0.37
LRAINFALL_NEG	−3.58	4.36	−0.82	0.47
LTEMP	−67.79	83.21	−0.81	0.47

(a) Note: * Statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Source: Author's own computation. (b) Source: Author's own computation using E-views 10.

Table 7a presents the long-run equation of retail price (LRP), farmgate price (LFP), rainfall (LRAINFALL), and temperature (LTEMP), where LRP is the dependent variable. Table 7a above shows that a unit increase in farmgate prices (LFP_POS) is associated with a 35.9% increase in retail prices, and the results are significant because the *p*-value is less than the 5% significance level, which means that there is a positive relationship between farmgate prices and retail prices. The relationship between the retail price of bread and negative changes in farmgate price is positive, meaning that a unit decrease in farmgate price is associated with a 10.5% decrease in retail price. However, the results are insignificant because the *p*-value exceeds the 5% significance level. The results also show the existence of long-run asymmetry between farmgate price and retail price, as the coefficient of LFP_POS is greater than that of LFP_NEG.

Moses (2020) states that the retail price of potatoes is more responsive to positive shocks in farm prices than they are to negative shocks, which leads to a conclusion of the existence of long-run asymmetry between farmgate prices and retail prices. The results were also the same with Ben Abdallah et al. (2020); they confirmed the existence of a long-run asymmetric relationship between raw milk, and all examined dairy product prices.

Rainfall has a positive relationship with the retail price of bread. Retail prices rise by 21.90% for every unit increase in rainfall; nevertheless, the results are not statistically significant because the *p*-value exceeds the significance level of 5%. The retail price of bread decreases by 40.07% for every unit decrease in rainfall; nevertheless, the results are not statistically significant because the *p*-value exceeds the significance level of 5%. Temperature has a negative relationship with retail price. A unit increase in temperature results in a 68.26% decrease in retail prices of bread and these results are insignificant because the *p*-value is greater than the 5% significance level.

Table 7b presents the long-run equation of farmgate price (LFP), wholesale price (LWSP), rainfall (LRAINFALL), and temperature (LTEMP), where LFP is the dependent variable. The response of farmgate prices to positive changes in wholesale prices is negative, meaning that a unit increase in wholesale prices will result in a 3.49% decrease in farmgate prices. A unit decrease in wholesale price (LWSP_NEG) is associated with a 10.98% increase

in farmgate price; this is because of the existence of a negative relationship, meaning that when one decreases, the other increases. Both of these results are insignificant because the p -value is greater than the 5% significance level. Since the coefficient on the positive and negative changes are different, it indicates asymmetry in the relationship between farmgate wheat prices and wholesale wheat prices.

Rainfall has a negative relationship with farmgate prices. A unit increase in rainfall results in a 4.80% decrease in the farmgate price, and a unit decrease in rainfall results in a 3.58% increase in the farmgate price. These results are insignificant because the p -value is greater than the 5% significance level. The temperature has a negative relationship with the farmgate price. A unit increase in temperature results in a 67.78% increase in the farmgate price and these results are insignificant because the p -value is greater than the 5% significance level.

The following Table 8a,b presents the short-run estimates of the nonlinear autoregressive distributed lag model for each pair.

Table 8. (a) Unrestricted constant no trend (short run): farmgate price and retail price. (b) Unrestricted constant no trend (short run): farmgate price and wholesale price.

(a)				
Variables	Coefficient	St. Error	T-Statistic	Probability
LFP_POS	−0.03	0.03	−0.91	0.39
LRAINFALL_POS	0.40	0.07	5.62 ***	0.01
LRAINFALL_NEG	0.02	0.06	0.43	0.68
LTEMP	0.14	0.20	0.69	0.51
ECM Coint Eq (−1)	−0.92	0.10	−8.63 ***	0.01
(b)				
Variables	Coefficient	St. Error	T-Statistic	Probability
LWSP_POS	1.7927	0.2548	7.0334 ***	0.0059
LWSP_NEG	−3.4775	0.5411	−6.4268 ***	0.0076
LRAINFALL_POS	−0.0736	0.2585	−0.2848	0.7943
LRAINFALL_NEG	−2.0056	0.3712	−5.4021 ***	0.0124
LTEMP	−12.5648	1.6898	−7.4355 ***	0.0050
ECM Coint Eq (−1)	−0.3430	0.0476	−7.2018 ***	0.0055

Note: (a) * Statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Source: Author's own computation. (b) * Statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Source: Author's own computation.

Table 8a presents the short-run equation of the retail price (LRP), farmgate price (LFP), rainfall (LRAINFALL), and temperature (LTEMP), where LRP is the dependent variable. In the short-run, retail prices and farmgate prices have a negative relationship, meaning that a unit increase in farmgate prices (LFP_POS) results in a 3.07% decrease in retail prices. However, the results are insignificant because the p -value is greater than the 5% significance level. The results show the existence of asymmetry in the short run. It is possible that cost adjustments, including packaging costs, are what resulted in the short-run asymmetric transmission (Ben Abdallah et al. 2020).

A unit increase in rainfall results in a 40.15% increase in retail price, and these results are significant, because the p -value is less than the 5% significance level and it is significant at 1% and the relationship is positive. A unit decrease in rainfall is associated with a 2.91% decrease in retail price; however, these results are insignificant because the p -value is greater than the 5% significance level. A unit increase in temperature is associated with a 14.36% increase in retail price and the results are insignificant because the p -value is greater than the 5% significance level and the relationship is positive.

The coefficient of cointegration equation (ECM Coint Eq (−1)) can be indicated as an error correction term. The ECM should have a coefficient that is negative and less than one and significant to ascertain the speed of adjustment and correlation between the short-run

and long-run variables, and the return to equilibrium. The statistical significance of the adjustment speed, which is -0.92 , is established by the p -value being less than 5% of the significance level. This clarifies that any short-term imbalances will be fixed during the first period and will be adjusted back to equilibrium at 92% of these imbalances.

Table 8b presents the short-run equation of the farmgate price (LFP), wholesale price (LWSP), rainfall (LRainfall), and temperature (LTEMP), where LFP is the dependent variable. From the table above, it is shown that a unit increase in wholesale prices is associated with a 1.79% increase in farmgate prices, and the results are significant at 1%, which means that there is a positive relationship between wholesale prices and farmgate prices. The response of farmgate prices to negative changes in wholesale prices is negative, meaning that a unit decrease in wholesale price is associated with a 3.47% increase in farmgate prices; these results are significant because the p -value is less than the 5% significance level, and there is an existence of asymmetry between the farmgate price of wheat and wholesale price of wheat.

A unit increase in rainfall results in a 0.07% decrease in farmgate prices, these results are insignificant because the p -value is greater than the 5% significance level. A unit decrease in rainfall results in a 2.01% increase in farmgate prices, these results are significant because the p -value is less than the 5% significance level and the relationship is negative. A unit increase in temperature results in a 12.56% increase in farmgate prices and these results are insignificant because the p -value is greater than the 5% significance level and the relationship is negative.

As the p -value is below the 5% significance level, the adjustment speed, which is -0.34 , is statistically significant. This clarifies that any short-term imbalances will be fixed during the first period and will be restored back to equilibrium at 34% of these imbalances.

4.7. Diagnostic Tests

Diagnostic tests are used to help identify issues like dynamic, omitted variables, non-constant errors, non-linearity, and long memory structures (Sekar 2010). The tests that are used in this section are tests for normality, serial correlation, and heteroskedasticity. The conclusion for each test is based on its null hypothesis, H_0 , and whether it is accepted or rejected. Table 9a,b presents the results of the diagnostic tests for each pair.

Table 9. (a) Diagnostic results: farmgate price and retail price. (b) Diagnostic results: farmgate price and wholesale price.

(a)				
Test	Null Hypothesis	T-Statistics	Probability	Results
Breusch–Godfrey LM test	There is no correlation	1.23	0.38	There is no correlation
Jarque–Bera test (JB)	Residuals are normally distributed	0.35	0.83	Normally distributed
Breusch–Pagan–Godfrey	There is homoscedasticity	1.76	0.25	There is homoscedasticity
White	No heteroscedasticity	0.51		No heteroscedasticity
(b)				
Test	Null Hypothesis	T-Statistics	Probability	Results
Breusch–Godfrey LM test	There is no correlation	0.0462	0.9567	There is no correlation
Jarque–Bera test (JB)	Residuals are normally distributed	3.4477	0.1783	Normally distributed
Breusch–Pagan–Godfrey	There is homoscedasticity	0.2553	0.9716	There is homoscedasticity
White	No heteroscedasticity	1.4586	0.4262	No heteroscedasticity

Source: Author's computation.

The diagnostic test for the pair of farmgate price and retail price is given in Table 9a. The Breusch–Godfrey LM test, a correlation test, yields a p -value of 0.38, over the 5% significance level. In other words, the null hypothesis—that there is no correlation—is accepted. The null hypothesis is accepted, and the residuals are normally distributed if the p -value for the normality test is higher than the 5% significance level. Given that the

Breusch–Pagan–Godfrey test's p -value is higher than the 5% significance level, the null hypothesis—that homoscedasticity exists—is accepted. The null hypothesis that there is no heteroscedasticity is accepted when the White test, the final diagnostic test, yields a p -value larger than the 5% significance level.

The diagnostic test for the pair of farmgate price and wholesale price is given in Table 9b. The Breusch–Godfrey LM test, which measures correlation, yields a p -value higher than the 5% significance level. In other words, the null hypothesis—that there is no correlation—is accepted. The null hypothesis is accepted, and the residuals are normally distributed if the p -value for the normality test is higher than the 5% significance level. Given that the Breusch–Pagan–Godfrey test's p -value is higher than the 5% significance level, the null hypothesis—that homoscedasticity exists—is accepted. The null hypothesis that there is no heteroscedasticity is accepted when the White test, the final diagnostic test, yields a p -value larger than the 5% significance level.

4.8. Stability Test

This paper employed two recursive tests which involve the CUSUM test and CUSUM of squares to check the model as to whether it is good or not. The stability test for both pairs is given in the figures below (Figures 3–6).

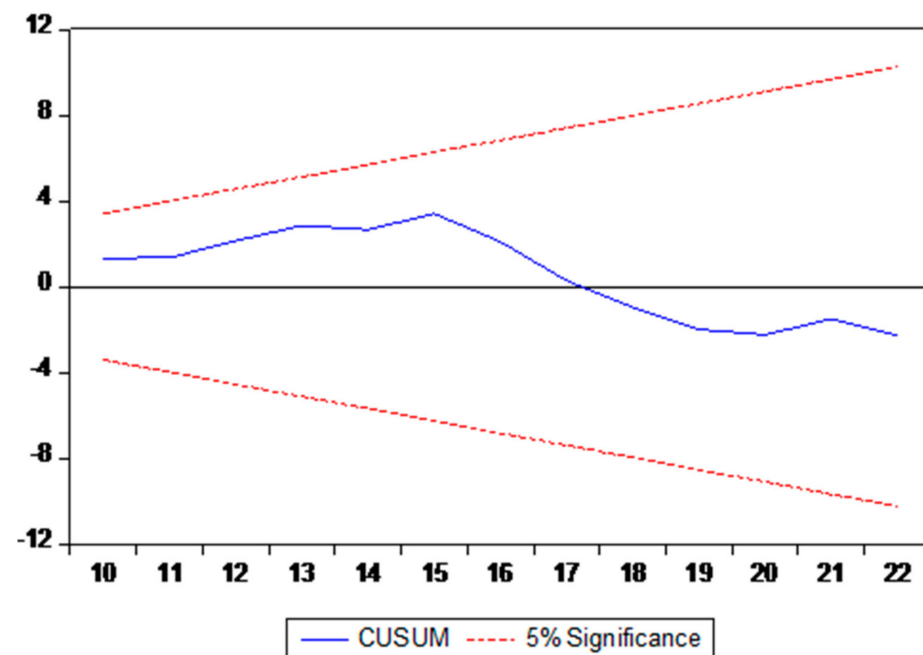


Figure 3. CUSUM test—farmgate price and retail price. Source: Author's own computation.

The CUSUM line is in between the 5% significance level, meaning that the series is stable, which is good for the model.

The CUSUM of square line is in between the 5% significance level, meaning that the series is stable, which is good for the model.

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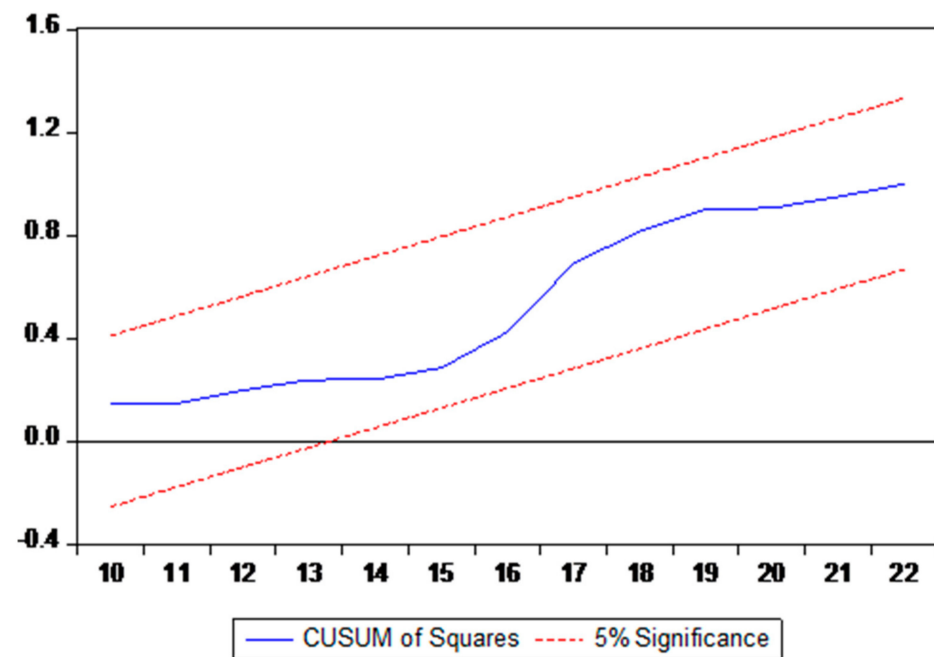


Figure 4. CUSUM of Squares test—farmgate price and retail price. Source: Author's own computation.

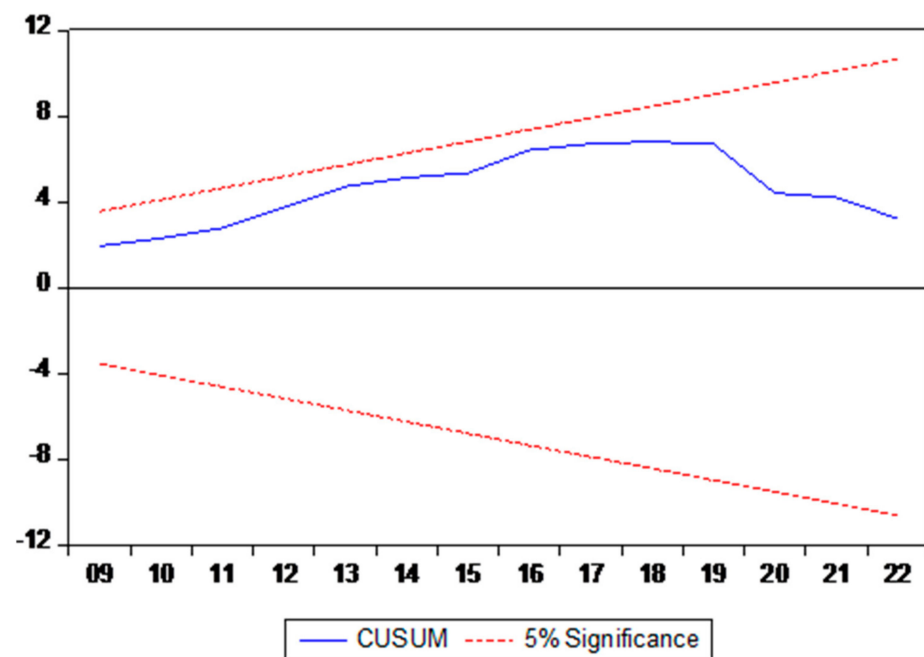


Figure 5. CUSUM test—farmgate price and wholesale price. Source: Author's own computation.

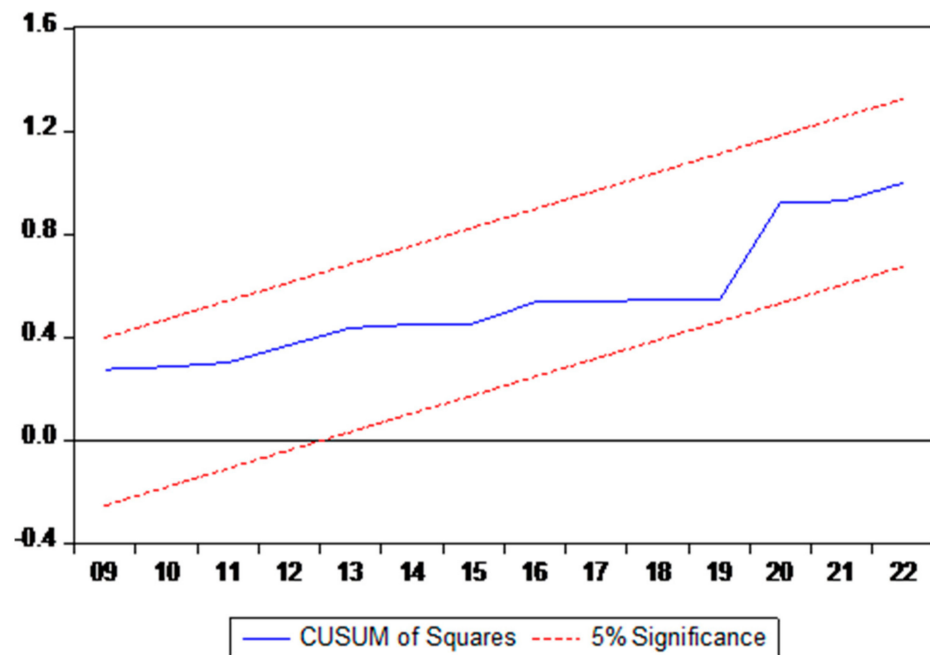


Figure 6. CUSUM of Squares test—farmgate price and wholesale price. Source: Author's own computation.

5. Conclusions and Recommendations

This paper can be related to the price theory, which states that for food and agricultural items, supply shocks have a greater impact on price formation than demand shocks, this is because demand tends to be steady due to established consumption habits (Mgale and Yan 2020). The other theory that the paper can be related to is the cost pass-through theory, which states that each market adjusts its prices of the products or services provided to meet the adjustments of its own costs. The existence of price asymmetry between wheat farmgate price, the wholesale price of wheat, and the retail price of bread can be related to both theories. The farm prices of wheat, which is the main ingredient for making bread, depend on the production of wheat; if there is more supply, then the prices will be less, and if there is less supply, the prices will be more. These price changes can affect retailers because it will not be easy for them to just change the prices of bread at the same time that the price of wheat changes, and therefore this will affect consumers. Government subsidies can assist in this matter because if there is a lower supply of wheat, farmers will not quickly change their prices. However, this does not affect the wholesalers because the margin between the farmgate price and wholesale price of wheat is relatively small, and the farmers receive a fair share of the final price paid by consumers. Price theory also assumes that consumers and producers behave rationally to maximise their individual utility and profits.

Market intervention can improve market efficiency and address asymmetric information through various measures. Asymmetric information can be addressed through information-related interventions. This can be by requiring firms to disclose relevant information, enabling investors and consumers to make informed decisions, and providing information, such as market data and research, also helps reduce information asymmetry. Regulatory interventions are another crucial tool to address asymmetric information, by certificating common standards, ensuring market participants meet minimum requirements, and by verifying market participants' credibility through licencing and accreditation mechanisms and enforcing mechanisms such as penalties for non-compliance. Effective implementation requires collaboration among regulatory bodies, institutions, and market participants. By leveraging technology, education, and economic incentives, South Africa can promote a more transparent and efficient market.

The findings of this study indicated that there is an existence of long-run and short-run asymmetry between the wheat farm price and the retail price of bread and between the wheat farmgate price and wholesale price of wheat. The relationship between wheat price and retail price is positive, and the relationship between farmgate price and wholesale price is negative. However, the results for the relationship between the farmgate price of wheat and wholesale price do not conform to the expectations of the study, which was a positive relationship between these prices. The existence of asymmetry between the farmgate price and retail price in South Africa can be caused by multiple factors such as marketing margins, value-added processes, taxes and levies, profit margins, and seasonality, to mention a few. The existence of asymmetry between farmgate price and wholesale price can be caused by market power, information asymmetry, transaction costs, and imperfect price transmission.

The South African government policy that has a significant impact on the price of wheat and bread is the trade policy. Trade policy is a government's strategy concerning international trade, including the regulation of imports and exports, and the protection of domestic industries. Many countries provide subsidies to their wheat farmers, while South Africa does not. The policy also states that the South African government has imposed tariffs on imported wheat to protect domestic producers, but this can increase the cost of wheat for consumers. The government's decision on subsidies, tariffs, and trade agreements can impact the profitability of wheat farming, the cost of wheat for consumers, and the overall availability of bread. For the government to be able to make well-informed decisions regarding food security, this study suggests that it accelerates its efforts to track food prices across the nation. Another recommendation made by the study is the provision of subsidies for wheat farmers to help the wheat industry reduce the cost of bread production and make bread more affordable and accessible for consumers.

The Sustainable Development Goals (SDGs) that the study aims to achieve are as follows: Zero hunger—ensuring access to safe, nutritious, and sufficient food such as bread.

Decent work and economic growth—promoting fair prices for wheat farmers and supporting sustainable agriculture.

Reduced inequalities—reducing the gap between the producer price of wheat, wholesale price of wheat, and the retail price of bread, ensuring fair returns for farmers and wholesalers, and affordable bread for consumers.

Partnership for the goals—collaboration with stakeholders, including government, farmers, wholesalers, and consumers to address price asymmetry and ensure a sustainable food system.

However, it will not be easy to implement these developments; there could be challenges faced. One of the biggest challenges would be the intervention of government by providing subsidies to the farmers, as the economy of South Africa is not performing well, but hopefully it will be included in the next budget speech. The findings of the study are the existence of asymmetry between the farmgate price of wheat, wholesale price of wheat, and retail price of bread. However, the study did not venture comprehensively into the underlying causes of the price asymmetry in South Africa; this is an area that requires further research. Since this paper is mainly focused on finding the asymmetry between prices, further research on the relationship between the prices (the farmgate price of wheat, wholesale price of wheat, and retail price of bread) can also be conducted, as it was not really specified in the analysis and findings. Further research on the relationship between prices can be done with or without the control variables mentioned in this study (rainfall and temperature).

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References

- Abdelaziz, Fatma, Amy William, Kibrom A. Abay, and Khalid Siddig. 2022. *An Assessment of Sudan's Wheat Value Chains: Exploring Key Bottlenecks and Challenges*. Washington: The International Food Policy Research Institute, vol. 4.
- Allen, David E., and Michael McAleer. 2021. A Nonlinear Autoregressive Distributed Lag (NARDL) Analysis of the ftse and s&p500 Indexes. *Risks* 9: 195.
- Arida, Agustina, Raja Masbar, M. Majid, and I. Indra. 2023. Does vertical asymmetric price transmission exist in the rice markets? *Agricultural and Resource Economics: International Scientific E-Journal* 9: 69–90. [CrossRef]
- Bakucs, Zoltán, Jan Falkowski, and Imre Fertő. 2013. *What Causes Asymmetric Price Transmission in Agro-Food Sector? Meta-analysis Perspective* (No. MT-DP-2013/3). IEHAS Discussion Papers. Budapest: IEHAS.
- Ben Abdallah, Marwa, Maria Fekete Farkas, and Zoltan Lakner. 2020. Analysis of dairy product price transmission in Hungary: A nonlinear ARDL model. *Agriculture* 10: 217. [CrossRef]
- Conforti, Piero. 2004. *Price Transmission in Selected Agricultural Markets*. FAO Commodity and Trade Policy Research Working Paper, 7. Rome: FAO.
- Cowling, Natalie. 2023. Producer Price Index of Wheat in South Africa from 2000 to 2019. Available online: <https://www.statista.com/statistics/1135803/producer-price-index-of-wheat-in-south-africa/> (accessed on 25 May 2023).
- Deb, Limon, Yoonsuk Lee, and Sang Hyeon Lee. 2020. Market integration and price transmission in the vertical supply chain of rice: Evidence from Bangladesh. *Agriculture* 10: 271. [CrossRef]
- Department of Agriculture, Land Reform and Rural Development. 2020. A Profile of the South African Wheat Market Value Chain. Available online: <https://old.dalrrd.gov.za/doaDev/sideMenu/Marketing/Annual%20Publications/Commodity%20Profiles/field%20crops/Wheat%20Market%20Value%20Chain%20Profile%202020.pdf> (accessed on 5 November 2024).
- Hillen, Judith. 2021. Vertical price transmission in Swiss dairy and cheese value chains. *Agricultural and Food Economics* 9: 1–21. [CrossRef]
- Jansen, Derek. 2023. Research Philosophy. Available online: <https://gradcoach.com/research-philosophy/> (accessed on 6 December 2023).
- Kriel, Glenneis. 2023. Wheat Production, Field Crops in South Africa. Available online: <https://southafrica.co.za/wheat-production.html> (accessed on 30 March 2023).
- Mandizvidza, Kudzai. 2013. Price Transmission in Tomato Markets of Limpopo Province, South Africa. Doctoral dissertation, University of Limpopo, Polokwane, South Africa.
- Matohlang Mohlatsane, Pascalina, Enoch Owusu-Sekyere, Henry Jordaan, Jonannes Hendrikus Barnard, and Leon Daniel Van Rensburg. 2018. Water Footprint Accounting Along the Wheat-Bread Value Chain: Implications for Sustainable and Productive Water Use Benchmarks. *Water* 10: 1167. [CrossRef]
- Mgale, Yohana James, and Yunxian Yan. 2020. Marketing efficiency and determinants of marketing channel choice by rice farmers in rural Tanzania: Evidence from Mbeya region, Tanzania. *Australian Journal of Agricultural and Resource Economics, Australian Agricultural and Resource Economics Society* 64: 1239–59. [CrossRef]
- Midgley, Stephanie J. E. 2016. *Commodity Value Chain Analysis for Wheat*. Cape Town: WWF-SA.
- Mitra, Sandip, Dilip Mookherjee, Maximo Torero, and Sujata Visaria. 2012. *Asymmetric Information and Middleman Margins. An Experiment with West Bengal Potato Farmers*. Cambridge: The Bureau for Research and Economic Analysis of Development (BREAD).
- Mosese, Douglas. 2020. Analysis of Vertical Price Transmission in the South African Potato Markets. Doctoral dissertation, University of Limpopo, Polokwane, South Africa.
- Mphateng, Molahlegi Aubrey. 2022. Spatial Price Transmission and Market Integration Analysis: The Case of Wheat Market in South Africa, 2010–2019. Doctoral dissertation, University of Limpopo, Polokwane, South Africa.
- Nguyen, Nga, and David Mobsby. 2016. *Farm-to-Retail Price Spread and Farm Share in Food Supply Chains: Background Paper*. Canberra: ABARE. [CrossRef]
- Omarjee, Lameez. 2022. Why South African Wheat Prices Are Hitting Record Highs. Available online: <https://www.news24.com/fin24/companies/why-south-african-wheat-prices-are-hitting-record-highs-20220517> (accessed on 25 May 2023).

- Pachauri, Rajendra K., Myles R. Allen, Vicente R. Barros, John Broome, Wolfgang Cramer, Renate Christ, John A. Church, L. Clarke, Q. Dahe, P. Dasgupta, and et al. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC, p. 151.
- Perloff, Jeffrey M., and Gordon C. Rausser. 1993. *The Effect of Asymmetrically Held Information and Market Power in Agricultural Markets*. Working Paper No. 264. Berkeley: University of California.
- Pettinger, Tejvan. 2022. Factors Determining the Price of Wheat. Available online: <https://www.economicshelp.org/blog/168151/economics/factors-determining-the-price-of-wheat/> (accessed on 27 March 2023).
- Prabhakaran, Selva. 2019. Augmented Dickey Fuller Test (ADF Test)—Must Read Guide. Available online: <https://www.machinelearningplus.com/time-series/augmented-dickey-fuller-test/> (accessed on 22 November 2024).
- Ramoshaba, Tshagofatso. 2019. Price Transmission and Causality Analysis of Cheese and Pasteurised Liquid Milk in South Africa from 2000 to 2016. Doctoral dissertation, University of Limpop, Polokwane, South Africa.
- Reliefweb. 2007. Southern Africa: Struggling with Souring Cereal Prices. Available online: <https://reliefweb.int/report/namibia/southern-africa-struggling-soaring-cereal-prices#:~:text=News%20and%20Press%20Release%20Source,Information%20and%20Early%20Warning%20System> (accessed on 22 November 2024).
- Rezitis, Anthony N. 2019. Investigating price transmission in the Finnish dairy sector: An asymmetric NARDL approach. *Empirical Economics* 57: 861–900. [CrossRef]
- Rose, Rachel, and Dimitrios Paparas. 2023. Price Transmission: The Case of the UK Dairy Market. *Commodities* 2: 73–93. [CrossRef]
- Ross, Sean. 2022. Theory of Asymmetric Information Definition & Challenges. Available online: <https://www.investopedia.com/ask/answers/042415/what-theory-asymmetric-information-economics.asp> (accessed on 7 September 2023).
- Sekar, P. 2010. Diagnostic checking of time series models. *Indian Journal of Science and Technology* 3: 1026–31. [CrossRef]
- Theunissen, Phillip. 2005. The Buying Power of Wheat. Available online: <http://www.computus.co.za/Artikels/WheatBuyPower.PDF> (accessed on 22 November 2024).
- Tifaoui, Said, and Stephan Von Cramon-Taubadel. 2017. Temporary sales prices and asymmetric price transmission. *Agribusiness* 33: 85–97. [CrossRef]
- Vaidya, Utpal. R. 2023. Essays in Mechanism Design. Doctoral dissertation, Northwestern University, Evanston, IL, USA.
- Winter Cereal Trust. 2007. Available online: https://sagl.co.za/wp-content/uploads/Reports/Wheat/2006.2007/WheatReport_2006-2007_3.pdf (accessed on 12 November 2024).
- Wollenweber, Bernard, J. R. Porter, and J. Schellberg. 2003. Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. *Journal of Agronomy and Crop Science* 189: 142–50. [CrossRef]

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