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Research Article

Keywords: NARDL model, Maize market, Wheat value chain, APT, South Africa, Market power

Posted Date: August 7th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10615322/v1

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Additional Declarations: The authors declare no competing interests.

Asymmetric price transmission and market integration in South Africa's maize and wheat value chains: evidence from a Nonlinear ARDL approach

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Abstract

This study investigates asymmetric price transmission (APT) in South Africa's maize and wheat value chains, focusing on whether producer-level price increases are passed on to consumers more rapidly or fully than price decreases are. In the context of highly concentrated retail markets and widespread reliance on staple foods, such asymmetries can significantly affect consumer welfare and market efficiency. Although the APT has received growing attention, existing studies often overlook critical features such as nonlinear adjustments, structural breaks, and macroeconomic shocks. Furthermore, few studies have compared staple commodities such as maize and wheat, which differ notably in value chain structure and market power dynamics. Using monthly data from January 2005 to March 2026, this study employs a Nonlinear Autoregressive Distributed Lag (NARDL) model to explore both short-run and long-run asymmetries between producer and retail prices. The findings reveal strong evidence of asymmetric transmission in the maize value chain, where price increases are transmitted to retail prices more quickly and completely than decreases. The wheat-to-bread chain shows a milder version of the same pattern in the long run, with short-run asymmetry confirmed for white bread but not for brown bread, which adjusts to producer price increases and decreases at a broadly similar pace. These results suggest that market power, non-transparent pricing mechanisms, and weak competition contribute to persistent price distortions. To address these issues, this study recommends stronger regulatory oversight, improved value chain transparency, inclusive access for smallholders, and real-time price monitoring. By tackling APT, policymakers can better protect consumers and foster fairer and more efficient staple food markets in South Africa and other emerging economies facing similar structural challenges.

Keywords: NARDL model: Maize market: Wheat value chain: APT: South Africa: Market power

Introduction

The persistent rise in food prices presents a significant challenge to economic stability and food security in South Africa, particularly for low-income households that allocate a disproportionately high share of their income to staple foods such as maize meal and bread. As one of the most unequal countries in the world, South Africa faces structural economic challenges that exacerbate food insecurity (Francis and Webster, 2019). One such challenge lies in the transmission of prices through the agricultural value chain. Inefficiencies in price transmission, often reinforced by concentrated market structures, can result in asymmetric price transmission (APT), whereby price increases at the farm, wholesale, or producer level are passed on to consumers more rapidly than price decreases (Padayachie, 2024). This study addresses the problem of vertical price transmission asymmetry in the South African maize and wheat markets, which are essential to food security. Despite their critical role in the national diet and economy, these markets are frequently characterized by price stickiness, lack of transparency, and a historically entrenched structure of high concentration that differs from many developing economies where markets remain more fragmented (Alemu and Ogundeji, 2010; Ramoroka and Muchopa, 2022; Swapi et al., 2024). Several studies have revealed instances of price collusion, anti-competitive practices and structural barriers that prevent cost savings from reaching end consumers (Competition Commission South Africa, 2021; Louw et al., 2017; Mncube, 2014). As a result, consumers face persistently high prices, even when input or producer prices fall (Peltzman, 2000). Such price behaviour intensifies the cost-of-living crisis and raises concerns about the functioning of staple food markets in South Africa.

Unlike many developing countries where staple food value chains are dominated by informal traders, South Africa's agri-food system is highly formalized and vertically integrated, with a small number of firms exercising significant influence over pricing and distribution (Dube et al., 2018; Greenberg, 2017, 2016). The South African Competition Commission has documented repeated instances of collusion and price fixing within essential food chains, including wheat, maize and bread (Competition Commission South Africa, 2021). This institutional and regulatory context, combined with legacy effects of market liberalisation, creates conditions under which price adjustments may be uneven across the value chain (Gaudin, 2018; Ray et al., 2006). In such settings, producers and wholesalers are often able to pass cost increases forward more readily than they transmit cost reductions downward. Understanding how prices adjust across different levels of these value chains is therefore critical for evaluating market performance and consumer welfare. Vertical price transmission refers to the process through which price changes at one level of the supply chain (e.g., producers or wholesalers) are reflected at other levels (e.g., retailers or consumers) (Kharin et al., 2017; Jensen and Møller, 2005). When this process is symmetric, price increases and decreases are transmitted at similar magnitudes and speeds (Jensen and Møller, 2005). However, in reality, especially in highly concentrated and formalised markets such as South Africa's, transmission often becomes asymmetrical. Numerous studies have shown that price increases tend to be transmitted more fully and rapidly than price decreases, a condition that harms consumers and signals market inefficiencies (Onegina et al., 2022; Sahara et al., 2022).

This study contributes to the literature by investigating asymmetric price transmission in South Africa's maize and wheat sectors using the NARDL approach. The analysis covers the period from January 2005 to December 2024 (monthly) and focuses on the transmission of prices from the producer to the retail level, particularly for maize meal, brown bread, and white bread. By

focusing on these staple products, the study captures both raw and processed food segments within highly concentrated value chains. The study seeks to determine whether positive and negative price shocks lead to differential long-run effects and whether price decreases are transmitted as efficiently as price increases. The study hypothesizes that there is no long-run relationship or asymmetric price transmission between producers and retail prices for wheat and maize.

By adopting a nonlinear and asymmetric modelling approach, this study aims to bridge methodological and empirical gaps in the South African literature on food price transmission. The findings are expected to have significant implications for policy formulation, including competition law enforcement, market transparency initiatives and consumer protection strategies. Moreover, by situating South Africa's experience within the broader developing-country literature, the study highlights how formalisation, concentration and regulation jointly shape price dynamics in staple food markets, offering insights that may extend beyond the South African context.

Literature review

Linear models in price transmission

Previous studies on agricultural commodity price transmission has focused on linear models, assuming a uniform adjustment path, regardless of the direction or magnitude of shocks. Techniques such as the standard Error Correction Model (ECM) and Vector Error Correction Model (VECM) have been widely used to examine cointegrated price relationships over time (Goodwin and Harper, 2000; von Cramon-Taubadel and Fahlbusch, 1994). While these methods provide useful insights into cointegrated price relationships, they are unable to capture nonlinear responses that frequently characterize agricultural markets (Kharin, 2021; Tavernier et al., 2009). Consequently, they may underestimate the extent of market inefficiencies and asymmetric pricing behaviour.

Threshold and nonlinear in price transmission

Advanced techniques such as threshold vector error correction model (TVECM), have attempted to capture some degree of asymmetry by allowing for different adjustments above and below certain thresholds (Ben-Kaabia and Gil, 2007). Nevertheless, TVECM models generally maintain the assumption of a symmetric long-run equilibrium relationship and mainly capture asymmetry in adjustment speeds. Notably, recent studies have highlighted limitations in these models. For instance, Bakhat et al. (2022) argue that asymmetry can manifest in speed and magnitude, suggesting that both dimensions must be studied to obtain a comprehensive understanding of price transmission. On the other hand, Fousekis et al. (2016) reinforce this argument by demonstrating that traditional ECM and TVECM techniques tend to ignore magnitude asymmetries due to their underlying assumption of a symmetric long-run relationship. This assumption can mask important nonlinearities in the price formation process, particularly in contexts where market distortions, policy interventions or structural shocks alter the equilibrium path of prices. Furthermore, Gonzalo and Pitarakis (2006) caution that mis-specifying the nature of the long-run relationship can lead to biased and inconsistent estimates

of both the equilibrium relationship and the adjustment dynamics. Therefore, disentangling nonlinearity in the long-run relationship from nonlinearity in short-run adjustments is crucial. To address these concerns, Fousekis et al. (2016) and Gervais (2011) propose using models that can accommodate both types of asymmetries, particularly the Nonlinear Autoregressive Distributed Lag (NARDL) model, which allows for asymmetric adjustment in both short- and long-run dynamics without requiring pre-testing for cointegration.

Although the NARDL technique offers several advantages, it is not without limitations. As highlighted by Harshana and Ratnasiri (2023), NARDL models assume a zero threshold in defining positive and negative shocks, which may not always accurately reflect the behavior of agricultural prices. Furthermore, this study emphasizes the importance of accounting for seasonality, market structure, and data transparency, especially in the context of perishable agricultural commodities (Harshana and Ratnasiri, 2023). Although their analysis is based on Sri Lanka, the challenges they identify, such as the effects of cartels, informal trading alliances, and the lack of disaggregated retail data, are strikingly relevant to South African markets.

Incorporating external shocks on price transmission estimation

Harshana and Ratnasiri (2023) point to another critical issue: the scarcity of robust empirical research that incorporates external shocks, such as policy changes, trade interventions, or environmental disruptions, into the price transmission framework. Similar to the findings of Barboza Martignone et al. (2022), their research critiques the failure of many existing studies to investigate how structural or exogenous shocks influence price behaviour along the supply chain. In the South African context, this critique is highly pertinent, given that few existing studies incorporate variables such as inflation, tariffs and consumer price indices into their models of price transmission. Undoubtedly, price transmission in the South African markets has been affected by shocks such as the COVID-19 pandemic (Pophiwa, Moroane, and Kenny, 2021), oil price fluctuations (Gupta and Modise, 2013) and geopolitical conflict such as the Russia-Ukraine conflict (Hartley and Gabriel, 2024), just to name a few. During the COVID-19 lockdowns, firm-level survey evidence from South Africa's maize value chain shows that, because maize is a storable and comparatively non-perishable commodity, the direct disruption to producer-to-retail marketing was limited; the more consequential channels were currency depreciation, shifting demand from the animal feed and export markets, and a temporarily larger exportable surplus, rather than a breakdown of the pricing chain itself (Meyer et al., 2022). Oil price shocks operate through a more indirect but persistent channel because South Africa imports the bulk of its liquid fuels, increases in crude oil prices raise diesel costs for milling, transport and farm operations (Ledwaba et al., 2025). Furthermore, this transition also feeds into producer and retail prices with a lag, even though a direct cointegrating relationship between crude oil and grain prices has been found to be inconsistent across commodities in the South African data (Ledwaba et al., 2025). On the other hand, The Russia-Ukraine conflict is particularly relevant for the wheat commodity. Notably, South Africa imports around 40% of its annual wheat consumption needs, with Russia alone historically supplying close to a fifth of these imports, so the disruption to Black Sea shipments in 2022 raised import replacement costs and contributed to the pass-through of global wheat price spikes into local flour and bread prices (Econ3x3, 2022). Maize, which is largely self-sufficient in South Africa, is far less directly exposed to this particular shock, illustrating that the two value chains can respond quite

differently to the same global disturbance. To date, none of this shock-specific evidence has yet been incorporated into a formal asymmetric price transmission model of the South African maize and wheat chains, which is the specific empirical gap this study addresses.

The South African context of asymmetric price transmission

Despite the growing body of literature on asymmetric price transmission (APT), research in the South African context remains limited in scope. Notably, existing studies have examined price transmission in selected food markets but have often overlooked critical econometric considerations, including nonlinear adjustments, structural breaks, and shock asymmetries (Padayachie, 2024; Swapi et al., 2024). Recent studies such as Swapi et al. (2024) found evidence of long-run positive asymmetry between farmgate, wholesale, and retail prices. Similarly, Padayachie (2024) reported instances of persistent market power abuse by firms, even after regulatory interventions. While these studies provide valuable insights into pricing asymmetries in key sectors, they fall short of accounting for unobserved influences such as inflation, macroeconomic disturbances, and structural changes. This omission limits the ability of their models to accurately capture real-world price dynamics and diminishes their usefulness for policy formulation. Therefore, taken together, these gaps point to specific shortcomings that this study addresses. Firstly, existing South African APT studies, including Swapi et al. (2024) on the wheat chain and Padayachie (2024) on competition enforcement more broadly, rely on shorter or single-commodity data series that do not extend into the post-2020 period, so they cannot capture how COVID-19, oil price volatility and the Russia-Ukraine conflict jointly reshaped price adjustment in the maize and wheat chains. Secondly, no existing South African study applies the NARDL model to both maize and wheat producer-to-retail transmission within a single, directly comparable framework using long monthly data. The coverage from January 2005 to March 2026 used here is, to the authors' knowledge, the longest series applied to this question in the South African literature, allowing several shock episodes to be captured within the estimation rather than treated anecdotally. Thirdly, by testing explicitly for structural breaks and by decomposing price changes into positive and negative components within the same model, this study is able to distinguish whether asymmetry in these markets is a stable structural feature of market power, as the theoretical framework below proposes, or a temporary artefact of the shocks that occurred within the sample period. This combination of long data coverage, cross-commodity comparison and explicit shock-period testing is what distinguishes this study from prior South African applications of the NARDL model.

Theoretical framework

To adequately understand the mechanisms behind APT in agricultural commodity supply chains, particularly in the South African context, it is essential to adopt an integrated theoretical lens. This study proposes a combined framework based on market power theory (MPT) and the theory of asymmetric information (TAI), which together explain how structural market dynamics and informational disparities distort price transmission (Auronen, 2003; Kakhbod and Lanzani, 2020). The combined framework adopts a general equilibrium approach by acknowledging the existence of different markets with transmission between them. While related theories such as transaction cost economics (emphasizing the costs of negotiating and enforcing contracts) (Rutatola and Mwagike, 2023; Frascarelli et al. 2021), price stickiness

(focusing on rigidities in price adjustments due to menu costs or psychological factors) (Kidane, 2022), and behavioral aspects of consumer response (e.g., loss aversion in pricing perceptions) (Higgins and Liberman, 2018) offer valuable insights into price dynamics, the dual-theory approach of Market Power and Asymmetric Information is most suitable here. It uniquely captures the interplay of power imbalances and informational inequalities, providing a more comprehensive explanation for APT in concentrated, information-scarce markets than these alternatives, which often overlook the strategic exploitation of asymmetries.

The MPT posits that firms with significant control over market share, particularly in downstream sectors such as retail and processing, can influence pricing decisions to preserve or enhance their profit margins (Bakucs et al., 2013; Vaidya, 2023). In the context of price transmission, this translates to a phenomenon in which retail firms are quicker to pass input cost increases to consumers but delay or dampen the transmission of cost decreases. This strategic behaviour leads to asymmetric outcomes that favor downstream actors, often at the expense of upstream suppliers and consumers. However, the exercise of market power is often reinforced and, in some cases, enabled by asymmetric information. According to Ross (2022), when one party in a transaction possesses more or better information than the other, market inefficiencies and welfare losses can occur. In agricultural markets, processors and retailers frequently have access to superior price forecasts, supply chain data, and market intelligence compared to smallholder farmers or consumers (Rausser et al., 1985). This information advantage allows dominant firms to optimize their pricing strategies and exploit the uncertainties and limited negotiating power of less-informed market participants. For instance, traders and retailers may use their informational advantage regarding expected harvest outcomes, international price movements, or policy changes to justify price hikes or resist downward price pressures, even when such changes are not fully grounded in actual market fundamentals (Mitra et al., 2020). Thus, asymmetric information amplifies the effects of market power by allowing firms to shape price narratives and obscure real cost structures, making it harder for upstream actors and consumers to challenge pricing behaviour or make informed decisions.

The interaction between these theories creates a synergistic feedback loop: firms with more market power accumulate and protect superior information, while those with better information use it to consolidate power. This dynamic is particularly potent in vertically concentrated supply chains, such as those for maize and wheat in South Africa, where oligopolistic bread millers and large retailers dominate downstream segments. For example, in South Africa's maize and wheat markets, characterized by high concentration among a few processors and retailers, market power enables rapid upward price transmission during global price spikes, while asymmetric information which is exacerbated by limited access to data from systems like the South African Grain Information Service (SAGIS) allows these firms to delay downward adjustments, citing uncertainties in harvest forecasts or policy interventions. This interplay is further intensified by South Africa's unique structural challenges, including historical legacies of land reform, fragmented smallholder farming, and reliance on volatile international markets, which amplify informational disparities and reduce upstream bargaining power.

Therefore, the interaction between market power and information asymmetry creates a feedback loop: firms with more power accumulate and protect superior information, and firms

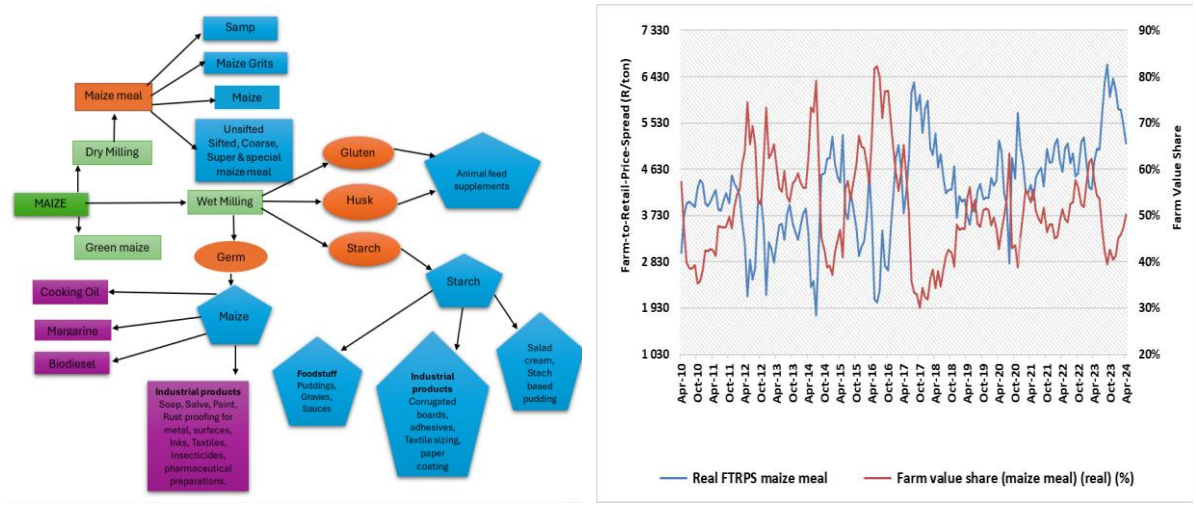
with better information use it to consolidate power. This dynamic is particularly potent in vertically concentrated supply chains, such as those for maize and wheat in South Africa. Retailers and large processors can use both their structural dominance and informational superiority to engage in pricing practices that lead to positive asymmetric price transmission, whereby price increases are rapidly and fully passed through to consumers, whereas decreases are sluggish or incomplete.

In this study, this integrated framework serves as the foundation for analysing the price relationships between the producer and retail levels in the maize and wheat value chains. The NARDL model is employed to empirically test the existence and degree of asymmetry in both short-run and long-run transmission processes. This econometric strategy aligns with the theoretical expectation that price behaviour is not symmetric, especially in environments characterized by unequal market power and imbalanced access to information. By grounding the empirical analysis in this combined theoretical lens, this study not only identifies whether APT exists but also seeks to explain why it occurs. This dual-theory approach provides a richer understanding of price behaviour in oligopolistic and information-scarce agricultural markets, contributing to more effective policy recommendations on competition regulation, transparency, and market access. Specifically, the findings could inform targeted interventions under South Africa's Competition Act, such as stricter scrutiny of anti-competitive pricing by dominant millers, enhanced transparency mandates for SAGIS data to reduce informational asymmetries, and consumer protection policies like price monitoring mechanisms to prevent welfare losses from delayed price decreases. These policy linkages would address the root causes of APT, fostering fairer value chains and improved market access for smallholder farmers.

Methods and materials

Study area

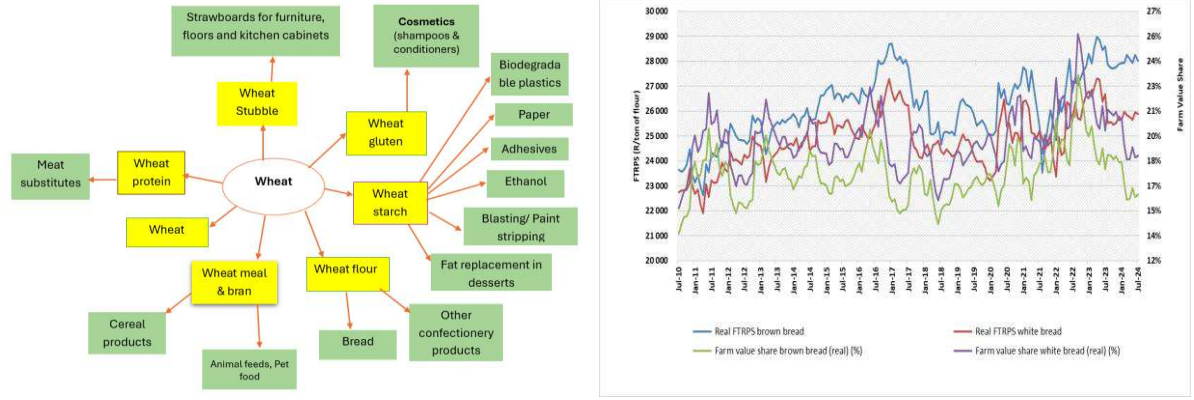
This study was conducted in South Africa, focusing on maize and wheat value chains. The maize value chain (Figure 1(a)) shows that maize can be processed (milled) or consumed as green maize (DALRRD, 2021a). Dry milling yields maize meal and related products such as samp, while wet milling yields further downstream goods including animal feed and cooking oil (DALRRD, 2021a). Because each stage of this chain constitutes a distinct market, a generalised equilibrium perspective is appropriate for analysing price transmission. This study, however, focuses specifically on the producer-to-retail segment, tracking the maize producer price against the maize meal retail price, since maize meal is the mostly consumed commodity in South Africa. Notably, the data shows that average producer price of maize in 2024 was R4130.42/ton (DALRRD, 2024), while the farm-to-retail price spread was R5 521.12/ton of maize meal (NAMC, 2024). On the other hand, Figure 1(b) illustrates the evolution of this farm-to-retail price spread across the full study period produced by the NAMC.



(a) (b)

Figure 1: South Africa's (a) maize value chain and (b) farm to retail price spread (Apr 2010 – Apr 2024)
Source: (DALRRD, 2021a; NAMC, 2024)

Figure 2(a) shows that wheat is processed into a range of intermediate products, including flour, starch, gluten and bran, which feed into further goods such as bread, ethanol and cosmetics. As with maize, this study narrows its focus to the producer-to-retail segment, specifically the wheat producer price and the flour retail price. The average wheat producer price in 2024 was R5 415.70 (DALRRD, 2024), while the farm-to-retail price spread was R27 967.48/ton of flour (NAMC, 2024). Figure 2(b) similarly presents the farm-to-retail price spread for flour over the study period.



(a) (b)

Figure 2: South Africa's (a) wheat value chain and (b) farm to retail price spread (Apr 2010 – Apr 2024)
Source: (DALRRD, 2021b; NAMC, 2024)

Study design

This section presents the methodology, including the data sources and analytical framework. The main purpose of this study is to determine whether positive and negative price shocks lead

to differential long-run effects and whether price decreases are transmitted as efficiently as price increases.

Data sources and radiality

The data was extracted from two reputable data sources, Statistics South Africa (StatsSA, 2026) and South African Grain Information Service (SAGIS, 2026). The data sources were selected because they provide the most complete and consistently reported national price series available for South Africa's maize and wheat chains over a multi-decade period, but their coverage and accuracy should be qualified. SAGIS (2026) data are compiled from formally registered grain handlers, silo owners and millers; this ensures consistent monthly reporting but does not capture transactions in informal or unregistered channels, which remain significant in parts of the maize market. Similarly, the StatsSA (2026) retail price series are collected from a sample of formal retail outlets concentrated in urban centres, and so may not fully reflect price levels or price behaviour in informal and rural markets, where a substantial share of low-income consumers purchase staple foods. Both series are also national averages, which can mask regional price disparities arising from transport costs, local market concentration and provincial supply conditions. Finally, as with any long-run secondary time series, occasional revisions, reporting gaps and changes in data collection methodology cannot be ruled out over the sample period, although no systematic breaks in reporting practice were identified for the variables used here. Despite these limitations, SAGIS (2026) and StatsSA (2026) remain the most authoritative and widely used sources for South African grain market data, and they underpin prior studies in this literature (Swapi et al., 2024; Padayachie, 2024). The study design was a longitudinal time series for a monthly period between January 2005 and March 2026.

Analytical framework

This study applied the NARDL model introduced by Shin et al. (2014), as it incorporates both the speed and magnitude of price adjustments. Market power is a key factor contributing to asymmetric price transmission in agricultural markets. When firms possess market power, they can influence the degree of price transmission between the stages of the value chain. In a perfectly competitive market, prices are transmitted symmetrically throughout the value chain. However, in markets where firms have some market power, positive asymmetry is often observed, with price increases being transmitted more quickly than price decreases. The market structure, particularly in oligopolistic settings, plays a crucial role in determining the direction and extent of asymmetry. For instance, oligopolistic firms may pass on price increases but not price decreases, resulting in positive asymmetry (Meyer and von Cramon-Taubadel 2004). The NARDL model is advantageous because of its simplicity and wide application in various fields, such as housing price analysis in Greece, asymmetric price transmission examination in the energy sector, and food price investigation in Sweden (Fousekis et al., 2016; Greenwood-Nimmo and Shin, 2013;Padayachie, 2024). Empirically, the NARDL model's decomposition of variables into positive and negative components, along with its symmetry tests and dynamic multipliers, operationalizes the framework's predictions, quantifying how market power enables rapid upward price transmissions while asymmetric information sustains delays in downward adjustments in South African maize and wheat chains (Meyer and von Cramon-

Taubadel, 2004; Bakucs et al., 2013; Swapi et al., 2024). For two time series variables, y_t and x_t $(where\ t\ = 1, 2, \dots T)$ the ARDL equation is expressed as follows (Fousekis et al., 2016);

$$\Delta y_t = a_0 + \rho y_{t-1} + \theta x_{t-1} + y z_t + \sum_{j=1}^{p-1} a_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta x_{t-j} + e_t \quad \text{(i)}$$

Where z_t denotes the vector of deterministic regressors (like seasons, trends, and other exogenous influencers with fixed lags) and u_t is an *iid* stochastic process. To test for cointegration between γ_t and x_t, the null hypothesis assumes no cointegration, implying that the coefficients of the lagged levels of these variables in the model are jointly zero ($\rho = \theta = 0$). If this holds, it suggests that the time series are not cointegrated. Pesaran et al. (2001) proposed testing this hypothesis using a modified F-test, known as the F_{PSS} test or, in cases where classical assumptions may be violated, a Wald test referred to as W_{PSS}. The decision rule is based on two critical bounds: the upper and lower bounds. If the calculated F_{PSS} and W_{PSS} statistic exceed the upper bound, the null hypothesis is rejected, indicating a long-run equilibrium relationship between γ_t and x_t. If the test statistic falls below the lower bound, there is no evidence of a cointegration. However, if the value lies between the two bounds, the results are inconclusive. Additionally, cointegration can be tested using the t_{BDM} test introduced by Banerjee et al. (1998). The test assesses whether $\rho = 0$ (no cointegration) against the alternative hypothesis that $\rho \neq 0$ (cointegration). Like the bounds approach, the t_{BDM} test uses critical upper and lower bounds to determine the outcome. If the test statistic surpasses the upper bound, cointegration is confirmed. However, if it is below the lower bound, the null of no cointegration is accepted; and if it falls between the bounds, the results remain inconclusive.

The ARDL model offers several advantages. It performs well with small sample sizes, making it more robust compared to other multivariate cointegration techniques. It is also considered more efficient than the Engel and Granger two-step approach. Moreover, the ARDL method does not require all time series variables to be integrated in the same order, adding flexibility to the model's design. However, the standard ARDL model assumes a linear combination of stochastic regressors, implying symmetric adjustments in both the short and long runs. To address potential asymmetries, Shin et al. (2014) introduced the Nonlinear ARDL (NARDL) model. This model decomposes x_t into its positive and negative partial sums, allowing for the identification of asymmetric effects in price adjustments over time. The equations are expressed as follows:

$$x_t = x_0 + x_t^+ + x_t^- \quad \text{(ii)}$$

Where:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0) \text{ and } x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \quad \text{(iii)}$$

Then, the symmetric long-run equilibrium relationship can be expressed using the following equation:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t \quad \text{(iv)}$$

where $\beta^+$and β^- represent the asymmetric long-run parameters associated with the positive and negative changes in x_t, respectively. When taking Equation 4 and combining it with the

ARDL model in Equation 1, Shin et al. (2014) arrived at the NARDL model, as presented in Equation 5.

$$y_t = a_0 + \rho y_{t-1} + \theta x_{t-1} + yz_t + \sum_{j=1}^{p-1} a_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta x_{t-j}\left(\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{t-j}^-\right) + e_t \quad \text{(v)}$$

Where $\theta^+ = -\frac{\rho}{\beta^+}$ and $\theta^- = -\frac{\rho}{\beta^-}$ represent the long-run asymmetric coefficients.

The empirical implementation of the NARDL model involves four key steps as follows. First, the NARDL equation was estimated using ordinary least squares (OLS). Second, the existence of an asymmetric cointegrating relationship between the levels of the variables $y_y, x_t^+$and x_t^- is tested. Following Shin et al. (2014), the null hypothesis of no cointegration ($\rho = \theta^+ = \theta^- = 0$) can be examined using the F_{PSS} or W_{PSS} statistics, while Banerjee et al. (1998) suggest using the t_{BDM} statistic to test whether $\rho = 0$. The third step assesses long- and short-run symmetry. Long-run symmetry is tested by evaluating the null hypothesis that the positive and negative coefficients are equal ($\beta^+ = \beta^-$), expressed as $-\theta^+/\rho = -\theta^-/\rho$, using a standard Wald test. For short-run symmetry, two forms are considered: pairwise (strong-form) symmetry, which tests whether the short-run positive and negative coefficients are equal at each lag ($\pi_j^+ = \pi_j^- \ for\ all\ j\ =, \ldots q-1$), and additive (weak-form) symmetry, which examines whether the cumulative effects of positive and negative changes are equal($\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$). Both tests rely on the Wald statistic. Finally, if asymmetry is detected in the long run, short run, or both, positive and negative dynamic multipliers are derived. These multipliers capture how y_t responds dynamically to unit changes in $x_t^+$and x_t^-, shedding light on the paths through which positive and negative shocks influence the dependent variable over time. These are calculated with equation 6 for x_t^+ and x_t^-, respectively.

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+} \text{ and } m_h^- = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t} \text{ with } h = 0, 1, 2 \quad \text{(vi)}$$

Note: As $h \to \infty$, the positive and negative dynamic multipliers m_h^+ and m_h^- converge to long-run coefficients $\beta^+ \ and\ \beta^-$, respectively. Analyzing these dynamic multipliers provides valuable insights into the paths of adjustment and the duration of disequilibrium following initial positive and negative price deviations. This allows for a deeper understanding of both short- and long-run asymmetry patterns. To account for structural breaks, a dummy variable was added to the NARDL (0= before break and 1= after break). Table 1 presents the description of the variables used in the study.

Table 1: Description of variables used.

Variable	Description
$lrbp$	log retail price of brown bread
$lrwp$	Log retail price of white bread
lpp	log producer price (wheat or maize)
$\Delta lrbp$	Differenced retail price of brown bread
$\Delta lrwp$	Differenced retail price of white bread
Δlpp	Differenced producer price

Results

Descriptive results

This section presents the descriptive statistics of the data. Table 2 presents the summary statistics for producer and retail maize prices from January 2005 to March 2026. The results show that retail prices for 1 kg of maize meal ranged between 2.18 and 15.51 during the period, with an average price of 7.85 South African rands. The producer prices for a ton of white maize ranged between 532.85 and 6822.81, with an average price of 2692.77 South African rands. For wheat, the results show that retail prices for 700 g of white bread ranged between 4.55 and 19.61 during the period with an average price of 11.87 South African rands. The retail price for brown bread ranged between 3.93 and 17.64, with an average of R10.74. The producer prices for a ton of white maize ranged between 1291.40 and 8023.33 with an average price of 4077.29 South African rands. The discriptive results shows notable volatility and distributional features in these price series. Relative price volatility, measured as the standard deviation expressed against the mean, was broadly similar across the retail products, while producer prices for both white maize and wheat displayed comparable or somewhat higher relative volatility. All five series are positively skewed, indicating that large upward price movements occurred more frequently than large downward movements over the sample period, an early indication of the type of asymmetry that the NARDL model is designed to test formally.

Table 2: Descriptive statistics

	Maize		Wheat		SAFEX Wheat price (R1ton)
Statistics	**Maize meal (R/kg)**	**SAFEX White maize price (R/1ton)**	**White bread (R/700g)**	**Brown bread (R700g)**	
Mean	7.85	2692.77	11.87	10.74	4077.29
Min	2.18	532.85	4.55	3.95	1291.40
Max	15.51	6822.81	19.61	17.64	8023.33
STD	3.26	1287.96	4.56	4.21	1576.12
Kurtosis	2.16	2.91	1.92	1.93	2.25
Skewness	0.49	0.68	0.08	0.12	0.19
Prob> chi2	0.000 ***	0.001 ***	0.000 ***	0.000 ***	0.001 ***

Note: *** is Sig at 1%

Figure 3 presents the natural logarithms of the producer prices for white maize and wheat and the retail prices for maize meal, brown bread, and white bread between January 2005 and March 2026. Natural logarithms are used to stabilize variance, linearize exponential trends, and facilitate the interpretation of price changes in percentage terms, which is particularly useful in time-series econometric analysis (Ogun, 2021; Taylor and Kingsman, 1979). All prices show upward trends, which have been more pronounced since 2005. Retail prices for brown bread show an increasing trend until 2009, prices drop until 2010, and then fluctuate. The spot prices for wheat and the retail price for white bread show an increasing trend throughout the period. For maize, the volatility of prices at the producer level appears to be much higher than that at the retail level.

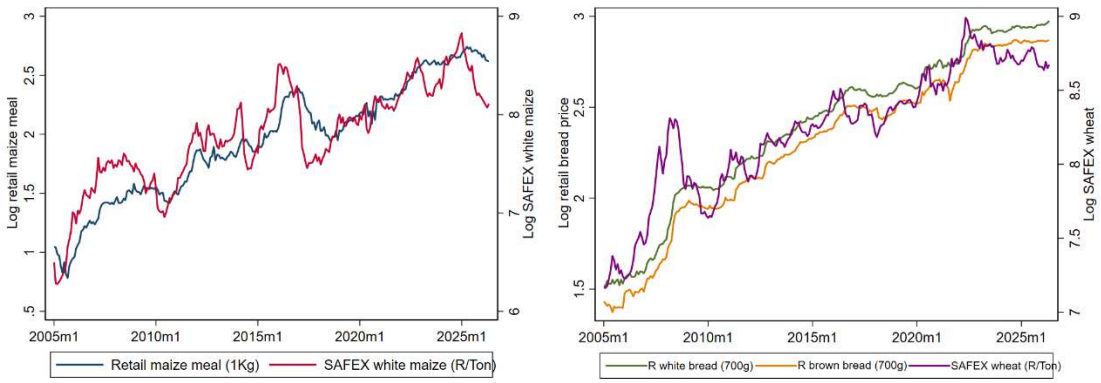
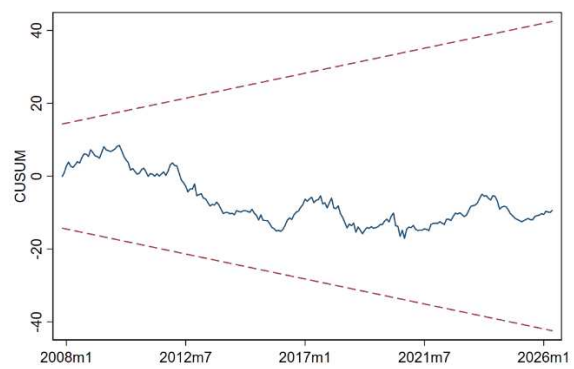


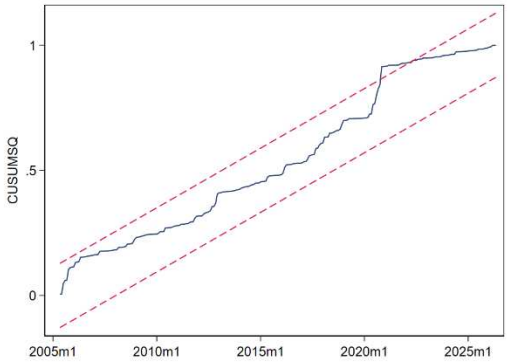
Figure 3: Natural logarithms of producer prices and retail prices (maize and wheat).

Empirical results and analysis

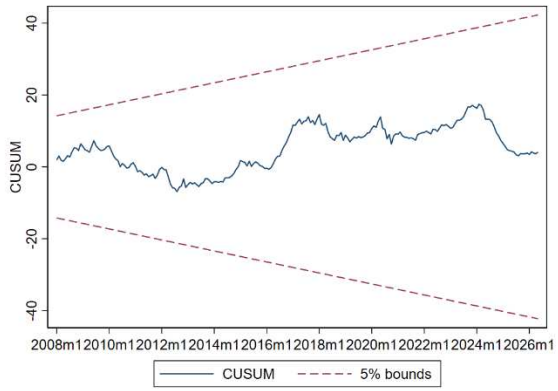
This section presents the study's empirical results. Figures 4 and 5 display the results of the Cumulative Sum (CUSUM) test. The CUSUM of squares test of stability for maize meal indicated the presence of a structural break in the data. However, after accounting for the structural break by including dummy variables, the corrected CUSUM of squares test suggested that the model was stable (Figure 4(d)). Similarly, for the bread price model, the initial CUSUM test shows evidence of a structural break. After incorporating dummy variables to account for the break, the corrected CUSUM test indicated stability in the model (Figure 5(c)). In addition, the CUSUM of squares test for the bread model also showed presence of a structural break in the data, then after adjusting for it by including dummies, the corrected CUSUM of squares test showing stability in the data (Figure 5 (d)). The exact structural breakes are discussed in the section below.

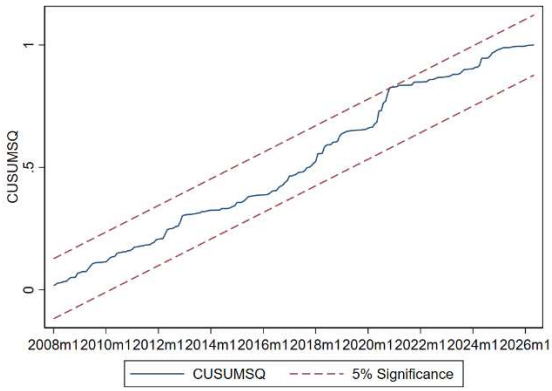


(a) CUSUM Test for lrp



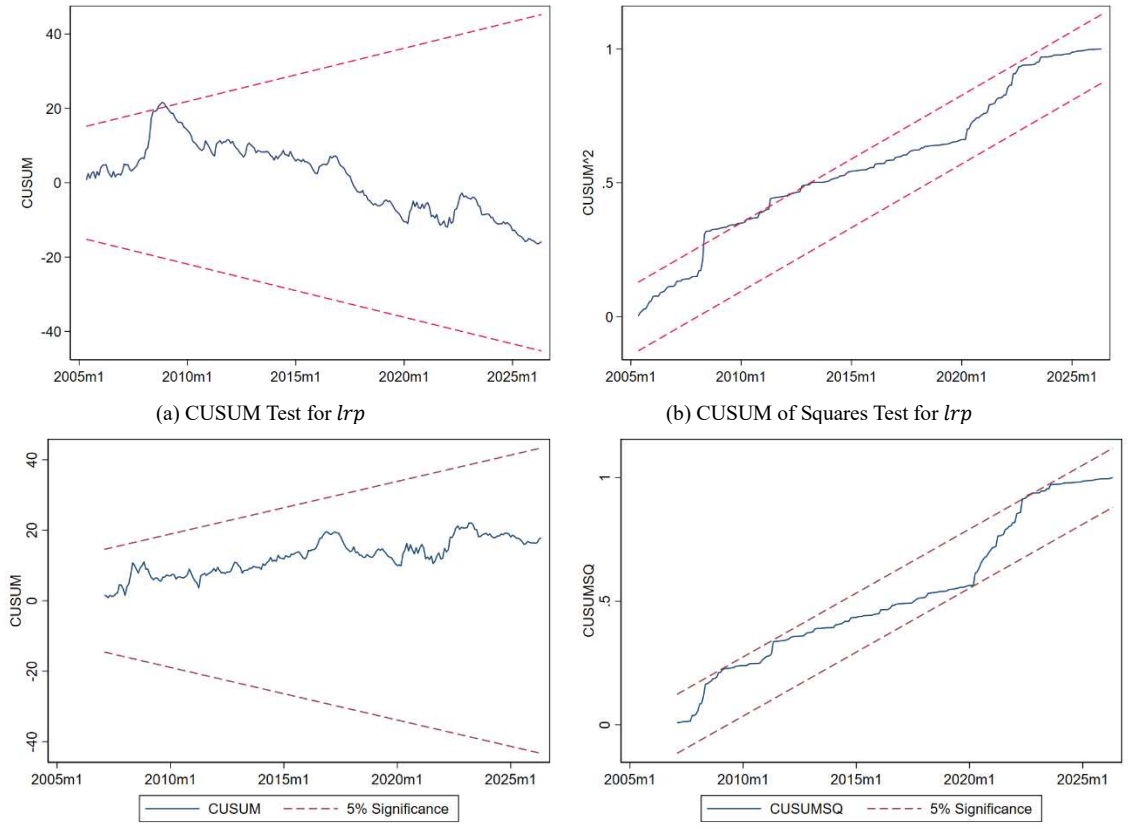
(b) CUSUM of Squares Test for lrp





(c) CUSUM Test for lrp with structural dummies (d) CUSUM of Squares Test for lrp with structural dummies

Figure 4: Test of structural stability for retail price of maize meal



(a) CUSUM Test for lrp (b) CUSUM of Squares Test for lrp

(c) CUSUM Test for lrp with structural dummies (d) CUSUM of Squares Test for lrp with structural dummies

Figure 5: Test of structural stability for retail price of bread (both white and brown included)

Table 3 presents the Bai-Perron test results for structural breaks (Bai and Perron, 1998). The test identified multiple breakpoints in both the maize meal and bread price series data. For maize meal, structural breaks were detected in July 2008, October 2011, February 2016, October 2019 and December 2022. For bread, breaks were observed in April 2008, June 2011, August 2014, January 2019, and June/July 2022 (white and brown bread break in the same months, except for the final break, which falls in June 2022 for white bread and July 2022 for brown bread). These breakpoints were subsequently incorporated into the analysis by including dummy variables. The identified structural breaks correspond to many major disruptions to global and domestic food markets. Notably, the break identified in bread prices in April/July 2008 aligns with the onset of the 2007-2008 global food price crisis, during which world wheat prices rose sharply on the back of poor harvests and export restrictions in major producing countries (FAO, 2009). While the 2011 maize meal and bread break correspond to the 2010-2011 food price spike associated with drought in the Black Sea region and Russia's wheat export ban (Hunt et al., 2021; Svanidze et al., 2022). On the other hand, the 2018 breaks in both series overlap with a period of heightened policy uncertainty in South Africa, including public debate over land expropriation without compensation, which may have affected investor and market sentiment in the agricultural sector (AgriSA, 2017). Finally, the breaks identified in 2022 correspond to the global supply chain disruptions and input-cost inflation (notably fertiliser prices) that followed the COVID-19 pandemic, immediately preceding the further shock to global wheat and maize markets caused by Russia's invasion of Ukraine in February 2022 (Arndt et al., 2023).

Table 3: Breakpoint test for maize meal and bread

Maize Model			**Wheat model**			
			Brown bread		**White bread**	
Break Test	F-statistic		F-statistic		F-statistic	Bai-Perron CV (1%)
0 vs 1	252.28 ***		228.29 ***		264.54 ***	12.29
2 vs 1	128.65 ***		222.92 ***		232.28 ***	13.89
3 vs 2	82.27 ***		128.65 ***		133.06 ***	14.80
4 vs 3	44.16 ***		95.63 ***		99.10 ***	15.28
5 vs 4	46.80 ***		77.24 ***		89.64 ***	15.76
	Break dates	Repartition	Break dates	Repartition	Break dates	Repartition
1	2008m7	2008m8	2008m4	2011m7	2008m4	2008m5
2	2011m10	2011m11	2011m6	2008m5	2011m6	2011m7
3	2016m2	2016m3	2014m8	2016m1	2014m8	2016m1
4	2019m10	2019m11	2019m1	2019m3	2019m1	2019m3
5	2022m12	2023m1	2022m7	2922m6	2022m6	2022m7

Note: *** is Sig at 1%

Table 4 presents the results of the Zivot-Andrews unit root test (Zivot and Andrews, 2002). Unlike conventional unit root testing models such as ADF and Phillips-Perron tests, which assume no structural break under the null and can spuriously indicate a unit root when a break is present, the Zivot-Andrews test endogenously identifies a single structural break and tests for a unit root conditional on it (Zivot and Andrews, 2002). This is particularly relevant here given the structural breaks subsequently confirmed by the Bai-Perron test (Table 3), making the Zivot-Andrews test the more appropriate choice for establishing the integration order of these series. The Zivot-Andrews Unit Root test accounts for structural breaks. The Test shows that white bread and wheat do not have unit roots at levels I(0). The rest of the variables did not have a unit root at the first difference, I(1).

Table 4: Zivot-Andrews unit root tests

Var		**Wheat model**		**Var**	**Maize model**	
		I(0)	**I(1)**		**I(0)**	**I(1)**
$lrbp$		-4.267	-15.414 ***	lrp	-4.385	-10.245 ***
$lrwp$		-4.944	-8.306 ***	lpp	-4.745	-13.193 ***
lpp		-4.852	-12.704 ***			
Critical values	1%	-5.57	-5.57		-5.34	-5.34
	5%	-5.08	-5.08		-4.80	-4.80

Note: Max lag= 3 for the wheat model and 6 for the maize model; Schwarz Information Criterion. *** and ** denote the rejection of the null hypothesis of a unit root at the 1 and 5% level, respectively.

Table 5 presents the results of the causality tests for the maize and wheat markets. To determine the causal relationships, the study relied on the bootstrapping simulation test of causality, as proposed by Hacker and Hatemi-J (2012). For the maize market, the results indicate a strong unidirectional causality from the log maize producer price (lpp) to log maize meal retail price (lrp), with a Chi-squared value of 55.639, significant at the 1% level. Conversely, causality from lrp to lpp is not significant, with a chi-squared value of 4.325, which falls below both the 5% and 1% critical values. These results indicate a unidirectional price transmission effect running from maize producer prices to retail prices, rather than a bidirectional relationship. In contrast, for the wheat market, there is evidence of bidirectional causality between log wheat producer price (lpp) to log retail bread price ($lrbp$), with a Chi-squared value of 16.160,

significant at the 5% level. Similarly, there is significant causality from $lrbp$ to lpp, also significant at the 5% level, with a chi-squared value of 13.032, confirming bidirectional causality between wheat producer prices and brown bread retail prices. Additionally, the results show unidirectional causality running from log wheat producer price (lpp) to log wheat retail wheat price ($lrwp$), with a Chi-squared value of 23.643, significant at the 1% level ($lpp \neq> lrwp$), while the reverse direction is not significant, with a chi-squared value of 5.867 ($lrwp \neq> lpp$). The one exception to this pattern of significant causality in the wheat market is the reverse-direction relationship from retail white bread price to producer price ($lrwp\ to\ lpp$), which was not significant. This lack of feedback from white bread retail prices back to producer prices may be due to the substitutability of wheat products at the retail level. Wheat can be processed into other products besides bread, such as wheat biscuits, even though maize producer prices can be governed by whether it is for human consumption or feed production. To capture the full price transmission of wheat and its retail products, a more extensive generalized equilibrium approach that considers other markets, such as flour, biscuits, bread, and cakes, is required (Bareith et al., 2024; Čechura and Jaghdani, 2021; Djuric and Götz, 2016). These findings contradict those of Bareith et al. (2024), who found cointegration and price transmission of wheat in Hungary. Ahmed et al. (2022) also found cointegration and price transmission in the wheat market in India. However, their study focused on spatially distributed markets at the same horizontal level in the value chain. Furthermore, it was found that the distance between markets was a significant threshold parameter that affected transaction costs. This could have affected the results of our study. Several structural and methodological differences are worth noting when comparing these wheat/bread findings for South Africa with those reported for Hungary and India. Firstly, both Bareith et al. (2024) and Ahmed et al. (2022) examine horizontal price transmission between spatially separated markets at the same level of the value chain, where transaction costs and transport distance are the primary frictions; the present study instead examines vertical transmission from producer to retail level within a single national market, where the relevant frictions are more likely to be retail and milling margins, market concentration, and contractual arrangements between millers and retailers rather than geographic distance. Secondly, South Africa's wheat-to-bread value chain is more concentrated at the milling and retail stages than the markets studied in Hungary and India, which may weaken the pass-through of producer price signals to the shelf regardless of distance effects. Thirdly, wheat in South Africa is fungible across multiple end uses bread, biscuits, and other baked goods so retail bread prices may respond to broader wheat-product demand conditions rather than tracking producer prices for wheat specifically, which is less likely to be the case in the more bread-specific supply chains examined in the comparator studies. Finally, differences in exchange rate exposure are relevant, since South Africa imports a substantial share of its wheat, so global price and currency movements may dominate over the domestic producer-to-retail linkage captured in this model, whereas Hungary and India are comparatively larger domestic wheat producers.

This contrast is consistent with underlying differences in the structure of the two value chains. South Africa is largely self-sufficient in maize, and the maize milling sector is highly concentrated, with a small number of vertically integrated firms accounting for most of the milling capacity and retail shelf presence (Competition Commission South Africa, 2021; Mncube, 2014). In such a concentrated, domestically self-contained market, retail and producer prices would be expected to move together, since the same small set of firms are exposed to, and help set, both ends of the price relationship consistent with the bidirectional causality found

here. While the wheat-to-bread chain is structured differently; three of the four tested directions are significant, however it shows even more pervasive transmission than maize. This is plausible given how the chain is priced rather than despite it. South Africa produces only around half of its domestic wheat requirement and imports the remainder, mainly from Black Sea origins (DALRRD, 2021b), so domestic producer prices for wheat, set on SAFEX, are anchored to import parity. If millers and retailers reference this same SAFEX benchmark when setting bread and wheat retail prices, rather than negotiating prices independently at each stage, that shared pricing anchor would tend to produce the tight co-movement observed here rather than weaken it. The milling and baking segment's documented history of price-fixing (Mncube, 2014) is consistent with this too. Notably, coordinated pricing among millers could reinforce rather than disrupt a common link to the SAFEX producer price.

Table 5: Causality test using bootstrap simulation technique

	Maize					**Wheat**			
Null hypothesis	Test value	CV (1%)	CV (5%)	Optimal lag	Null hypothesis	Test value	CV (1%)	CV (5%)	Optimal lag
$lpp \neq> lrp$	55.639 ***	18.214	12.786	4	$lpp \neq> lrbp$	16.160 **	17.380	12.149	3
$lrp \neq> lpp$	4.325	15.997	10.749	4	$lrbp \neq> lpp$	13.032 **	14.693	9.643	3
					$lpp \neq> lrwp$	23.643 ***	17.083	11.819	3
					$lrwp \neq> lpp$	5.867	16.284	11.284	3

Note: the symbol $\neq>$ means that A does not cause B; CV represent the critical values. The optimal lag length in each VAR model was selected based on the Hatemi-J Criterion. The bootstrap simulations for the causality tests were conducted using 10000 simulations. ** and *** denotes rejection of the null hypothesis at the 5 and 1% levels.

Table 6 presents the results of the asymmetric cointegration tests for the maize and wheat markets. The results show that the F_{PSS} statistic for all models exceeded the upper critical value for I(1) at the 1% level, confirming the presence of a long-run relationship. Specifically, in the maize market, the F_{PSS} statistic for the NARDL (6) model with long-run (LR) and short-run (SR) asymmetry was 43.121, significant at the 1% level. Similarly, the t_{BDM} statistic for the NARDL (6) model with both long-run and short-run asymmetry was -9.040, which exceeds both the 5% and 1% critical value bounds in absolute terms, confirming rejection of the null hypothesis of no cointegration at the 1% level and providing strong evidence of a long-run relationship between maize producer and retail prices.

The F_{PSS} statistic for brown bread in the NARDL (1) model with LR and SR asymmetry was 19.991, and for white bread, it was 20.169, both significant at the 1% level. Additionally, the t_{BDM} values of -4.761 and -4.708 for brown and white bread, respectively, exceed the 1% critical value bound in absolute terms, confirming strong long-run linkages. The study adopted a conservative approach to selecting critical values by employing $k = 1$ in testing for the null hypothesis (Shin et al., 2014). The findings confirm that asymmetric price adjustments exist between producer and retail markets, with stronger evidence of cointegration in the maize market compared to the wheat markets. These results suggest that price asymmetries in food markets could be driven by differences in supply chain structures and price transmission mechanisms across commodities. In Bangladesh, Alam and Jha, (2020) also found that there was price asymmetries in the wheat and flour markets with a faster response in the increase in downstream flour markets than when it falls. Some of the reasons for price transmission include market power by the retailers, market structure, asymmetric information as well as costs in inventory holding, adjustment and search (Alam and Jha, 2020). The study by Alam and Jha, (2020) however concentrated on the price transmission between wholesale and retail of flour.

In South Africa, the big 5 retailers (Shoprite, Pick n Pay, Spar, Woolworths and Walmart's Cambridge Foods) control 60% of all retail (USDA, 2025). This market power emboldens them to restrict negative pricing strategies due to price instabilities and whether any prices changes are permanent or transitory. A policy brief by Ningi, (2025) also showed that there was asymmetric price transmission in the wheat and maize sectors. The main reasons for this asymmetry were market concentration, pricing strategies, inflexible costs and regulatory challenges (Ningi, 2025).

Table 6: Bound test for asymmetric cointegration

	Maize	**Wheat**	
		Brown bread	White bread
Statistic	NARDL (6) model with LR and SR Asymmetry	NARDL (1) model with LR and SR Asymmetry	NARDL (1) model with LR and SR Asymmetry
F_{PSS}	43.121***	19.991***	20.169 ***
t_{BDM}	-9.040 ***	-4.761***	-4.708 ***
1% (5%) level of significance, the pair of CV (bounds) for PSS and BDM statistic are 6.84 to 7.84 (-4.94 to -5.73) and -3.967 to -4.53 (-3.39 to -3.93).		1% (5%) level of significance, the pair of CV (bounds) for PSS and BDM statistic are 6.84 to 7.84 (-4.94 to -5.73) and -3.97 to -4.55 (-3.41 to -3.96).	

Note: CV represent the critical values. **, *** is significant at 5 and 1%

Table 7 presents the test results for price transmission in both the maize and wheat markets. The results indicate a significant relationship between producer and retail prices across all models. For the maize market, the NARDL model with both long-run (LR) and short-run (SR) asymmetry reveals a strong relationship, with a W_{LR} statistic of 23.1, significant at the 1% level. When short-run symmetry is imposed, price transmission remains significant, with a W_{LR} value of 63.49. The W_{SR} statistic for maize also confirms short-run price transmission, with a value of 3.323, significant at the 1% level. For the wheat market, the results for brown bread indicate a robust price transmission mechanism. The NARDL model with LR and SR asymmetry shows a highly significant W_{LR} value of 12.02, while short-run symmetry yields a significant W_{LR} statistic of 24.13, confirming a strong link between producer and retail prices. Similarly, for white bread, the W_{LR} statistic of 3.588 (significant at the 10% level) in the asymmetric model and 19.14 (significant at the 1% level) in the symmetric model further confirm strong price transmission. Short-run price adjustments in the wheat market display no significant asymmetry, once tested formally via the Wald test. For brown bread, the W_{SR} statistic is 0.743, which is not significant, indicating no evidence of short-run asymmetry for brown bread once tested formally via the Wald test. For white bread, the W_{SR} value is 0.069, which was significant, indicating evidence of short-run asymmetry for white bread. The results suggest that long-run price transmission is significant for both maize and wheat. The formally tested short-run asymmetry (via the Wald test) is only present in both the maize market and white bread short-run asymmetry which rejects the null of symmetry. The differences in transmission strength highlight the varying dynamics of price adjustments across agricultural commodities, likely influenced by supply chain structures, market competitiveness, and external economic shocks.

These results suggest that maize and bread markets behave quite differently when producer prices change. In the maize market, retail maize meal prices respond quickly and fully when producer prices rise but respond more slowly and only partially when producer prices fall increases are passed on to consumers almost immediately, while decreases take longer to reach

the shelf and are not fully passed through. On the other hand, the white bread market displays the same asymmetric pattern, with retail prices adjusting quickly to producer price increases but lagging and incomplete adjustment following decreases. In contrast, the brown bread market behaves differently. Notably, retail prices adjust to producer price increases and decreases at a broadly similar pace and to a similar extent, in both the long run and the short run, with the Wald tests failing to reject short-run symmetry.

Table 7: Long- and short run symmetry test

	Maize		**Bread** (Brown)		White	
Statistic	Producer to retail price transmission		Producer to retail price transmission			
	NARDL model with LR and SR asymmetry	NARDL model with SR symmetry imposed	NARDL model with LR and SR asymmetry	NARDL model with SR symmetry imposed	NARDL model with LR and SR asymmetry	NARDL model with SR symmetry imposed
W_{LR}	23.1 ***	63.49 ***	12.02 ***	24.13 ***	3.588 *	19.14 ***
W_{SR}	3.323 ***		0.069		0.743	

Note: W_{LR} denotes the Wald test for the null of long-run symmetry. W_{SR} denotes the Wald test for the null of the additive (weak-form) symmetry. p-values are displayed in parentheses. ** and *** denotes rejection of the null hypothesis of symmetry at the 5 and 1% levels.

Tables 8 and 9 presents the parameter estimates and diagnostic test results for the NARDL models analysing price transmission in maize, white bread, and brown bread. The results for retail maize meal prices indicate a strong price transmission mechanism. The long-run asymmetric effects show that an increase in producer prices lpp_{t-1}^{+} leads to a 0.088 rise in retail prices, while a decrease lpp_{t-1}^{-} results in a slightly smaller impact of 0.077. The short-run dynamics also show significant effects, though the model does not decompose these lagged terms into separate positive and negative components: a one-month lagged producer price change reduces retail prices by 0.367, a two-month lag reduces prices by 0.130, a three-month lag increases prices by 0.174, and a four-month lag reduces prices by 0.112 (all significant at the 5% and 1% levels). Similar findings are observed in Emediegwu and Rogna (2024) who also found strong price transmission mechanisms from markets like maize, rice and wheat in developing countries. The R-squared value was 0.419, and there was no presence of heteroskedasticity as suggested by a non-significant Breusch-Pagan test. Together, these diagnostics suggest that the model is both well-fitted and statistically reliable, supporting the validity of the observed asymmetric price transmission effects. In practical terms, this means that when producer prices for maize rise, retailers pass on more of that increase, and pass it on faster, than when producer prices fall. Consumers therefore feel the full effect of price hikes quickly but only see partial and delayed relief when producer prices ease.

Table 8: NARD estimation results for retail maize meal price

Maize model			
Var	Coeff	Std error	P-value
lrp_{t-1}	-0.133	0.032	0.000 ***
lpp_{t-1}^{+}	0.088	0.018	0.000 ***
lpp_{t-1}^{-}	0.077	0.159	0.000 ***
Δlpp_{t-1}	-0.367	0.064	0.001 ***
Δlpp_{t-2}	-0.130	0.050	0.027 **

	Δlpp_{t-3}	0.174	0.050	0.019 ***
	Δlpp_{t-4}	-0.112	0.050	0.071 **
cons		0.106	0.031	0.002 ***
Asymmetry statistics long-term effect				
		Coeff	F-static	p-value
	βlpp^{+}	0.663	0.034	0.000 ***
	βlpp^{-}	-0.580	0.043	0.000 ***
Statistics diagnostics				
R^2				0.419
Adj R				0.369
Portmateau test			53.388	0.076
Breusch–Pagan			0.044	0.833
Ramsey test			1.536	0.206
Jarque-Bera			1.217	0544

Note: The superscripts "+" and "–" denote positive and negative partial sums, respectively. $\beta^{+}$and β^{-} are the estimated asymmetric long-run coefficients associated with positive and negative changes, respectively. p-values are displayed in parentheses. *** and ** denote significance at the 1 and 5% levels, respectively. $lrp\ and\ lpp$ denotes logged retail price for maize meal and logged maize producer price.

Furthermore, in the white and brown bread markets, the estimated coefficients indicate strong asymmetric price transmission. The long-run estimates show that a 1% increase in producer prices lpp_{t-1}^{+} leads to a 0.044 increase in white bread prices and a 0.060 increase in brown bread prices, while negative shocks lead to a 0.037 decrease in white bread prices and a 0.046 decrease. For white bread, the short-run coefficients are consistent with this pattern, with upward price adjustments exerting a slightly stronger effect than downward ones, in line with the significant short-run asymmetry confirmed by the Wald test. For brown bread, by contrast, the short-run coefficients show no meaningful difference between upward and downward adjustments, consistent with the Wald test's failure to reject short-run symmetry. In practical terms, white bread prices respond faster and more fully to producer price increases than to decreases, mirroring the pattern seen in the maize market, while brown bread prices adjust to increases and decreases at a broadly similar pace. Similar findings are observed in Emediegwu and Rogna (2024) who also found strong price transmission mechanisms from markets like maize, rice and wheat in developing countries. The diagnostic tests for both bread models indicate no autocorrelation (Portmanteau test) but some heteroskedasticity in the white bread model (Breusch-Pagan test p = 0.002). The Ramsey RESET test suggests no misspecification for both white bread model (p = 0.507) and brown bread model (p = 0.644). The Jarque-Bera test results indicate that the error terms are not normally distributed in both models. Worth noting, while these violations do not bias the long-run and short-run coefficient estimates, they may compromise the reliability of the associated standard errors and significance tests; given the relatively large sample size, however, the estimators are expected to be reasonably well-behaved asymptotically.

Table 9: NARD estimation results for retail bread prices

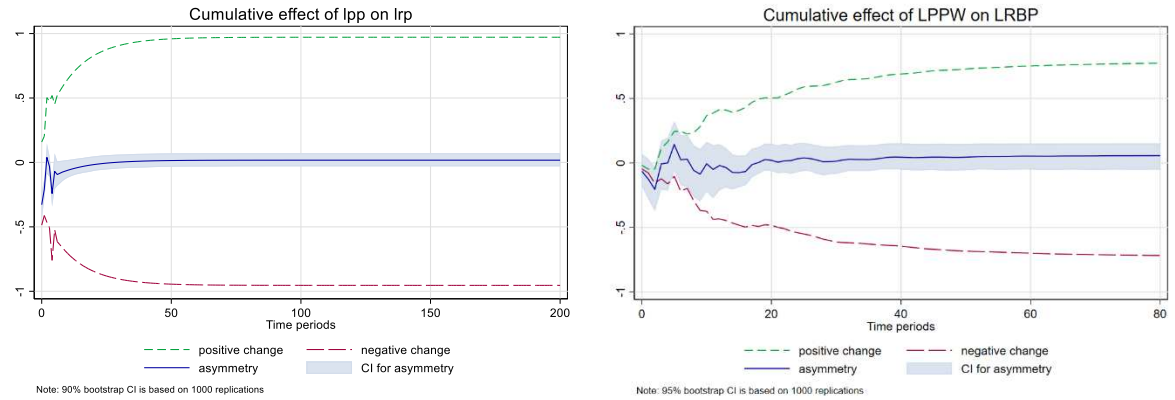
White bread				**Brown bread model**			
Var	Coeff	Std error	P-value	Var	Coeff	Std error	P-value
lrp_{t-1}	-0.062	0.019	0.001 ***	$lrwp_{t-1}$	-0.095	0.022	0.000 ***
lpp_{t-1}^{+}	0.044	0.089	0.000 ***	lpp_{t-1}^{+}	0.060	0.011	0.000 ***
lpp_{t-1}^{-}	0.037	0.081	0.000 ***	lpp_{t-1}^{-}	0.046	0.010	0.000 ***
Δlpp_{t}^{+}	0.062	0.299	0.037 **	Δlpp_{t-3}^{+}	0.088	0.038	0.022 **
Δlpp_{t-3}^{+}	0.059	0.032	0.070 *	Δlpp_{t-3}^{-}	-0.070	0.041	0.089 *
Δlpp_{t}^{-}	0.105	0.037	0.006 ***				

Δlpp_{t-1}^{-}	-0.061	0.036	0.099 *				
cons	0.091	0.299	0.000	cons	0.134	0.032	0.000 ***
Asymmetry statistics long-term effect							
	F-static		P-value		F-Static		P-value
βlpp^{+}	0.711		0.000 ***		0.628		0.000 ***
βlpp^{-}	-0.603		0.000 ***		-0.487		0.000 ***
Statistics diagnostics							
R^2			0.294				0.224
Adj R			0.258				0.210
Portmateau test	32.989		0.776		36.554		0.626
Breusch–Pagan	0.999		0.002		0.213		0.644
Ramsey test	0.778		0.507		0.041		0.989
Jarque-Bera	130.632		0.000		621.812		0.000

Note: The superscripts "+" and "–" denote positive and negative partial sums, respectively. $\beta^{+}$and β^{-} are the estimated asymmetric long-run coefficients associated with positive and negative changes, respectively. p-values are displayed in parentheses. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively. $lrp, lrwp. lpp$ denotes logged retail price for brown bread, logged retail price for white bread and logged wheat producer price.In terms of magnitude, the long-run effects captured by β^{+} and β^{-} highlight the asymmetric transmission of price shocks in the maize and wheat markets. For retail maize meal prices, both positive (β^{+} = 0.663, p = 0.000) and negative (β^{-} = -0.580, p = 0.000) producer price shocks significantly affect retail prices, suggesting that both cost increases and decreases are passed through, though not necessarily at the same rate. This indicates a relatively strong price transmission mechanism in the maize meal market. For retail bread prices, the results show a similar pattern across both white and brown bread. The long-run estimates reveal that positive and negative producer price shocks differ in magnitude, with the positive coefficient exceeding the negative one in absolute terms for both products (β^{+} = 0.711, p = 0.000; β^{-} = -0.603, p = 0.000) for white bread, and for brown bread (β^{+} = 0.628, p = 0.000; β^{-} = -0.487, p = 0.000). Rather than being more symmetric than maize meal, the absolute gap between the positive and negative long-run coefficients is, if anything, larger for bread (0.108) for white bread and (0.141) for brown bread than for maize meal (0.083), and the long-run Wald tests reported in Table 7 confirm that this asymmetry is statistically significant for all three products, at the 1% level for maize meal and brown bread and the 10% level for white bread. In other words, long-run price transmission is asymmetric across both value chains, and the degree of asymmetry is, by this measure, at least as pronounced in the wheat-to-bread chain as in the maize chain. However, the short-run dynamics reveal notable differences. In the maize meal model, lagged changes in producer prices (Δlpp) exhibit significant effects at lags 1 through 4. The estimated one- to four-month lag coefficients are -0.367, -0.130, 0.174 and -0.112 respectively (see Table 8), indicating that short-run pass-through is not instantaneous but builds up over several months. In contrast, for white and brown bread, the short-run estimates are explicitly decomposed into positive and negative components and show negative and significant responses to producer price shocks at different lags, with larger negative effects suggesting potential downward price rigidity. Put simply, both maize meal and bread prices show statistically significant long-run asymmetry between price increases and decreases, of a broadly similar or greater magnitude in the bread market; the clearer contrast between the two chains is that only the bread models formally test and decompose asymmetry in the short run, whereas the maize meal model's short-run terms are estimated without a positive/negative split.

Overall, the results reveal a more nuanced contrast between the maize and wheat value chains than a simple "long-run symmetric, short-run asymmetric" split. In the maize market, both long-run and short-run asymmetry are statistically significant (Table 7: W_{LR}= 23.1, W_{SR} = 3.323, both significant at the 1% level), with positive producer price shocks transmitted more strongly to retail prices than negative shocks, consistent with the "rockets and feathers" pattern documented in other developing-country cereal markets. In the wheat-to-bread market, long-run asymmetry is also statistically significant for both brown bread (W_{LR} = 12.02, 1% level) and white bread (W_{LR} = 3.588, 10% level), so the long-run pass-through of positive and negative producer price shocks cannot be described as symmetric; if anything, the raw gap between the positive and negative long-run coefficients is somewhat larger for bread than for maize meal. Where the wheat-to-bread chain does differ from maize is in the short run: the Wald tests for short-run asymmetry are not significant for brown bread (W_{SR} = 0.743) while significant for white bread (W_{SR} = 0.069) and maize meal shows significant short-run asymmetry. These results suggest that both value chains exhibit persistent long-run asymmetry consistent with market power effects, while the maize meal and white bead chain additionally displays statistically significant short-run asymmetry that is not formally detected in the brown bead.

Figure 6 presents the dynamic multipliers of price transmission from producer to retail level for maize meal (Figure 6(a)) and for white and brown bread (Figure 6 (b)). For maize, retail prices respond to positive and negative producer price shocks at a similar rate immediately after the shock, but the two paths diverge over time: the cumulative response to a price increase settles at a higher level than the cumulative response to a price decrease of the same size, and full equilibrium correction is only reached after approximately 15 months. For bread, the long-run asymmetry between the positive and negative multipliers is statistically significant for both brown and white bread (Table 9). The positive multipliers again settle above the negative ones, at approximately 0.71 versus 0.60 for white bread and 0.62 versus 0.48 for brown bread, in line with the milder long-run asymmetry found for these chains in Table 7. Notably, the asymmetry series (the difference between the two multipliers) settles at a small positive value rather than returning to zero, and its 95% bootstrap confidence interval excludes zero over much of the adjustment horizon, reinforcing the statistically significant long-run asymmetry reported for both brown and white bread in Table 7. Consistent with this, the two multipliers should not be read as converging to the same long-run level.



(a) (b)

Figure 6: Dynamic multipliers. Producer to retail (a) Maizemeal and (b) brown and white bread

Conclusions and policy recommendations

This study examined APT in South Africa's maize and wheat value chains using an NARDL model. The findings reveal that in the maize market, particularly between producer prices and retail maize meal prices, there is strong evidence of both long-run and short-run asymmetries. Price increases at the producer level are transmitted to consumers more quickly and fully than price decreases, confirming the "rockets and feathers" phenomenon. In contrast, wheat-based products, such as brown and white bread, exhibit relatively more symmetric price adjustments in the long run. In the short run, this asymmetry is statistically confirmed for white bread but not for brown bread, which adjusts to producer price increases and decreases at a broadly similar pace. Causality tests reveal a different pattern: the maize chain shows only unidirectional causality, running from producer to retail prices, while the wheat chain shows bidirectional causality between producer and brown bread prices, and significant unidirectional causality from producer to white bread prices. Structural break analysis also reveals that major events, such as the COVID-19 pandemic and global market disruptions, have significantly altered price transmission patterns over time. These findings suggest the presence of market rigidities and possible market power, especially in the maize sector, where a few vertically integrated firms may influence pricing behaviour. The high-cost share of raw maize (approximately 75%) in maize meal production further amplifies the transmission of price shocks to consumers.

These adjustment speeds carry practical implications for consumers, producers, and policymakers. For consumers, the slow, asymmetric adjustment in the maize market means that relief from falling producer prices is delayed and only partially passed through, while cost increases reach the shelf quickly and in full, effectively imposing a persistent affordability penalty on a staple food that lower-income households rely on most heavily. White bread shows a similar, if milder, pattern, meaning this affordability penalty is not confined to maize alone. For producers and retailers, the faster and larger pass-through of price increases than decreases suggest limited competitive pressure to share cost savings with consumers, which is consistent with the concentrated structure of maize milling and retail described earlier in the paper. For policymakers, the extended maize adjustment period strengthens the case for the price-monitoring and transparency measures recommended below. Brown bread's lack of statistically significant short-run rigidity is instructive here: it shows that such short-run pass-through delays are not an inevitable feature of South African staple food markets and can plausibly be narrowed through targeted intervention, even though the same cannot yet be said for maize or white bread.

Based on these insights, several policy recommendations are warranted. Firstly, competition enforcement should be strengthened through concrete, sector-specific mechanisms rather than general monitoring. The Competition Commission should conduct a follow-up market inquiry specifically into maize milling and retail margins, similar in scope to its 2021 essential food pricing inquiry, with the power to compel disclosure of cost and margin data from the small number of dominant millers and retailers identified in this study. Given the precedent set by the 2014 wheat flour cartel case (Mncube, 2014), the Commission should also introduce routine ex-post margin audits for example, an annual review comparing changes in producer prices to

changes in retail maize meal and bread prices with automatic referral for investigation where retail prices rise faster than, or fall more slowly than, producer prices by a specified threshold.

Secondly, market transparency should be enhanced through a mandatory, publicly accessible price-margin dashboard, maintained by the National Agricultural Marketing Council or a similar body, that tracks the monthly spread between SAFEX producer prices and average retail prices for maize meal, white bread, and brown bread. Millers and major retailers above a defined market-share threshold should be required to report cost breakdowns (grain, milling, distribution, and retail margin components) on a quarterly basis, mirroring the disaggregated cost-reporting requirements the Competition Commission has already used in prior food-sector inquiries, so that widening margins can be flagged and investigated before they become entrenched.

Study limitations and future areas of research

This study is subject to limitations that should be considered when interpreting its findings. Firstly, the analysis relies exclusively on the NARDL framework; while this approach is well suited to detecting asymmetric long-run and short-run price relationships, it cannot itself identify the underlying cause of the asymmetries observed, and the market power explanation offered above should accordingly be read as one plausible interpretation among others. Secondly, the bivariate specification, following common practice in this literature, does not control for other potentially relevant factors, such as exchange rate movements, input costs (e.g., fuel, fertiliser, and electricity), or import volumes, any of which could independently influence retail prices and confound the estimated relationships. Finally, the retail price series are national averages drawn from formal retail outlets, as noted earlier, and cannot capture regional price variation or price behaviour in informal markets, which may differ from the patterns identified here.

Acknowledgements

The author gratefully acknowledges the anonymous reviewers for their valuable comments and suggestions, which greatly improved the quality of this manuscript.

Availability of data and materials

Data is freely available online (StatsSA, 2026; SAGIS, 2026)

Declarations

Competing interests

None.

Informed consent

This article does not contain any studies with human participants performed by any of the authors

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