Economic Research Southern Africa

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ERSA working paper 926

March 2026

Quantifying the impact of international food price spillovers on the South African domestic market: Short- and long-term dynamics and transmission channels

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Abstract

This study quantifies the degree of return and volatility risk transmission from the global food market to the South African food market for the period from January 2010 to December 2023. It employs the TVP-VAR-based frequency connectedness to quantify and observe the evolution of both return and volatility risk transmission from the global food market to the South African food market. It also uses the quantile regression technique to identify the main driving factors of both return and volatility spillover from the international food market into the South African market. Results show a slightly higher level of return connectedness than volatility connectedness among the food markets and that shocks from the global food market dominate shocks from the South African food market. While return shocks appear to be more of a short-term phenomenon, volatility shocks are mainly driven by long-term factors. The degrees of shocks transmission are significantly higher when we use the five main global food types (meat, dairy, cereals, oil, and sugar) instead of the composite index of global food prices, especially in terms of volatility. In addition, an increase in geopolitical risks, equity market returns in South Africa, oil prices, and the COVID-19 pandemic were the main drivers of the transmission of return risk from the global food market to the South African food market. However, the depreciation of the Rand value decreased the spillover level. Regarding volatility risk transmission, the gold price, the South African equity, and the fixed income market return are the main drivers of volatility shock transmission from the global food market into the South African food market. The study recommends that South Africa strengthen domestic food production and diversify to build resilience against global food market shocks, especially by supporting vulnerable crops like barley, sorghum, and wheat. Policymakers should also implement strategic reserves, develop short-term risk management tools, integrate energy and food policy, monitor financial-commodity market linkages, and apply macroprudential regulations to mitigate the impact of global return and volatility spillovers on local food markets.

Keywords: Inflation; Food prices; Risk transmission; Driving factors; Frequency-based connectedness; South Africa

JEL: C13; C32; C31

1 Introduction

The concept of price stability dates back to early economic thought and the formation of stable economies centuries ago. Interestingly, it has become increasingly more important due to its interrelationship with other key macroeconomic objectives. Food price stability, in particular, is linked to at least four of the United Nations' Sustainable Development Goals (SDGs), namely Goal 8 - decent work and economic growth, Goal 10 - reduced inequalities, Goal 2: zero hunger, and Goal 12 - responsible consumption and production. Its ability to spread across economies is also worth noting due to increasing globalization and global value chains. The recent twin crisis of the COVID-19 pandemic and the Russia-Ukraine war revalidated the notion of the interconnectedness of macro economies, the reality of spillover effects, and the need to be cautious of transmission channels that tend to import potential instruments of destabilisation, such as inflation.

Fluctuations in international food prices can potentially affect domestic food inflation, influencing the cost of living and economic stability, and could translate to worrying leaps of domestic inflation. The extent to which international food price spillovers impact the domestic economy varies with country characteristics; therefore, there is a need to quantify the impact at the country level. Although South Africa is the country with the most self-sufficient food production in the SADC region, it is still exposed to global food import shocks. For example, sorghum import increased from 768 tons in 2022 to 35,000 tons in 2023 in South Africa (Department of Agriculture, Land Reform and Rural Development South Africa, 2023) and only 42. 6% self-sufficiency in wheat in 2020 (International Trade Administration, United States of America, 2024). In addition, quantifying the impact of food import shocks is relevant for South Africa as a country and to the region that depends on South Africa for monetary stability and agricultural supplies.

Four key factors that could determine the impact of international food price spillovers on domestic markets include market integration and supply chain efficiency, economic factors such as exchange and inflation rates, government interventions, and geopolitical stability. South Africa is arguably one of the countries with the highest predisposition to these factors in Africa. South Africa belongs to the Southern African Development Community, African Union, Common Market for Eastern and Southern Africa, Southern African Customs Union, African Continental Free Trade Area, and BRICS regional integrations, as well as several other bilateral trade and non-trade alliances with other countries, which makes its South African economy highly integrated. Regarding overall regional integration, the 2019 African Regional Integration Index report ranked South Africa first among 54 African countries with an index of 0.625 (United Nations Economic Commission for Africa; African Union Commission; African Development Bank, 2019).

Since the apartheid era, South Africa has registered a number of geo-political tensions which include some records of xenophobic violence attacks, labour strikes and industrial actions, political fragmentations, as well as global shocks such as the global financial crisis, the COVID-19 pandemic and the Russia-Ukraine war. In particular, inflation in South Africa rose by about 120% from 3.2% in 2020 (in the wake of the COVID-19 pandemic) to 7% in 2022 (World Bank, 2024). This is an indication of a correlation and potential causation relationship between the COVID-19 crisis and inflation in South Africa. Such a huge increase in inflation has the potential to increase unemployment, dependency ratio, poverty, reduce welfare, and create civil unrest. For example, the total South African unemployment rate (% of labour force) increased from 29.2% to 33.3% during the same period (World Bank 2024). So, understanding the extent to which spillover effects drive inflation is essential to address inflation in general. In the past, the South African government has implemented several commendable measures to address inflation targeting. Some of them include inflation targeting in 2000, tightening monetary policy between 2002 and 2003, interest rate hikes between 2006 and 2008 and 2014 and 2016, interest rate cuts during the 2008-2009 global financial crisis, and the monetary policy response to COVID-19 in 2020. However, the statistical evidence shown above suggests that these theories have not been very effective in curtailing the spillover effects. Moreover, the dynamism of global connectedness and human expectations that largely drive inflation require frequent empirical analysis of the impact of international prices in general and international food prices in particular, on the South African domestic market.

The dangers of international food price spillovers on domestic economies are well-detailed in the literature. In the short run, it can intensify inflationary pressures in the South African economy leading to monetary policy challenges (Ha et al., 2019; Adams & Ichino, 2020), reducing purchasing power leading to consumer hardship (Timmer, 2015; World Bank, 2021), and can translate into social unrest and political instability (Bellemare, 2015). In the long run, it could lead to food insecurity issues (Rakotoarisoa, et al., 2011), exacerbate economic inequality and rural poverty (Ivanic & Martin, 2008; High Level Panel of Experts on Food Security and Nutrition, 2011), and could spur up structural economic issues such as deterring investors and/or the need for resource re-allocation (von Braun, 2008; FAO, 2011).

Nevertheless, the key empirical studies on food price inflation in South Africa that are close to the focus of this study, only include Van Wyk and Dlamini (2018), Iddrisu and Alagidede (2020), Sikuka (2021) and Nell (2000). Our study contributes to the exiting empirical literature in that, it employs robust econometric techniques – the novel Time-Varying Parameter Vector Autoregressive (TVP-VAR) based frequency Connectedness, to quantify the level of international food price spillovers on domestic food inflation in South Africa, distinguishing short-term volatility from longer-term structural effects and will also identify the transmission channels through which international food inflation contributes to domestic food inflation. The channels examined include exchange rates, equity markets (wealth), commodity markets (crude oil and gold), and geopolitical tensions. TPV-VAR is advantageous because it improves forecasting accuracy, better handles nonlinearities and captures structural changes over time. Beyond identifying the short-term volatility and long-term dynamics of international food price spillovers on domestic inflation, the study provides tailored policy solutions that address both immediate and long-term challenges.

Several empirical works highlight key determinants of inflation in South Africa, but the quantification of the impact of international food price spillovers on South Africa is not yet adequately clear and in any case needs to be re-investigated in light of the current macroeconomic realities and global connectedness. It is on this premise that this study seeks to respond to the question: to what extent do short and long-run dynamics impact food price spillovers in the South African domestic market, and what are the potential transmission channels? Specifically, the study seeks to:

- Quantify the impact: Assess the level of international food price spillovers on domestic food inflation in South Africa, distinguishing short-term from longer-term dynamics.
- Identify transmission channels: Examine the various channels through which changes in international food prices are transmitted to South Africa, including exchange rates, equity markets, commodity markets, and geopolitical tensions.
- Infer policy implications: Provide policy recommendations based on the findings to help policymakers in South Africa mitigate the adverse effects of international food price fluctuations on domestic food inflation.

This study contributes valuable insights into the mechanisms through which international food prices influence food inflation within the South African context. This section will be followed by a detailed review of the theoretical and empirical literature on the subject in section 2. Section 3 presents the data sources and description as well as the empirical strategy used to ascertain the objectives. Section 4 discusses the results and policy inferences while section 5 constitutes the conclusion and recommendations inferred from the findings.

2 Literature review

This section examines the theoretical and empirical foundation linking internal food price fluctuations to domestic markets. Theoretically, the Cost of Production Theory, tested by Cobb and Douglas in 1928, asserts that prices are influenced by the costs incurred by producers in producing goods and services. The prices charged by producers need to cover their costs, including raw materials, labour, and overheads. In competitive markets, prices tend to gravitate towards the cost of production in the long run. The cost of production theory confirms the cost push theory, which became popular during the 1970s, when most economies experienced stagflation. The theory was developed by John Maynard Keynes, who focused more on the demand side in his work in "The General Theory of Employment, Interest and Money (1936). Also, authors such as Gordon (1985) added to this theory, focusing on the supply side, highlighting how an increase in the cost of production may lead to an increase in the final goods.

The Volatility transmission theory has evolved through the contribution of various researchers. These include studies such as Gardner (1975), Heien (1980), Wohlgenant (1989), Holloway (1991) and McCorriston et al. (1998; 2001), which explain the impact of international price fluctuations. Gardner (1975) examined the relationship between farm and retail prices. The partial equilibrium framework involves a linear approximation of the price change and quantity of inputs arising from new technology and weather conditions. Exchange rate volatility is heavily influenced by responses to risks and uncertainties due to commodity financialisation and hedging (Thuy & Thuy, 2019). This demonstrates, among others, that the openness of an economy to international exchange remains a vital mechanism through which the international economic environment influences the domestic market.

Price transmission theory is developed and studied by economists (Baffes & Gardner 2003; Posner, 2014). The theory argues that changes in international food prices can have a direct impact on domestic prices through a variety of mechanisms. Furthermore, price transmission theory is closely related to market integration and measured in terms of transmission elasticity, which is defined as the percentage change in one market's price that results in a percentage change in another. Price shocks between supply chains, markets, or related markets are essential for market integration to occur (Zungo & Kilima). Furthermore, the inter-commodity price transmission theory posits that price changes in one commodity can affect prices in another related commodity. The inter-commodity price transmission theory is more important when the products are complementary or substitutes. Researchers, including Mishra (2023) and Morale et al. (2021) have contributed to the theory by analysing the relationships and price dynamics between agricultural products.

On the empirical angle, Selliah et al. (2015) empirically posit that domestic prices in Sri Lanka are co-integrated with global food prices, demonstrating that while domestic policies can impact pricing, they cannot insulate the home market from global price patterns over time. Similarly, Mittal et al. (2018) highlighted that excessive volatility in food prices produces uncertainty and can negatively influence the food supply chain and societal development, underlining the importance of effective policy responses to offset these effects. International food price shocks were found to considerably impact local price indices in Latin America, implying that domestic inflation is tightly linked to global price movements (Jalil & Zea, 2011). Garcia-German et al., (2016) concluded within European economies that consumer prices in different member nations respond differently to specific international price indices, indicating some variations in the structure and efficiency of respective food markets. Yao and Cao (2015) used co-integration analysis to examine the link between soybean import volume, domestic price, and international price. Their findings indicated that import volume and international prices influenced domestic soybean prices. During the global food crisis of 2007 to 2008, Baltzer (2014) noted that South Africa had a close link between international and domestic prices, unlike other countries where such transmission was negligible.

Ramoroka and Muchopa (2022) investigated the price transmission of maize and wheat in South Africa, discovering that international price fluctuations for these important commodities considerably impact domestic prices. This inter-commodity relationship is critical for understanding how global price shocks disseminate across the domestic market. This is supported by the findings of Ianchovichina et al. (2014), who discovered that the transmission of worldwide price movements to domestic prices is frequently asymmetric, with rises in global prices being more readily reflected in local markets than declines. Minot (2011) investigated the transmission of prices from global grain markets to 60 markets in Sub-Saharan Africa, revealing a statistically meaningful long-term link in just 13 of the 62 prices investigated. He also discovers that rice prices are more closely related to world markets than maize prices, likely because most African countries are nearly self-sufficient in maize but import a major portion of their rice requirements. Robles and Torero (2010) discovered empirical evidence of price transmission from foreign markets to domestic pricing for many food goods in four Latin American nations. Ceballos et al. (2017) investigated the short-term price and volatility transmission from main grain commodities to 41 domestic food products across 27 African, Latin American, and South Asian nations. In terms of price transmission, they only found significant interactions between international and domestic markets in a few circumstances. Only one-quarter of the maize markets evaluated showed statistically significant volatility transmission, but more than half of the rice markets and all wheat markets did. Volatility transmission appears to be more likely when trade (imports or exports) is large relative to domestic needs.

Birthal et al. (2019) identified production shocks, seasonality, internal trade, export policies, and intermediaries' market strength as variables driving onion price volatility in India. A study conducted in Iraq found that fluctuations in crude oil prices considerably impact food prices, highlighting the interconnectivity of international resource price fluctuation and food markets (Mohammed, 2022). Furthermore, Udoh and Egwaikhide demonstrate that international oil price volatility significantly affects domestic food price instability in Nigeria. Anderson (2012) shows that while some governments try to protect their internal markets from worldwide price changes by trade restrictions, such efforts frequently result in increased volatility rather than stability.

Ertuğrul and Seven (2023) analysed dynamic spillovers between international and Turkish food prices using several methods, including Autoregressive Distributed Lag (ARDL), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Markov Switching Regression (MSR). The results, particularly from the MSR and DCC GARCH approaches, revealed structural adjustments in food price dynamics, with varying associations between low and high volatility regimes. These findings are consistent with those of Baffes and Dennis (2013). The ARDL, FMOLS and DOLS models showed a positive relationship between exchange rate increases and Turkish international food prices. Furthermore, an increase in oil prices decreased both Turkish and global food prices.

Monteiro and Jammer (2024) investigated the price spillover dynamics between the grain and livestock markets in South Africa, highlighting how fluctuations in global grain prices may lead to corresponding changes in local livestock prices. The study's findings suggest that domestic markets are sensitive to international price movements, which can lead to food inflation and negatively impact food security, particularly for the poor, as emphasised by Van Wyk and Dlamini (2018). The study's findings align with those of Umoru and Amedu (2022), who identified significant volatility spillovers from international to domestic markets. Furthermore, the inter-commodity price transmission theory posits that price changes in one commodity can affect prices in another related commodity. Balcilar and Bekun (2020) explored the spillover dynamics across price inflation and selected agricultural commodity prices in Nigeria. The empirical findings of the study revealed that the total spillover effect was approximately 75 per cent, suggesting a high interconnection of the prices of selected commodities (groundnut, soybeans, sorghum, barley, maize, cocoa, rice, and wheat), commodity prices and inflation. Similarly, Fasanya and Odudu (2020) investigated the spillovers of returns and volatility among the main agricultural commodities in Nigeria, including spillovers in wheat, rice, soybeans, groundnuts, and palm oil. Empirical findings support Balcilar and Bekun (2020), who also found evidence of interdependence among the main selected agricultural commodities.

Similarly, Ling, Deb, and Wenying (2023) analysed the direction and magnitude of price and volatility transmission from international to domestic markets in 42 developing countries using the Multivariate Generalized Autoregressive Conditional Heteroskedasticity framework on monthly price data spanning from January 2003 to November 2022 of major consumed agricultural commodities covering 42 developing countries in the world. Among the 75 sample markets, volatility spillover from their markets is statistically significant for 71 tested markets; volatility spillovers from international to domestic markets are statistically significant for 21 tested markets; and asymmetric effects are statistically significant in 19 tested markets.

Ertuğrul and Seven (2023) suggest that developing countries should address structural challenges in the food supply chain and manage short-term inflationary issues related to unprocessed foods to ensure production sustainability. Conforti (2004) uses an error correction model to study price transmission in 16 countries, three of which are in Sub-Saharan Africa. He generally finds that the extent of price transmission in Sub-Saharan African countries is lower than in Asian and Latin American countries. Akanni (2020) equally settled that directional linkinge exists between food prices and exchange rates, subject to the obtained spillover indexes. Abidoye and Labuschagne (2014) demonstrate that world maize prices significantly influence the South African maize market, with a long-run relationship established through a threshold cointegration approach, indicating that approximately 98% of changes in world prices are eventually transmitted to local prices.

The literature, as mentioned above, demonstrates that the transmission of international food prices to the domestic market is characterised by short- and long-term dynamics driven by various channels, including market integration, domestic policy responses, and socioeconomic factors. The extant literature reveals a high association between global price changes and local food costs. Equally, evidence of limited and recent studies addressing international price spillover to developing regions in general and South Africa in particular is evident. It is within this backdrop that this study examines the impact of international food price spillovers on the South African domestic market. This study will employ the time-varying parameter vector-autoregressive (TVP-VAR) based frequency connectedness model, which is the novel TVP-VAR-based frequency connectedness technique of Ando et al. (2022). This will permit the realisation of risk spillovers across a system of two or more variables across different frequencies, where the frequencies represent different time scales.

3 Data and empirical methods

3.1 Empirical methods

3.1.1 The TVP-VAR-based frequency connectedness model

Following the first objective of this study, we employ the recently introduced technique for frequency connectedness, within the TVP-VAR framework. As noted by Chatziantoniou et al. (2023), this approach is a blend of concepts offered by Barunik and Křehlík (2018) and Antonakakis et al. (2020). Indeed, this method of spillover analysis has been noted to circumvent some limitations of the rolling-window VAR technique, such as the burden of arbitrary selection of window size, loss of observations, and difficulty in adjustment to extreme events, which creates high sensitivity of estimated parameters to outliers.

In simpler terms, the TVP-VAR model allows the relationships between variables to evolve over time rather than remain constant. Unlike traditional VAR models that assume fixed coefficients, TVP-VAR permits the strength and direction of connections between variables to change gradually across the sample period. This flexibility is particularly valuable when analyzing return and volatility spillovers between global food markets and domestic food prices in South Africa, as the nature of these relationships has likely shifted due to changes in trade policies, exchange rate dynamics, structural economic reforms, and varying degrees of market integration over time. The model essentially re-estimates the interdependencies at each time point, capturing how the transmission of price shocks from global food markets to South African domestic prices may have strengthened, weakened, or changed direction across different periods. For example, the relationship between global food prices and South African domestic prices in 2010 may differ from 2023 due to changes in trade policies or market integration. The model continuously updates to capture these shifting dynamics. This technique, therefore, measures how variables influence each other, while allowing these influences to strengthen, weaken, or change direction over time.

The TVP-VAR connectedness model evolves as follows:

$$x_t = \Phi_t x_{t-1} + \epsilon_t, \qquad \epsilon_t \sim N(0, \Sigma_t) \tag{1}$$

$$vec(\Phi_t) = vec(\Phi_{t-1}) + \upsilon_t, \qquad \upsilon_t \sim N(0, R_t) \tag{2}$$

where, x_t, x_{t-1}, and ϵ_t denote vectors with dimension $N \times 1$, corresponding to all food price series at time t, $t-1$, and the associated error term, respectively. Φ_t and Σ_t are NxN dimensional matrices associated with coefficients from the time-varying VAR and the time-varying variance–covariances, while $vec(\Phi_t)$ and υ_t are N^2x1 dimensional vectors, whereas R_t is an N^2xN^2 dimensional matrix, respectively.

Following the Generalized Forecast Error Variance Decomposition (GFEVD) of Koop et al. (1996) and Pesaran and Shin (1998), the estimated TVP-VAR model may be transformed into a moving average (TVP-VMA) equivalence expressed as: $x_t = \sum_{i=1}^{p} \Phi_{it} x_{t-i} + \epsilon_t = \sum_{j=0}^{\infty} \Psi_{jt} \epsilon_{t-j}$. GFEVD may be described as a shock attribution analysis which breaks down price movements to identify what percentage comes from each source. For instance, if South African food prices increase, GFEVD tells you how much of that increase came from global price shocks versus domestic factors. Moreover, Chatziantoniou et al. (2023) note that the GFEVD improves over its orthogonal counterpart by yielding invariant outputs irrespective of variable ordering, which may be recognized as the influence a shock in variable j exerts on variable i relative to its forecast error variance. This may be stated as follows:

$$\theta_{ijt}(H) = \frac{(\Sigma_t)_{jj}^{-1} \sum_{h=0}^{H} ((\Psi_h \Sigma_t)_{ijt})^2}{\sum_{h=0}^{H} (\Psi_h \Sigma_t \Psi_h^{'})_{ii}} \tag{3}$$

$$\tilde{\theta}_{ijt}(H) = \frac{\theta_{ijt}(H)}{\sum_{k=1}^{N} \theta_{ijt}(H)} \tag{4}$$

where $\tilde{\theta}ijt(H)$ denotes the contribution of the jth variable to the variance of the forecast error of the ith variable at horizon H. Based on normalization, the rows of $\tilde{\theta}ijt(H)$ adds up to one, yielding in $\tilde{\theta}ijt$. Besides, following this process, these identities are derived: $\sum i = 1^N \tilde{\theta}ijt(H) = 1$ and $\sum j = 1^N \sum_{i=1}^{N} \tilde{\theta}_{ijt}(H) = N$.

Following this, all the connectedness measures may be obtained beginning with the net pairwise connectedness: $NPDC_{ijt}(H) = \tilde{\theta}_{ijt}(H) - \tilde{\theta}_{jit}(H)$. Hence, $NPDC_{ijt}(H) > 0$ ($NPDC_{ijt}(H) < 0$), which indicates that variable j exerts more (less) influence on variable i than the reverse. Two metrics, TO, and $FROM$ capture the total directional connectedness, respectively expressed as:

$$TO_{it}(H) = \sum_{i=1, i \neq j}^{N} \tilde{\theta}_{jit}(H) \tag{5}$$

$$FROM_{it}(H) = \sum_{i=1, i \neq j}^{N} \tilde{\theta}_{ijt}(H) \tag{6}$$

where the first metric (TO) accounts for the degree to which shocks in variable i propagate to all others j, while the second ($FROM$) is associated with the extent to which variable i is influenced by shocks in all other variables j. Consequently, the total net directional connectedness, calculated as $NET_{it}(H) = TO_{it}(H) - FROM_{it}(H)$ corresponds to the differential influence that variable i exerts on the network. $NET_{it} > 0$ suggests that variable i mostly influences the other variables j instead of being influenced by them, making it a net transmitter of shocks. In contrast, $NET_{it} < 0$ indicates that variable i is more influenced by other variables j, making it a net shock receiver.

The TVP-VAR connectedness technique permits an estimation of the degree of network interconnectedness by capturing the average influence a shock in one variable wields on all other variables. This measure indicates the degree of market risk, with higher values suggesting an increase in risk transmission and vice versa. This may be defined as:

$$TCI_t(H) = \frac{N}{N-1}\sum_{i=1}^{N} TO_{it}(H) \tag{7}$$

$$= \frac{N}{N-1}\sum_{i=1}^{N} FROM_{it}(H) \tag{8}$$

The connectedness measures derived above provide distinct insights into the dynamics of spillover transmission between global and South African food markets. Total Connectedness Index (TCI) represents the overall degree of interdependence across all markets in the system, measuring what percentage of total forecast error variance comes from spillovers rather than own shocks. A higher TCI indicates that markets are highly integrated and shocks readily propagate across borders. TO Others connectedness measures the directional spillover that a specific market transmits to all other markets in the system, indicating its role as a shock transmitter; for instance, high TO Others values for global food markets would suggest they are significant sources of price volatility affecting South African domestic prices. FROM Others connectedness captures the spillover a market receives from all other markets, reflecting its vulnerability or exposure to external shocks; high FROM Others values for South African food prices would indicate strong dependence on global market movements. Net Directional Connectedness, calculated as the difference between TO Others and FROM Others, reveals whether a market is predominantly a transmitter (positive net) or receiver (negative net) of shocks. In the context of food markets, global markets typically exhibit positive net connectedness while small open economies like South Africa show negative net values, confirming their role as net shock receivers. Together, these metrics provide a comprehensive picture of how price shocks and volatility flow between global and domestic food markets, with important implications for food security policy, price stabilization strategies, and understanding South Africa's vulnerability to international commodity price fluctuations.

Whereas the measures above relate to connectedness in the time domain, the TVP-VAR-based frequency connectedness technique extends the analysis to account for connectedness in the frequency domain using the spectral decomposition approach for structural VAR models. Hence, the frequency connectedness technique is a time-horizon spillover analysis that separates spillovers into short-term (days to weeks), medium-term (months), and long-term (years) effects. This matters because a price shock might have immediate impact but fade quickly, or it might take months to fully transmit but then persist. For food markets, short-term connectedness captures daily trading volatility, medium-term captures seasonal and trade patterns, while long-term reveals fundamental market integration. This type of analysis identifies whether spillovers are temporary quick reactions or permanent structural connections by decomposing them across different time horizons. Here, the frequency response function, $\Phi(e^{-i\omega}) = \sum_{h=0}^{\infty} e^{-i\omega h}\Psi_h$, where $i = \sqrt{-1}$ and ω denotes the frequency while the spectral density of x_t at frequency ω, is associated with the Fourier transformation of the $TVP - VMA(\infty)$ as:

$$S_x(\omega) = \sum_{h=-\infty}^{\infty} E(x_t x_{t-h}^{'})e^{-i\omega h} = \Psi_t(e^{-i\omega h})\Sigma_t \Psi_t^{'}(e^{+i\omega h}) \tag{9}$$

The frequency-based GFEVD becomes a fusion of the spectral density and the GFEVD. Similar to the time domain situation, the frequency-based GFEVD is normalize as follows:

$$\theta_{ijt}(H) = \frac{(\Sigma_t)_{jj}^{-1}|\sum_{h=0}^{\infty}(\Psi_t(e^{-i\omega h})\Sigma_t)_{ijt}|^2}{\sum_{h=0}^{\infty}(\Psi_t(e^{-i\omega h})\Sigma_t\Psi_t(e^{+i\omega h}))_{ii}} \tag{10}$$

$$\tilde{\theta}_{ijt}(\omega) = \frac{\theta_{ijt}(\omega)}{\sum_{k=1}^{N}\theta_{ijt}(\omega)} \tag{11}$$

$\tilde{\theta}_{ijt}(\omega)$ denotes the share of the spectrum of the ith variable at a given frequency ω that is due to a shock in the jth variable, and functions as a within-frequency indicator.

In contrast to connectedness at a single frequency, the short- and long-term connectedness may be derived by blending all frequencies within a specific range, $d = (a, b) : a, b \in (-\pi, \pi), a < b$:

$$\tilde{\theta}_{ijt}(d) = \int_a^b \tilde{\theta}_{ijt}(\omega)d\omega \tag{12}$$

Consequently, similar indicators of connectedness may be derived, with similar interpretations while conforming to frequency connectedness that proffer valuable insights about spillovers at specific frequency horizon d:

$$NPDC_{ijt}(d) = \tilde{\theta}_{ijt}(d) - \tilde{\theta}_{jit}(d) \tag{13}$$

$$TO_{it}(d) = \sum_{i=1, i\neq j}^{N} \tilde{\theta}_{jit}(d) \tag{14}$$

$$FROM_{it}(d) = \sum_{i=1, i\neq j}^{N} \tilde{\theta}_{ijt}(d) \tag{15}$$

$$NET_{it}(d) = TO_{it}(d) - FROM_{it}(d) \tag{16}$$

$$TCI_t(d) = \frac{N}{N-1}\sum_{i=1}^{N} TO_{it}(d) \tag{17}$$

$$= \frac{N}{N-1}\sum_{i=1}^{N} FROM_{it}(d) \tag{18}$$

Whereas all these measures offer insights specific to a particular domain, they do not capture the overall impact. Following Barunik and Křehlík (2018), the contribution of each frequency domain measures d relative to the overall system is weighed by, $\Gamma(d) = \sum_{i,j=1}^{N} \tilde{\theta}_{ijt}(d)/N$.

$$N\tilde{P}DC_{ijt}(d) = \Gamma(d)\ .\ NPDC_{ijt}(d) \tag{19}$$

$$T\tilde{O}_{it}(d) = \Gamma(d)\ .\ TO_{it}(d) \tag{20}$$

$$FR\tilde{O}M_{it}(d) = \Gamma(d)\ .\ FROM_{it}(d) \tag{21}$$

$$N\tilde{E}T_{it}(d) = \Gamma(d)\ .\ NET_{it}(d) \tag{22}$$

$$T\tilde{C}I_t(H) = \Gamma(d)\ .\ TCI_t(d) \tag{23}$$

3.1.2 The quantile regression (QR) model

The second phase of our empirical analysis relates to identifying the factors that drive the evolution of spillovers among global food prices and domestic food prices in South Africa. To achieve this, we rely on the QR analysis of Koenker and Bassett (1978). Whereas the QR follows a similar structure to linear regression analysis, it permits us to explore the existence of asymmetric effects of the selected factors on multiple quantiles of the level of spillovers among global food prices and domestic food prices in South Africa. Hence, the QR is a conditional relationship analysis that examines how relationships differ across market conditions. Instead of looking only at average relationships, it analyzes what happens during extreme conditions, when prices are very low (bottom quantile), normal (median), or very high (top quantile). For example, global food price shocks might barely affect South African prices during calm periods but have massive impact during crisis periods. This approach reveals asymmetric effects that average-based methods miss, showing that the relationship between global and domestic food prices may depend on market stress levels. Among other advantages, Conyon and He (2017) argue that whereas the traditional OLS model predicts the average or conditional mean association between an independent variable X and the explained variable Y, the QR technique permits the prediction of specific parts of the distribution of the explained variable, including the conditional median effect on Y of a change in the independent variable X. Hence, with respect to the objectives of this study, the QR approach enables us to uncover potential non-monotonic effects of the chosen factors on the evolution of spillovers among global food prices and domestic food prices in South Africa across its different quantiles.

Our QR model evolves from a baseline OLS specification as follows:

$$r_t = \beta_0 + \beta_1 \gamma_t' + \psi D_t + \nu_t \tag{24}$$

where r_t is the total connectedness index (TCI) retrieved from the TVP-VAR based frequency connectedness analysis described above at time t, while γ_t' is the set of driving factors at time t. The driving factors include indexes of geopolitical risks, monetary policy uncertainty, trade policy uncertainty and the South African equity market. It also includes exchange rate, interest rate, gold and oil prices. D_t represents a crisis dummy associated with the period of the first wave of COVID-19. Specifically, the dummy variable is defined as $D_t = 1$ if the observation t falls within the 1st of January 2020 to 1st of December 2021 timeframe, and $D_t = 0$ if otherwise. ν_t is a random error term.

The QR technique expresses the conditional τth quantile of the dependent variable for some value of $\tau \in (0, 1)$. Thus, the conditional quantile model for q_t, given x_t, may be expressed as:

$$Q_{q_t}(\tau/x_t) = \alpha^\tau + x_t' \beta^\tau \tag{25}$$

where $Q_{q_t}(\tau/x_t)$ denotes the conditional τth quantile of the dependent variable q_t; α^τ represents the intercept, which is set to depend on τ. Also, β^τ is the vector of coefficients associated with τth quantile while *x'* is a vector of explanatory variables. As noted in Koenker and Basset (1978), the coefficients of the τth quantile of the conditional distribution are expressed as a solution to the minimization problem below:

$$\underset{\hat{\beta} \in \Re^k}{min} \left[\sum_{t:\, q_t \geq \alpha^\tau + x_t'\hat{\beta}^\tau} \tau |q_t - \alpha^\tau - x_t'\hat{\beta}^\tau| + \sum_{t:\, q_t < \alpha^\tau + x_t'\hat{\beta}^\tau} (1-\tau)|q_t - \alpha^\tau - x_t'\hat{\beta}^\tau| \right] \tag{26}$$

This may be re-written as a minimization of the weighted deviations from the conditional quantile as follows:

$$\underset{\hat{\beta} \in \Re^k}{min} \sum_t \rho_\tau (q_t - \alpha^\tau - x_t'\hat{\beta}^\tau) \tag{27}$$

where ρ_τ represents a weighting factor known as a check function, expressed for any $\tau \in (0, 1)$ as:

$$\rho_\tau(\xi_t) = \begin{cases} \tau \xi_t, & if \quad \xi_t \geq 0 \\ (\tau - 1)\xi_t, & if \quad \xi_t < 0 \end{cases} \tag{28}$$

where $\xi_t = q_t - \alpha^\tau - x_t'\beta^\tau$. Hence, as noted by past studies, quantile regression represents a weighted regression with different weights assigned to data points, depending on whether the points fall above or below the line of best fit. Put differently, quantile regression technique minimizes the sum of residuals, given that the weight of τ is assigned to positive residuals while the weight of $1 - \tau$ is assigned to negative residuals. This study uses three quantiles (τ = 0.25, 0.50, 0.75), which enables us to capture crucial quantiles of the distribution of the retrieved TCI. The low level of connectedness among global food prices and domestic food prices in South Africa is represented by the 0.25 quantile; the medium is represented by the 0.5, while the higher level is represented by 0.75 quantiles, respectively.

3.2 Data

To analyse the degree of spillovers among global food prices and domestic food prices in South Africa, we use monthly global food price indexes from the Food and Agriculture Organisation (FAO) of the United Nations World Food Situation and major domestic food prices in South Africa for the period from January 2010 to December 2023. We use the FAO Food Price Indexes, which measure the monthly international prices of five main food classes, to derive a composite measure of global food price index (GFPI) using Principal Component Analysis. Indeed, the GFPI corresponds to the first principal component derived from the prices of the five main food types. In our further analysis, we also focus on the connectedness among decomposed world food price indexes using the five commodity group price indexes, including meat (Meatw), dairy (Dairyw), cereal (Cerealw), oilseed (Oilsw) and sugar (Sugerw). This enables us to shed further light on the degree of spillovers from each commodity group price to the South African domestic market. To capture the South African domestic food market, we rely on the prices of seven major food types, including barley (Barley-SA), maize (Maize-SA), oats (Oats-SA), sorghum (Sorghum-SA), soybeans (Soybeans-SA), sunflower (Sunflower-SA), and wheat (Wheat-SA). This enables us to explore the extent of vulnerability and influence of each major food type in South Africa in the presence of external shocks from the global food market.

Furthermore, we examine the factors that drive the evolution of the degree of risk spillovers among global food prices and domestic food prices in South Africa using several factors including the indexes of geopolitical risks (GPRI), Monetary Policy Uncertainty (USMPU), and the South Africa equity market (FTSESA). It also includes the Rand to U.S. dollar exchange rate (RNDUSD), interest rate (TBLRT), gold (GLDPR) and oil prices (OILPR). In particular, to capture the level of monetary policy uncertainty for the world, we used the monetary policy uncertainty of the United States while for the effects of stock market performance in South Africa on food price spillovers, we use the FTSE South Africa index returns. For the effects of exchange rates, we use the Rand to US dollar exchange rate. For interest rates, we use the South Africa 10-year bond rate while for gold and oil markets, we use the spot prices of gold and WTI crude oil. Lastly, we included a dummy variable (COVID) to capture the effect of the COVID-19 pandemic on risk spillover among the food markets in our sample. The dummy variable takes a value of 1 for the period from December 2019 until November 2021 and 0 otherwise. All food price indexes were retrieved from the FAO United Nations database, while the indexes of geopolitical risk and US monetary policy uncertainty were taken from the Policy Uncertainty reports of Baker et al. (n.d.). The remaining variables were retrieved from Refinitiv Eikon Datastream International.

The variables used in the quantile regressions were chosen because they represent the most realistic pathways through which global conditions affect food prices in an open and financially integrated economy like South Africa's. Geopolitical risk captures disruptions in global trade routes, conflict-driven supply shortages and uncertainty shocks that directly shape global food availability. Oil prices were included because energy is a major cost in food transportation, fertiliser production and agricultural machinery, meaning that shifts in oil markets can quickly spill into food prices. Exchange rates reflect South Africa's exposure to imports, while equity and fixed-income market indicators capture how investor behaviour and financial market movements interact with commodity markets. The inclusion of gold and monetary policy uncertainty reflects the role of global and domestic confidence in shaping risk behaviour. Finally, the COVID-19 dummy isolates the effect of a unique crisis that simultaneously disrupted supply chains, labour markets and consumer behaviour.

Geopolitical risks, USA monetary policy uncertainty, and gold prices represent critical global uncertainty channels that amplify food price volatility transmission to South Africa. Geopolitical tensions—including conflicts, trade disputes, and political instability in major food-producing regions directly disrupt global supply chains, restrict trade flows, and create uncertainty that drives speculative activity in commodity markets, thereby intensifying price volatility that transmits to import-dependent economies like South Africa. USA monetary policy uncertainty exerts significant influence through multiple channels: tightening monetary policy strengthens the US dollar, making dollar-denominated food commodities more expensive for emerging markets; higher US interest rates increase storage costs and reduce speculative positions in commodity markets; and monetary policy shifts alter global capital flows, affecting exchange rates and inflation expectations in emerging economies. Gold prices serve as a barometer of global economic uncertainty and risk aversion, with rising gold prices typically signaling flight-to-safety behavior that coincides with increased commodity price volatility; moreover, gold and agricultural commodities often exhibit positive correlation during crisis periods as both serve as inflation hedges, meaning heightened gold price volatility can signal broader commodity market instability that affects food prices.

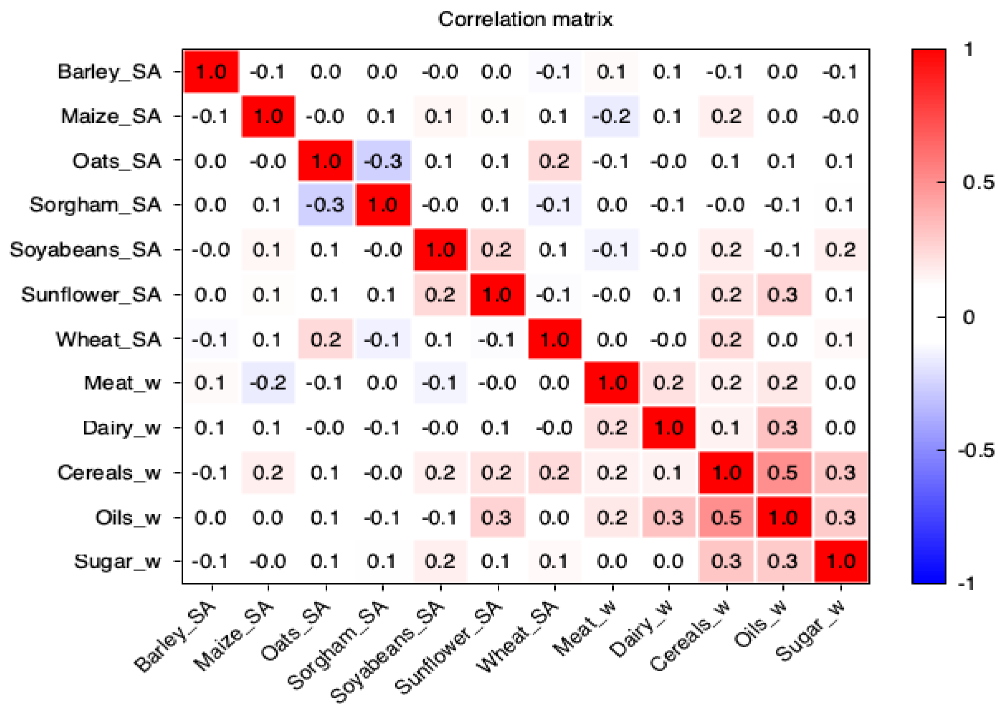
Oil prices and South Africa's 10-year sovereign bond rate capture the energy cost and domestic financial conditions channels through which global shocks transmit to local food markets. Oil prices are fundamental to food production and distribution costs, affecting agricultural input prices (fertilizers, pesticides derived from petrochemicals), transportation and logistics expenses, and the relative profitability of biofuel production that diverts crops from food use; consequently, oil price volatility directly increases food production costs globally and domestically while also serving as a proxy for global inflation pressures that co-move with food commodity prices. The South African 10-year sovereign bond rate reflects domestic macroeconomic stability, inflation expectations, and country risk premium, serving as a critical transmission mechanism for global shocks into the domestic economy. Rising bond yields signal tighter financial conditions, higher borrowing costs for agricultural producers and food retailers, currency depreciation pressures that make food imports more expensive, and broader economic stress that can amplify the pass-through of global food price shocks to consumers. Together, these variables capture the multi-dimensional pathways: supply chain disruptions, monetary conditions, energy costs, and domestic financial stability, through which global food market volatility propagates into South African domestic food prices, providing a comprehensive framework for understanding spillover dynamics in an emerging market context.

Table 1 presents the descriptive statistics for both return and volatility of food prices. As may be seen, all food prices exhibited positive returns during the period under study except for the price of sugar in the global market. Also, Sunflower has the highest price return while Sugar has the least. In terms of volatility, the Barley market in South Africa appears to be the most volatile, while Meat prices in the world market are the least.

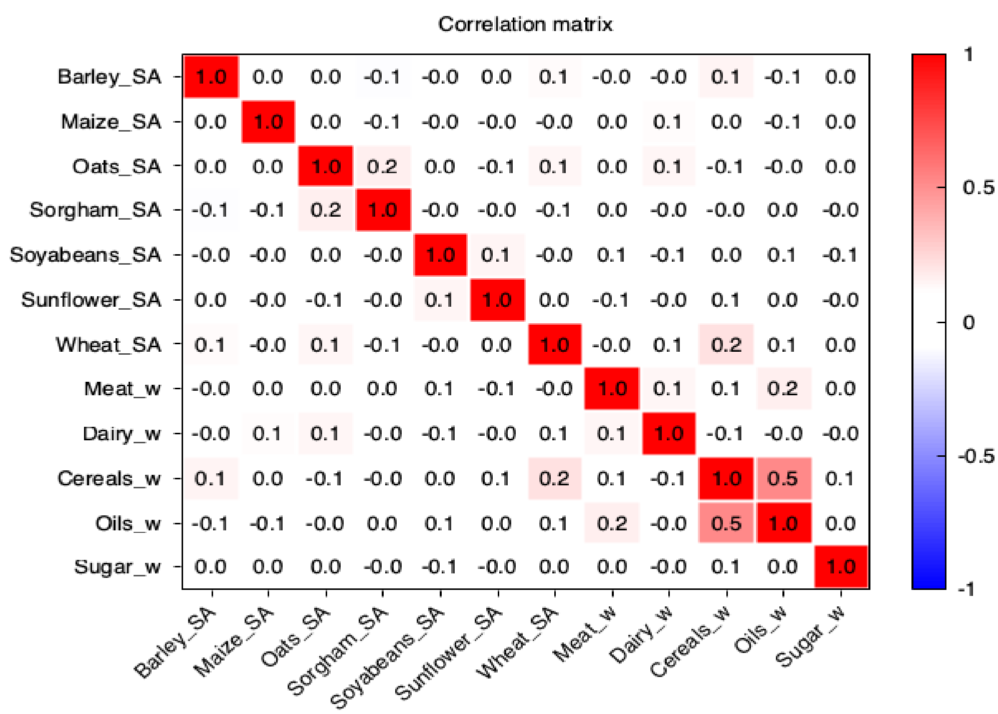
Table 1: Descriptive statistics

	Variable	Mean	Median	Std. Dev.	Minimum	Maximum
Return						
	Barley_SA	0.00405	0	0.155	-0.688	0.635
	Maize_SA	0.00568	0.0078	0.0992	-0.491	0.42
	Oats_SA	0.00604	0.00117	0.11	-0.422	0.417
	Sorghum_SA	0.00568	0.00862	0.132	-0.456	0.309
	Soyabeans_SA	0.00608	0.000904	0.108	-0.442	0.611
	Sunflower_SA	0.00667	0.00507	0.0997	-0.34	0.471
	Wheat_SA	0.00647	0.00657	0.0893	-0.235	0.449
	Meat_w	0.00163	0.00307	0.0196	-0.0561	0.0478
	Dairy_w	0.000512	0.0015	0.0341	-0.089	0.105
	Cereals_w	0.00133	-0.00316	0.038	-0.122	0.17
	Oils_w	0.000795	-0.00712	0.0547	-0.227	0.222
	Sugar_w	-0.00119	-0.00332	0.0695	-0.309	0.191
Volatility						
	Barley_SA	0.024	0.00284	0.0631	0	0.474
	Maize_SA	0.00982	0.00261	0.0268	0	0.241
	Oats_SA	0.0121	0.00184	0.0273	0	0.178
	Sorghum_SA	0.0173	0.00383	0.0333	0	0.208
	Soyabeans_SA	0.0116	0.00169	0.0368	0	0.373
	Sunflower_SA	0.00993	0.00239	0.0242	1.04E-07	0.222
	Wheat_SA	0.00797	0.00228	0.0189	7.63E-06	0.201
	Meat_w	0.000386	0.00015	0.000533	4.39E-12	0.0032
	Dairy_w	0.00116	0.000517	0.0018	1.39E-08	0.011
	Cereals_w	0.00144	0.000407	0.00362	1.37E-07	0.0289
	Oils_w	0.00297	0.000957	0.00622	2.34E-06	0.0514
	Sugar_w	0.00481	0.00164	0.00998	1.03E-06	0.0957

Note: "SA" and "w" denote South African and world food prices respectively while Std. Dev. represent the standard deviation.



(i) Correlation among return series



(ii) Correlation among volatility series

Figure 1: Evolution of frequency-based spillover among world food prices and food prices in South Africa

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Note: "SA" and "w" denote South African and world food prices respectively.

Figure 1 shows the correlation matrix using heat maps for both return and volatility in Panels (i) and (ii), respectively. As may be seen, correlations among the food markets are stronger in terms of returns than in terms of volatility. The strongest correlation is positive between the oil seed and cereal prices in the global market, both in terms of returns and volatility. This is followed by a negative correlation between oats and sorghum prices in the South African market.

4 Results and discussion

This section presents the empirical results and discussion of total dynamic connectedness and risk transmission among South African domestic food prices and the global food prices based on a TVP-VAR-based frequency connectedness model with the order of lag chosen based on the Akaike Information Criterion and a 12-step-ahead forecast horizon. In addition to the total dynamic connectedness results, which are estimated without considering the dynamic effects of events that may have occurred at specific points in time, the results also comprise results from the analysis that make use of high-frequency values as well as results from the use of low-frequency values marked by the † and ‡ symbols, respectively. Indeed, these additional results correspond to the dynamics of short-term and long-term risk transmission among these food prices. Our analysis explores the degree of total, short-term and long-term spillovers among South African domestic food prices and the composite global food price index, realised using the principal component analysis as well as with selected global food prices as listed in the previous section. We also examine the changes in spillovers across both changes in food prices and the volatility of these food prices.

4.1 Impact of international food price spillovers on domestic food inflation in South Africa

Beginning with spillovers among South African domestic food and the composite global food price return, Table 2 shows that the total connectedness index (TCI) is about 20.9%, which comprises 13.8% associated with the short-term and 7.2% for the long-term. This finding indicates that about 20.9% of forecast error variance in this network of South African domestic and global food prices may be ascribed to innovations within the system, while the remaining ones is due to idiosyncratic shocks in each market. This finding is similar to that of Agyei and Bossman (2023) who found that TCI between corn and stock returns from African markets is 19.68%, but differs considerably from Lawrence et al., (2024) who established a TCI of 62% among South African equity sectors, indicating a high level of interconnectedness, however, this study was not focused on food prices. It is also interesting to note that risk transmission is mainly due to short-term developments, as shown by a stronger short-term connectedness index of about 13.8% as opposed to a long-term connectedness of about 7.2%. Indeed, values along the main diagonal of the table show each variable's idiosyncratic shocks, while all off-diagonal elements correspond to the interaction among changes in food prices within this particular network. For instance, the global composite food price index exhibits the highest degree of average idiosyncratic shocks of 91.35% (24.26% in the short-term and 67.10% in the long-term) while the remaining 8.65% are due to interactions with the chosen South African food prices within the network. This suggests negligible risk transmission from the South African domestic food market to the global food market. In contrast, the sorghum market in South Africa has the least of 71.09% (48.50% in the short-term and 22.59% in the long-term). This implies that the Sorghum market in South Africa is much more influenced by developments within the estimated network than other food types.

Furthermore, each food market's net total directional spillovers reveal some interesting results. First, on average, the soybean market is the main net transmitter of shocks into the network (29.33%), while the remaining South African food markets are net risk receivers. It is interesting to note that the soybean market in South Africa remains the main source of shocks transmission across both the short- and long-term. However, it is worth also noting that in the short-term, oats, sunflower, and maize markets are also net-transmitters of shocks (1.60%, 1.55%, and 0.05%, respectively) while the remaining South African food markets are net-receivers of shocks within the system. This suggests that shocks in the Soybean market appear to dominate shocks from the remaining markets across both frequencies. At the same time, those of Oats, Sunflower, and Maize have only short-term overwhelming effects across other food markets. In the long term, in addition to the soybean market, sorghum and Wheat markets also dominate shocks from the system to become net shock transmitters, emphasising their long-term shock transmission potentials. Regarding shocks transmission from the global food market, we find that the global food price index (GFPI) is a net-transmitter of risks to the system (3.89%), indicating that the global food market sends stronger shocks into the South African food market than it receives from it. Shocks from the global food market overwhelms the domestic food market in South Africa both in the short- and long-term, with about 3.89% and 0.79% to the system, respectively. This suggests that the South African domestic food market is influenced more strongly by shocks from the global food market in the short-term than in the long-term. This finding corroborates those of Lee and Park (2013) and Minot (2011), who used other methods to show that world food price changes are transmitted to domestic markets, including South Africa, in the short run and in the long run. This is a call for the use of appropriate policy options to insulate the South African domestic food market from both short- and long-term shocks from the global food market.

Results of the degree of interactions using changes in prices of South African domestic food prices and the five different global food prices are presented in 3. As may be seen, total connectedness is about 34.96%, indicating that the degree of spillovers is stronger when we consider interactions with individual global food markets. Similar to previous results, we find that spillovers among these food markets are mostly driven by long-term development, as shown by a stronger long-term total connectedness index of about 21.11% against the short-term connectedness index of about 13.85%. On average, the net total directional connectedness shows that return risk spillovers from the global food market is mainly driven by development in the world market for cereals (20.68%), followed by oil seeds (16.13%) and meat (13.13%) while the world market for the remaining foods appear to be vulnerable to shocks from the South African food market, especially the world markets for sugar (-18.22%), followed by that of dairy (-5.30%). On the other hand, only the South African soybean market is not vulnerable to shocks spillovers from the system (18.51%) both in the short-term (14.96%) and long-term (3.55%), while the remaining South African food markets are net-receivers of shocks. While the results remain unchanged for all markets when we consider the short-term and long-term dynamics, it is interesting to note that the South African oats market is a net-transmitter of shocks (1.42%) to the system in the short-term, while the sorghum, sunflower, and wheat markets are net-transmitters of shocks in the long-term. Moreover, Figure 2 displays the time variation in total, short- and long-term dynamic return connectedness among the composite global food price index and food prices in South Africa. As may be seen, stronger levels of connectedness with the composite index of global food prices were witnessed around the beginning of our study period in 2010. However, the spillover levels have been decreasing towards the end of the sample period.

We proceed to consider the degree of connectedness among the volatility of the domestic food prices in South Africa and the volatility of the composite global food price index as shown in 4. Here, we find that the total degree of volatility connectedness is 20.90%. The total volatility connectedness breaks down to 8.99% and 11.91% for short- and long-term connectedness, respectively. Hence, like dynamic connectedness with price changes, we find that volatility connectedness among South African domestic food prices and the composite global food prices is driven by long-term factors. It is interesting to note that the composite food price index volatility is a net-transmitter of shocks on average (1.68%) and in the long-term (4.70%). However, unlike return connectedness, the composite global food price index is a short-term net receiver of shocks from the system (-3.02%). This indicates that although spillover from price changes in the global food market may on average have greater implications on food prices in South Africa (3.89%), especially in the short-term (3.10%), the volatility of global food prices impacts more strongly on the volatility of domestic food prices in South Africa in the long-term (4.70%). Hence, it is important to formulate and implement relevant policies that can reduce the degree of volatility spillover from the global food market into the domestic food market in South Africa. Besides, such a policy must have a long-term focus, given that volatility spillover appears to be more driven by long-term dynamics. Also, the soyabean market in South Africa appears to be the dominant source of volatility risk transmission within this system (24%), followed by the wheat market (21.37%), while the remaining markets are net-receivers of shocks led by the sunflower market (-16.80). The frequency-based results also suggest that while the soyabean market in South Africa may lead to long-term shocks transmission among these food types, wheat plays this role in the short term (13.96%).

Regarding the results of the degree of volatility interactions using volatility in prices of South African domestic food prices and the various global food prices as presented in 5 it can be seen that the degree of total connectedness is about 51.92%, suggesting that the degree of volatility spillovers is significantly more substantial than return spillovers when we consider interactions with the five global food types. However, in consonance with previous results, we find that spillovers among these food markets are driven mainly by long-term interactions, as shown by a stronger long-term total connectedness index of about 28.72% against the short-term connectedness index of about 23.20%. On average, the net total directional connectedness shows that volatility risk spillovers from the global food market is mainly driven by developments in the world market for oil seeds (18.08%), sugar (16.04%) and cereals (9.65%) while the remaining world food types appear to be vulnerable to shocks from the system, especially the world markets for dairy (-26.83%), followed by that of meat (-23.87%). On the other hand, the South African markets for oats (-13.18%) are vulnerable to volatility spillovers from the system. While this is the case for all these foods across both short- and long-term, Sunflower is a net-transmitter of shocks in the long-term (7.96%) while the remaining South African food markets are net-transmitters of shocks to the system across both the short- and long-term. Moreover, Figure 2 Panel (ii) displays the time variation in total, short- and long-term volatility dynamic connectedness, respectively. Like the earlier findings, stronger levels of connectedness with the composite index of global food prices appear at the beginning of the data sample in 2010 but decrease towards the end of the study period after a notable increase during the period of the COVID-19 pandemic.

Simply put, the quantile regressions show that global shocks do not affect South Africa's food markets in a uniform way; instead, their impact becomes much stronger when the food system is already under pressure. For example, geopolitical tensions and oil prices matter far more when spillovers are already high, as seen in the upper quantile of the model. This means that during stressful periods, such as conflict, supply disruptions or global uncertainty, even small increases in these global risks can intensify price pressures for South African households and businesses. Also, the study finds that some crops, especially soybeans, sorghum and wheat, tend to spread their price changes to the rest of the local food system more strongly than others. This means that when these specific foods become expensive internationally, they raise the overall level of price pressure in South Africa more than the other crops do. The positive role of domestic equity market returns suggests that when financial markets are booming, they can unintentionally amplify food price pressures, as investors shift risk appetite toward commodities. At the same time, the finding that a weaker rand reduces spillovers implies that currency depreciation may act as a short-term cushion by making imports relatively more expensive and slowing the direct transmission of global food shocks. Overall, the results highlight that policymakers cannot rely solely on average relationships; the strongest effects occur during moments of strain, when international shocks, local market sentiment and energy prices interact to magnify food inflation there is a need to strengthen exports and reduce vulnerability to shocks by producing more locally, building reserves, or protecting the most affected crops.

4.2 Drivers of total connectedness

As per our second broad objective, we explore the possible channels of both return and volatility shocks transmission from the global food price index into the system using the time-varying total, short- and long-term total connectedness indexes retrieved from the system. The frequency-based time-varying degrees of return and volatility spillovers from the composite global food price index being modelled are presented in Fig. 3. As may be seen, the degree of spillover from the global food price index was strongest from the beginning of our study period until around 2016, during which a notable decrease was witnessed both in terms of return and volatility and across short- and long-term. In terms of return spillover from the global food price index, long-term spillover dominates short-term spillover throughout the study period. Also, return spillover appears to have intensified during the COVID-19 pandemic. In terms of volatility spillover, there are notable periods of stronger short-term spillovers than long-term spillovers at the beginning of our study period. Although the degree of volatility spillover from the global food price index also decreased after 2016, it appears not to have increased significantly during the COVID-19 pandemic, as exhibited by return spillover.

Table 6 shows the effects of the chosen driving factors of risk spillover from the global food price index under the total, short- and long-term and across three quantiles that correspond to the low, medium and high levels of risk spillover. For total return spillover from the global food price index, results show that an increase in geopolitical risks, equity market returns in South Africa, oil prices and the COVID-19 pandemic were the main drivers of risk transmission from the global food market into the South African food market. More specifically, a one-unit increase in geopolitical risk or oil prices raises spillovers by a disproportionately large amount in the upper quantiles compared to the middle or lower quantiles, meaning that the price impact accelerates when markets are already unsettled. However, the depreciation of the value of the Rand decreased the level of spillovers, while the remaining factors, including monetary policy uncertainty and the fixed income market, had statistically insignificant effects across all quantiles. This finding reveals the potential of the evolution of geopolitical tensions, equity market gains, the situation of the oil market as well as health emergencies in propagating shocks across global food markets. Indeed, geopolitical tensions and pandemics such as COVID-19 have profound implications for the global crude oil market and supply chain, which can disrupt the efficiency in the flow of food around the world, leading to shock transmission, especially for countries like South Africa that are largely dependent on the international food markets. These results remain largely the same across the short- and long-term, except for a few changes. For instance, in the short term, an increase in the price of gold increases risk transmission, while an increase in the U.S. monetary policy shocks and COVID-19 decreased risk transmission.

Table 7 displays the driving factors of volatility spillover across both total as well as short- and long-term, and quantiles. Relative to return spillover, we find that the South African equity return and the fixed income market are the main drivers of volatility risks from the global food market to the South African market, while the remaining factors mediate volatility risk transmission, except for the gold price, which is not statistically significant across all quantiles. That is, a percentage change in domestic equity market returns translates into a larger percentage change in spillovers at higher quantiles, showing that investor optimism or pessimism can significantly amplify food price pressures. These findings remain mainly unchanged except for the gold price, which becomes a positive driver of volatility spillover from the global food market into the South African food market in the short term. These findings reveal the potential of volatility transmissions, increasing through rising returns in equity and the fixed income markets in South Africa. Even small, seemingly minor changes in key drivers can thus lead to relatively large percentage shifts in both return and volatility spillovers when the system is already fragile. It also suggests that most channels of return risk transmission are not necessarily significant channels of volatility transmission.

Summarily, the analysis of volatility spillovers reveals that uncertainty in South Africa's financial markets plays a central role in transmitting global food price instability into domestic markets. The equity and fixed-income markets emerge as key channels through which volatility travels, especially at higher quantiles, meaning that when financial markets become jittery, local food markets become more sensitive to global turbulence. This finding carries important economic meaning: (i) price swings in food are not just driven by supply and demand but also by how investors react to broader economic conditions; (ii) the insignificance of gold prices across most quantiles reinforces the idea that safe-haven assets such as gold offer limited protection when food markets face global uncertainty. In a nutshell, the volatility results show that financial stability is as essential as agricultural, sorghum, and wheat markets dominate, serving as global food price turbulence that is more easily transmitted into domestic prices.

5 Conclusion and Recommendation

Motivated by the high integration index of South Africa, its rising inflation and global shocks such as the Russia-Ukraine war and the COVID-19 pandemic, this study sought to quantify the degree of return and volatility risk transmission from the global food market to the South African food market for the period from January 2010 to December 2023. This study contributes valuable insights into the mechanisms through which international food prices influence food inflation within the South African context by examining specific channels, which include exchange rates, equity markets (wealth), commodity markets (crude oil and gold), and geopolitical tension. The study employs the recent TVP-VAR-based frequency connectedness to quantify and observe the evolution of both return and volatility risk transmission from the global to the South African food market. Generally, the results show a slightly higher level of return connectedness than volatility connectedness among the food markets and that shocks from the global food market dominate shocks from the South African food market. The study finds that the total connectedness index (TCI) is about 20.93%, whereof 13.8% is associated with the short-term and 7.2% with the long-term. This implies that recorded risk transmission is mainly due to short-term developments rather than long-term connectedness.

Furthermore, the soyabean market is the main net transmitter of shocks into the system, while the remaining South African food markets (barley, maize, oats, sorghum, sunflower and wheat) are net risk receivers on average. However, this varies considerably in terms of short- and long-run dynamics. In the short term, oats, sunflower, and maize markets are net transmitters of shocks, while barley, sorghum, and wheat are net receivers of shocks within the system. In the long run, only shocks from the soybean market, sorghum, and wheat markets dominate shocks, which are net shock transmitters. More importantly, the study finds that the global food price index (GFPI) is a net-transmitter of risks to the domestic food market in South Africa in the short-term, long-term and on average. The study also finds that the degree of total connectedness between the degree of interactions using changes in prices of South African domestic food prices and the five different global food prices is about 34.96%, indicating that the degree of spillovers is stronger when we consider interactions with individual global food markets. Its effects are slightly stronger in the long term. Similar to the return connectedness, the total degree of volatility connectedness is 20.90% with 8.99% and 11.91% associated with the short- and long-term connectedness, respectively. Meanwhile, the TCI of the volatility connectedness among world food prices and food prices in South Africa is 51.92, which is higher than that of the return connectedness interacting with individual global food markets, but has a similar trend of a higher long-term effect than the short term.

The findings above suggest several policy implications for South Africa. There is a need to strengthen food market resilience through domestic food production and diversification, since South African food markets are largely net receivers of global shocks. Special support should target vulnerable markets like Barley, Sorghum, and Wheat, especially in the short term. Given the dominance of global shocks in driving domestic prices and the volatility of key markets like soybeans, the government should implement or scale up strategic food reserves, buffer stocks, and price stabilisation mechanisms for essential staples; there is a need to establish strategic reserves and food price stabilisation policies. The government of South Africa could also consider designing short-term risk management tools for farmers and traders, such as short-term insurance products, forward contracts, or weather-indexed insurance, to cushion producers and traders against volatility, especially for those farming seasonal crops. The findings further infer that policymakers and regulators should monitor global soybeans, oats, sunflower, and maize markets more closely, as these are significant shock transmitters. Custom trade policies, import buffers, or hedging mechanisms can be designed specifically around these crops.

The study employs the quantile regression technique to identify the main driving factors of both return and volatility spillover from the international food market into the South African market, which constitutes the second broad objective. The findings show that, for total return spillover from the global food price index, an increase in geopolitical risks, equity market returns in South Africa, oil prices and the COVID-19 pandemic were the main drivers of risk transmission from the global food market into the South African food market. While the depreciation of the Rand's value decreased the spillover level, the remaining factors, including monetary policy uncertainty and the fixed income market, had statistically insignificant effects across all quantiles. Hence, fiscal and monetary policies must incorporate contingency planning for future global events such as pandemics and conflicts, and consider creating a food price risk index or early warning system to track incoming shocks. Furthermore, since oil prices influence food price spillovers, there's a need for integrated energy-food policy planning. Subsidies, fuel price smoothing, or investment in alternative fuel sources (e.g., solar irrigation) could reduce the exposure of food markets to oil price spikes. In addition, the role of equity market returns suggests that wealth effects and investor sentiment may amplify food price volatility, therefore regulators should monitor the interlinkages between financial markets and commodity markets, especially in times of crisis, and consider macroprudential tools to dampen excessive risk-taking.

Additionally, the analysis of the driving factors of volatility spillover across both total as well as the short- and long-term quantiles shows that the South African equity return and the fixed income market are the main channels through which volatility from the global food market spills over into the South African market, while the remaining factors mediate volatility risk transmission, except for the gold price that is not statistically significant across all quantiles. Hence, the need exists to promote diversification of portfolios or implement macroprudential regulations (e.g., countercyclical capital buffers, stress testing) in the equity and bond markets to mitigate the impact of external shocks and strengthen financial market resilience. Since gold prices are not statistically significant in mediating volatility, there may be a need to recognise the limited role of gold as a hedge and avoid overreliance on gold as a hedge against food-market-driven financial risks. Finally, the government could consider managing exposure in fixed income markets by reviewing government borrowing strategies to reduce exposure to interest rate shocks and inflationary risks related to global food price spikes.

Table 2: Return connectedness between global food price index and food prices in South Africa

	Barley_SA	Maize_SA	Oats_SA	Sorghum_SA	Soyabeans_SA	Sunflower_SA	Wheat_SA	GFPI	FROM others
Barley_SA	77.80	5.39	1.02	1.26	4.18	4.73	3.77	1.85	22.20
	57.55†	4.92†	0.87†	0.63†	3.55†	3.35†	3.54†	1.33†	18.18†
	20.25‡	0.47‡	0.15‡	0.63‡	0.63‡	1.38‡	0.23‡	0.52‡	4.02‡
Maize_SA	2.86	79.25	3.27	3.19	7.20	1.68	1.15	1.40	20.75
	1.57†	44.53†	2.54†	1.46†	2.40†	1.17†	0.97†	0.38†	10.48†
	1.30‡	34.72‡	0.73‡	1.73‡	4.80‡	0.51‡	0.18 ‡	1.02‡	10.27‡
Oats_SA	1.08	0.75	71.46	7.24	10.14	3.79	4.70	0.83	28.54
	0.72†	0.59†	44.66†	3.41†	5.98†	3.31†	3.71†	0.23†	17.95†
	0.36‡	0.16‡	26.80‡	3.84‡	4.16‡	0.48‡	0.99‡	0.60‡	10.59‡
Sorghum_SA	1.11	2.48	9.49	71.09	10.98	1.87	2.15	0.84	28.91
	0.98†	1.16†	8.48†	48.50†	9.22†	1.26†	1.57†	0.29†	22.96†
	0.12‡	1.32‡	1.01‡	22.59‡	1.76‡	0.61‡	0.58‡	0.55‡	5.95‡
Soybeans_SA	2.73	2.06	1.33	0.85	83.86	3.82	3.87	1.48	16.14
	1.42†	0.92†	0.87†	0.59†	49.05†	2.02†	2.01†	0.64†	8.48†
	1.31‡	1.13‡	0.46‡	0.27‡	34.81‡	1.80‡	1.86‡	0.84‡	7.66‡
Sunflower_SA	1.43	3.55	2.18	2.14	7.01	79.24	0.72	3.72	20.76
	1.14†	2.25†	1.42†	1.20†	3.24†	48.37†	0.63†	2.02†	11.91†
	0.29‡	1.30‡	0.76‡	0.93‡	3.77‡	30.87‡	0.09‡	1.70‡	8.85‡
Wheat_SA	3.19	0.82	5.92	2.95	4.42	1.79	78.50	2.41	21.50
	2.84†	0.63†	5.17†	2.51†	3.70†	1.42†	54.66†	0.97†	17.23†
	0.35‡	0.19‡	0.76‡	0.45‡	0.72‡	0.36‡	23.84‡	1.44‡	4.26‡
GFPIF	0.44	0.23	0.40	0.20	1.54	3.00	2.82	91.35	8.65
	0.24†	0.06†	0.20†	0.11†	0.57†	0.93†	0.66†	24.26†	2.76†
	0.20‡	0.17‡	0.21‡	0.09‡	0.97‡	2.08‡	2.17‡	67.10‡	5.88‡
TO others	12.84	15.28	23.62	17.83	45.47	20.69	19.19	12.54	167.45
	8.92†	10.53†	19.55†	9.90†	28.66†	13.46†	13.09†	5.86†	109.96†
	3.93‡	4.75‡	4.07‡	7.94‡	16.81‡	7.23‡	6.09‡	6.68‡	57.49‡
Inc. Own	90.64	94.53	95.07	88.92	129.33	99.93	97.69	103.89	
	66.46†	55.05†	64.20†	58.40†	77.72†	61.83†	67.75†	30.12†	TCI
	24.18‡	39.47‡	30.87‡	30.52‡	51.61‡	38.10‡	29.94‡	73.77‡	
Net	**-9.36**	**-5.47**	**-4.93**	**-11.08**	**29.33**	**-0.07**	**-2.31**	**3.89**	**20.93**
	-9.26†	**0.05†**	**1.60 †**	**-13.07†**	**20.19†**	**1.55†**	**-4.14 †**	**3.10†**	**13.75†**
	-0.09‡	**-5.52‡**	**-6.52‡**	**1.99‡**	**9.14‡**	**-1.62‡**	**1.83 ‡**	**0.79‡**	**7.19‡**

Note: "SA" denotes South African food price, while GFPIF is the global food price index factor extracted through principal component analysis. TO represents shocks sent from the variable i to the system, while Inc. Own represents shocks from the variable i to the system, including its own market, respectively. FROM denotes the amount of shocks received by the variable i from the system, while 'NET' is the difference between 'TO' and 'FROM'. TCI is the total connectedness index. † and ‡ represent short-term and long-term connectedness. Total, short-term, and long-term TCI are 20.93, 13.75, and 7.19, respectively, implying that short-term connectedness is stronger than long-term connectedness.

Table 3: Return connectedness among world food prices and food prices in South Africa

	Barley_SA	Maize_SA	Oats_SA	Sorghum_SA	Soyabeans_SA	Sunflower_SA	Wheat_SA	Meat_w	Dairy_w	Cereals_w	Oils_w	Sugar_w	FROM others
Barley_SA	63.93	4.26	1.45	2.15	3.31	4.24	3.30	5.26	1.41	3.90	4.97	1.82	36.07
	46.07†	3.92†	0.91†	1.16†	2.51†	3.27†	2.98†	0.92†	0.47†	2.91†	2.08†	0.92†	22.05†
	17.86‡	0.34‡	0.54‡	0.99‡	0.80‡	0.97‡	0.32‡	4.34‡	0.94‡	0.99‡	2.88‡	0.90‡	14.02‡
Maize_SA	1.90	69.77	3.16	2.61	6.71	1.93	1.64	5.75	1.36	2.28	1.03	1.86	30.23
	0.89†	39.83†	2.16†	1.16†	1.99†	1.01†	1.10†	0.72†	0.54†	0.53†	0.35†	0.70†	11.15†
	1.01‡	29.94‡	1.01‡	1.45‡	4.71‡	0.92‡	0.54‡	5.03‡	0.82‡	1.76‡	0.68‡	1.16‡	19.09‡
Oats_SA	0.60	0.78	68.24	8.91	6.17	2.65	4.24	2.86	2.75	0.77	1.29	0.74	31.76
	0.32†	0.37†	41.90†	4.25†	3.99†	2.35†	2.92†	1.03†	1.86†	0.36†	0.47†	0.31†	18.24†
	0.28‡	0.41‡	26.34‡	4.66‡	2.18‡	0.31‡	1.32‡	1.83‡	0.88‡	0.41‡	0.82‡	0.42‡	13.52‡
Sorghum_SA	0.75	3.10	7.76	67.27	7.72	2.11	2.23	2.47	3.19	1.38	1.10	0.94	32.73
	0.62†	1.77†	6.75†	46.05†	6.64†	1.60†	1.32†	1.55†	2.08†	0.94†	0.62†	0.54†	24.42†
	0.13‡	1.33‡	1.01‡	21.22‡	1.08‡	0.51‡	0.91‡	0.92‡	1.11‡	0.44‡	0.48 ‡	0.40‡	8.32‡
Soybeans_SA	2.16	1.00	1.38	0.77	70.20	4.94	3.23	5.73	1.75	4.05	2.35	2.43	29.80
	1.06†	0.46†	0.65†	0.51†	42.29†	1.77†	1.48†	1.05†	0.44†	1.22†	1.42†	0.83†	10.89†
	1.11‡	0.54‡	0.73‡	0.26‡	27.91‡	3.18‡	1.75‡	4.68‡	1.31‡	2.83‡	0.92‡	1.61‡	18.91‡
Sunflower_SA	0.90	2.98	1.83	2.41	7.07	63.43	1.24	1.64	2.22	5.15	9.02	2.13	36.57
	0.60†	2.05†	1.22†	1.21†	3.73†	38.89†	0.92†	0.51†	1.36†	2.17†	3.54†	1.62†	18.92†
	0.30‡	0.93‡	0.61‡	1.19‡	3.33‡	24.54‡	0.32‡	1.13‡	0.86‡	2.98‡	5.48‡	0.51‡	17.65‡
Wheat_SA	2.44	0.61	6.23	3.06	4.08	1.41	71.04	0.75	1.24	6.67	1.92	0.56	28.96
	2.11†	0.50†	5.45†	2.55†	3.15†	1.16†	49.12†	0.35†	0.61†	3.02†	0.44†	0.29†	19.64†
	0.33‡	0.11‡	0.78‡	0.50‡	0.94‡	0.24‡	21.92‡	0.40‡	0.64‡	3.65‡	1.47‡	0.26‡	9.33‡
Meatw	1.48	0.85	2.06	0.89	2.25	2.40	1.06	67.01	5.64	8.97	6.64	0.76	32.99
	0.45†	0.19†	0.30†	0.20†	0.47†	0.69†	0.12†	12.86†	0.93†	0.31†	0.81†	0.18†	4.66†
	1.03‡	0.66‡	1.76‡	0.68‡	1.78‡	1.71‡	0.94‡	54.14‡	4.71‡	8.66‡	5.83‡	0.58‡	28.34‡
Dairyw	0.86	1.25	2.93	2.06	1.67	1.75	1.63	8.83	67.38	2.62	7.24	1.80	32.62
	0.26†	0.52†	0.52†	1.31†	0.70†	0.27†	0.48†	0.69†	18.87†	0.37†	1.29†	0.42†	6.83†
	0.59‡	0.72‡	2.40‡	0.76‡	0.97‡	1.48‡	1.16‡	8.13‡	48.51‡	2.25‡	5.95‡	1.38‡	25.79‡
Cerealsw	1.15	0.31	0.83	2.00	2.18	3.31	5.73	4.40	1.61	57.33	15.51	5.66	42.67
	0.69†	0.07†	0.22†	0.33†	0.48†	0.84†	1.04†	0.39†	0.24†	15.18†	2.97†	1.75†	9.03†
	0.45‡	0.23‡	0.60‡	1.66‡	1.70‡	2.47‡	4.69‡	4.02‡	1.37‡	42.15‡	12.54‡	3.91‡	33.65‡
Oilsw	0.79	0.48	1.14	0.61	2.88	5.53	1.65	5.31	4.89	14.72	56.89	5.10	43.11
	0.21†	0.19†	0.45†	0.25†	0.92†	2.21†	0.56†	1.15†	0.94†	4.11†	17.93†	0.82†	11.81†
	0.58‡	0.29‡	0.70‡	0.36‡	1.96‡	3.33‡	1.09‡	4.17‡	3.95‡	10.61‡	38.96‡	4.28‡	31.30‡
Sugarw	1.64	1.53	2.33	1.06	4.27	4.57	1.21	3.12	1.26	12.85	8.18	58.00	42.00
	0.78†	0.43†	1.03†	0.68†	1.26†	0.82†	0.27†	0.58†	0.21†	1.49†	1.05†	20.60†	8.62†
	0.86‡	1.10‡	1.30‡	0.38‡	3.02‡	3.74‡	0.93‡	2.54‡	1.04‡	11.36‡	7.12‡	37.40‡	33.39‡
TO others	14.66	17.15	31.09	26.52	48.31	34.84	27.16	46.12	27.32	63.36	59.24	23.78	419.54
	8.00†	10.48†	19.66†	13.62†	25.84†	15.99†	13.18†	8.93†	9.69†	17.43†	15.04†	8.38†	166.24†
	6.66‡	6.67‡	11.43‡	12.90‡	22.46‡	18.85‡	13.98‡	37.19‡	17.63‡	45.93‡	44.20‡	15.41‡	253.30‡
Inc. Own	78.58	86.92	99.33	93.79	118.51	98.27	98.19	113.13	94.70	120.68	116.13	81.78	
	54.06†	50.31†	61.56†	59.67†	68.13†	54.88†	62.30†	21.80†	28.56†	32.61†	32.97†	28.98†	**TCI**
	24.52‡	36.61‡	37.77‡	34.12‡	50.38‡	43.39‡	35.89‡	91.33‡	66.13‡	88.07‡	83.16‡	52.81‡	
Net	**-21.42**	**-13.08**	**-0.67**	**-6.21**	**18.51**	**-1.73**	**-1.81**	**13.13**	**-5.30**	**20.68**	**16.13**	**-18.22**	**34.96**
	-14.06†	**-0.67†**	**1.42†**	**-10.80†**	**14.96†**	**-2.93†**	**-6.46†**	**4.28†**	**2.86†**	**8.40†**	**3.23†**	**-0.24†**	**13.85†**
	-7.36‡	**-12.41 ‡**	**-2.09‡**	**4.59 ‡**	**3.55‡**	**1.20‡**	**4.65‡**	**8.85‡**	**-8.16‡**	**12.28‡**	**12.89‡**	**-17.98‡**	**21.11‡**

Note: "SA" denotes South African food price, while GFPIF is the global food price index factor extracted through principal component analysis. TO represents shocks sent from the variable i to the system, while Inc. Own represents shocks from the variable i to the system, including its own market, respectively. FROM denotes the amount of shocks received by the variable i from the system, while 'NET' is the difference between 'TO' and 'FROM'. TCI is the total connectedness index. † and ‡ represent short-term and long-term connectedness. Total, short-term, and long-term TCI are 20.93, 13.75, and 7.19, respectively, implying that short-term connectedness is stronger than long-term connectedness.

Table 4: Volatility connectedness between global food prices and the composite food price index in South Africa

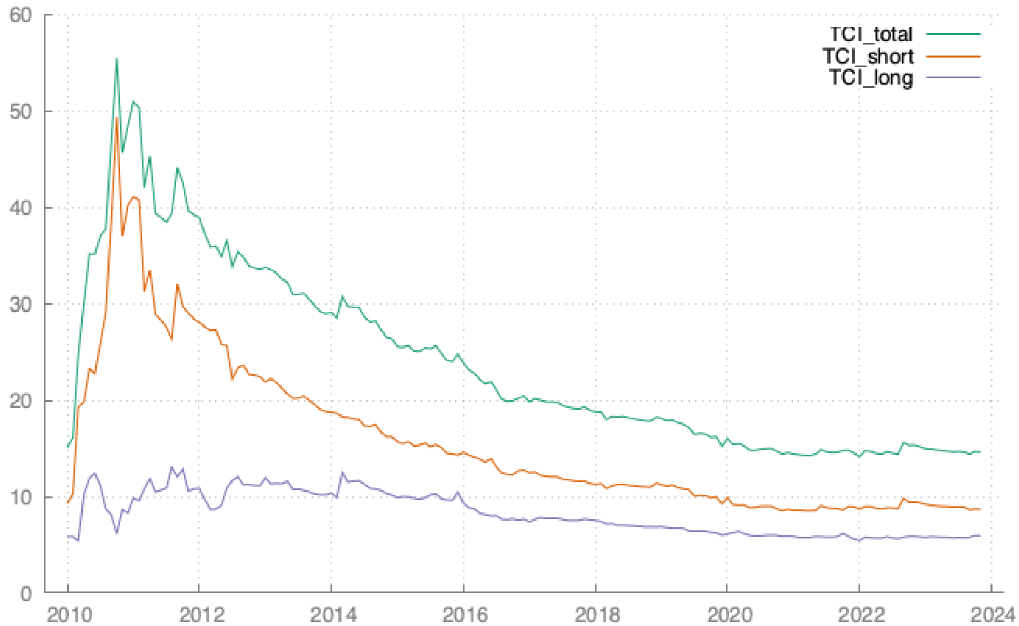
	Barley_SA	Maize_SA	Oats_SA	Sorghum_SA	Soyabeans_SA	Sunflower_SA	Wheat_SA	GFPI	FROM others
Barley_SA	71.75	0.46	1.31	1.19	12.87	3.47	5.65	3.30	28.25
	25.27†	0.24†	0.61†	0.45†	1.73†	0.67†	2.78†	0.41†	6.88†
	46.48‡	0.23‡	0.70‡	0.73‡	11.14‡	2.81‡	2.88‡	2.89‡	21.37‡
Maize_SA	3.47	78.17	2.86	1.46	3.16	4.11	5.56	1.21	21.83
	1.31†	44.73†	1.94†	1.08†	1.09†	3.15†	3.22†	0.31†	12.10†
	2.16‡	33.44‡	0.92‡	0.37‡	2.07‡	0.96‡	2.34‡	0.90‡	9.72‡
Oats_SA	4.03	1.20	75.54	4.98	4.10	2.30	3.54	4.31	24.46
	1.53†	0.63†	39.65†	1.81†	1.85†	0.84†	2.33†	1.04†	10.03†
	2.50‡	0.57‡	35.88‡	3.17‡	2.25‡	1.47‡	1.21‡	3.26‡	14.43‡
Sorghum_SA	2.11	0.81	4.53	80.52	7.33	1.10	1.46	2.14	19.48
	0.74†	0.27†	1.78†	34.03†	1.86†	0.41†	0.65†	0.54†	6.26†
	1.37‡	0.54‡	2.76‡	46.49‡	5.47‡	0.68‡	0.81‡	1.60‡	13.23‡
Soybeans_SA	2.16	0.32	0.98	0.84	92.69	1.23	0.75	1.03	7.31
	0.85†	0.10†	0.39†	0.22†	29.36†	0.44†	0.26†	0.12†	2.37†
	1.32‡	0.23‡	0.60‡	0.61‡	63.33‡	0.79‡	0.49‡	0.91‡	4.94‡
Sunflower_SA	4.28	3.87	2.82	1.57	2.45	65.66	17.13	2.22	34.34
	2.71†	1.16†	1.03†	0.82†	0.81†	34.82†	11.60†	0.35†	18.48†
	1.57‡	2.71‡	1.79‡	0.75‡	1.64‡	30.84‡	5.53‡	1.87‡	15.87‡
Wheat_SA	5.14	3.26	1.88	0.73	0.95	4.55	82.25	1.24	17.75
	3.10†	1.96†	1.36†	0.44†	0.43†	2.00†	45.71†	0.36†	9.65†
	2.04‡	1.30‡	0.52‡	0.29‡	0.52‡	2.55‡	36.53‡	0.88‡	8.10‡
GFPIF	3.80	0.22	2.17	0.43	1.33	0.79	5.03	86.24	13.76
	1.82†	0.11†	0.68†	0.19†	0.35†	0.21†	2.79†	33.89†	6.14†
	1.98‡	0.11‡	1.49‡	0.24‡	0.98‡	0.58‡	2.24‡	52.35‡	7.62‡
TO others	24.98	10.15	16.56	11.20	32.19	17.55	39.12	15.44	167.19
	12.05†	4.47†	7.79†	5.02†	8.12†	7.71†	23.62†	3.12†	71.91†
	12.93‡	5.68‡	8.77‡	6.17‡	24.07‡	9.84‡	15.50‡	12.32‡	95.28‡
Inc. Own	96.73	88.32	92.10	91.71	124.88	83.20	121.37	101.68	
	37.32†	49.21†	47.44†	39.05†	37.49†	42.53†	69.33†	37.01†	**TCI**
	59.41‡	39.12‡	44.66‡	52.67‡	87.40‡	40.67‡	52.04‡	64.67‡	
Net	**-3.27**	**-11.68**	**-7.90**	**-8.29**	**24.88**	**-16.80**	**21.37**	**1.68**	**20.90**
	5.17†	**-7.63 †**	**-2.24†**	**-1.23†**	**5.76†**	**-10.76†**	**13.96 †**	**-3.02†**	**8.99†**
	-8.44‡	**-4.05‡**	**-5.66 ‡**	**-7.05‡**	**19.13‡**	**-6.03‡**	**7.40‡**	**4.70‡**	**11.91‡**

Note: "SA" denotes South African food price, while GFPIF is the global food price index factor extracted through principal component analysis. TO represents shocks sent from the variable i to the system, while Inc. Own represents shocks from the variable i to the system, including its own market, respectively. FROM denotes the amount of shocks received by the variable i from the system, while 'NET' is the difference between 'TO' and 'FROM'. TCI is the total connectedness index. † and ‡ represent short-term and long-term connectedness. Total, short-term, and long-term TCI are 20.93, 13.75, and 7.19, respectively, implying that short-term connectedness is stronger than long-term connectedness.

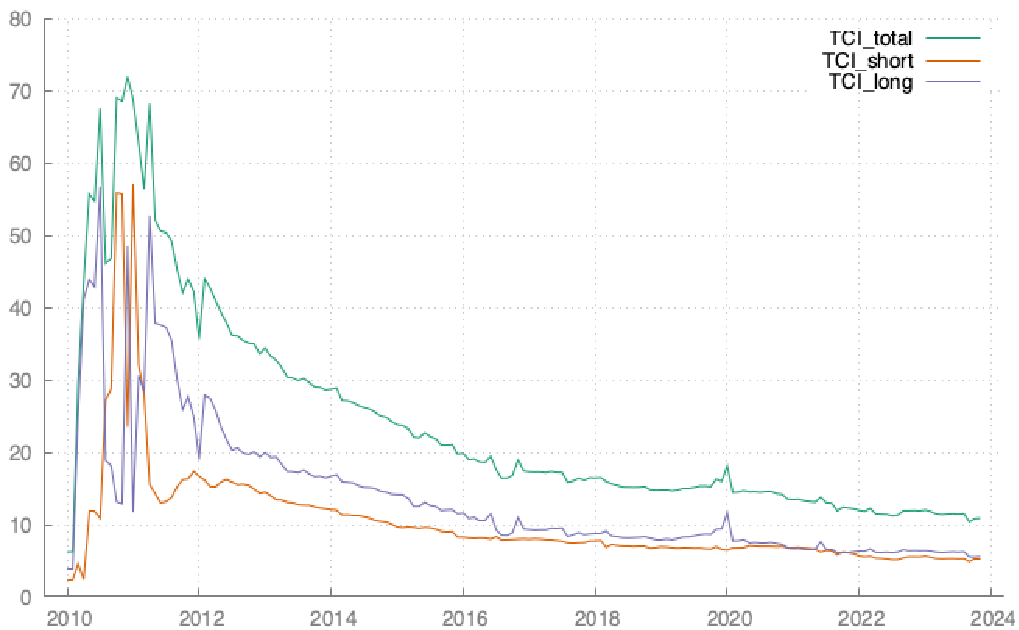
Table 5: Volatility connectedness among world food prices and food prices in South Africa

	Barley_SA	Maize_SA	Oats_SA	Sorghum_SA	Soyabeans_SA	Sunflower_SA	Wheat_SA	Meat_w	Dairy_w	Cereals_w	Oils_w	Sugar_w	FROM others
Barley_SA	57.28	2.18	1.32	5.24	8.23	1.79	5.46	1.24	1.70	6.60	4.01	4.96	42.72
	19.24†	0.40†	0.38†	1.56†	0.95†	0.88†	0.80†	0.29†	1.20†	1.96†	2.16†	2.29†	12.87†
	38.04‡	1.78‡	0.94‡	3.68‡	7.28‡	0.91‡	4.66‡	0.95‡	0.50‡	4.63‡	1.85‡	2.67‡	29.85‡
Maize_SA	1.58	50.16	0.67	10.41	2.86	2.30	5.64	1.12	1.64	8.82	8.41	6.41	49.84
	0.94†	25.76†	0.41†	4.09†	1.57†	1.36†	4.10†	0.40†	1.44†	3.48†	4.18†	2.23†	24.20†
	0.64‡	24.40‡	0.26‡	6.32‡	1.29‡	0.94‡	1.54‡	0.72‡	0.20‡	5.33‡	4.23‡	4.17‡	25.65‡
Oats_SA	1.83	1.14	54.80	6.20	2.79	5.54	4.55	2.10	2.70	4.39	9.94	4.03	45.20
	1.40†	0.76†	27.54†	3.54†	1.25†	3.02†	2.29†	0.93†	2.25†	2.47†	6.05†	2.71†	26.68†
	0.42‡	0.39‡	27.26‡	2.65‡	1.54‡	2.52‡	2.25‡	1.17‡	0.45‡	1.91‡	3.90‡	1.32‡	18.53‡
Sorghum_SA	1.43	1.96	1.72	47.50	2.76	3.59	2.46	1.39	2.54	12.26	10.83	11.56	52.50
	1.05†	1.10†	0.78†	21.29†	1.79†	2.55†	0.65†	0.46†	1.89†	6.56†	6.87 †	5.72†	29.43†
	0.39‡	0.85‡	0.94‡	26.21‡	0.97‡	1.04‡	1.82‡	0.93‡	0.65‡	5.70 ‡	3.95‡	5.83‡	23.07‡
Soybeans_SA	2.30	0.71	0.88	5.88	62.74	3.33	1.61	5.40	1.32	3.42	6.36	6.06	37.26
	1.16†	0.26†	0.31†	0.94†	19.88†	1.24†	0.18†	0.76†	0.70†	0.94†	1.49†	1.96†	9.94†
	1.14‡	0.46‡	0.57‡	4.94‡	42.85‡	2.09‡	1.43‡	4.64‡	0.62‡	2.48 ‡	4.87‡	4.10‡	27.32‡
Sunflower_SA	1.48	1.13	2.21	12.80	5.16	45.42	6.68	1.40	1.21	8.11	8.50	5.91	54.58
	0.62†	0.43†	0.77†	1.29†	1.44†	20.05†	3.95†	0.43†	0.42†	2.20†	2.87†	2.18†	16.61†
	0.85‡	0.71‡	1.44‡	11.50‡	3.72‡	25.37‡	2.73‡	0.96‡	0.79‡	5.91‡	5.63‡	3.73‡	37.97‡
Wheat_SA	1.38	0.86	1.08	3.23	2.08	1.82	74.99	3.76	1.60	2.10	2.48	4.61	25.01
	0.78†	0.35†	0.41†	1.01†	0.62†	0.82†	35.77†	0.69†	1.11†	0.91†	1.24†	2.42†	10.34†
	0.60‡	0.51‡	0.67‡	2.23‡	1.46‡	1.01‡	39.21‡	3.08‡	0.50‡	1.18‡	1.24‡	2.19‡	14.67‡
Meatw	2.57	2.58	1.75	8.56	4.32	4.48	2.08	46.05	6.63	6.52	6.48	7.98	53.95
	0.82†	0.44†	0.58†	1.69†	1.29†	1.76†	0.53†	14.88†	2.67†	2.02†	3.70†	1.69†	17.18†
	1.76‡	2.14‡	1.17‡	6.87‡	3.03‡	2.72‡	1.56‡	31.17‡	3.96‡	4.50‡	2.78‡	6.29‡	36.77‡
Dairyw	2.38	2.27	1.32	10.01	3.97	3.22	2.07	7.23	45.76	6.32	5.47	9.99	54.24
	1.61†	0.84†	0.81†	3.97†	2.30†	2.09†	0.99†	2.08†	21.51†	3.40†	4.14†	3.04†	25.26†
	0.77‡	1.44‡	0.51‡	6.03‡	1.67‡	1.13‡	1.08‡	5.15‡	24.25‡	2.91‡	1.33‡	6.95‡	28.98‡
Cerealsw	1.85	2.68	0.75	10.79	3.23	3.67	30.80	2.39	1.63	24.18	8.00	10.04	75.82
	0.76†	1.60†	0.44†	4.53†	1.20†	2.36†	10.84†	0.32†	1.05†	12.83†	5.83†	4.71†	33.66†
	1.09‡	1.08‡	0.31‡	6.25‡	2.03‡	1.31‡	19.95‡	2.07‡	0.58‡	11.35‡	2.17‡	5.33‡	42.17‡
Oilsw	1.65	3.25	1.23	12.87	5.40	6.56	1.58	3.16	3.78	12.00	36.04	12.48	63.96
	1.36†	1.93†	0.96†	6.40†	2.56†	5.01†	1.19†	0.94†	3.07†	7.34†	20.15†	7.29†	38.05†
	0.29‡	1.32‡	0.27‡	6.47‡	2.85‡	1.54‡	0.38‡	2.22‡	0.71‡	4.66‡	15.89‡	5.19‡	25.91‡
Sugarw	2.20	5.97	0.71	12.45	5.75	5.10	5.72	0.90	2.65	14.95	11.58	32.02	67.98
	1.57†	2.28†	0.44†	5.13†	3.07†	3.49†	1.51†	0.31†	1.99†	6.76†	7.68†	15.90†	34.21†
	0.63‡	3.69‡	0.27‡	7.32‡	2.68‡	1.61‡	4.21‡	0.59‡	0.67‡	8.19‡	3.90‡	16.12‡	33.77‡
TO others	20.66	24.75	13.63	98.43	46.55	41.40	68.64	30.08	27.41	85.47	82.04	84.01	623.08
	12.07†	10.37†	6.30†	34.16†	18.02†	24.57†	27.04†	7.60†	17.80†	38.05†	46.20†	36.25†	278.43†
	8.59‡	14.38‡	7.33‡	64.27‡	28.53‡	16.83‡	41.60‡	22.48‡	9.62‡	47.42‡	35.84‡	47.77‡	344.65‡
Inc. Own	77.94	74.91	68.43	145.93	109.29	86.82	143.63	76.13	73.17	109.65	118.08	116.04	
	31.31†	36.12†	33.84†	55.46†	37.91†	44.62†	62.81†	22.47†	39.30†	50.88†	66.35†	52.15†	**TCI**
	46.62‡	38.78‡	34.59‡	90.48‡	71.38‡	42.20‡	80.81‡	53.65‡	33.87‡	58.77‡	51.74‡	63.88‡	
Net	**-22.06**	**-25.09**	**-31.57**	**45.93**	**9.29**	**-13.18**	**43.63**	**-23.87**	**-26.83**	**9.65**	**18.08**	**16.04**	**51.92**
	-0.80†	**-13.83†**	**-20.38 †**	**4.73†**	**8.08**	**7.96†**	**16.70†**	**-9.58†**	**-7.47†**	**4.39†**	**8.16 †**	**2.04†**	**23.20†**
	-21.26‡	**-11.26‡**	**-11.19‡**	**41.20‡**	**1.20‡**	**-21.14‡**	**26.93‡**	**-14.29‡**	**-19.37‡**	**5.25‡**	**9.93‡**	**14.00‡**	**28.72‡**

Note: "SA" denotes South African food price, while GFPIF is the global food price index factor extracted through principal component analysis. TO represents shocks sent from the variable i to the system, while Inc. Own represents shocks from the variable i to the system, including its own market, respectively. FROM denotes the amount of shocks received by the variable i from the system, while 'NET' is the difference between 'TO' and 'FROM'. TCI is the total connectedness index. † and ‡ represent short-term and long-term connectedness. Total, short-term, and long-term TCI are 20.93, 13.75, and 7.19, respectively, implying that short-term connectedness is stronger than long-term connectedness.



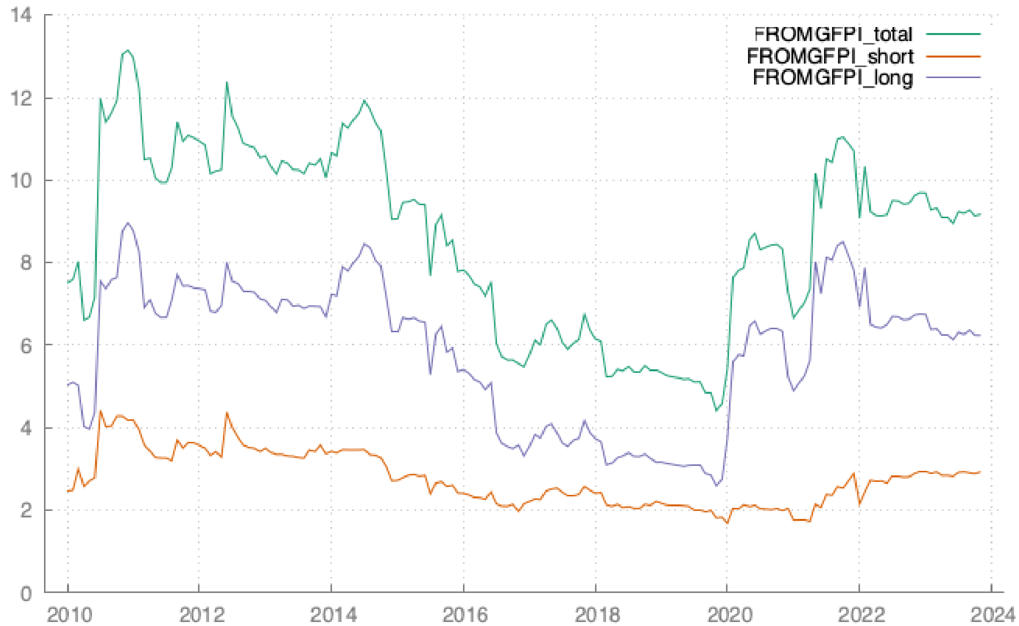
(i) Plot of time-varying total, short- and long-term return connectedness



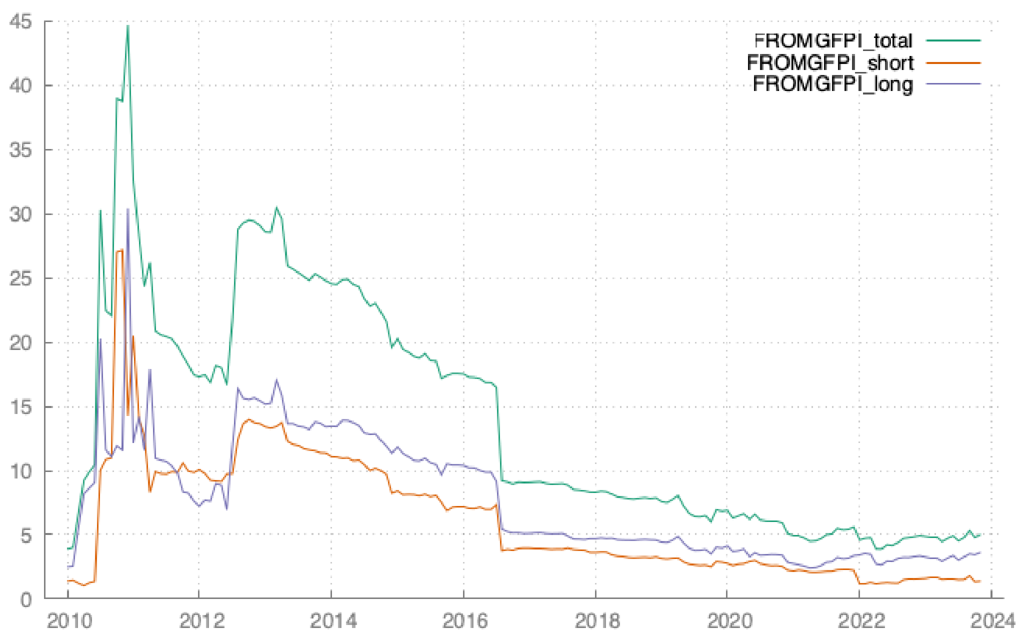
(ii) Plot of time-varying total, short- and long-term volatility connectedness

Figure 2: Evolution of return and volatility connectedness between the composite global food price index and food prices in South Africa

Note: Green, orange and purple lines represent the Total, Short-term† and Long-term‡ total connectedness index, respectively.



(i) Plot of time-varying return spillover from global food price index



(ii) Plot of time-varying volatility spillover from global food price index

Figure 3: Evolution of return and volatility spillover from global food price index to food prices in South Africa

Note: Green, orange and purple lines represent the Total, Short-term† and Long-term‡ total connectedness index, respectively.

Table 6: Drivers of frequency-based return spillovers from global food price index to food prices in South Africa

Variables	Return spillover from GFPI_total			Return spillover from GFPI_short-term			Return spillover from GFPI_long-term		
	Quantiles								
	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Const.	-1.321***	0.837***	1.299***	0.263	0.537*	0.816***	-2.855***	0.028	0.359
	(0.641)	(0.356)	(0.230)	(0.301)	(0.286)	(0.163)	(0.650)	(0.325)	(0.303)
GPRI	0.117	-0.002	0.117***	-0.028	-0.056	-0.005	0.201	0.099	0.194***
	(0.129)	(0.071)	(0.047)	(0.061)	(0.057)	(0.032)	(0.131)	(0.065)	(0.061)
USMPU	-0.101	0.003	0.001	-0.055*	-0.041	-0.014	-0.096	0.005	-0.004
	(0.063)	(0.035)	(0.023)	(0.029)	(0.028)	(0.016)	(0.064)	(0.161)	(0.030)
RNDUSD	-0.043	-0.149**	-0.242***	-0.229***	-0.184***	-0.253***	-0.055	-0.140**	-0.203***
	(0.134)	(0.074)	(0.048)	(0.063)	(0.060)	(0.034)	(0.136)	(0.068)	(0.063)
FTSESA	1.353*	0.861**	0.118	0.805**	0.925***	0.003	1.618**	0.602*	0.259
	(0.709)	(0.395)	(0.255)	(0.333)	(0.317)	(0.180)	(0.720)	(0.361)	(0.335)
GLDPR	-0.226	-0.130	0.326	-0.188	-0.245	0.307*	-0.381	-0.170	0.235
	(0.618)	(0.343)	(0.222)	(0.290)	(0.276)	(0.157)	(0.627)	(0.314)	(0.293)
OILPR	0.787***	0.402***	0.247***	0.385***	0.333***	0.243***	0.953***	0.384***	0.277***
	(0.093)	(0.052)	(0.033)	(0.044)	(0.042)	(0.024)	(0.095)	(0.047)	(0.044)
BNDRT	-0.009	0.038	0.003	-0.027	0.011	-0.001	-0.010	0.031	0.011
	(0.074)	(0.042)	(0.027)	(0.035)	(0.033)	(0.019)	(0.076)	(0.038)	(0.035)
COVID	0.228***	0.180***	0.135***	-0.128***	-0.144***	-0.171***	0.399***	0.319***	0.257***
	(0.088)	(0.049)	(0.031)	(0.042)	(0.039)	(0.023)	(0.089)	(0.044)	(0.041)

Note: GPRI, USMPU, RNDUSD, FTSESA, GLDPR, OILPR, BNDRT and COVID denote geopolitical risk index, the US monetary policy, Rand to US dollar excahnge rate, FTSE South Africa index, gold prices, oil prices, South Africa 10-year sovereign bond rate and COVID-19 crisis dummy, respectively. ***, ** and * represent significance at 1%, 5% and 10% levels, respectively.

Table 7: Drivers of frequency-based volatility spillovers from global food price index to food prices in South Africa

Variables	Volatility spillover from GFPI_total			Volatility spillover from GFPI_short-term			Volatility spillover from GFPI_long-term		
	Quantiles								
	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Const.	8.708***	9.658***	10.79***	10.77***	11.89***	14.58***	6.374***	7.004***	10.52***
	(0.305)	(0.716)	(0.797)	(0.377)	(0.896)	(0.721)	(0.350)	(0.481)	(0.625)
GPRI	-0.129**	-0.082	-0.119	-0.371***	-0.413**	-0.207***	-0.048	0.052	-0.114
	(0.062)	(0.144)	(0.161)	(0.076)	(0.180)	(0.145)	(0.071)	(0.097)	(0.126)
USMPU	-0.095***	-0.186***	-0.199**	-0.126***	-0.220	-0.263	-0.045	-0.175***	-0.217***
	(0.030)	(0.071)	(0.079)	(0.037)	(0.088)	(0.071)	(0.034)	(0.048)	(0.062)
RNDUSD	-1.549***	-1.694***	-1.763***	-1.913***	-2.012***	-2.668***	-1.210***	-1.284***	-1.714***
	(0492)	(0.150)	(0.167)	(0.079)	(0.187)	(0.151)	(0.073)	(0.101)	(0.131)
FTSESA	0.741**	0.771	0.784	0.551	1.741*	1.025	0.688*	0.757	0.002
	(0.338)	(0.793)	(0.883)	(0.417)	(0.992)	(0.799)	(0.388)	(0.533)	(0.693)
GLDPR	0.327	-0.171	-0.967	0.633*	-0.018	-0.360	0.233	-0.360	-0.675
	(0.295)	(0.691)	(0.769)	(0.364)	(0.865)	(0.696)	(0.388)	(0.464)	(0.604)
OILPR	-0.371***	-0.421***	-0.486***	-0.555***	-0.566***	-0.899***	-0.305***	-0.329***	-0.565***
	(0.047)	(0.105)	(0.117)	(0.055)	(0.131)	(0.105)	(0.051)	(0.070)	(0.091)
BNDRT	0.119***	0.124	0.009	0.124***	0.174*	0.165**	0.096**	0.094*	0.002
	(0.035)	(0.083)	(0.093)	(0.044)	(0.104)	(0.084)	(0.041)	(0.056)	(0.073)
COVID	-0.418***	-0.387***	-0.649***	-0.392***	-0.407***	-0.429***	-0.446***	-0.421***	-0.747***
	(0.042)	(0.098)	(0.110)	(0.052)	(0.123)	(0.099)	(0.048)	(0.066)	(0.086)

Note: GPRI, USMPU, RNDUSD, FTSESA, GLDPR, OILPR, BNDRT and COVID denote geopolitical risk index, the US monetary policy, Rand to US dollar excahnge rate, FTSE South Africa index, gold prices, oil prices, South Africa 10-year sovereign bond rate and COVID-19 crisis dummy, respectively. ***, ** and * represent significance at 1%, 5% and 10% levels, respectively.

Acknowledgement: We gratefully acknowledge the financial support provided by Economic Research Southern Africa (ERSA). Their commitment to promoting rigorous, policy-relevant economic research and strengthening research capacity in the region is sincerely appreciated.

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Appendix: Contextual Glossary of Technical Terms

Connectedness Index (TCI): A score showing how tightly markets move together; higher values mean more shared risk.

Equity Market Returns: Gains or losses in the stock market; included because financial markets influence food commodity prices.

Frequency Connectedness: A method that separates short- and long-term spillovers using signal-processing tools.

Geopolitical Risk Index: A measure of global political tension, conflict, and instability.

Long-Term Connectedness: Deeper structural influences that persist over months or years.

Monetary Policy Uncertainty: How unsure markets are about future interest rates and policy decisions.

Net Transmitter/Receiver: Whether a market mainly spreads shocks (transmitter) or absorbs them (receiver).

Quantile Regression: A technique that examines how predictors behave at different levels of the outcome, e.g., low, medium, or high spillover periods.

Return Spillover: How price changes in one market affect price changes in another.

Short-Term Connectedness: Quick, immediate transmission effects lasting a few days or months.

Spillover: When shocks in one market (global food prices) spread into another market (South Africa's domestic food prices).

TVP-VAR: A statistical model that tracks changing relationships between variables over time, rather than assuming they stay constant.

Volatility Spillover: How instability or uncertainty in one market is transmitted into another.