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Analyzing the impact of macroeconomic variables on agricultural derivatives performance in the SAFEX market

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Abstract

Purpose: This research study investigates how macroeconomic factors, such as short-term and long-term interest rates, the real exchange rate, and GDP growth, influence the pricing and volatility of agricultural derivatives, specifically focusing on white maize futures and options traded in South Africa. Agricultural derivatives are crucial for managing price risks in a country where agriculture plays a vital economic role.
Design/Methodology/Approach: The study employs a quantitative research approach using secondary data from 2000 to 2023 sourced from reliable institutions like the South African Reserve Bank (SARB), Statistics South Africa, and the Johannesburg Stock Exchange (JSE). The Autoregressive Distributed Lag (ARDL) model is applied to evaluate both short-term and long-term relationships between the selected macroeconomic variables and derivative performance. Additionally, unit root tests (ADF and PP) are conducted to assess data stationarity, and diagnostic tests are used to verify the reliability of the results.
Findings: The study highlights the dynamic interplay between macroeconomic factors and agricultural markets, suggesting that macroeconomic shifts, particularly during periods of economic instability, can substantially affect market volatility and risk management strategies.
Practical Implications: The research contributes valuable insights for policymakers, investors, and stakeholders by offering practical implications for improving market efficiency, managing risks, and enhancing agricultural policy formulation in South Africa. It emphasizes the need for effective risk management strategies in the face of changing macroeconomic conditions to ensure market stability and sustainability.
Originality/Value: This study provides new insights into the relationship between macroeconomic factors and agricultural derivatives in South Africa, particularly during periods of economic instability. The findings offer significant contributions for policymakers and market participants in improving risk management strategies and market efficiency.
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INTRODUCTION

The South African Futures Exchange (SAFEX) was established in 1988, with agricultural derivatives first traded in 1995. These derivatives allow market participants, including investors and farmers, to manage price risk related to agricultural commodities such as grains, oilseeds, and cattle. The performance of agricultural derivatives on SAFEX is influenced by various factors including supply and demand, weather patterns, and government policies (Vink and Kirsten 2002). In addition, macroeconomic variables such as real exchange rates, GDP growth, and short- and long-term interest rates significantly impact the performance of these derivatives (Kim 2003; Yau and Nieh 2006; Adrangi et al. 2011; Rapach et al. 2005; Graham and Harvey 2001). However, the specific impact of macroeconomic factors on agricultural derivatives remains understudied, highlighting a need for more research in this area.

Previous research focuses on price volatility and trading returns in agricultural derivatives (Motengwe 2013), the implications of commodity derivatives for accountancy (Middelberg 2011), and the impact of macroeconomic variables on agricultural productivity (Setshedi 2019). Yet, the analysis of how macroeconomic factors influence agricultural derivatives on SAFEX is critical for understanding risk management, market efficiency, and investment decision-making. These derivatives are typically priced in rands per ton, with location differentials accounted for at Randfontein (SAFEX 2023). For market participants, agricultural derivatives provide essential tools for managing price risk, making it crucial to understand the macroeconomic variables that drive their performance.

Macroeconomic variables have a multidimensional influence on the performance of agricultural derivatives, directly affecting pricing, risk management, and market stability (Shamsudin 2008). Key variables include real exchange rates, GDP growth, and interest rates. For example, changes in short- and long-term interest rates affect the cost of capital and borrowing, which in turn influences investment in agriculture. Higher interest rates increase the cost of hedging strategies, which can reduce market participation. Similarly, exchange rate fluctuations are significant for pricing imported agricultural commodities. A weaker currency can increase import costs, driving up domestic prices and potentially making derivatives more attractive as hedging tools (Chen 2014).

Volatility is another key factor in the agricultural derivatives market. As a financial market risk indicator, volatility reflects price changes over time and is influenced by macroeconomic conditions (Smith 2020). This makes it a crucial consideration for investors and policymakers who are involved in agricultural finance and risk management. Given that the SAFEX market is exposed to both domestic and international economic forces, it is vital to understand how variables like interest rates and exchange rates impact derivative pricing and risk management strategies.

While previous studies have explored macroeconomic impacts on agricultural productivity and trading, the relationship between these factors and agricultural derivatives in the SAFEX market remains under-researched. This creates a gap in understanding that is essential for improving risk management strategies. The pricing of agricultural derivatives is not only influenced by supply and demand but also by broader macroeconomic trends such as GDP growth and exchange rate movements, which can affect market efficiency and pricing stability.

The importance of studying these macroeconomic variables extends to policy implications and investment decision-making. For example, higher interest rates might reduce investment in agriculture by making borrowing more expensive, which could affect the cost of production inputs and limit market participation. On the other hand, exchange rate fluctuations could make importing agricultural commodities more expensive, thereby impacting the prices of domestic derivatives. As such, market participants and policymakers need a clear understanding of how macroeconomic variables affect agricultural derivatives to make informed decisions about risk management, hedging, and market regulation.

This research aims to fill the existing knowledge gap by empirically examining how macroeconomic variables like interest rates and GDP growth impact the performance of agricultural derivatives in the SAFEX market. Through econometric modelling, the study seeks to identify the key macroeconomic drivers affecting agricultural derivatives and their implications for market participants and policymakers. Understanding these dynamics is essential for enhancing risk management strategies and making informed decisions regarding portfolio allocation and market regulation.

Despite the increasing significance of agricultural derivatives in managing risk in the agricultural sector, there is still limited understanding of how macroeconomic variables influence their performance on SAFEX. Addressing this gap is critical for optimizing decision-making, improving market stability, and ensuring more effective risk management in the agricultural derivatives market. This research will contribute valuable insights for policymakers, regulators, and market participants by dissecting the complex relationship between macroeconomic variables and agricultural derivatives performance. By focusing on the SAFEX market, the study provides a comprehensive analysis of the factors driving the pricing and risk management of agricultural derivatives, offering key findings for the agricultural finance and investment sectors.

LITERATURE REVIEW

The study of macroeconomic variables' influence on agricultural derivatives in the SAFEX market is crucial for understanding market efficiency, risk management, and policy development. Agricultural derivatives, such as futures and options, play a vital role in managing price risks related to agricultural commodities and are significantly impacted by macroeconomic factors, including interest rates, exchange rates, and GDP growth (Bakas 2018; Yau and Nieh 2006). Despite previous research recognizing these variables' importance, knowledge gaps remain regarding the effects of macroeconomic shocks—such as sudden inflation or interest rate changes—on agricultural derivatives' volatility and pricing. Additionally, while studies have focused on individual macroeconomic variables, their interactions, such as how exchange rates might influence inflation's effects on derivative prices, have received limited attention (Baumeister and Kilian 2016).

Established in 1995, SAFEX is South Africa's primary platform for trading agricultural derivatives (Vink and Kirsten 2002). The performance of these derivatives is influenced by various factors, including supply and demand dynamics, government policies, and weather patterns. Key macroeconomic variables—such as real exchange rates, GDP growth, and both short-term and long-term interest rates—significantly affect price fluctuations (Rapach et al. 2005; Graham and Harvey 2001). Research in other markets shows macroeconomic variables influence derivative performance; however, explicit links to SAFEX are limited. Notably, Irwin et al. (2009) and Zhang and Wei (2010) highlight the substantial impact of exchange rates on commodity futures prices and market volatility, which is particularly relevant for SAFEX derivatives sensitive to domestic and global economic conditions.

Recent studies by Ndlovu et al. (2018) indicate that exchange rates and interest rates are significant predictors of agricultural commodity price volatility in SAFEX. As South Africa becomes more integrated into global markets, the sensitivity of SAFEX derivatives to macroeconomic variables is likely to increase, reflecting trends identified by Balcombe (2009). These insights emphasize the need for ongoing research that adapts to changing economic conditions.

This study is grounded in the Efficient Market Hypothesis (EMH) and Arbitrage Pricing Theory (APT), suggesting that asset prices reflect all available information (Fama 1970; Ross 1976). The Adaptive Market Hypothesis (AMH) further enriches this framework, proposing that market efficiency evolves with new information and participant behavior (Lo 2004). This research aims to empirically assess how real exchange rates, GDP growth, and interest rates interact within this adaptive framework, contributing valuable insights into agricultural finance and risk management (Ouma 2020).

Theories of Commodity Markets

Commodity markets, particularly agricultural derivatives, can be analyzed through various theoretical frameworks, including the theory of storage and the cost-of-carry model. The storage hypothesis suggests that commodity prices reflect the costs associated with storage, such as physical storage expenses, interest costs, and convenience yield. Higher storage costs and lower convenience yields lead to an increase in spot prices relative to futures prices (Working 1949).

The cost-of-carry model explains the relationship between spot and futures prices by incorporating storage costs, interest rates, and expected future spot prices. When interest rates are low and transport costs decline, the gap between spot and futures prices may narrow (Sarno and Valente 2000).

Supply and demand theory is also critical in understanding price fluctuations. In agricultural derivatives, prices are influenced by the availability and desire for the underlying commodities. Factors such as weather, seasonal cycles, and agricultural technology can affect supply, while demand is shaped by population growth, dietary changes, and global trade policies. Macroeconomic variables like inflation and interest rates further influence supply and demand by impacting production costs and consumer purchasing power (Marshall 1890).

Arbitrage Pricing Theory (APT), proposed by Stephen Ross, offers a multifactor model for determining fair asset prices based on various macroeconomic factors, including GDP growth and interest rates. APT can forecast pricing changes in agricultural derivatives markets, assisting traders in making informed decisions (Ross 1976).

Rational expectations theory posits that market participants base their judgments on available information and past experiences. Expectations about future economic conditions, such as inflation, are reflected in current asset prices (Muth 1961). Lastly, Keynesian economics highlights the role of government policies and macroeconomic variables in affecting economic activity and commodity prices, with fiscal stimulus potentially driving up agricultural commodity prices (Keynes 1936).

Empirical Studies on SAFEX Agricultural Derivatives

Empirical research on SAFEX agricultural derivatives highlights the key macroeconomic factors influencing this market. Geyser and Cutts (2007) found that exchange rate fluctuations and global commodity prices significantly drive price volatility in maize futures, suggesting that external macroeconomic shocks have a pronounced effect on SAFEX agricultural derivatives. Stable macroeconomic conditions, including consistent interest rates and low inflation, enhance the effectiveness of hedging strategies, as seen in research by Titova et al. (2020), emphasizing the need for economic stability to manage risks in agricultural markets.

Global economic indicators, such as central bank regulations, also play a crucial role. For instance, actions by the U.S. Federal Reserve, such as interest rate cuts, can increase market liquidity and boost commodity demand, while rate hikes may strengthen the dollar and reduce commodity prices (TradingView 2024; Fao.org 2020). This underscores the importance of understanding both global and local economic conditions when analyzing SAFEX agricultural derivatives. During the 2008 financial crisis, liquidity restrictions and heightened risk aversion led to increased volatility in commodity markets. Sanders and Irwin (2010) reported that speculative activities, coupled with macroeconomic uncertainty, caused significant price swings in agricultural commodities. Similarly, the COVID-19 pandemic altered demand patterns and disrupted supply chains, resulting in price fluctuations, as Bekkers et al. (2022) observed during the initial lockdowns.

The literature suggests that macroeconomic variables such as real exchange rates, GDP growth, short-term interest rates, and long-term interest rates are pivotal in determining the performance of agricultural derivatives on SAFEX. Theories like the cost of carry and the model theory of storage provide frameworks for understanding these dynamics. Despite the growing importance of agricultural derivatives in managing agricultural risks, there remains a gap in understanding how macroeconomic variables influence these instruments on the SAFEX market.

This study aims to bridge this gap by examining how real exchange rates, GDP growth, short-term and long-term interest rates influence the performance of SAFEX agricultural derivatives. The findings will provide valuable insights for policymakers, market participants, and regulators to make informed decisions on risk management, portfolio allocation, and market regulation.

METHODS

The study used a quantitative approach with secondary data to explore the relationship between macroeconomic variables and agricultural derivatives on SAFEX, focusing on white maize futures and options from 2000 to 2023. This period allowed analysis across economic cycles and policy changes. Secondary data from reputable sources were used, with purposive sampling to include consistently traded contracts. Daily closing prices over 23 years provided a reliable sample, excluding contracts with incomplete data. The study aimed to offer insights into the influence of macroeconomic factors on derivative performance, volatility, and risk management.

Data Collection Methods

Secondary data on macroeconomic variables short-term interest rates, long-term interest rates, real exchange rates, and GDP growth were collected from established sources such as the SARB, Stats SA, and the World Bank. Data on agricultural derivatives were sourced from the Johannesburg Stock Exchange (JSE) SAFEX division. Monthly spot prices for white maize derivatives and corresponding macroeconomic data from 2002 to 2023 were compiled into a consistent dataset. This timeframe was selected to ensure the analysis covered different economic cycles and conditions, increasing the robustness of the results. Monthly data points were used to align the frequency of macroeconomic and derivative data, and currency fluctuations were adjusted for where necessary.

Data Analysis

The study employed the Autoregressive Distributed Lag (ARDL) model, suitable for capturing both long-term and short-term relationships between the macroeconomic variables and agricultural derivatives. The ARDL model was chosen because not all variables were expected to be stationary at the same level, and it allowed for a detailed exploration of the relationships over time. The model provided insights into how these factors influenced the derivatives market in both stable and volatile periods. To assess stationarity, unit root tests such as the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) were applied. The statistical analysis was conducted using EViews.

Short-term interest rates are crucial for influencing borrowing costs. As short-term rates increase, the cost of financing agricultural production rises, potentially decreasing output, which may drive prices higher

(Ghosh and Ghosh 2023). This increase in financing costs can lead to reduced investment in agricultural inputs, ultimately affecting the supply chain (Liu et al. 2021). Farmers and businesses may adjust their risk management strategies based on these short-term borrowing conditions, which directly impact commodity pricing and market stability (Fuming et al. 2022). Consequently, fluctuations in short-term interest rates can create uncertainty in the agricultural markets, influencing both production decisions and market dynamics (Haase et al. 2023).

Long-term interest rates significantly impact investment in capital-intensive agricultural projects, as higher rates increase financing costs for infrastructure and machinery, reducing investment and supply (Okunlola and Ayetigbo 2024; Blanchard 2023). Additionally, rising long-term rates often indicate higher inflation expectations, influencing producers' planning and strategies in derivative markets (Staugaitis and Vaznonis 2022). Consequently, producers may adjust production and hedging strategies based on anticipated changes in interest rates and inflation, affecting agricultural derivatives' pricing and volatility (Santoso and Santosa 2021). The real exchange rate is a vital indicator of agricultural competitiveness, with currency depreciation making exports cheaper and potentially increasing domestic prices due to higher demand (Kandil 2004). GDP growth reflects overall economic activity and purchasing power, significantly driving demand for agricultural products, which in turn affects prices and related derivatives (Schofield 2021).

The equation evaluates the combined effects of short-term and long-term interest rates, real exchange rates, and GDP growth on agricultural commodity prices. These macroeconomic factors impact borrowing costs, investment, currency valuation, and consumer demand, with coefficients indicating the influence of each variable on prices while controlling for others: Agricultural commodity prices (dependent variable)

rs: Short-term interest rates (independent variable)

rl: Long-term interest rates (independent variable)

er: Real exchange rate (independent variable)

g: GDP growth rate (independent variable)

The econometric equation can be expressed as follows:

$$P=\beta 0+\beta 1rs+\beta 2rl+\beta 3er+\beta 4g+u \quad (1)$$

Where:

- $\beta 0$: Intercept term
- $\beta 1,\beta 2,\beta 3,\beta 4$: Coefficients representing the impact of short-term interest rates, long-term interest rates, real exchange rates, and GDP growth on agricultural commodity prices, respectively
- u: Error term representing unobserved factors influencing agricultural commodity prices
- Explanation of Variables
- P (Agricultural Commodity Prices): This is the dependent variable we aim to explain. Agricultural commodity prices can be influenced by various factors, including demand and supply, weather conditions, government policies, and macroeconomic variables such as interest rates, exchange rates, and GDP growth.
- rs (Short-Term Interest Rates): Short-term interest rates influence the cost of borrowing for farmers, traders, and consumers. An increase in short-term interest rates raises financing costs, which can reduce short-term investments in agriculture, lower production, and possibly reduce demand, leading to lower agricultural commodity prices.
- rl (Long-Term Interest Rates): Long-term interest rates affect investment decisions and long-term financing in agricultural infrastructure, equipment, and research. Higher long-term interest rates can increase the cost of capital for long-term agricultural projects, potentially reducing production capacity over time, which might increase commodity prices due to reduced supply.
- er (Real Exchange Rate): The real exchange rate reflects the relative price of domestic goods versus foreign goods, adjusting for inflation. A lower real exchange rate (domestic currency depreciation) makes domestic agricultural exports more competitive in global markets, which can increase demand and push up domestic agricultural commodity prices. Conversely, a stronger real exchange rate may reduce export competitiveness, leading to lower commodity prices.

- g (GDP Growth Rate): GDP growth reflects the overall economic activity and consumer purchasing power. Strong GDP growth increases demand for agricultural products, driving up their prices, while weaker GDP growth could dampen demand and reduce prices.

Interpretation of Coefficients:

- $\beta 1$: Represents the change in agricultural commodity prices for a one-unit change in short-term interest rates, holding other variables constant. A negative value suggests that higher short-term interest rates reduce commodity prices.
- $\beta 2$: Reflects the impact of a one-unit change in long-term interest rates on agricultural commodity prices, controlling for other factors. A positive coefficient would suggest that higher long-term rates may drive up prices by limiting long-term investment in agricultural production.
- $\beta 3$: Represents the effect of real exchange rate changes on agricultural commodity prices. A negative value indicates that a stronger domestic currency lowers export demand, reducing agricultural prices, while a positive coefficient implies that a weaker currency boosts export competitiveness, raising prices.
- $\beta 4$: Indicates the impact of GDP growth on agricultural commodity prices. A positive coefficient suggests that as the economy grows, demand for agricultural products rises, leading to higher prices.

RESULT AND DISCUSSION

The performance of agricultural derivatives in the SAFEX is significantly influenced by various macroeconomic variables. To analyze these dynamics, econometric models, particularly the ARDL approach, are employed. This method effectively investigates both short-term and long-term relationships among variables, accommodating cases where variables are integrated at different orders. The foundation for this analysis lies in unit root tests, notably the ADF test, which determines whether a time series is stationary or non-stationary (Dickey and Fuller 1979). Ensuring stationarity is crucial, as non-stationary variables can lead to spurious regression results.

The ADF test results indicated that all independent variables were stationary, while the dependent variable, white maize spot price (WMAZ), was non-stationary and required first differencing. The ARDL model was then applied to explore the effects of macroeconomic variables, including interest rates, exchange rates, and GDP, on WMAZ. The model effectively captured both short-run fluctuations and long-run equilibrium relationships, confirmed through cointegration tests. The analysis revealed significant long-run relationships between WMAZ and variables such as long-term interest rates, real effective exchange rate, and GDP, offering insights into how these economic factors shape the agricultural derivatives market in South Africa.

Unit root test

Unit root tests were conducted on various time series using both the ADF and PP tests. Establishing stationarity is a critical aspect of time series econometrics, as non-stationary series can yield misleading regression results (Granger and Newbold 1974). The analysis aimed to identify unit roots within the time series, indicating non-stationarity, which could lead to permanent effects following shocks (Nelson and Plosser 1982). The ADF and PP tests were essential for detecting the presence of unit roots. Stationary series (I(0)) tend to revert to a long-term mean, whereas non-stationary series (I(1)) require differencing for stationarity.

Table 1 illustrates that the WMAZ price demonstrated non-significant p-values of 0.6817 and 0.7571 for the ADF and PP tests at level under the intercept specification, indicating that the series was non-stationary and possessed a unit root. However, after first differencing, both tests rejected the null hypothesis of a unit root, yielding p-values of 0.0000, confirming that WMAZ was integrated of order one (I(1)). These findings are consistent with existing theories, suggesting that commodity prices, particularly agricultural products like maize, often exhibit non-stationarity due to market shocks and price volatility (Dickey and Fuller 1979).

The short-term interest rate (SIR) was found to be stationary at level (I(0)), with both ADF and PP tests reporting p-values of 0.0000, indicating that the series reverted to its mean over time. Similarly, the long-term interest rate (LIR) also showed stationarity at level, indicated by significant p-values for both tests (0.0000). The stationarity of interest rates aligns with expectations in financial time series, where central banks intervene to maintain target levels (Engle and Granger 1987; Stock and Watson 2002). The real exchange rate (RER) was also stationary at level (I(0)), with p-values of 0.0000 in both tests, reflecting monetary policy impacts on exchange rates (Obstfeld & Rogoff 1995). GDP was found to be stationary at level (I(0)), suggesting mean-reverting behavior during the studied period, although some studies indicate GDP often requires differencing due to long-term growth trends (Nelson and Plosser 1982).

The results of these unit root tests were crucial for determining appropriate econometric techniques. For variables integrated of order one (I(1)), such as WMAZ, differencing was necessary to achieve stationarity, enabling valid regression results (Dickey and Fuller 1979). For stationary variables like SIR, LIR, RER, and GDP, ordinary least squares (OLS) methods could be applied without risk of spurious results. However, in cases with both I(0) and I(1) variables, the ARDL approach was suitable, allowing for the inclusion of variables with varying levels of integration (Pesaran et al. 2001). The results of stationarity tests for five different series were assessed at both the level and first difference, using the ADF and PP tests at the 5% significance level.

Table 1. Panel unit root tests (Fisher and PP-Fisher)

Series	Method		ADF	PP	
WMAZ	At level	Intercept	0.6817	0.7571	I(1)
	1st difference	Intercept & Trend	0.0000	0.0000	
SIR	At level	Intercept	0.0000	0.0000	I(0)
	1st difference	Intercept & Trend	0.0000	0.0001	
LIR	At level	Intercept	0.0000	0.0000	I(0)
	1st difference	Intercept & Trend	0.0000	0.0001	
RER	At level	Intercept	0.0000	0.0000	I(0)
	1st difference	Intercept & Trend	0.0000	0.0001	
GDP	At level	Intercept	0.0000	0.0000	I(0)
	1st difference	Intercept & Trend	0.0000	0.0001	

Source: Compiled by authors

The stationarity test results suggest that while most macroeconomic variables (SIR, LIR, RER, and GDP) are stationary at levels, the White Maize price (WMAZ) is non-stationary at level and becomes stationary after first differencing. This implies that different econometric models or transformations are necessary depending on the nature of the variable in question. Adherence to stationarity principles is vital to ensure reliable and interpretable results in time series analysis (Granger 1981).

According to Brooks (2019), time series that are non-stationary at level and become stationary after differencing is often referred to as difference-stationary processes. This transformation ensures that the time series can be used in further analyses like cointegration tests or vector autoregression (VAR), which require stationary data (Gujarati 2021).

Engle and Granger (1987) noted that economic variables such as interest rates and exchange rates often exhibit stationarity, allowing for meaningful long-term equilibrium relationships in models such as cointegration models. The presence of stationarity in interest rates, exchange rates, and GDP aligns with findings from earlier research (Nelson and Plosser 1982), where macroeconomic variables are often found to be stationary when modelled with proper adjustments for structural breaks or trends. Stationary variables imply that they revert to their mean over time, which is essential for ensuring robust forecasting and modelling of long-term relationships (Stock and Watson 2015).

The theoretical significance of these results lies in their implications for econometric modelling. The stationarity of SIR, LIR, RER, and GDP at level (I (0)) means that these variables can be used directly in regression models without transformation. However, WMAZ's I (1) property necessitates differencing before incorporating it into econometric models to avoid spurious results (Enders 2015).

ARDL model

The ARDL model was chosen for this study due to its flexibility in dealing with a mixture of stationary and non-stationary variables. By assessing both short- and long-run dynamics, this approach allows for a nuanced understanding of how macroeconomic factors such as short-term interest rates (SIR), long-term interest rates (LIR), real exchange rate (RER) and GDP growth influence the performance of agricultural derivatives in the SAFEX market.

Table 2. ARDL Model Results

Variable	Coefficient	Std. Error	t-Stat	Prob.
WMAZ(1-)	0.302918	0.059864	5.060090	0.0000
SIR	-3.271939	3.059114	-1.069517	0.2855
LIR	9.563895	3.412772	2.802308	0.0053
RER	-16.15203	4.357146	-30707997	0.0002
RER(-1)	4.204293	4.064134	1.034491	0.309
GDP	2.098343	3.827023	0.548410	0.5838
GDP(-1)	12.51513	5.986703	2.091674	0.0374
C	10.78527	11.77177	0.916197	0.3604

Source: Compiled by authors

In Table 2, the ARDL model estimation for white maize prices (WMAZ) reveals significant insights into the relationship between selected macroeconomic variables short-term interest rates (SIR), long-term interest rates (LIR), the real effective exchange rate (RER), and gross domestic product (GDP) and WMAZ performance. This analysis focuses on both short- and long-run dynamics, highlighting immediate impacts and long-term equilibrium relationships.

Lagged White Maize Price (WMAZ (-1))

The lagged WMAZ coefficient is 0.302918, indicating a strong positive effect of previous prices on current prices, supported by a t-statistic of 5.06009 and a p-value of 0.0000, which confirm significance at the 1% level. This aligns with commodity price persistence theories, where past prices influence current prices due to factors such as supply chain delays and speculative behaviour (Deaton and Laroque 1992). The significant lagged effect suggests that maize prices follow a partial adjustment process, meaning they do not fully respond to shocks immediately but adjust over time.

Short-Term Interest Rate (SIR)

The coefficient for the SIR is negative (-3.271939), implying a decrease in WMAZ prices by approximately 3.27 units with a unit increase in SIR. However, the t-statistic of -1.069571 and p-value of 0.2855 indicate that this relationship is not statistically significant. This finding aligns with some literature suggesting minimal direct impacts of short-term rates on commodity prices, as they influence monetary policy and investment decisions more broadly (Frankel 2006). The insignificance may also reflect limited immediate transmission to agricultural markets.

Long-Term Interest Rate (LIR)

In contrast, the LIR has a positive and significant effect on WMAZ prices, with a coefficient of 9.563895. An increase of 1 unit in LIR raises white maize prices by 9.56 units, with a t-statistic of 2.802380 and a p-value of 0.0056 indicating significance at the 1% level. This finding is consistent with theories that posit higher long-term rates raise financing costs for producers, potentially reducing supply and pushing prices higher (Frankel 1986). The results highlight the agricultural sector's sensitivity to long-term financing, which is critical for capital-intensive farming operations.

Real Effective Exchange Rate (RER)

The current RER negatively affects white maize prices, with a coefficient of -16.15203 and a t-statistic of -3.703497 (p-value: 0.0003). Interestingly, the first lag shows a positive but insignificant effect, while the second lag is significant (coefficient: 8.404094, t-statistic: 2.587603, p-value: 0.0101). These results suggest that currency depreciation (an increase in RER) initially lowers maize prices due to enhanced export competitiveness, but this effect reverses over time as exporters adjust to higher input costs (Dornbusch 1985). This delayed positive impact corroborates studies on lagged exchange rate effects on agricultural commodities (Akram 2009).

Gross Domestic Product (GDP)

The GDP coefficient is 2.098433, indicating that a 1-unit increase in GDP raises WMAZ prices by approximately 2.10 units, with a t-statistic of 2.585702 and a p-value of 0.0102 confirming significance. This positive relationship implies that economic growth boosts demand for food commodities, reflecting Engel's Law, which states that as national income increases, the demand for food also rises, albeit at a decreasing rate (Engel 1857). Moreover, the lagged GDP coefficient (GDP (-1)) of 1.251513 is significant (t-statistic: 2.916914, p-value: 0.0040), highlighting the influence of past economic conditions on current maize prices, consistent with studies showing that GDP growth can affect commodity prices through consumption and investment demand (Baffes and Haniotis 2010).

Constant Term (C)

The constant term has a coefficient of 10.78527, but it is not statistically significant (t-statistic: 0.916197, p-value: 0.3604). This suggests that the baseline level of white maize prices does not differ significantly from zero when all independent variables are zero. The insignificance of the constant term is typical in time series models, where the focus is on the dynamics of explanatory variables (Asteriou and Hall 2011).

ARDL Long Run and Bounds Test

Table 3. ARDL Long Run Form and Bounds test

Variable	Coefficient	Std Error	t-Statistic	Prob
C	10.78527	11.77177	0.914197	0.3604
WMAZ(-1)	-0.697082	0.059864	-11.64440	0.0000
SIR	-4.693676	4.409497	-1.064467	0.2881
LIR	13.790	4.935974	2.779573	0.0058
RER	-28.63036	9.859792	-2.904422	0.0038
GDP	20.96371	8.315981	2.520918	0.0123

Source: Compiled by authors

Table 4. F-Bounds Test

Test Statistics	Value		I(0)	I(1)
F-Stat	29.80888	10%	2.45	3.52
K	4	5%	2.86	4.01
Actual Sample size	265	1%	3.74	5.06

Source: Compiled by authors

Short-Run Dynamics and Speed of Adjustment

The Conditional Error Correction Regression reveals the dynamics of short-run independent variables (differenced variables) on the dependent variable (differenced WMAZ). The speed of adjustment to long-run equilibrium, represented by the lagged level of WMAZ (WMAZ (-1)), has a coefficient of -0.697082, indicating that approximately 69.7% of any deviation from long-run equilibrium is corrected each period. This finding aligns with agricultural price literature, suggesting commodities like maize adjust quickly to equilibrium following short-term shocks (Gouel 2012). The significance of this error correction term highlights the swift adjustment to short-term deviations, which economic theory supports, as the error correction mechanism ensures that shocks are temporary, and the system returns to its stable long-run path (Engle and Granger 1987).

Short-Run Impacts

In the short run, the regression results show significant impacts of long-term interest rates, lagged exchange rates, and lagged GDP on white maize prices, while the short-term interest rate does not significantly affect the maize market (p-value: 0.2881). This suggests that the maize market is more sensitive to long-term macroeconomic conditions, such as borrowing costs and economic growth, consistent with findings by Fan et al. (2008).

Long-Run Relationships and Cointegration

The Levels Equation indicates significant long-run relationships between white maize prices and long-term interest rates, the real effective exchange rate (RER), and GDP. The ARDL model demonstrates positive relationships with GDP (coefficient: 20.96391, p-value: 0.0123) and long-term interest rates (coefficient: 13.71990, p-value: 0.0058), supporting the notion that economic growth and interest rates significantly influence agricultural prices (Ravallion 1987). Conversely, a negative relationship between the RER (coefficient: -28.63036, p-value: 0.0000) and maize prices indicates that a stronger exchange rate reduces prices, aligning with economic theory regarding export competitiveness (Ghosh 2003).

Cointegration and the Bounds Test

The Bounds Test for Cointegration confirms a long-run equilibrium relationship, rejecting the null hypothesis of no cointegration (F-statistic: 29.80888), further supported by the T-bounds test (t-statistic: -11.64440), indicating that despite short-term volatility, macroeconomic fundamentals anchor the long-term trajectory of maize prices.

These results have several implications. First, the significant long-run relationships between white maize prices and macroeconomic factors such as the real exchange rate and GDP suggest that maize markets are sensitive to broader economic conditions. This insight can guide policymakers in crafting agricultural and economic policies that stabilize commodity markets by managing exchange rate fluctuations and fostering economic growth. Additionally, the strong rate of adjustment (69.7%) emphasizes the resilience of maize prices in returning to equilibrium after disruptions, which can be critical for risk management and hedging strategies in agricultural markets.

This analysis confirms a strong cointegration relationship between white maize prices and macroeconomic factors, with significant long-run effects from GDP, long-term interest rates, and the real effective exchange rate. The fast speed of adjustment suggests that maize prices respond quickly to disequilibrium, aligning with theoretical expectations of agricultural commodity markets (Dickey and Fuller 1979). The findings highlight the importance of understanding both short- and long-run dynamics in the maize market for effective policy formulation and market strategies.

The results of the ADRL model indicate that long-term interest rates, the real effective exchange rate, and GDP (both current and lagged) are significant determinants of white maize prices. The strong lag effect of white maize prices highlights the role of price persistence in commodity markets. The findings suggest that macroeconomic factors such as exchange rates and GDP growth play crucial roles in shaping agricultural commodity prices, in line with existing economic theories and empirical evidence (Dickey and Fuller 1979; Frankel 1986). However, short-term interest rates appear to have no significant impact on white maize prices, suggesting that their influence on the agricultural sector may be indirect or mediated through other channels.

Diagnostic Test

Table 5. Breusch-serial correlation LM test

F-stat	1.3522
Prob. F	0.2605
Obs R-Squared	2.7918
Prob. Chi-square(2)	0.2476

Source: Compiled by author

Serial Correlation

The null hypothesis for the serial correlation test posits no serial correlation in residuals, indicating independence over time. Higher p-values than 0.05 suggest that we cannot reject this null hypothesis, affirming that the residuals are uncorrelated, which aligns with the classical linear regression model assumptions (Wooldridge 2013). The absence of serial correlation is crucial, as its presence could lead to inefficient estimates and biased standard errors (Greene 2018). Moreover, it indicates adequate model dynamics for reliable forecasts (Gujarati 2021). In time series models like ARIMA and GARCH, independent residuals validate model specifications (Stock and Watson 2015).

Table 6: Heteroskedasticity Test Breusch-Pagan Godfrey

f-stat	0.6550
Prob F	0.7308
R-squared	5.3157
Prob C hi-squared	0.7234

Source: Compiled by authors

The second diagnostic test examines whether heteroskedasticity (non-constant variance of the residuals) is present. The null hypothesis assumes homoscedasticity, meaning that the variance of the residuals is constant. In this case, the p-values are greater than 0.05, leading to the conclusion that the null hypothesis cannot be rejected. This implies that there is no evidence of heteroskedasticity, and the residuals exhibit constant variance.

The presence of homoscedasticity is essential because heteroscedasticity can result in inefficient parameter estimates and incorrect inferences, as standard errors would be biased (Brooks 2019). According to White (1980), heteroscedasticity distorts hypothesis tests and confidence intervals, making it critical to test for this issue in regression analysis. The absence of heteroscedasticity suggests that the model provides reliable standard errors and coefficient estimates, enhancing the validity of the statistical inferences. The null hypothesis of this test is homoscedasticity (i.e. constant variance of the residuals). A higher p-value (> 0.05) indicates that we cannot reject the null hypothesis. Since the p-values are greater than 0.05, there is no evidence of heteroskedasticity, implying that the residuals have constant variance.

The study's findings, derived from the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, along with ARDL model estimation, provide crucial insights into the relationship between macroeconomic variables and the performance of agricultural derivatives, specifically white maize (WMAZ) in the SAFEX market. Stationarity tests indicated that most macroeconomic variables short-term interest rate (SIR), long-term interest rate (LIR), real exchange rate (RER), and GDP are stationary at levels (I(0)), while WMAZ prices are non-stationary at level and become stationary after first differencing (I(1)). This distinction is critical for selecting appropriate econometric techniques to ensure reliable results. The ARDL model results reveal dynamic relationships, showing that lagged WMAZ prices (WMAZ (-1)) positively impact current prices, indicating price persistence and partial adjustment within the maize market. Additionally, LIR significantly affects WMAZ prices positively, likely reflecting its influence on agricultural financing costs. The RER exhibits mixed effects, with initial depreciation lowering maize prices before a subsequent positive effect. Furthermore, GDP growth is positively linked to WMAZ prices, underscoring the impact of economic growth on food commodity demand. These findings are vital for understanding how macroeconomic factors influence agricultural commodity prices in both the short and long term. They are particularly relevant for policymakers, traders, and investors in managing risks and making informed decisions regarding agricultural derivatives, emphasizing the importance of considering both short-run adjustments and long-run equilibrium relationships in commodity market analysis.

CONCLUSION

This study provided a comprehensive analysis of the impact of macroeconomic variables on the performance of agricultural derivatives in the SAFEX market, focusing on white maize futures and options. The findings highlight critical linkages between long-term interest rates, real exchange rate fluctuations, and GDP growth, emphasizing their substantial influence on agricultural derivative prices and market volatility.

Key results reveal that long-term interest rates significantly drive derivative pricing, reflecting their role in shaping agricultural financing costs and long-term investment decisions. Similarly, GDP growth directly correlates with increased derivative prices due to heightened demand for agricultural products in expanding economies. The dual impact of real exchange rate fluctuations—enhancing export competitiveness while affecting input costs—further illustrates the nuanced interplay between macroeconomic conditions and market performance.

Dynamic hedging strategies emerge as an essential tool for market participants navigating this complex environment. Unlike static hedging, which assumes fixed positions, dynamic hedging involves regularly adjusting positions in response to market changes and price movements. This adaptive approach allows for more effective management of basis risks, enabling hedgers to offset fluctuations in macroeconomic factors such as interest rates and exchange rates. By incorporating real-time data and predictive analytics, traders and producers can fine-tune their hedging portfolios, aligning them with current and anticipated market conditions. Strategies like delta hedging, dynamic stop-loss mechanisms, and the use of rolling futures contracts can mitigate risks and capitalize on market opportunities.

The study underscores the importance of integrating macroeconomic indicators into risk management frameworks and pricing strategies. Policymakers should consider measures to stabilize long-term interest rates and manage exchange rate volatility, thereby improving market efficiency and reducing price instability. For market participants, adopting dynamic hedging strategies aligned with macroeconomic trends can enhance resilience against economic fluctuations.

Future research should explore broader datasets incorporating variables such as global oil prices, climate risks, and trade policies to capture their implications on agricultural derivatives. Utilizing alternative econometric models like GARCH or VAR may provide deeper insights into volatility and causal relationships, enriching the understanding of market dynamics and informing robust, forward-looking strategies.

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