Risk Management in Agricultural Productivity: Assessing the Impact of Macroeconomic Volatility in South Africa

Colwyn Daniélle Fourie[1], Daniel Mokatsanyane[2]

Abstract: Economists universally champion the shift for moving from an agrarian to formal economy, while this structural transition entails substantial risks concerning the vital role of domestic agriculture in maintaining food security, creating employment and generating revenue. This study further advances the knowledge regarding efforts to achieve synergy between the fields of economics and agriculture, focusing on the resulting challenges in risks stemming from their mutual influence. The objective of this study is to examine the impact of macroeconomic volatility on agricultural productivity. Quarterly data is used to examine the short run and long run relationship between these variables, using a Vector Error Correction Model (VECM). Quarterly data effectively captures the short-term, cyclical and seasonal dynamics amongst the variables of interest. The main findings of this study are that macroeconomic volatility has a greater long-term impact on agricultural productivity due to the longer production cycles from planting to harvesting, that is highly dependent on externalities. This emphasises that more rigorous focus is needed on the systemic and spill-over effects of policy and economic decisions on agricultural productivity, and the subsequent effect on the welfare of end consumers.

Keywords: Agricultural productivity; risk management; macroeconomic volatility; South Africa

JEL Classification: E23, E44, Q11, Q13, Q1

1. Introduction

A vital component of the South African economy, the agricultural sector, has several functions beyond production. Its contributions include creating employment opportunities, boosting export revenue and guaranteeing food security. By directly creating 800,000 employment opportunities and accounting for 3% of GDP, it plays a significant role in the labour market (Jonck & Mabaso, 2025). Sihlobo (2024) stated that South Africa's agricultural sector continuously realised export activity with aggregated exports of US $13,2 billion for 2023, despite trade bottleneck challenges at ports. According to the

[1] Researcher, North-West University, Vanderbijlpark, South Africa, Address: PO Box 1174, Vanderbijlpark, 1900, South Africa, E-mail: daniellefourie99123@gmail.com.
[2] Programme Leader for Risk Management, North-West University, Vanderbijlpark, South Africa, Address: PO Box 1174, Vanderbijlpark, 1900, South Africa, Corresponding author: danny.mokatsanyane@nwu.ac.za.

World Bank's 2022 data, the South African agricultural sector covers the largest land area of the continent, Africa, amounting to 79,4% of the land area (World Bank, 2022). Although South Africa is a water-scarce country, strong agricultural practices has been implemented, such as irrigation regimes mitigating the impact of droughts according to AgriSA (2024). Although AgriSA (2024) notes agricultural practices such as irrigation regimes currently mitigating drought risk, these offer a partial defence against escalating climate change and prolonged periods of low rainfall - a failure of these systems would cause catastrophic, national level deviations.

Given the dynamic and risk-prone nature of agriculture, understanding the broader macroeconomic risks affecting productivity is vital. The agricultural sector is constantly exposed to various types of risks ascribed to adverse outcomes, resulting in lower yields and incomes, having even more devastating outcomes, including bankruptcy and food insecurity (Komarek et al., 2020). Despite its significance in the economy, the agricultural sector in South Africa is increasingly vulnerable to macroeconomic volatility — a challenge that threatens productivity and long-term sustainability of this crucial sector. According to Setshedi and Mosikari (2019), it is critical to comprehend how exports of agriculture is linked to exchange rates in South Africa, thus the importance of including this variable is justified. Setoboli et al. (2012) states that the agricultural sector's position can be shown in terms of its productivity being maximized, while minimizing input costs.

While global studies have explored macroeconomic influences in broad terms, context-specific analyses within South Africa remain limited (Setshedi & Mosikari, 2019). Most research focusses on individual risks, such as production risk, without considering how various macroeconomic risks interact to affect food security and agricultural productivity (Girdžiūtė, 2012; Jankelova et al., 2017; Komarek et al., 2020; Bencova et al., 2021). This study fills a critical gap by analysing macroeconomic volatility using a dynamic approach to quantify its compounded impact on agricultural productivity. The macroeconomic variables considered for this study include interest rates, inflation rates, real exchange rates and agricultural investments. Economic diversification is crucial, because agriculture's GDP contribution is important for the economy. However, issues such as fluctuating exchange rates, high interest rates, growing fuel and energy prices and climate change pose a threat to the sustainability of agriculture (Iorember et al., 2024).

This study adds to the knowledge on risk mitigation techniques in the industry by examining the ways in which these macroeconomic factors' volatility affects agricultural productivity and increases agricultural risks in South Africa. The primary objective of this research study is to assess the extent to which macroeconomic volatility influences agricultural productivity in South Africa by applying a dynamic model, aimed to offer insights into more robust risk management strategies for agricultural development.

2. Literature Review

2.1. Introduction

Understanding the impact and interrelation of volatility within the macroeconomic environment and agricultural productivity is crucial to direct the decision-making of producers. The focus of the literature review is to synthesize existing research on macroeconomic variables, such as exchange rate fluctuations, interest rate changes and inflation, and their consequences on agricultural production. This review establishes a comprehensive framework for understanding the adverse consequences of volatile economic environments on this vital sector, by examining the theoretical evidence from South Africa, as well as developing and developed countries.

2.2. Theoretical Literature

This section represents the economic theories that relates to the macroeconomic variables affecting the productivity of the agricultural sector. Macroeconomic variables in conformity to other factors such as environmental and technological factors, has repercussions on agricultural productivity from a national and international perspective. The theories of comparative advantage, demand and supply and the input-output model will be discussed and assessed.

2.2.1. Theory of Comparative Advantage

The core of neoclassical trade theories is ascribed by comparative advantage, with it being driven either by technology or factor endowment (Costinot, 2009). Argued by Ricardo in the 19th century, it states that countries benefit from trade with each other by focussing on products they are best at producing and buying the products they are not good at producing from other countries (Costinot, 2009). It emphasizes that countries have different cost structures and opportunity costs and that they can produce more efficiently when focusing on their individual strengths (365 Financial Analyst, 2025). This theory is further used to argue that it is an important consideration for developing countries to join forces with free trade regimes as it results in increased living standards (Organisation for Economic Co-ordination and Development, 2011). However, it gets more complex when factors of production, scarcity of resources, the labour and employment situation of countries and their ability to have trade agreements with mutual benefits are considered (Belloc, 2006). The theory assumes that labour and capital remain immobile between nations, that there are no trade surpluses or deficits, all resources are fully employed, and that trade is described as a comparative-static dynamic (Schumacher, 2016).

Modern economics such as the neoclassical theory uses microeconomic tools including, opportunity costs, production possibility frontiers, social indifference curves and optimised production-consumption equilibriums to describe how countries benefit from free international trade (Schumacher, 2013). There however remain several questions on why opportunity costs differ among nations, with the Heckscher-Ohlin model assuming that this is a result of different factors of production endowments (Leamer, 1995).

Economists explain deviations in comparative advantage as the result of labour and capital not being able to move between nations on current comparative advantages (Schumacher, 2013), disregarding fluctuations over time because of innovation or increased or decreased investments. Additionally, the theory assumes constant returns to scale, but larger production scales results in lower per unit costs, known as economies of scale and thus smaller countries may struggle to emulate larger economies due to scale disadvantages (Ethier & Roy, 2009). The theory assumes free trade, excluding trade barriers, such as tariffs or quotas, that will distort comparative advantages and affect trading benefits for different countries and potentially lead to balance of payment deficits and decreased production when producers are reliant on importing inputs from other countries (Britannica, 2025). Transporting costs may outweigh the advantages of saving costs from specializing in production as lower transport costs are more advantageous for countries to specialize in goods where they have comparative advantages (OECD, 2009). Lastly, comparative advantage may not benefit all individuals or sectors equally since it overlooks non-economic factors such as geopolitics or cultural preferences that affects trade patterns (Sheppard, 2012). This is due to countries with strong geopolitical ties tending to trade more with each other due to lower trade barriers, decreased political risk and increased trust (Qiu et al., 2024). Cultures that value independence and are self-reliant may foster innovation and creativity that can result in comparative advantage for some industries that require new advancements (Siswanti, 2022).

This theory will be applied towards South African agricultural exports and how the country can maximise outputs given external macroeconomic conditions. It is applicable as South Africa has a diverse agricultural sector with different regions having natural endowments, such as water resources, that lend themselves to the production of agricultural products. Furthermore, South Africa is an exporter of agricultural products, thus the sector is linked to international trade and the principles of comparative advantage. The theory of comparative advantage advocates for specialization that may result in increased productivity but also exposes the sector to increased risk from external fluctuations. South African commodities may be vulnerable to deviations in the prices of commodity prices, changes in demand and international market dynamics. A volatile exchange rate can impact the comparative advantage of South African agricultural exports, as a strong currency (Rand), results in costly exports and lower priced imports affecting the profitability of export-oriented agricultural producers and increases competition from imports for domestic producers.

2.2.2. Theory of Demand and Supply

This fundamental economic theory illustrates how prices are determined in a market (Morell, 2015). It indicates that when demand exceeds supply, prices tend to increase and vice versa (Gale, 1955). These forces interact to establish an equilibrium price and quantity (Mankiw, 1998). Demand represents the quantity of a set agricultural product consumers are willing and able to purchase, whereas supply represent the quantity of an agricultural product that producers are willing and able to offer. Macroeconomic factors significantly influence the supply of these products, causing shifts in the supply and consequently affecting the market price (Setshedi & Mosikari, 2019). Considering the variables of the study, the impact of interest rates affects borrowing costs, in essence increasing the cost of financing necessary inputs, including fertilizers, seeds and machinery, as well as investments in farm infrastructures (Economic Research Division, 2010). This increased cost of production results in less profitable agricultural activities, potentially leading to a decrease in supply (Kirechev, 2025). Demand being constant or increasing combined with the reduction in supply results in higher prices and lower quantities (Trostle, 2008). Agricultural supply, however, reacts slow to price change adjustments due to the seasonality of commodities resulting in lags in production, and fixed capital investments (International Monetary Fund & United Nations Conference on Trade and Development, 2011).

Exchange rates affect the cost of imported agricultural inputs such as pesticides and the revenue generated from exported products (Edwards & Hlotshwayo, 2020). A weaker domestic currency increases production costs, decreasing supply domestically (Nedbank, 2024). On the other end, foreign markets' demand for cheaper exports results in a decrease in domestic supply available (Basevi, 1970). Inflation increases price levels and results in higher input costs, such as fuel and labor (Langemeier, 2022). This increase reduces profitability at current output prices, leading to decreased supply (Langemeier, 2022). Macroeconomic factors significantly alter the supply of agricultural products by influencing production costs and trade dynamics (Kargbo, 2007). These shifts in supply, considering the basic principles of supply and demand theory, lead to changes in the market equilibrium price and quantity of agricultural products (Nerlove & Bachman, 1960). Understanding these relationships is crucial for policymakers and stakeholders in the agricultural sector. Volatility in any determinant of agricultural production can result in shifts in demand and supply curves, that will result in fluctuations of price and quantity for agricultural producers and consumers (Balcombe, 2009).

The relevance of this theory relates to the explanation on how prices for agricultural products are determined and affected by volatility in the macroeconomic environment, that affects the cost of production directly. Market risk for agricultural producers is driven by fluctuations in demand and supply due to the deregulated and globalized market. Changes in supply and demand results in disequilibrium and price fluctuations. Furthermore, macroeconomic factors, amongst others inflation and exchange rates, affect the cost of agricultural products.

2.2.3. Theory of Demand and Supply

With a focus on specifying required quantities of inputs to produce each output, with each output potentially an input to another process is defined by the input-output model (Kitzes, 2013). This model is a framework for understanding inter-sectoral linkages of an economy (Public Policy and Analysis, 2024). It depicts flows of goods and services between industries, as well as these industries and final consumers including households, exports et cetera (Førsund, 1985). The core of this model is the input-output table (Statistics South Africa, 2017) which shows intermediate consumption (value of inputs purchased from one sector by another sector to produce its output), final demand (value of goods and services sold by a sector to final consumers) and total output (value of goods and services produced by a sector). The I-O model will be adapted to highlight the agricultural sector and the crucial linkages with other industries. These sectors are inherently connected – agriculture is a provider of raw materials for food processing and transport facilitates the movement of these inputs and outputs (Saari et al., 2013).

Energy is a significant input for various agricultural activities such as irrigation, machinery operations and heating or cooling, as well as transport and food processing (OECD, 2017). An increase in these costs will have a direct effect resulting in increased input costs leading to higher costs per unit of output (Gamtessa & Olani, 2018). Indirectly, it will result in increased operational costs of the transport sector, affecting transportation costs of inputs and outputs (Gamtessa & Olani, 2018). Similarly, food processing will have higher energy costs, thus increasing the cost of processed products (Wang, 2014). The I-O model quantifies the total effect on output, including indirect impacts transmitted through transport and food processing sectors (Aponte, 2025). By analysis of the Leontief inverse, it is evident how an initial shock in energy prices propagates through the economic system, affecting productivity and the prices of commodities (Miranda-Pinto et al., 2024). By employing the input-output model, this study will provide a framework to disentangle the direct and indirect impacts of macroeconomic volatility; specifically changes in interest rates, on agricultural productivity in South Africa, quantify the interconnection between this sector and key related sectors in the transmission of these macroeconomic shocks and provide a comprehensive understanding on how macroeconomic volatility and instability can cascade through the economy and affect productivity beyond just direct effects within the sector.

The I-O model has various limitations, including being a static model, where constant levels of technology and linear relationships are assumed and may not be an accurate representation of a dynamic sector in the economy (Zhang et al., 2014). Furthermore, the model assumes homogeneity within sectors, which is not true, and the I-O model does not incorporate behavioural factors of decision-making by producers and consumers (Zhang et al., 2014).

The agricultural sector does not stand in isolation from other sectors, but rather it depends on inputs from other sectors in the form of fertilizers, machinery etc, and provides outputs to other sectors in the form of food processing or retail (CSIR, 2022). The Input-output model maps these interdependencies between sectors where macroeconomic volatility can result in chain reactions in these linkages, thus affecting input costs for agricultural production and the demand for its outputs. Furthermore, the I-O model can disaggregate and analyse the specific sub-sectors within the agricultural sector such as horticulture and livestock (Hansson, 2009). This allows for identification of the specific activities that are susceptible to macroeconomic changes.

2.3. Empirical Literature

Ramaila et al. (2011) indicated that developing countries are afflicted to fluctuations in agricultural productivity due to factors including, investment in research and development, capital, and augmented inputs. This study further indicated that agricultural productivity increased greater in developed countries in comparison to developing countries due to the forementioned factors. This relates back to the Input-Output theory that focuses on the required quantities of inputs necessary to deliver an output. Ramaila et al. (2011) further states that agricultural growth is dependent on technological change, efficient input use and preservation of natural resources. Gollin (2010) found that large magnitudes of the population of developing countries are engaged in agriculture and that this sector accounts for substantial share of GDP and exports. Further this study found that reallocation of labour and resources can be a primary source of productivity gains and increases in income. However, this study found that it is difficult to establish clear causality due to challenges arising from econometric identification, the complexity of cross-country comparisons, country-specific factors and historical events introduce endogeneity and confounding factors. This study emphasizes the importance of using investments as an independent variable as it found that investments in agricultural research yields high internal rates of return that further contributes to productivity growth and associated gains, even though the mechanisms of these gains are complex.

Kadir and Tunggal (2015) found that exchange rates, net exports, government expenditure and interest rates significantly influence productivity in the short term by using an Autoregressive Distributed Lag model. Amadi-Robert and Okuduwor (2022) concluded that trade openness, money supply, inflation rates, government expenditure and exchange rates significantly determines levels of productivity in conjunction with Ramaila et al., Cheng et al., Setshedi and Mosikari (2019), Kadir and Tunggal (2015), and Amadi-Robert and Okuduwor (2022) with regards to government expenditure and exchange rates, this study however focussed on agricultural production in Nigeria, but with a novel focus on a wider timeline from 1986 to 2020 using an ARDL model. This study can be used for a comparison between the developing countries, Nigeria and South Africa to understand how macroeconomic volatility can affect developing countries. Timidi and Ayunku (2024) focussed on credit to the private sector, broad money supply, monetary policy rate, inflation rate, lending rate and agricultural sector performance, using an Autoregressive Distributed Lag model and found that the lending rate is the most influential factor affecting performance in the sector.

Setshedi and Mosikari (2019) empirically analysed the influence of macroeconomic variables on agricultural productivity within South Africa, and found that GDP, government expenditure (GE), gross capital formation (GCF) and real interest rates (RINT) have a positive correlation with agricultural productivity in the long run. However, GDP and cross capital formation have a negative correlation with productivity. This correlation indicates that over an extended period, an increase in one factor results in an increase in agricultural productivity. This further implies a sustained relationship where advancements in areas results in increased yields of agricultural productivity per unit of inputs. The study focused on data from 1975 to 2016; thus, it excludes recent economic events that occurred. This emphasises a critical gap for more recent consideration for agricultural producers. It is important to take these events into consideration and explore the effect and understanding of macroeconomic variables on the agricultural sector and the necessity of risk management within this sector.

Kargbo (2011) used on Vector Error Correction Model to conclude that interest rates, inflation rate and money supply shocks significantly and persistently affects productivity and that M3 and interest rate shocks causes cost-price squeezes. Okeke and Okeke (2022) found that money supply, exchange rates and inflation positively correlate with productivity and that commercial bank loans on agriculture, interest rates and government expenditure have an inverse effect on output. Fadeyi et al. (2019) used a general computable equilibrium analysis to conclude that the during the financial crisis of 2008, a decrease in trade resulted in a decline of agricultural outputs, affecting household consumption and increasing poverty and inequality. Muzari (2016) concluded that efforts should be made in linking production with markets, thus cutting the production costs of producers and increases profitability and competitiveness of Sub-Saharan African products in international markets.

The relationship between macroeconomic factors, investments and agricultural productivity, especially in developing economies, is analysed in detail by existing literature. Research by Ramaila et al. (2011), Gollin (2010), Cheng et al. (2010), Kadir and Tunggal (2015), Amadi-Robert and Okuduwor (2022), Timidi and Ayunku (2024), Kargbo (2011), Okeke and Okeke (2022), Fadeyi et al. (2019) and Muzari (2016) has explored how elements such as investment in research and development, capital, input efficiency and macroeconomic variables (including exchange rates, interest rates, government expenditure, money supply, inflation and trade openness) can influence the productivity of agriculture and economic growth.

However, even with the contribution of these studies, there is still a void with respect to the literature concerning the effects of macroeconomic volatility on agricultural productivity in South Africa. Setshedi and Mosikari (2019) conducted an empirical analysis in South Africa, but the data from this study ranges only as far as 2016 and does not contain subsequent economic developments. This results in the implications of more recent economic environmental changes and the associated risk management needs in South African agriculture not being fully examined. Amadi-Robert and Okuduwor (2022) assess similar impacts in Nigeria and allow for cross-country comparisons, but the need exists for research to be updated specific for the South African environment, to evaluate the impact of recent macroeconomic trends on the agricultural sector. This would benefit policymakers, producers and stakeholders who seek ways to address the challenges they currently encounter and encourage sustainable long-term agricultural growth in the region.

3. Methodology

3.1. Introduction

This section outlines the methodology employed to analyse the long-run and short-run dynamic relationships between selected macroeconomic variables and the impact on agricultural productivity. It details the data sources, variable definitions, period of study, preliminary data analysis, model specification and necessary diagnostic tests.

3.2. Data and Variables

The study utilises quarterly time series data from 2000Q1 to 2024Q4. The table below indicates the variables examined, its measurement, where data was collected from and a summary of the expected relationships that will be discussed:

Table 1. Summary of variables

Variable	Description / Measurement	Source	Expected Relationship
Dependent Variable			
Agricultural Production (AP)	Measured by multi-factor productivity, which captures growth in output not explained by the quantity of inputs. It reflects technical progress, workplace improvements, and economies of scale.	Quantec EasyData	—
Independent Variables (Macroeconomic Volatility Indicators)			
Real Exchange Rate (RER)	Foreign exchange rate: South African cents per US dollar (middle rate, R1 = 100 cents).	South African Reserve Bank (SARB)	**Negative**, as a depreciation increases the cost of imported inputs such as machinery.
Inflation Rate (INF)	Inflation expectations: financial analysts' forecast for the current year.	South African Reserve Bank (SARB)	**Negative**, as higher inflation raises the cost of inputs such as fertilizer.
Interest Rate (IR)	Repo rate (average % per annum).	Quantec EasyData	**Negative**, as higher interest expenses reduce profitability and discourage agricultural investment.
Agricultural Investments (ARI)	Gross fixed capital formation in agriculture, forestry, and fishing (investment).	South African Reserve Bank (SARB)	**Positive**, as higher investment leads to improved machinery, productivity, and efficiency.

3.3. Preliminary Data Analysis

First, a logarithmic transformation will be applied before unit root tests to normalise the series and allow for the interpretation of coefficients as elasticities. The following formula is used for logarithmic transformation:

$$Y = \log_b(X)$$

$$b^Y = x$$

Equation 1. Formula for logarithmic transformation

3.3.1. Unit Root Tests

Preceding model estimation, all variables (dependant and independent) will be tested for stationarity using formal unit root tests such as the Augmented-Dickey Fuller (ADF) and Phillps-Perron (PP) test. Non-stationary series will be differenced to order 1 (or higher) to achieve stationarity as per the requirements of the VECM framework. Stationary data ensures that statistical properties remain constant over time, thus it provides reliable results (TigerData, 2024).

3.3.1.1. Augmented-Dickey Fuller (ADF)

The Augmented-Dickey Fuller unit root test is an extension of the Dickey-Fuller test that incorporates lagged terms of the differenced series to address autocorrelation that the Dickey-Fuller test may miss. The test is represented by the following equation:

$$\Delta Y_t = \propto Y_{t-1} + \sum_{k=1}^{K} \theta_k \Delta Y_{t-k} + \mu_t$$

Equation 2. Formula representing the Augmented-Dickey Fuller test

Where:

- k is the number of lags or autoregressive terms
- $\Delta Y_{t-1} = Y_{t-1} - Y_{t-2}, \Delta Y_{t-2} = Y_{t-2} - Y_{t-3}$ and so on
- $\sum_{k=1}^{K} \theta_k \Delta Y_{t-k}$ are the additional autoregressive terms

3.3.1.2. Phillips-Perron

The Phillips-Perron is similar to the Augmented-Dickey Fuller test; however, it is more robust to a wider range of statistical issues. The Phillips-Perron test corrects for serial correlation in the error term non-parametrically, thus the number of lagged difference terms is not necessary to specify. The Phillips-Perron test is represented by the following equation:

$$\Delta y_{t-1} = \alpha_0 + \gamma Y_{t-1} + e_t$$

Equation 3. Formula representing the Phillips-Perron test

3.3.2. Optimal Lag Selection

The appropriate number of lags (p) for the underlying Vector Autoregression (VAR) framework will be determined using standard information criteria, such as the Akaike Information Criteria (AIC), Schwarz Bayesian Criterion (SBC/BIC) and the Hannan-Quinn Information Criterion (HQ). This step is crucial as an incorrect lag length can lead to misspecification errors and biased results.

3.3.3. Cointegration Testing

The requirement for VECM is that the variables must be cointegrated i.e. share a long run equilibrium relationship, thus the Johansen Cointegration test will be used to determine the number of independent cointegrating relationships (r) among the k non-stationary variables. A significant number of cointegrating relationships $(r > 0)$ confirms the existence of a long run equilibrium and justifies the use of the VECM.

3.4. General VECM Model Equation

The VECM is a restricted VAR that is used when time series are cointegrated. The VECM explicitly integrates both the short run dynamics and the long run equilibrium relationship. The general form of the VECM for a set of k cointegrated $I(1)$ variables is specified as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-1} + BX_t + \epsilon_t$$

Equation 4. Formula representing the general Vector Error Correction Model

Where:

- Δ is the first difference operator, $\Delta Y_t = Y_t - Y_{t-1}$
- p is the optimal lag length determined in the preliminary analysis
- Π is the long run coefficient matrix, $\Pi = \propto \beta'$. This matrix contains the information about the cointegration relationships.
    - $\propto$ is a $k\ x\ r$ matrix of adjustment coefficients (speed of adjustment) which measures how quickly the variables adjust to restore the long-run equilibrium following a shock.
    - β' is a $r\ x\ k$ matrix of cointegrating vectors, which represents the long run equilibrium relationships between the variables.
- Γ_i are the short-run dynamic coefficient matrices.
- X_t is a vector of deterministic terms.
- ϵ_t is a vector of white noise error terms.

3.5. Expected Relationships

Based on economic theory and empirical evidence the following relationships between the macroeconomic variables and agricultural productivity is hypothesized. Firstly, the Balassa-Samuelson effect posits that as a country's productivity in tradable sectors such as agriculture and manufacturing increases more than its non-tradable sector such as services, the real exchange rate appreciates (Couharde et al., 2020). In the case of South Africa, the Balassa-Samuelson effect found a negative effect as productivity growth in non-tradable sectors outpaces the tradable sector that includes agriculture, which leads to a real exchange rate depreciation (Dadam et al., 2019). This results in a significant distributional effect further resulting in the goods from low-productivity agricultural sector being more expensive for households and weakened competitiveness in global markets. This further is confirmed by the findings of Adekunle and Ndukwe (2018) within the context of Nigeria.

The rational expectations theory posits that economic agents such as agricultural producers make decisions based on all available information as well as past experiences rather than just historical trends (Eckstein, 1984). This has implications on how agricultural producers respond to inflation. The theory further posits that the impact of inflation on agricultural production is dependent on whether inflation was anticipated or unanticipated (Modigliani & Shiller, 1973). If agricultural producers can accurately predict inflation, their behaviours and prices can be adjusted to account for inflation that reduces the negative impact on profitability (Ukoha, 2007). Furthermore, the theory assumes economic agents are rational optimizers who use relevant information to maximise profits (McCallum, 1980). For agricultural producers specifically, this assumes that they predict future prices inclusive of inflation, when making decisions on what to plant, quantities to produce and which inputs to use (Allen. 1994). However, unanticipated inflation may lead to cost-price squeeze for agricultural producers as the prices of inputs such as fertilizers, fuel and seeds may increase at a faster rate than the prices these producers receive for their products, thus affecting profitability while increasing debt and financial risk (Centre for Coordination of Agricultural Research and Development for Southern Africa, 2025). Thus, a negative effect is expected in line with the study of Janet (2024). Furthermore, the rational expectations theory explains how agricultural producers' expectations surrounding future interest rates directly influences their investment decisions and in essence their productivity (Bojnec & Latruffe, 2011). The agricultural sector often relies on debt to finance operations and long-term investments such as the acquisition of land, new machinery and new technologies to implement (Fi-compass, 2020). The rational expectation theory posits that agricultural producers will anticipate future interest rates when increasing debt (Modigliani & Shiller, 1973). If expectations are that that interest rates will increase, producers may increase investments to secure lower interest repayments at the current rate and the opposite when interest rates decrease to await "cheaper" financing (Masole, 2021). Furthermore, increased interest rates will result in producers adjusting budgets for protection against higher interest expenses that leads to reduced expenditure on critical inputs such fertilizer and labour thus affecting short-term productivity (Lele, 1990). Thus, a negative effect is expected in conjunction to the study of Okeke and Okeke (2022).

Finally, the expectations of gross capital formation (agricultural investments) are explained by the Solow-Swan model and more recently, the endogenous growth theory. The Solow-Swan model posits that gross capital formation, or the investment in physical capital and infrastructure, is a key determinant of productivity such as in the agricultural sector (Uddin et al., 2025). In the short-term, capital accumulation results in increased output per worker in the short-term. However, the model assumes that as you increase more capital to a fixed amount of labour and land, the marginal productivity of the capital will decline, thus indicating that although investment in crucial, it is not sustainable solely in the long-term for growth (Romer, 1990). The Solow-Swan model further posits that sustained economic growth including in agriculture, is motivated by exogenous technological progress (Chukwuemeka Ogugua, 2024) such as new crop varieties, better fertilizers and advanced farming techniques in the agricultural sector (EOS Data Analytics, 2025). The endogenous growth theory addresses the limitations of the Solow-Swan model by positing that technological progress is not just an external factor, but that long-term growth is a result of internal factors such as research and development and investment in human capital (Kasongo & Makamu, 2024). This theory suggests that investment in agricultural research, education for agricultural producers and the innovation of new technologies drives productivity (Agriculture Institute, 2024). These are known as positive externalities or knowledge spillovers that advances the sector and thus leading to increased productivity. Thus, a positive effect is expected, similar to the study of Ramaila et al. (2011).

3.6. Diagnostic Tests

After estimation, the following diagnostic tests will be conducted on the residuals of the estimated VECM to ensure the validity and reliability of the model:

3.6.1. Autocorrelation/Serial Correlation

After estimating the main regression model, it is mandatory to test the residuals for first- and higher order autocorrelation. Autocorrelation violates the assumption that the error terms are independently distributed, leading to inefficient parameter estimates which compromises the validity of hypothesis testing. The LM test statistic is based on the coefficient of determination (R^2) from the auxiliary number of observations (T). The statistic is given by:

$$LM = T \cdot R^2 \sim \chi^2(p)$$

Equation 5. Formula for the estimation of autocorrelation

3.6.2. Normality

This test determines if the residuals are normally distributed as it is a key assumption for valid statistical inference. The Jarque-Bera test will be applied to test for normality, with the null hypothesis (H_0) that the residuals are normally distributed. If the p-value is greater than 0,05 it confirms normality.

Hypotheses:

H_0: the residuals are normally distributed

H_1: the residuals are not normally distributed

$$JB = \frac{n}{6}(S^2 + \frac{(K-3)^2}{4})$$

Equation 6. Formula for the estimation of normally spread data

3.6.3. Heteroskedasticity

This test ensures that the variance of the error term is constant over time, which is essential for the estimated standard errors and t-statistics to be reliable. The ARCH-LM test (Autoregressive Conditional Heteroskedasticity) or White's test will be applied, with the null hypothesis (H_0) is that the residuals have no conditional heteroskedasticity/constant variance.

$$LM = T \cdot R^2 \sim \chi^2(K^2 \cdot m)$$

Equation 7. Formula for the estimation of heteroskedasticity

4. Empirical Findings and Discussion

The findings of the study explain how fluctuations in macroeconomic variables affect agricultural productivity in South Africa. The period assessed ranges from 2000 to 2024 with the methodologies from section 3 applied in this section. Section 4.1 summarises the descriptive statistics of the data such as the mean and skewness, while section 4.2 analyses the correlation between the selected variables. Section 4.3 indicates the stationarity nature of the data. Section 4.4 graphically illustrates the spread of the data and analyses the external shocks that resulted in these trends. Finally, section 4.5 sets out the results from the VECM model employed, with section 4.6 indicative of the diagnostic tests to verify if any assumptions were violated.

4.1. Descriptive Statistics and Graphical Analysis

Time series data specifically involving macroeconomics portray stochastic trends that can be eradicated by differencing of the series (Setshedi & Mosikari, 2019). Assessing the descriptive statistics of the data is an important step to simplify and understand the complexities of the data by summarising key features, which assists in identifying trends and patterns (Yellapu, 2018).

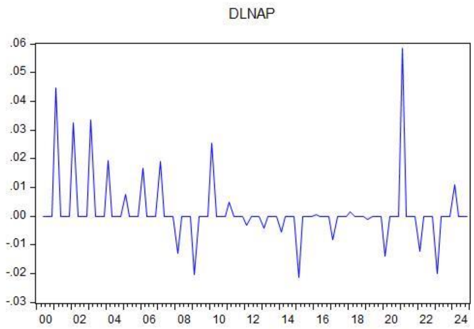
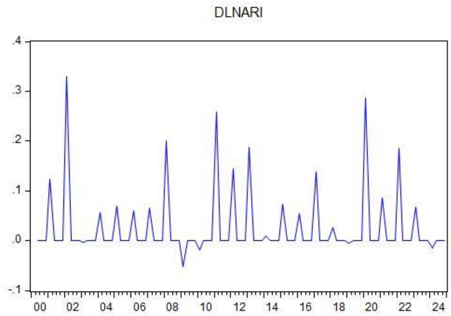
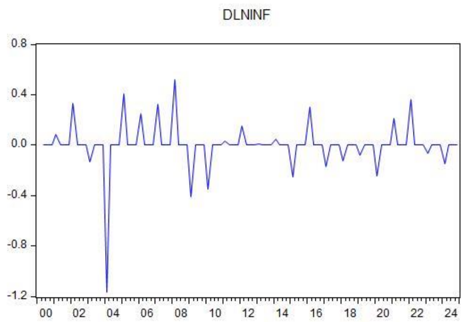
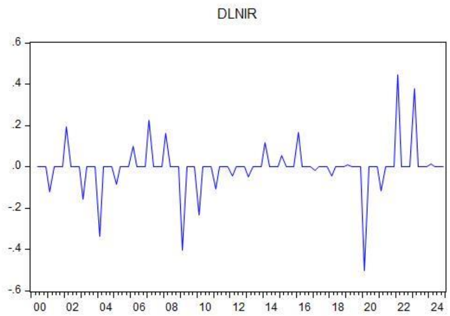
Table 2. Summary of Descriptive Statistics

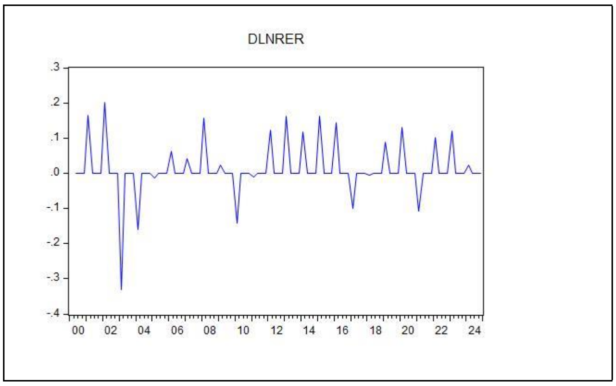
	AP	ARI	INF	IR	RER
Mean	99.8743	25023.5600	5.5850	7.5200	1095.8580
Median	200.3981	20171.0000	5.6000	7.0000	965.0225
Standard Deviation	3.8902	17019.6200	1.6144	2.4458	395.9276
Skewness	-1.7512	0.9040	0.7953	0.5779	0.5512

Kurtosis	5.8857	2.6586	4.5661	2.4525	1.9515
Jarque-Bera Probability	0.0000	0.0009	0.0000	0.0331	0.0080

According to table 2, the Jarque-Bera probability indicates that the data does not follow a normal distribution as the probability value for all variables are lower than 0,05. The importance of normal distribution is that it enables researchers to make inferences and comparisons. However, non-stationary data has statistical properties such as the mean and variance that changes over time thus leading to a distribution not being constant or non-normal. When the residuals are not normally spread, the p-values and confidence intervals from the OLS model might be unreliable and invalid, resulting in inaccurate conclusions about the impact of macroeconomic volatility on agricultural production. This thus necessitates the transformation of the data to a logarithmic function to make its distribution more normal.

Table 3. Graphical analysis of data at 1st difference for analysis of trends

Agricultural Productivity (AP)	Agricultural Investments (ARI)
	
Inflation Rate (INF)	Interest Rate (IR)
	
Real Exchange Rate (RER)	



From table 3 externalities can be seen such as the 2008 financial crisis in the inflation rate due to soaring global food and oil prices, conversely to the significant decrease in 2004 resultant from a strengthened rand and lower food prices. Furthermore, an upward trend can be witnessed in AP from 2000 to 2008 because of favourable weather conditions and no country-wide droughts for over a decade (Vink & van Rooyen, 2009). This was also coincided with deregulation of the marketing sector that dismantled control boards and emphasised export-oriented horticultural crops (Vink & van Rooyen, 2009). For the 2021-year agricultural productivity saw growth because of both large harvests and high crop prices that benefitted agricultural producers (Sihlobo, 2021).

4.2. Correlation Analysis

Table 4 indicates that all variables, dependant and independent, are correctly correlated and can be regressed on one equation without affecting any results.

Table 4. Summary of correlation between variables

	AP	ARI	INF	IR	RER
AP	1.0000				
ARI	0.3299	1.0000			
INF	-0.0741	-0.1855	1.0000		
IR	-0.5894	-0.4877	0.5887	1.0000	-0.3434
RER	0.1060	0.9333	-0.0933	-0.3434	1.0000

4.3. Stationarity Tests

The first step in the Box-Jenkins approach is to ensure that the data is stationary by assessing the results of the Augmented-Dickey Fuller (ADF) and Phillips-Perron (PP).

Table 5. Summary of ADF and PP for data at level and first difference

		Level		First Difference	
Variable	**Trend specification**	**Augmented-Dickey Fuller**	**Phillips-Perron**	**Augmented-Dickey Fuller**	**Phillips-Perron**
LNAP	None	0.9593	0.9617	0.0000	0.0000
	Intercept	0.0076	0.0029	0.0000	0.0000
	Intercept & trend	0.1590	0.1128	0.0000	0.0000
LNARI	None	0.9999	1.0000	0.0016	0.0000
	Intercept	0.8292	0.8226	0.0000	0.0001
	Intercept & trend	0.0170	0.0228	0.0000	0.0000

LNINF	None	0.4718	0.4718	0.0000	0.0000
	Intercept	0.0426	0.0232	0.0000	0.0000
	Intercept & trend	0.1438	0.0862	0.0000	0.0000
LNIR	None	0.2514	0.4302	0.0000	0.0000
	Intercept	0.1180	0.2672	0.0002	0.0000
	Intercept & trend	0.3268	0.6789	0.0006	0.0000
LNRER	None	0.9053	0.9652	0.0002	0.0000
	Intercept	0.8968	0.9123	0.0021	0.0000
	Intercept & trend	0.2168	0.5972	0.0086	0.0000

Table 5 indicates the stationarity of the data at level. From above it is evident by majority that the data is not stationary at level, depending on which trend specification was used. Non-stationary data is spurious and will result in unreliable forecasts and conclusions, thus first differencing must be applied to further check for stationarity. The ADF and PP is used alongside each other to ensure the robustness and reliability of the stationarity (unit root) findings. The ADF accounts for autocorrelation with lagged differences, while PP conversely uses a non-parametric correction that provides complementary checks and more comprehensive assessment of the stationarity. Table 4 further indicates after first differencing was applied that the data is stationary at a 5% confidence interval, as the probability values are lower than 0,05. Thus, the data can be used for reliable and robust analysis and forecasts as the trends and seasonality is essentially removed by this process. Inflation and agricultural yields often trend upwards or downward over years, indicating in the mean constantly shifting.

4.4. Model Specification and Results

4.4.1. Johansen Cointegration Results

It is important to determine the existence of a long run relationship between the stationary variables. Cointegration is used to ascertain the long run relationship between chosen macroeconomic variables and agricultural productivity. Assessing the existence of long run relationships and using the results to draw conclusions are essential for making significant economic conclusions. The results from the Johansen cointegration test are shown below:

Table 6. Johansen cointegration summary

	Trace test			Max-eigenvalue test		
Hypothesized no, of CE(s)	**Trace statistic**	**0.05 Critical value**	**Probability value**	**Max-Eigen statistic**	**0.05 Critical value**	**Probability value**
None*	111.4940	69.8189	0.0000	36.6797	33.8769	0.0225
At most 1*	74.8143	47.8561	0.0000	30.0103	27.5843	0.0239
At most 2*	29.7971	29.7971	0.0005	24.2162	21.1316	0.0178
At most 3*	15.4947	15.4947	0.0078	14.2105	14.2646	0.0510
At most 4*	3.8415	3.8415	0.0116	6.3772	3.8415	0.0116

The trace test, as well as the Max-Eigen test indicates that there is at least 5 cointegrating equations that exist at a 5% significance level. The null hypothesis of no cointegrating vectors is rejected as the trace statistic as well as the Max-Eigen statistic is greater (or at some equal to) the 5% critical values. The rejection of the null hypothesis indicates that there is a long run relationship between variables. The cointegrating equations supports the notion that macroeconomic volatility and agricultural productivity is intrinsically and fundamentally connected over time. Thus, macroeconomic factors are contained within a stable long-term relationship with agricultural productivity.

4.5. Vector Error Correction Model Results

The Vector Error Correction Model captures the long run equilibrium and short run adjustments between the selected variables which is crucial as volatility in macroeconomic variables often share a stable, long run equilibrium. Further, the VECM models the adjustment in the short run to correct deviations from the long run equilibrium which is vital for understanding the immediate effect of these variables on agricultural productivity. Table 7 indicates the long run results of the VECM, while table 8 indicates the short run results.

Table 7. Long run parameters results

Order	Adjustment Coefficients
DLNAP	1.0000
DLNARI	-0.3204 (0.0718) [-4.4604]
DLNINF	0.0855 (0.0271) [3.1585]
DLNIR	-0.0466 (0.0346) [-1.3484]
DLNRER	0.0153 (0.0578) [0.2654]
C	0.0065

The long run equation is used to determine if there is a positive or negative relation between the selected variables. Table 7 indicates that agricultural investments result in a 32% move in the opposite direction of agricultural productivity in the long run as well as interest rates at a rate of 4,6%. However, inflation and the real exchange rate result in a distinctive 8,5% and 1,5% move in the same direction as agricultural productivity. This confirms that despite short term fluctuations in the variables, macroeconomic volatility and agricultural productivity are tied together and will eventually converge back to an equilibrium path, thus a temporary externality will not permanently drive the system off course. The findings of the interest rate decrease agricultural productivity is a contrast of the study by Setshedi and Mosikari (2019) that found that an increase in interest rates will result in an increase in agricultural productivity. Furthermore, a contrast is seen to this study as the real exchange rate increasing results in an increase in agricultural productivity, although it is not statistically significant in the long run.

Table 8. Error correction adjustment

Error Correction	DLNAP	DLNARI	DLNINF	DLNIR	DLNRER
	-0.3733 (0.1644) [-2.2702]	3.5741 (1.0219) [3.4975]	-5.6689 (3.4346) [-1.6505]	0.0330 (2.1975) [0.0150]	2.2695 (1.3225) [1.7161]

Table 8 indicates the speed of adjustment of each variable to disequilibrium in the long-run relationship(s). Only DLNAP and DLNINF has statistical significance, this indicates that despite short-term externalities, the variables share a stable, long-run equilibrium relationship, although they are non-stationary at level, but they do not drift apart permanently. A negative coefficient indicates that if agricultural productivity is above its long-run equilibrium, the change in productivity in the next period will be negative, resulting in a push back to the equilibrium. The agricultural productivity is significant due to its negative coefficient; thus, agricultural productivity is an endogenous variable that bears the burden of short-run adjustment to correct the long-run disequilibrium. For the variables DLNARI, DLNIR and DLNRER the error correction term is insignificant and is weakly exogenous. This implies that although this forms part of the long-run relationship with agricultural productivity, it is not variables that adjusts in the short run to correct disequilibrium and its short run dynamics are independent of the long-run error.

Table 9. Short run parameters

	DLNAP	DLNARI	DLNINF	DLNIR	DLNRER
DLNAP (-1)	-0.3733 (0.1644) [-2.2702]	-3.1023 (1.1577) [-2.6796]	5.0053 (3.8910) [1.2864]	-0.0060 (2.4895) [-0.0024]	-1.8529 (1.4982) [-1.2188]
DLNAP (-2)	-0.2872 (0.1766) [-1.6261]	-2.630362 (1.09755) [-2.39658]	4.341637 (3.68876) [1.17699]	0.021015 (2.36011) [0.00890]	-1.382379 (1.42035) [-0.97327]
DLNAP (-3)	-0.2068 (0.1758) [-1.1763]	-2.8363 (1.0926) [-2.5958]	3.4826 (3.6723) [0.9484]	-0.2689 (2.3496) [-0.1145]	-1.4049 (1.4140) [-0.9936]
DLNAP (-4)	-0.0074 (0.1683) [-0.0442]	0.8584 (1.0457) [0.8209]	8.3359 (3.5145) [2.3718]	2.8413 (2.2486) [1.2636]	-0.5920 (1.3533) [-0.4375]
DLNAP (-5)	-0.0037 (0.1407) [-0.0264]	0.4292 (0.8741) [0.4910]	4.1680 (2.9379) [1.4187]	1.4207 (1.8797) [0.7558]	-0.2960 (1.1312) [-0.2617]
DLNARI (-1)	-0.1047 (0.0483) [-2.1693]	0.1316 (0.2999) [0.4387]	-1.1585 (1.0080) [-1.1493]	0.1877 (0.6450) [0.2911]	0.5924 (0.3881) [1.5264]
DLNARI (-2)	-0.0898 (0.0415) [-2.1626]	0.1184 (0.2581) [0.4589]	-0.5015 (0.8675) [-0.5781]	0.3649 (0.5550) [0.6574]	0.4580 (0.3340) [1.3712]
DLNARI (-3)	-0.0714 (0.0355) [-2.0100]	0.0518 (0.2207) [0.2349]	-0.2637 (0.7416) [-0.3556]	0.3246 (0.4745) [0.6841]	0.3539 (0.2856) [1.2394]
DLNARI (-4)	-0.0217 (0.0288) [-0.7529]	0.1240 (0.1789) [0.6934]	-0.4215 (0.6011) [-0.7011]	0.0900 (0.3846) [0.2339]	0.1613 (0.2315) [0.6969]
DLNARI (-5)	-0.0108 (0.0198) [-0.5461]	0.0620 (0.1233) [0.5030]	-0.2107 (0.4144) [-0.5086]	0.0450 (0.2651) [0.1697]	0.0807 (0.1596) [0.5055]
DLINF (-1)	0.0283 (0.0134) [2.1125]	-0.2282 (0.0832) [-2.7411]	-0.3684 (0.2798) [-1.3169]	0.0060 (0.1790) [0.0334]	-0.1554 (0.1077) [-1.4430]
DLNINF (-2)	0.0247 (0.0119) [2.0831]	-0.1509 (0.0737) [-2.0488]	-0.2213 (0.2475) [-0.8941]	0.0148 (0.1584) [0.0933]	-0.1169 (0.0953) [-1.2268]

DLNINF (-3)	0.0189 (0.0111) [1.7009]	-0.1066 (0.0690) [-1.5429]	-0.1392 (0.2320) [-0.5999]	0.0056 (0.1484) [0.0374]	-0.0845 (0.0893) [-0.9453]
DLNINF (-4)	0.0104 (0.0098) [1.0637]	-0.1269 (0.0607) [-2.0905]	-0.2993 (0.2040) [-1.4672]	-0.0024 (0.1305) [-0.0186]	-0.0780 (0.0786) [-0.9928]
DLNINF (-5)	0.0052 (0.0077) [0.6733]	-0.0634 (0.0480) [-1.3231]	-0.1497 (0.1612) [-0.9286]	-0.0012 (0.1031) [-0.0118]	-0.0390 (0.0621) [-0.6293]
DLNIR (-1)	-0.01233 (0.0136) [-0.9053]	0.1026 (0.0847) [1.212]	-0.1853 (0.2846) [-0.6512]	-0.8559 (0.1821) [-4.7005]	0.0425 (0.1096) [0.3879]
DLNIR (-2)	-0.0073 (0.0162) [-0.4491]	0.0387 (0.1007 [0.3839]	-0.1065 (0.3384) [-0.3148]	-0.7133 (0.2165) [-3.2940]	-0.0207 (0.1303) [-0.1591]
DLNIR (-3)	0.0034 (0.0172) [0.1998]	0.0203 (0.1068) [0.1906]	-0.0718 (0.3588) [-0.2002]	-0.5954 (0.2296) [-2.5938]	-0.0460 (0.1382) [-0.3331]
DLNIR (-4)	-0.0368 (0.0168) [-2.1931]	-0.0583 (0.1043) [-0.5593]	-0.1151 (0.3504) [-0.3284]	-0.2014 (0.2242) [-0.8984]	0.0092 (0.1349) [0.0680]
DLNIR (-5)	-0.0184 (0.0137) [-1.3449]	-0.0292 (0.0850) [-0.3430]	-0.0575 (0.2857) [-0.2014]	-0.1007 (0.1828) [-0.5509]	0.0046 (0.1100) [0.0417]
DLNRER (-1)	0.0079 (0.0251) [0.3166]	-0.0617 (0.1558) [-0.3957]	-0.2520 (0.5237) [-0.4811]	-0.1185 (0.3351) [-0.3537]	-0.8577 (0.2017) [-4.2531]
DLNRER (-2)	0.0101 (0.0295) [0.3435]	-0.0685 (0.1836) [-0.3731]	-0.5909 (0.6171) [-0.9576]	-0.2365 (0.3948) [-0.5991]	-0.6805 (0.2376) [-2.8639]
DLNRER (-3)	0.0036 (0.0301) [0.1186]	-0.0980 (0.1869) [-0.5243]	-0.6180 (0.6284) [-0.9835]	-0.2009 (0.4020) [-0.4998]	-0.5583 (0.2420) [-2.3074]
DLNRER (-4)	0.0295 (0.0285) [1.0359]	0.2624 (0.1768) [1.4843]	0.7837 (0.5943) [1.3188]	0.0990 (0.3802) [0.2603]	-0.1384 (0.2288) [-0.6047]
DLNRER (-5)	0.0147 (0.0235) [0.6268]	0.1312 (0.1461) [0.8980]	0.3919 (0.4911) [0.7979]	0.0495 (0.3142) [0.1575]	-0.0692 (0.1891) [-0.3659]
C	-0.0002 (0.0010) [-0.1496]	-0.0013 (0.0063) [-0.2103]	-0.0005 (0.0212) [-0.0219]	0.0013 (0.0136) [0.0959]	-0.0011 (0.0082) [-0.1381]

A significant short-run parameter confirms a direct, immediate impact of the past volatility on current productivity growth. The coefficient measures the percentage or unit change in current agricultural productivity growth resulting from a one-unit change in macroeconomic volatility variable's growth that occurred i periods ago. This section provides the specific, immediate mechanism through which macroeconomic shocks translate into a change in the agricultural sector. A significant short-run parameter indicates that even after accounting for the long-run pressure to return to equilibrium, the variables still have independent, temporary relationships that drive their immediate fluctuations. Table 9 indicates an own-variable dynamic where current agricultural growth is significantly influenced by its own growth rate from a previous quarter. Furthermore, DLNARI indicates a cross-variable spillover where DLNAP decreases by 3.1% within the first quarter, as well as a decrease in agricultural productivity of 2.6% and 2.8% respectively from one period to another. Statistically significant short-run parameters provide evidence of the temporary dynamic transmission of shocks between macroeconomic volatility and agricultural productivity. DLINF is witnessed to have a short run effect on agricultural productivity from the 4th period, thus indicating a longer period before the effects of volatility within this variable is observed. Cross-variable short run dynamics can be witnessed such as DLNARI on DLINF after the 1st, 2nd and 4th time period. This can be due to several reasons that are two-fold. The initial capital cost of new and expensive machinery or infrastructure that is passed down to consumers, however investment in improved seeds, modern irrigation, better machinery and other factors may stabilise or lower food prices (Get Farms, 2024). Finally, an own-variable dynamic of DLNRER can be seen on its own past values indicating a real exchange rate inertia. This indicates that fluctuations in the real exchange rate have a lagged impact on the sector's competitiveness and profitability that may hinder efficient price transmissions from international markets to domestic markets. This further indicates that market rigidities, policy distortions and crippling infrastructure affects the agricultural sector (Liefert & Persaud, 2009).

4.6. Diagnostic Tests

This section sets out the diagnostic tests conducted by the study to verify whether any of these assumptions have not been violated. The following diagnostic tests are employed:

4.6.1. Autocorrelation

Table 10. Autocorrelation test results

Lag	Probability
1	0.9971
2	0.0000
3	0.0035
4	0.0003
5	0.0204
6	0.0113

From table 10 it is clear that there is no autocorrelation among the variables at different lags due to the probability value being higher than the confidence interval of 5% i.e. 0.05. No autocorrelation indicates that the error terms are independent, thus the errors from one period does not influence the errors in subsequent periods. This is indicative of a well specified model, and the results are reliable. No autocorrelation in the VECM model indicates that all systematic information has been captured, and the correct lag structure was selected.

4.6.2. Heteroskedasticity

Table 11. Heteroskedasticity test results

Chi-sq	df	Prob
585.3878	780	1.0000

Table 11 indicates that the null hypothesis should not be rejected as there is no presence of heteroskedasticity of residuals, thus model diagnostics can be trusted allowing for valid conclusions and predictions. This indicates that the variance of the residuals is constant across all levels of the independent variables, and the model is deemed valid for standard inference. Thus, the coefficients for the short run dynamics and the long run cointegrating relationships are estimated efficiently. Furthermore, the standard errors, t-statistics, F-statistics, and p-values are reliable. Finally, it confirms a well-specified model that is not distorted from noise over time.

4.6.3. Normality

Table 12. Normality test results

Component	Kurtosis	Skewness	Jarque-Bera
1	0.0000	0.4583	0.0000
2	0.0000	0.0017	0.0000
3	0.0000	0.0000	0.0000
4	0.0000	0.6014	0.0000
5	0.0000	0.0000	0.0000
Joint	0.0000	0.0000	0.0000

The Jarque-Bera results indicates that the null hypothesis of normally spread residuals should be rejected to conclude that the residuals is not normally spread. This is due to the evident skewness. As the results are above 0 it indicates positive skewness with a further indication of moderate skewness. Further it indicates a few high outliers that pulls the tail of the distribution to the right. Various reasons for the can be ascribed such as climate related shocks as agricultural productivity is highly susceptible to weather patterns (World Bank, 2022), economic instability where high inflation (CCARDESA, 2025) and volatile interest rates (Sun & Katchova, 2024) result in extreme financial outcomes for agricultural producers. Furthermore, inadequate infrastructure hinders agricultural investment and market access (Khapayi & Celliers, 2016), volatile exchange rates impacting costs of imported inputs (Choga & Mashao, 2025) and underdeveloped supply chains (HarvestSA, 2024) may lead to this skewness as well.

The results of this analysis establish that macroeconomic volatility constitutes a significant and multi-faceted impediment to sustainable agricultural productivity. Elevated interest rates systematically increase the cost of financing essential capital goods, thus disincentivising critical investment Concurrently, volatile exchange rates has detrimental effects on the cost of importing certain inputs causing inflationary pressures towards end consumers.

5. Conclusion

This study confirms that the South African agricultural sector, which is a cornerstone of the national economy, is significantly exposed to the volatilities of macroeconomic environments. By employing a dynamic modelling approach, this research moved beyond analysing individual risks to quantify the compounded impact of fluctuating interest rates, inflation, real exchange rates, and agricultural investments on the sector's productivity. The results underscore that while operational risks such as drought are managed through practices such as irrigation, these measures are insufficient to insulate the sector from systemic economic pressures. Volatility in exchange rates directly influences export profitability, while unpredictable interest and inflation rates can stifle crucial long-term investment, thus threatening the industry's sustainability and its vital role in job creation and food security. The findings of this study emphasise the long-term effect that macroeconomic volatility has on agricultural productivity due to long production cycles and external influences such as weather. Furthermore, short term fluctuations such as interest rates and inflation are often absorbed by the long-term biological and seasonal processes of the agricultural sector.

5.1. Recommendations

The following recommendations are aimed at fostering a more resilient and sustainable agricultural sector, capable of mitigating and adapting to external economic shocks. Due to agricultural profits being sensitive to fluctuating input costs and unstable export returns, macroeconomic stability is crucial to plan in the long term for this sector. It is thus of cardinal importance that there is an enhancement of monetary and fiscal policy coordination to reduce interest rate volatility and long-term inflation expectations, specifically policies aimed at minimising currency-induced import inflation that places emerging and smallholder farmers in cost-price squeezes. A further national priority must be to improve logistical infrastructure that directly translates to reduced input and export costs, softening the impact of macroeconomic externalities and giving South African agricultural products a competitive edge in international and domestic markets. Further research should investigate the combined impact of climate volatility and macroeconomic volatility to determine if these compound to create disproportionately severe declines in agricultural productivity for different farm types. Further research can further evaluate the effectiveness of risk management instruments in stabilizing income across different farmer demographics in South Africa. However, the main constraint for such research is the availability of data, thus collaboration is necessary for harmonizing data needs between stakeholders such as researchers, technology providers and argicultural representatives.

Acknowledgement

I would like to express my sincere gratitude to everyone who supported me throughout the research and writing of this manuscript. First and foremost, I am profoundly grateful to God for the strength, wisdom, and perseverance provided to me during this journey. To my supervisor, Mr. Danny Mokatsanyane, I owe a great debt of gratitude for his invaluable guidance, patience and insightful feedback. His mentorship has been instrumental in shaping this work. To my partner, I am deeply thankful for your unwavering belief in me, the emotional support, late night motivational talks, and the many sacrifices you made to allow me time to focus on this research. My heartfelt thanks go to my parents and sisters, for their lifelong encouragement and for instilling in me the value of education and hard work. Finally, I would like to thank my friends and colleagues for their camaraderie and for providing a much-needed sounding board during the more challenging phases of our honour's year. And last but not least, to each agricultural producer, thank you and God bless!

References

365 Financial Analyst. (2025, June). *Understanding Comparative Advantage and absolute advantage in international trade*. https://365financialanalyst.com/knowledge-hub/economics/comparative-advantage-and-absoluteadvantage/

Adekunle, W., & Ndukwe, C. I. (2018). The impact of exchange rate dynamics on agricultural output performance in Nigeria. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3214757

Agbo, M. S. H. (2023). Forecasting agricultural price volatility of some export crops in Egypt using ARIMA/GARCH model. *Review of Economics and Political Science*, *8*(2), 123–133.

Agricultural Institute. (2024). *Endogenous growth theory: Beyond capital and labor*. https://agriculture.institute/agricultural-policy/endogenous-growth-theory-beyond-capital-labor/

AgriSA. (2024, April). *South Africa's agricultural sector equipped to navigate the drought*. https://agrisa.org.za/centre-of-excellence-economics/south-africas-agricultural-sector-equipped-to-navigate-the-drought/

Allen, P. G. (1994). Economic forecasting in agriculture. *International Journal of Forecasting*, *10*(1), 81–135. https://doi.org/10.1016/0169-2070(94)90052-3

Amadi-Robert, C. C., & Okuduwor, A. A. (2022). The implication of macroeconomic environment on agricultural productivity in Nigeria. *Journal of Economics, Management & Social Science*, *8*(1), 1–15.

Aponte, F. R. (2025). Economics interdependencies and sectoral impacts: An input-output analysis of the Norwegian fisheries and aquaculture sector amidst COVID-19. *Fisheries Research*, *281*, 107247. https://doi.org/10.1016/j.fishres.2024.107247

Balcombe, K. (2011). The nature and determinants of volatility in agricultural prices: An empirical study. In A. Prakash (Ed.), *Safeguarding food security in volatile global markets* (pp. 85–106). Food and Agriculture Organization of the United Nations.

Basevi, G. (1970). Domestic demand and ability to export. *Journal of Political Economy*, *78*(2), 330–337.

Belloc, M. (2006). Institutions and international trade: A reconsideration of comparative advantage. *Journal of Economic Surveys*, *20*(1), 3–26.

Bencova, T., & Boháčiková, A. (2021). How to deal with global concept of risk in agriculture? Comparative overview of the literature. *SHS Web of Conferences, 92*, 03001. https://doi.org/10.1051/shsconf/20219203001

Bojnec, Š., & Latruffe, L. (2011). Financing availability and investment decisions of Slovenian farms during the transition to a market economy. *Journal of Applied Economics*, *14*(2), 297–317. https://doi.org/10.1016/S1514-0326(11)60017-7

Britannica. (2025). *International trade: Simplified theory of comparative advantage*. https://www.britannica.com/money/international-trade/Simplified-theory-of-comparative-advantage

Center for Coordination of Agricultural Research and Development for Southern Africa. (2025, September). *Inflation impacts food systems resilience in Southern Africa*. https://www.ccardesa.org/inflation-impacts-food-systems-resilience-southern-africa

Choga, I., & Mashao, T. C. (2025). The impact of exchange rate volatility on South African agricultural exports. *Economies*, *13*(9), 247. https://doi.org/10.3390/economies13090247

Chukwuemeka Ogugua, A. (2024). A theoretical and empirical literature on economic growth. *Advanced Research in Economics and Business Strategy Journal*, *5*(2), 7–16.

Costinot, A. (2009). On the origins of comparative advantage. *Journal of International Economics*, *77*(2), 255–264. https://doi.org/10.1016/j.jinteco.2009.01.007

Couharde, C., Delatte, A. L., Grekou, C., Mignon, V., & Morvillier, F. (2020). Measuring the Balassa-Samuelson effect: A guidance on the RPROD database. *International Economics*, *161*, 237–247. https://doi.org/10.1016/j.inteco.2019.11.011

Council for Scientific and Industrial Research. (2022). *Improved food security in South Africa through a more circular agricultural sector* (Report No. CSIR/AAFH/AGRPR/2022/0001/A).

Dadam, V., Hanusch, M., & Viegi, N. (2019). *Why South Africa is cheap for the rich and expensive for the poor* (Policy Research Working Paper No. 8945). World Bank Group. https://openknowledge.worldbank.org/handle/10986/32098

Deshpande, R. S. (1996). Demand and supply of agricultural commodities – A review. *Indian Journal of Agricultural Economics*, *51*, 270–287.

Eckstein, Z. (1984). A rational expectations model of agricultural supply. *Journal of Political Economy, 92*(1), 1–19. https://doi.org/10.1086/261204

Economic Research Division. (2010). *Increasing farm debt amid decreasing interest rates: An explanation*. Department of Agriculture, Forestry and Fisheries. https://www.nda.gov.za/images/Branches/Economica%20Development%20Trade%20and%20Marketing/Statistc%20and%20%20Economic%20Analysis/economic-analysis/2010-analytic-reports-of-key-macroeconomic-issues-increasing-farm-debt-amid-decreasing-interest-rate_p33728.pdf

Edwards, L., & Hlatshwayo, A. (2020). *Exchange rates and firm export performance in South Africa* (WIDER Working Paper No. 2020/1). UNU-WIDER.

EOS Data Analytics. (2025). *Agricultural technologies & advanced ways of farming*. https://eos.com/blog/agricultural-technology/

Ethier, W. J., & Roy, J. R. (2009). External economies of scale and comparative advantage. In T. Kamihigashi & L. Zhao (Eds.), *International trade and economic dynamics* (pp. 165–183). Springer. https://doi.org/10.1007/978-3-540-78676-4_10

Fadeyi, O. A., Sedibe, M. M., van der Westhuizen, C., & Igene, L. (2019). Financial crises and the South African agricultural sector: A computable general equilibrium analysis. *African Journal of Business and Economic Research*, *14*(3), 71–92.

Fi-compass. (2020). *Financial needs in the agriculture and agri-food sectors in the European Union*. https://www.fi-compass.eu/sites/default/files/publications/financial_needs_agriculture_agrifood_sectors_eu_summary.pdf

Førsund, F. R. (1985). Input-output models, national economic models, and the environment. In A. V. Kneese & J. L. Sweeney (Eds.), *Handbook of natural resource and energy economics* (Vol. 1, pp. 325–341). Elsevier.

Gale, D. (1955). The law of supply and demand. *Mathematica Scandinavica, 3*(1), 155–169.

Gamtessa, S., & Olani, A. B. (2018). Energy price, energy efficiency, and capital productivity: Empirical investigations and policy implications. *Energy Economics*, *72*, 650–666. https://doi.org/10.1016/j.eneco.2018.05.006

Get Farms. (2024). *How to use agricultural land to control inflation effectively*. https://getfarms.in/how-to-use-agricultural-land-to-control-inflation-effectively

Girdžiūtė, L. (2012). Risks in agriculture and opportunities of their integrated evaluation. *Procedia - Social and Behavioral Sciences*, *62*, 783–790. https://doi.org/10.1016/j.sbspro.2012.09.132

Gollin, D. (2010). Agricultural productivity and economic growth. *Handbook of Agricultural Economics*, *4*, 3825–3866. https://doi.org/10.1016/S1574-0072(09)04073-0

Hansson, H. (2009). Economics impacts of agriculture in Sweden: A disaggregated input-output approach. *Food Economics*, *6*(2), 119–133.

HarvestSA. (2024, September). *Corruption, water scarcity, and outdated farming hold Africa back*. https://www.harvestsa.co.za/2024/09/26/corruption-water-scarcity-and-outdated-farming-hold-africa-back/

International Monetary Fund & United Nations Conference on Trade and Development. (2011). *Price volatility in food and agricultural markets: Policy responses*. FAO Open Knowledge Repository. https://openknowledge.fao.org/server/api/core/bitstreams/a9e794ab-dbad-4a4f-9d90-93ccd4aae3f5/content

Iorember, P. T., Yusoff, N. Y. M., Abachi, P. T., Usman, O., & Alola, A. A. (2024). Effect of exchange rate uncertainty, energy prices and sectoral spending on agriculture value added, household consumption, and domestic investment. *Heliyon*, *11*(14), e30138. https://doi.org/10.1016/j.heliyon.2024.e30138

Janet, O. J. (2024). Impact of inflation on agricultural output in Nigeria. *Research Invention Journal of Current Research in Humanities and Social Sciences*, *3*(2), 8–13.

Jankelova, N., Masar, D., & Moricova, S. (2017). Risk factors in the agriculture sector. *Agricultural Economics (Zemědělská ekonomika)*, *63*(6), 247–258. https://doi.org/10.17221/212/2016-AGRICECON

Jonck, P., & Mabaso, C. (2025). Decent work and economic growth in the South African agricultural sector. *South African Journal of Business Management*, *56*(1), a5076. https://doi.org/10.4102/sajbm.v56i1.5076

Kadir, S. U., & Tunggal, N. Z. (2015). The impact of macroeconomic variables toward agricultural productivity in Malaysia. *Southeast Asia Journal of Contemporary Business, Economics and Law*, *8*(3), 21–27.

Kargbo, J. M. (2007). The effect of macroeconomic factors on South African agriculture. *Applied Economics*, *39*(17), 2211–2230. https://doi.org/10.1080/00036840600619623

Kasongo, A., & Makamu, T. (2024). Innovation and economic growth: An empirical analysis for African countries. *African Journal of Science, Technology, Innovation and Development*, *16*(6), 751–760.

Kaur, P., Stoltzfus, J., & Yellapu, V. (2018). Descriptive statistics. *International Journal of Academic Medicine*, *4*(1), 60–63. https://doi.org/10.4103/IJAM.IJAM_7_18

Khapayi, M., & Celliers, P. R. (2016). Factors limiting and preventing emerging farmers to progress to commercial agricultural farming in the King William's Town area of the Eastern Cape Province, South Africa. *South African Journal of Agricultural Extension*, *44*(1), 25–41. https://doi.org/10.17159/2413-3221/2016/v44n1a374

Kirechev, D. (2021). Improving access to finance for agricultural holdings as a factor for the sustainability of agricultural financing in Bulgaria. *Trakia Journal of Sciences*, *19*(1), 197–206. https://doi.org/10.15547/tjs.2021.s1.029

Kitzes, J. (2013). An introduction to environmentally extended input-output analysis. *Resources*, *2*(4), 489–503. https://doi.org/10.3390/resources2040489

Komarek, A. M., De Pinto, A., & Smith, V. H. (2020). A review of types of risks in agriculture: What we know and what we need to know. *Agricultural Systems*, *178*, 102783. https://doi.org/10.1016/j.agsy.2019.102783

Langemeier, M. (2022). Trends in general inflation and farm input prices. *Farmdoc Daily, 12*(56), 1–5.

Leamer, E. E. (1995). The Heckscher-Ohlin model in theory and practice. *Princeton Studies in International Finance*, No. 77. Princeton University Press.

Lele, U. (1990). Structural adjustment, agricultural development and the poor: Some lessons from the Malawian experience. *World Development*, *18*(9), 1207–1219.

Liefert, W., & Persaud, S. (2009). *The transmission of exchange rate changes to agricultural prices*. Economic Research Report No. 76. U.S. Department of Agriculture, Economic Research Service.

Mankiw, N. G. (1998). The market forces of supply and demand. *Principles of Microeconomics*, *4*, 61–87.

Masole, M. (2021). *The direct and indirect effect of interest rates on economic growth in Botswana*. Master's thesis, University of the Witwatersrand.

McCallum, B. T. (1980). The significance of rational expectations theory. *Challenge*, *22*(6), 37–43.

Miranda-Pinto, J., Pescatori, M. A., Stuermer, M., & Wang, X. (2024). *Beyond energy: Inflationary effects of metals price shocks in production networks*. Working Paper No. 24/1. International Monetary Fund.

Modigliani, F., & Shiller, R. (1973). Inflation, rational expectations and the term structure of interest rates. *Economica*, *40*(157), 12–43.

Morell, A. (2015). Demand, supply and markets. In *Economics methods for lawyers* (pp. 32–61).

Murdock, C. W. (2019). *Why Ricardo's theory of comparative advantage regarding foreign trade doesn't work in today's global economy: Labor arbitrage, disloyal capital, WTO violations and national security implications*. SSRN. https://dx.doi.org/10.2139/ssrn.3373832

Muzari, W. (2016). Agricultural productivity and food security in Sub-Saharan Africa. *International Journal of Science and Research*, *5*(1), 1769–1776.

Nedbank. (2024). *How currency fluctuations can affect your finances*. https://personal.nedbank.co.za/learn/blog/currency-fluctuations-and-why-they-matter.html

Nerlove, M., & Bachman, K. L. (1960). The analysis of changes in agricultural supply: Problems and approaches. *Journal of Farm Economics*, *42*(3), 531–554.

OECD. (2011). *Globalisation, comparative advantage and the changing dynamics of trade*. https://www.oecd.org/content/dam/oecd/en/publications/reports/2011/10/globalisation-comparative-advantage-and-the-changing-dynamics-of-trade_g1g13926/9789264113084-en.pdf

OECD. (2017). *Improving energy efficiency in the agro-food chain*. https://www.oecd.org/content/dam/oecd/en/publications/reports/2017/08/improving-energy-efficiency-in-the-agro-food-chain_g1g7ce8c/9789264278530-en.pdf

Okeke, D. C., & Okeke, O. R. (2022). Macroeconomic variables and agricultural output in Nigeria. *Medicon Agriculture & Environmental Sciences*, *2*(1), 43–49.

Organization for Economic Co-operation and Development. (2009). *How transport costs shape the spatial pattern of economic activity*. OECD Discussion Paper No. 2009-13. OECD Publishing. https://doi.org/10.1787/5kmmr3j65tg0-en

Public Policy and Analysis. (2024). *Inter-sectoral input-output analysis: A tool for economic evaluation*. https://pubadmin.institute/public-policy-and-analysis/inter-sectoral-input-output-analysis-economic-evaluation

Qiu, H., Xia, D., & Yetman, J. (2024). Deconstructing global trade: The role of geopolitical alignment. *BIS Quarterly Review*, 33–48. https://www.bis.org/publ/qtrpdf/r_qt2409c.htm

Romer, P. M. (1990). Capital, labor, and productivity. *Brookings Papers on Economic Activity. Microeconomics*, *1990*, 337–367. https://doi.org/10.2307/2534785

Saari, M. Y., Alias, E. F., & Chik, N. A. (2013). The importance of the agricultural sector to the Malaysian economy: Analysis of inter-industry linkages. *Journal of Social Sciences and Humanities*, *21*, 173–188.

Schumacher, R. (2013). Deconstructing the theory of comparative advantage. *World Social and Economic Review*, *2013*(2), 83–105.

Setoboli, T., Tshuma, N., & Sibanda, E. (2024). Improving agricultural efficiency in Zimbabwe: A labour productivity analysis. *Journal of Research and Innovation in Social Science*, *8*(3), 2193–2208.

Setshedi, C., & Mosikari, T. J. (2019). Empirical analysis of macro-economic variables towards agricultural productivity in South Africa. *Italian Review of Agricultural Economics*, *74*(2), 3–15.

Sheppard, E. (2012). Trade, globalization and uneven development: Entanglements of geographical political economy. *Progress in Human Geography*, *36*(1), 44–71.

Sihlobo, W. (2021). *The good news in 2021 is in the agricultural sector*. Econ3x3. https://www.econ3x3.org/article/good-news-2021-agricultural-sector#:~:text=Introduction%5B1%5D,in%20South%20Africa%20and%20globally

Sihlobo, W. (2024, March 2). *South Africa's agricultural exports hit a new record despite logistical constraints*. Agricultural Economics Today. https://wandilesihlobo.com/2024/03/02/south-africas-agricultural-exports-hit-record-despite-logistical-bars/

Siswanti, Y. (2022). The influence of organizational culture to innovation behavior: A hierarchical linear modelling approach. *Journal of International Conference Proceedings, 5*(5), 267–284.

Statistics South Africa. (2017). *Input-output tables for South Africa, 2013 and 2014* (Report No. 04-04-02). https://www.statssa.gov.za/publications/Report-04-04-02/Report-04-04-022014.pdf

Sun, Z., & Katchova, A. L. (2024). The relationship between interest rates and agricultural commodity price dynamics. *Agribusiness*. Advance online publication. https://doi.org/10.1002/agr.21984

TigerData. (2024). *Stationary time-series analysis*. https://www.tigerdata.com/learn/stationary-time-series-analysis

Timidi, B. D., & Ayunku, E. P. (2024). The impact of selected macroeconomic variables on agricultural sector performance in Nigeria. *African Journal of Management and Business Research*, *17*(1), 308–325.

Trostle, R. (2008). *Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices*. US Department of Energy Paper No. WRS—0801.

Uddin, M. R., Sadik, N., & Rahman, M. M. (2025). Globalization, physical capital, and human capital nexus with economic growth: Evidence from BIMSTEC. *Research in Globalization*, *10*, 100284.

Ukoha, O. O. (2007). *Relative price variability and inflation: Evidence from the agricultural sector in Nigeria*. Research Paper No. 171. African Economic Research Consortium.

Vink, N., & van Rooyen, J. (2009). *The economic performance of agriculture in South Africa since 1994: Implications for food security*. DBSA Working Paper No. 17. Development Bank of Southern Africa.

Wang, L. (2014). Energy efficiency technologies for sustainable food processing. *Energy Efficiency*, *7*(5), 791–810.

World Bank. (2022). *Agricultural land (% of land area) – South Africa* [Dataset]. https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=ZA

World Bank. (2022, October 17). *What you need to know about food security and climate change*. https://www.worldbank.org/en/news/feature/2022/10/17/what-you-need-to-know-about-food-security-and-climate-change

Zhang, L., Hu, Q., & Zhang, F. (2014). Input-output modelling for urban energy consumption in Beijing: Dynamics and comparison. *PLoS ONE*, *9*(3), e8985. https://doi.org/10.1371/journal.pone.0089855