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Comparative analysis of futures contract cross-hedging effectiveness for soybean: models and insights

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ABSTRACT
The purpose of this research is to investigate the use of cross-hedging in the South African soybean market, by using the JSE BEAN contract as a cross-hedge instrument for the JSE SOYA contract. The research study involves a detailed assessment of the data, which includes the use of stationarity tests such as the Phillips-Perron and Augmented Dickey-Fuller, as well as the Johansen co-integration approach to analyse long-term relationships between the variables. To evaluate the efficiency of cross-hedging strategies, three distinct hedging models are used: the ordinary least squares (OLS) model, error correction model (ECM) and EC-GARCH. The results demonstrate that these models produce significant hedge ratios. Through back-testing and the application of hedging strategies, it is determined that the JSE BEAN contract holds the potential to serve as a cross-hedge for the JSE SOYA contract in the South African soybean market. This study provides useful information for market participants and model selection in the context of cross-hedging.

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1. Introduction

Commodity trading and derivatives play an important role in the soybean market by providing essential risk management tools and facilitating effective price discovery (Pirrong 2014). The significance of commodity trading extends beyond mere transactions; it serves as a crucial platform for market participants, such as soybean producers, buyers and speculators by enabling them to manage price risk effectively. This management is accomplished by the strategic use of derivatives such as futures and options contracts, which not only protect against negative price movements, but also a more predictable income stream and thus reducing the risk of financial losses (Roche 2020). Additionally, commodity trading improves market liquidity and allows effective price formation through the interaction of supply and demand factors. In general, the availability and use of derivatives in soybean commodity trading enhances market stability, bolsters risk management capabilities and improved overall efficiency, benefiting all stakeholders involved in the soybean value chain (Zheng and Wang 2013; Ranganathan and Ananthakumar 2014; Raucci et al. 2019). It is however important to note that there also exists literature that presents alternative views on the benefits of futures trading in the context of soybean commodity trading. According to Mitchell (2010) the relationship between soybean futures contracts and market efficiency highlights the instability and unpredictability of trading rules, implying that derivatives can occasionally contribute

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to market volatility. Gayatri et al. (2023) show empirical evidence that a restriction on futures trading resulted in severe disruption in the spot market, negatively impacting price discovery and risk management. Liccardo (2013) highlighted the dual role of derivatives in potentially stabilising markets, but also by introducting new risks. This illustrates the complex impact derivatives have on financial stability across different markets. Further research is needed to explore these differences in more detail to better understand the conditions that influence the effectiveness of derivatives in commodity trading.

Building upon the importance of risk management, cross-hedging emerges as a valuable risk management strategy widely adopted in commodity trading to mitigate the price risk associated with specific commodities when direct hedging instruments are not available (Aven, 2016) or are less efficient (Zainudin and Mohamad 2021; Olson, Vivian, and Wohar 2019). Cross-hedging involves using a related futures contract that exhibits a similar price behaviour, although not an exact match, to the underlying commodity being hedged (Anderson and Danthine 1981). Successful cross-hedging depends on factors such as a strong positive or negative correlation, accurate estimation of the hedge ratio and the ability to maintain a stable hedge ratio over time (Eaker and Grant 1987). In less efficient markets, the lack of liquidity and market depth, compounded by structural market issues (Mongi and Dhouha 2016) such as logistical constraints, can lead to challenges in finding a direct hedge. Cross-hedging becomes a valuable tool in such scenarios, allowing market participants to leverage positively correlated assets to manage risk (Ankirchner et al., 2012). The ability to use cross-hedging in these markets not only provides a risk management solution but also enhances market functionality by introducing additional trading strategies. Moreover, cross-hedging can contribute to improved profitability versus no hedging or using an ineffective direct instrument. By reducing the volatility of cash flows and protecting against adverse price movements, businesses can stabilise their financial performance. Junttila et al. (2018) illustrate this through the commodity market-based hedging against stock market risk, using crude oil and gold as examples during times of financial crisis. The strategic use of cross-hedging allows firms to lock in favourable prices, thus improving the predictability of profits. Chang and Wong (2002) confirmed the potential for cross-hedging to enhance profitability across different financial instruments. Cross-hedging serves as a robust risk management strategy in less efficient markets, offering a means to mitigate risk and enhance profitability.

The literature supports the notion that cross-hedging is not only a theoretical concept but a practical tool that has been successfully implemented across various market conditions and asset classes (Anderson and Danthine 1981; Woo, Horowitz, and Hoang 2001; Vukina & Anderson, 1993; Kim et al., 2015; Ran, 2007). Cross-hedging provides additional benefits to agricultural derivative markets. It allows exposure to markets that do not have specific hedging mechanisms, assisting in the management of price changes in unsupported commodities (Fernando and Anderson 2022). It also allows for the selection of appropriate risk management instruments based on correlation and historical patterns. This adaptability enables customised risk management techniques based on market conditions and personal preferences (Fernando and Anderson 2022). Cross-hedging also benefits agricultural markets by increasing liquidity, promoting efficient price discovery and minimising information asymmetry (JSE 2023a). In general, this improves the dynamics of the market by increasing the accuracy and fairness of the market. Furthermore, it provides a cost-effective risk management strategy, particularly when direct hedging choices for certain assets are few or expensive (Fernando and Anderson 2022).

In the context of the soybean market, market participants can engage in cross-hedging by using futures contracts for other crops, such as maize or sunflower seed, that demonstrate a robust correlation with soybean prices. By adopting this approach, market participants can safeguard themselves against adverse price movements in soybeans, even in the absence of a dedicated soybean futures contract, although they should be mindful of basis risk and the need for a strong correlation between the hedged commodity and the futures contract being hedged (Pennings and Meulenberg 1997).

South Africa has an active and successful soybean futures contract.

This alternative strategy not only facilitates effective risk mitigation and provides market participants with a valuable tool to manage their soybean price exposure.

South Africa's soybean production, while still minor in comparison to other countries, has experienced a remarkable surge in recent years. According to DALRRD (2021), production soared to approximately 2.33 million tonnes in the 2021/22 season, a substantial increase from the modest output of around 210,000 tonnes in the early 2000s (see Figure 1). This increase is attributed to a confluence of factors, including heightened demand, ideal weather conditions and technological breakthroughs (Viatte 2001). Moreover, Van der Linde (2023) further emphasised the pivotal role of ongoing technical progress in propelling the domestic soybean sector's productivity gains and expansion, highlighting the significance of commercialising genetically modified (GM) cultivars, promoting crop rotation benefits and strategically investing in crushing capacity. Summer grain input costs in South Africa also impacted farmers' decisions; for example, rising fertiliser prices can shift attention to soybeans, which require less fertiliser and potentially yield better returns (Erickson et al. 2009). This was evident with the large increase in the area planted in the 2022/23 marketing season due to the sharp increase in fertiliser prices, as indicated in Figure 1. As a result of market dynamics, this shift may boost soybean supply, as indicated by the increase in production during the 2022/23 marketing season. South Africa is a major producer and consumer of soybeans in Africa, with production almost nine times greater than three decades ago (USDA 2021). The surge in production corresponds to an expansion in cultivated hectares, rising from just over 134,000 hectares in 2000/01 to more than 1,148,000 hectares in 2022/23 (CEC 2002, 2023; SAGIS 2023).

South Africa's demand for soybean products has recently increased, due to purported health benefits and limited domestic crushing capacity (Van der Vyver, Nordier, and Verwey 2018; Nordier 2021). According to estimates, soybean consumption is divided into three sectors: 88.7% for oil and oilcake production, 10.1% for animal feed (particularly in the broiler and egg industries) and 1.2% for human consumption (DALRRD 2021). Most animal feed formulas continue to use soybean oil cake as the principal protein source (SAGL 2022; AFMA 2023). South Africa, a net importer of soybeans previously, experienced its first large deep-sea export in the 2022/23 marketing

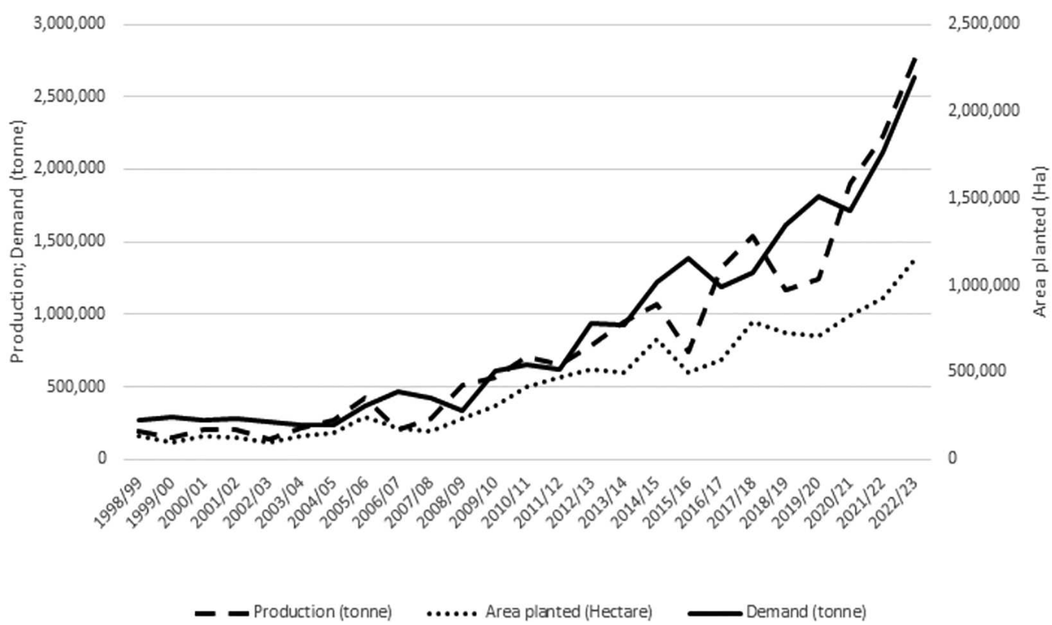

Figure 1. Soybean production, area planted and demand in South Africa. Source: CEC (2002), CEC (2023), SAGIS (2023).

season, signalling a shift in the country's trade dynamics (SAGIS 2023). This movement represents a possible shift from a net importer to a more export-oriented economy, reflecting changes in production and trading patterns.

South Africa's soybean market is deregulated (Van Zyl et al. 2001; Vink and Schirmer 2002; Vink 2003; Nordier 2021), with prices for soybean freely traded on the Agricultural Products Division of the JSE. Parity prices define the price ranges between which soybean prices move. Import parity reflects the cost of importing soybeans, whereas export parity prices reflect the price at which South Africa can competitively export (Geyser 2013). When the local supply of soybeans is greater than the domestic demand, prices tend to trade lower. To stimulate demand and increase market opportunities, South Africa must find importers willing to buy our soybeans. Logistical restrictions in deep-sea ports might cause local soybean prices to fall below export parity levels, causing prices to fall further until prices are competitive enough for exports from alternative ports, via Mozambique as an example. These difficulties in capitalising on export parity prices have a negative impact on farming profitability and diminished investment incentives, introducing risks to the supply chain (Voora et al., 2020).

When a crop trades for long periods below export parity, several risks are created for the supply chain, including reduced profitability, a decreased incentive to invest in production (Voora et al., 2020), the risk of reduced quality of the old crop and reduced storage space as the old crop is redelivered through the silo receipt system (Delouche et al., 1973; McDonald, 1999; Vikhe, 2016; Guo et al., 2022; Koskosidis et al., 2022). Furthermore, lower prices may also lead to a reduction in investment in research and development of new soybean varieties, which could impact the long-term viability of the industry (Voora et al., 2020). In general, the risk of prices trading below export parity highlights the importance of ensuring that South African soybean farmers receive fair prices for their crops to maintain a sustainable and profitable industry.

The South African soybean market requires effective hedging strategies to manage price risk and ensure profitability. The JSE BEAN contract, a cash-settled agreement based on the Chicago Mercantile Exchange (CME) bean contract, offers a possible alternative. This article critically assesses its suitability and effectiveness as a cross-hedging solution. Specifically, it investigates whether the JSE BEAN contract may be seamlessly integrated into complete risk management strategies that are consistent with global trading activity, particular in volatile markets. Furthermore, this study seeks to establish the JSE BEAN contract's ability to provide tailored risk mitigation measures, which could improve profitability and stabilise prices for South African soybean producers engaging in a variety of commodity and currency trading activities. The analysis of cross-hedging is necessitated by observations that the JSE SOYA contract sometimes trades below export parity levels, implying that it may not respond appropriately and timely to changing market conditions, highlighting the need for a different hedging approach. A comparison analysis of the JSE BEAN and SOYA contracts will also be performed to determine their various contributions to generating higher risk-adjusted returns.

The JSE BEAN contract is chosen as a cross-hedge for the JSE SOYA contract for several reasons. Firstly, the JSE BEAN contract is essentially the CME soybean contract traded in Rand terms. It offers local market participants exposure to the CME market dynamics without the additional burden of hedging against currency risk. As the contract is traded in Rand, it simplifies the financial operations for local market participants and aligns their investment more closely with economic factors. Additionally, the JSE BEAN contract is cash settled only. This feature eliminates any potential impact that logistical constraints might have on price movements as the contract is solely focused on financial outcomes based on the commodity's price movements. Finally, the underlying asset of the JSE BEAN contract, being tied to the CME soybean futures contract, reflects the market sentiments worldwide. This makes it an ideal tool for cross-hedging, as it responds to global agricultural supply and demand shifts and other economic factors that influence soybean prices. Possible limitations of using international contracts as hedging instruments are possible low liquidity of the contract or that the contracts may not accurately reflect local import parity or industry prices,

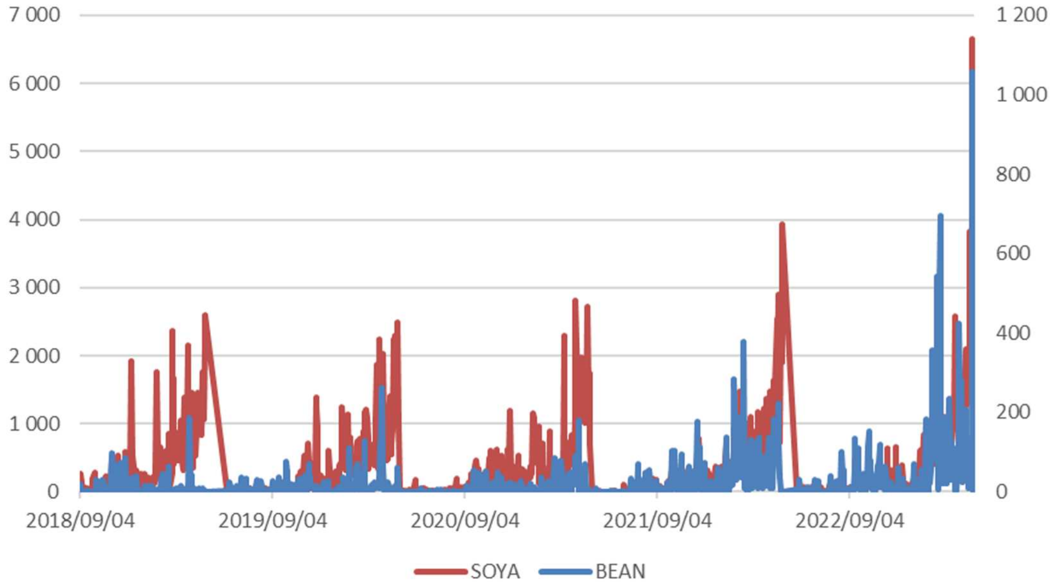

Figure 2. May contract volumes for JSE SOYA and JSE BEAN contracts. Source: JSE (2023b, 2023c).

impacting their effectiveness in managing price exposure (Van der Vyver, Barnard, and Nordier 2022). Figure 2 shows the volumes traded for the JSE BEAN and JSE SOYA May contracts from 2019 to 2023.

Although the volume of the JSE BEAN contract is very low, it does show a marked increase over time, suggesting that liquidity in the contract is improving.

The study is structured as follows. The second section provides an overview of the extant literature. The third section 3 describes the data and the methods used. The fourth section presents empirical findings, while the fifth section acts as the study conclusion.

2. Literature review

Cross-hedging is a risk management strategy applied when direct hedging is not available or when the direct hedging instruments do not align with the hedger's risk exposure (Miller 1982). This technique involves using futures or forward contracts for related commodities which exhibit correlated price movements (Hieronymus 1977; Rahman, Turner, and Costa 2001) which could potentially lead to beneficial outcomes under specific market conditions. One of the first formal studies of cross-hedging was undertaken by Anderson and Danthine (1981), who suggest its usage across various futures markets. It was worth noting that, at the time, empirical findings were not used to cross-validate the stated theoretical justifications. It is important to note that cross-hedging should be considered when traditional alternatives are inadequate or misaligned with the hedger's specific risks. Cross-hedging could be considered a complementary strategy of particular relevance when traditional instruments like the JSE SOYA contract cannot fully address unique market dynamics or specific risk profiles. While this is not a superior strategy by any means, it is crucial in cases where the JSE SOYA contract's scope cannot effectively handle complex or atypical risks.

Furthermore, cross-hedging allows the use of futures contracts to hedge cash commodities that cannot be delivered according to the terms of the futures contract, thereby accommodating disparities in location and quality among the cash and futures commodities (Miller 1985). Cross-hedging, in its most basic form, involves using futures contracts for a single commodity to hedge against a cash commodity position, while multiple cross-hedging involves hedging a cash commodity position with futures contracts involving two or more distinct commodities (Elam, Miller, and Holder 1986; Rahman, Turner, and Costa 2001). Cross-hedging necessitates speculation in the relationship between cash and futures prices for distinguished commodities, as opposed to direct hedging, which involves speculation in the relationship between cash and futures prices for the same commodity (Hieronymus 1977; Elam, Miller, and Holder 1986). Absolute price risks are substituted by relative, or basis, price risks in both direct and cross-hedging.

2.1 Cross-hedging agricultural products

In risk management, cross-hedging techniques using futures contracts for agricultural commodities have been extensively studied. Brinker, Parcell, and Dhuyvetter (2007, 2009) found that cross-hedging distiller dried grains (DDGs) with soybean meal futures were more effective than conventional techniques (Penone, Giampietri, and Trestini 2021). Franken and Parcell (2011) demonstrated that composite hedges using futures of maize and soybean meal improved the effectiveness of the hedge for fish meal. Similarly, Rahman, Turner, and Costa (2001) identified soybean meal futures as a viable cross-hedging mechanism for cottonseed meal.

Buhr (1996) noted the trend of feeding Holstein steers to slaughter weights, highlighting benefits like growth uniformity and carcass composition. Elam and Donnell (1992) found that maize futures could reduce cow ration expenses by up to 54%. Hayenga and DiPietre (1982a, 1982b) showed live hog and cattle futures that effectively hedged wholesale pig and beef cuts, while Rout, Das, and Rao (2021) explored agricultural market price discovery and hedging mechanisms.

Recent research includes Pennings and Meulenberg (1997) on market depth-cost risk, Barrera, Cañón, and Sánchez (2020) on cross-hedging electrical derivatives with agricultural products and Samal and Das (2023) on aluminium futures in India. Bieroth (2010) used live cattle futures to reduce beef price volatility, and Naeem et al. (2021) found that cryptocurrencies offered downside risk hedging for commodities (Nekhili and Sultan 2022; Iyer 2022). Woo, Horowitz, and Hoang (2001) focused on electricity forward contracts for cross-hedging (Maitra et al. 2022). Tan (2002) investigated currency cross-hedging for jet fuel using crude and heating oil (Susilo et al. 2020).

Hedging airline fuel remains contentious. Morrell and Swan (2006) and Hashim and Shunmugam (2009) offered varying views on its effectiveness. Adams and Gerner (2012) and Berghöfer and Lucey (2014) examined jet fuel cross-hedging with mixed results (Rout, Das, and Rao 2021). Brooks, Davies, and Kim (2007) demonstrated cross-hedging strategies for equities, while Zainudin and Mohamad (2021) assessed cross-hedging between UK and global stock index futures.

While there have been few studies analysing commodity cross-hedging in South Africa, such as the study by Van der Vyver, Barnard, and Nordier (2022) which found that SAFEX contracts do not fully reflect local market conditions and suggested that crushers might consider using contracts from Argentina as a hedge against price risk.

2.2 Hedging model

Cross-hedging strategies have developed over time to include methodologies such as Ordinary Least Squares (OLS)-regression, Error Correction Model (ECM), and EC-ARCH and/ or GARCH models (Behm 2013).

Initially, linear OLS regressions were important in estimating optimal cross-hedging by comparing spot price fluctuations to futures prices, resulting in the minimum variance hedge ratio (MVHR) (Clark, Lesourd, and Thiéblemont 2001). This regression approach, influenced by Johnson (1960), Stein, Goss, and Yamey (1961), Ederington (1979) and expanded by Figlewshi (1984), faced criticism for nonstationary data. However, Nelson and Plosser (1982) demonstrated that employing nonstationary-level data in regressions could yield misleading outcomes. Benninga, Eldor, and Zilcha (1983) addressed this with a log price difference model.

The failure of the OLS regression to account for co-integration led to a downward bias in hedge ratios, known as under-hedging (Hill and Schneeweis 1981; Cecchetti, Cumby, and Figlewski 1988; Ghosh 1993; Lien 1996). Ghosh (1993) introduced ECMs to address this, with a focus on short-term dynamics and long-term equilibrium (Ghosh 1993; Ghosh and Clayton 1996). Static hedging models, despite their simplicity, fail to consider the time-varying nature of spot and futures returns (assumption of a timeless relationship among spot and futures). Autocorrelated errors in static models, leading to a subsequent decline in statistical efficiency, can be addressed using Cochrane-Orcutt transformation and vector autoregression (VAR) (Lien and Tse 1999; Bradburn et al. 2003).

Dynamic models like GARCH (Engle 1982; Bollerslev 1986) address the time-varying relationships, but may overestimate variance (Wei, Wang, and Huang 2011). Realised volatility (RV) (Anderson and Bollerslev 1998; Koopman, Jungbacker, and Hol 2005) and realised covariance (Rcov) matrices from high-frequency data provide unbiased estimators but have practical limitations (Barndorff-Nielsen and Shephard 2004; Barndorff-Nielsen et al. 2011; Zhang 2011). The realised MVHR (RMVHR) by Markopoulou, Skintzi, and Refenes (2016) uses high-frequency data, but its applicability in diverse markets like South Africa remains unknown (Miao et al. 2017).

3. Econometric methodology and data

3.1 Methodology

Cross-hedging is a risk management strategy that involves taking positions in futures or forwards of related commodities when direct derivatives are unavailable. Effective cross-hedging requires a strong correlation between spot and futures (or forward) prices. Johnson (1960) stressed the variance of portfolio returns as a key metric in assessing portfolio risk, noting that establishing the optimal hedge ratio involves minimising the variance of portfolio returns.

The futures price of a commodity at time t are represented as F_t (i.e., BEAN futures price), while S_t denotes the current spot price of the underlying (i.e., SOYA-spot price). Assuming a constant variance-covariance matrix for portfolio returns over time, one can express the returns in a manner consistent with Glen and Jorion (1993) and Mun and Morgan (1997) when dealing with the return from a cross-hedged position.

$$R_t = \Delta S_t - h\Delta F_t \tag{1}$$

where h denotes the static ratio of the commodity; ΔS_t denotes the change in spot price S_t (i.e., SOYA) or the 1st log difference, $S_{t+1} - S_t$at time t; and ΔF_t denotes the 1st log difference of the futures price, $F_{t+1} - F_t$ (i.e., BEAN). The variance of R_t is:

$$Var(R_t) = Var(\Delta S_t) + h^2 Var(\Delta F_t) - 2hCov(\Delta S_t, \Delta F_t) \tag{2}$$

The minimum variance of R_t is achieved by computing the first derivative of Equation (2) concerning the hedge ratio and subsequently setting this derivative to zero:

$$\frac{dVar(R_t)}{dh} = 2hVar(\Delta F_t) - 2hCov(\Delta S_t, \Delta F_t) = 0 \tag{3}$$

The terms within Equation (3) can be reorganised accordingly:

$$h^* = \frac{Cov(\Delta S_t, \Delta F_t)}{Var(\Delta F_t)} \tag{4}$$

The parameter h^* denotes the minimum variance hedge ratio (MVHR), in Equation (4), and according to Hsu and Chen (2014), this is the most used hedge ratio and is deemed optimal for minimising variability in portfolio returns. Furthermore, since the correlation coefficient of ΔS_t and ΔF_t is:

$$\rho = \frac{Cov(\Delta S_t, \Delta F_t)}{SD(\Delta S_t)\; SD(\Delta F_t)} \tag{5}$$

where $SD(\Delta S_t)$ and $SD(\Delta F_t)$ denotes the standard deviations of ΔS_t and ΔF_t, respectively. Therefore, the optimal hedge ratio in Equation (4) is equivalent to:

$$h^* = \rho \frac{SD(\Delta S_t)}{SD(\Delta F_t)} \tag{6}$$

The objective of the article is to assess the optimal hedge ratio, exploring h^* estimated by various econometric models.

3.1.1 Model I: ordinary least squares (OLS)

The relationship between S_t and F_t can be formulated in a manner that includes ε_t, under the assumption that ε_t exhibits homoscedasticity, lacks serial correlation and maintains independence and identical distribution over time, represented by a mathematical model:

$$S_t = \propto_0 + \propto_1 F_t + \varepsilon_t \tag{7}$$

where ε_t exhibits homoscedastic, serially uncorrelated and distributed independently and identically over time. However, these assumptions do not match the time series price data used in this study. The assumptions regarding the error term in the statistical model become problematic when applied to financial time series data, given the challenges posed by changing volatility, autocorrelation, non-stationarity and fat tails. These features, such as varying volatility in financial markets, autocorrelation in price movements and nonstationarity involving changing mean and variance, violate critical assumptions like constant error term variance and serially uncorrelated errors. Furthermore, the frequent occurrence of extreme events in financial data deviates from the normal distribution assumption for the error term. As a result, these issues render the assumed error term characteristics inappropriate for accurately modelling the relationship between variables in this study (Tsay 2005; Hamilton 2020).

However, to derive the MVHR, as described in Equation (4) the 1st difference of S_t and F_t, are taken. For simplicity, the equation below is used, with the spot being hedged by a single futures contract expiring at t:

$$\Delta S_t = \alpha + \beta \Delta F_t + u_t \tag{8}$$

where S_t refers to the daily log returns of spot; F_t refers to the daily log returns of futures; $u_t \sim i.i.d\; N(0, \sigma^2)$ refers to the residual series; and β is variance minimising and equivalent to the value of h^*, i.e., the hedge ratio.

The efficiency of the cross-hedging tool is determined by the explanatory power estimated from Equation (8). If the model can account for 100% of the total variation in spot price changes, any additional costs incurred due to an increase in spot prices are entirely offset by gains from the long futures position. Within the empirical aspect of this research study, particular attention is paid to measures of explanatory power, such as the R^2 or log-likelihood value.

3.1.2 Model II: error correction model (ECM)

The simplicity of Equation (8) ignores the long-term relationship between the spot price and the futures price, which can lead to excessive differencing. The R^2-value, often used to evaluate the effectiveness of hedging and compare different hedging instruments, assumes stability and ignores co-integrating relationships between the respective variables. Ghosh (1993) recommends ECMs to improve precision, leveraging co-integrating relationships among spot and futures prices, for superior forecasting and insights into the rate at which variables adjust or revert to equilibrium. This estimate allows hedgers to assess the expected time frame for deviations between spot and futures prices to normalise, offering valuable information for informed decision-making.

The subsequent error correction model (ECM) can be employed once confirming the presence of a co-integration relationship (Asteriou and Hall 2021):

$$\Delta S_{\boldsymbol{t}} = \propto + \beta \Delta F_{\boldsymbol{t}} + \lambda \varepsilon_{t-1} + \sum_{k} \gamma_k \Delta F_{t-k} + \sum_{i} \delta_i \Delta S_{t-1} + u_t \tag{9}$$

where ε_{t-1} denotes the error correction term, which is derived from a regression of $\ln S_t$ on F_t; β denotes the optimal minimum variance hedge ratio; λ denotes the adjustment parameter, which is the rate at which short-term deviations approach the long-term equilibrium (i.e., as the magnitude of λ increases, the sensitivity of the S_t to the prior period's departure from the long-term equilibrium amplifies); and γ_k and δ_i denotes the measurement of short-term dynamics resulting from lagged changes in spot and futures prices.

In contrast to simple regression, the ECM framework incorporates the autoregressive structure of spot and futures price fluctuations (Brooks 2002). Compared to a simple regression setup, the explained variation of spot price fluctuations and the accuracy with which the hedge ratio is predicted are typically substantially higher.

3.1.3 Model III: EC-GARCH

In both the OLS and the ECM models, persistent heteroskedasticity within the error term impacts standard error accuracy. Financial asset prices show clustered volatility due to specific exogenous events, showing prolonged periods of high or low volatility. Recognising this clustering volatility increases the accuracy of the hedge ratio estimation. To address this, Engle (1982) developed the Autoregressive Conditional Heteroscedastic (ARCH) model, which accounts for both mean and conditional variance, offering a more comprehensive representation of the volatility structure and is given by:

$$\Delta S_t = \propto + \beta_1 \Delta F_t + \sum_{k} \gamma_k \Delta F_{t-k} + \sum_{i} \delta_i \Delta S_{t-1} + u_t$$

$$u_t \sim \ iid\ N(\mu, \sigma_t^2)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 \tag{10}$$

Bollerslev (1986) expanded upon the ARCH farmwork, enabling the conditional variance to follow an autoregressive moving average process. In this approach, the variance of the residuals is influenced by both prior values of the squared residuals and ad lagged terms of the variance. The resulting specification, known as the Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model, was further refined by Baillie and Myers (1991) as GARCH (*p,q*):

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_1 u_{t-1}^2 + \sum_{i=j}^{q} \gamma_j \sigma_{t-j}^2 \tag{11}$$

where $\sum_{i=1}^{p} \alpha_1 u_{t-1}^2$ refers to as an ARCH term; and $\sum_{i=j}^{q} \gamma_j \sigma_{t-j}^2$ refers to the GARCH term.

The GARCH model is extensively applied to model volatility in financial time series. In particular, the GARCH model offers enhanced efficiency and mitigates the risk of overfitting the data (Brooks 2002). In the context of this research study, the selected model is characterised by an order of GARCH (1,1), which signifies the inclusion of an ARCH term and one GARCH term within the model structure.

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \gamma_j \sigma_{t-j}^2 \tag{12}$$

Due to the probable coexistence of a shared long-term stochastic trend in spot and futures price variables, alongside the presence of heteroscedastic residuals in the aforementioned models, a GARCH model incorporating error correction is preferred. Specifically, the EC-GARCH (1,1) models are defined as follows (Asteriou and Hall 2021):

$$\Delta S_t = \propto + \beta_1 \Delta F_t + \beta_2 \varepsilon_{t-1} + \sum_k \gamma_k \Delta F_{t-k} + \sum_i \delta_i \Delta S_{t-1} + u_t$$

$$u_t = v_t \sigma_t; \;\; v_t \sim N(0, 1)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \gamma_j \sigma_{t-j}^2 \tag{13}$$

The EC-GARCH model confers the advantage of incorporating the consideration of conditional variance into an enhanced error-corrected model. To elaborate, the EC-GARCH specification outlined in Equation (13) concurrently addresses both the volatility within the time series process and the enduring association between S_t and F_t.

3.1.4 Hedging effectiveness

Traditionally, assessing hedge effectiveness relied on the adjusted-R^2 derived from regression models, with the slope coefficient acting as the optimal hedge ratio. Accepted benchmarks often show a correlation coefficient of 0.90 or an adjusted R-squared of 0.80 or more (Finnerty and Grant 2002). However, as Juhl, Kawaller, and Koch (2012) point out, there is disagreement on how these regression models should be configured, given the challenges they pose in terms of overfitting and interpretation. With more regressors and more sophisticated models, utilising adjusted-R^2 for gauging hedge effectiveness appears inadequate. Ghosh (1993) employed the adjusted-R^2 to determine the optimal hedge ratio, while Adams and Gerner (2012) used the logarithmic likelihood measure to choose models and hedge ratios. Recognising potential misunderstanding, this study calculates hedge effectiveness individually for each model. To address this, a "R^2 analog method" (Juhl, Kawaller, and Koch 2012) method generates R^2 individually for each model. The R^2 can be independently calculated for the models using the following:

$$R^2 \; Analogue = 1 - \frac{SSE^*}{SST^*} \tag{14}$$

where SSE^* denotes the error sum of errors of squares that quantifies the overall variability present within the time series $(\Delta S_t - \beta \ln F_t)$; β denotes the optimal hedge ratio ascertained through regression model; and SST^* denotes the total sum of squares, quantifying the overall variation in ΔS_t around its mean. This method mentioned above would facilitate precise comparisons across various models, offering a more accurate assessment of hedge effectiveness compared to prior research (Juhl, Kawaller, and Koch 2012).

The primary objective of employing a hedge strategy is mitigation of risk. While this study gives numerous hedge ratios, empirical verification is essential. Thus, this study backtests two of Dreyer's (2020) ten hedging strategies to evaluate the effectiveness of cross-hedging the SOYA with the BEAN contract. This evaluation centres on risk reduction and profitability assurance as key metrics to determine effectiveness of these strategies, in addition to seeing whether the BEAN contract can deliver a better return.

3.2 Data

This study gathered historical data for near-month futures contract prices (SOYA-spot price) and the corresponding prices of the cross-hedge instrument, JSE BEAN futures prices (BEAN). Daily time series data from 15 June 2010 to 13 September 2023 were sourced from Refinitiv (formally known as Thomson Reuters Financial and Risk) (Refinitiv 2023), and the official website of the JSE (2023b,

Table 1. Johansen (1991) co-integration test results (Tr and L-max statistic).

Hypothesised	Trace statistic	0.5 critical value	t-prob.
H_0:$r = 0$	1961.61	15.49	0.00*
H_0:$r \leq 0$	872.46	3.84	0.00*
Hypothesised	L-max statistic	0.5 critical value	t-prob.
H_0:$r = 0$	1089.15	14.26	0.00*
H_0:$r \leq 0$	872.46	3.84	0.00*

*Rejection at the 95% confidence level.
Max-eigenvalue and Trace's test indicates two co-integrating equation(s) at the 5% significance level.

2023c). To ensure a comprehensive dataset, a dual-sourcing approach was adopted, as neither database independently contained the complete dataset. The integration of data from both Refinitiv and the JSE resulted in a total of 3305 observations for each variable under study. To address the issue of missing data, a rigorous examination of specific dates was conducted. An average formula was applied to estimate values for the missing data on specific dates, providing a balanced and representative dataset for analysis.

In the realm of time-series analysis, it is imperative to undertake multiple tests on the data for precise model specification. These analyses encompass the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

- Testing for stationarity: The ADF, PP and KPSS tests are used in time-series analysis. ADF and PP look for unit roots, while KPSS seeks stationarity. Type II errors (Brooks 2002) can be mitigated by using both unit root and stationarity checks. The optimal lag amount for these evaluations is determined by the Schwartz Information Criterion (SIC).
- Confirming stationarity: If the data are not stationary, undergoes conversion using a log-first difference transformation. Through this transformation, the nonstationary level data is changed into a stationary series. Both level data and log-difference data should be used for the stationarity and unit root of one test (Asteriou and Hall 2021).
- Cointegration analysis: After the establishment of stationarity, the cointegration with the soybean spot price is evaluated. Cointegration denotes the interdependence of two series that are influenced by similar causes. By examining the error term from an OLS regression, the Johansen cointegration approach (Johansen 1991) validates this interdependence. Nonstationary variables are indicated by a lack of co-integration, whereas co-integration series produce stationary error terms (Johansen 1991).

The assessment of stationarity of the error term was examined using the PP- and ADF tests. The results of the PP and ADF tests for all price levels and the respective log differences are not recorded here. However, the author can provide detailed test results on request. Table 1 of the Johansen cointegration test, on the other hand, shows the rejection of nonstationarity in the error term, indicating cointegration of the soybean futures price. Therefore, the inclusion of an error specification is deemed justified.

4. Empirical results

4.1 Hedge ratios

The OLS-model analysis demonstrates a significant coefficient for the MVHR, quantified by the hedge ratio of 0.84, but falls short of the conventional 80% threshold typically indicative of high hedge effectiveness (Juhl, Kawaller, and Koch 2012). A high adjusted-R^2 (47%) implies that SOYA variability is explained by changes in BEAN, suggesting that the fluctuations in the SOYA-spot price (prices of the near-month futures contracts) can be accounted for by the changes in prices of JSE BEAN futures contracts The correlation between prices of May BEAN futures contracts and SOYA near-month futures contracts, establishing BEAN as a dependable indicator of SOYA-spot price fluctuations.

Table 2. Summary of hedging model estimates.

	Model I: OLS	Model II: ECM	Model III: ECM with GARCH errors
Constant	0.25 (1.12)	−0.03 (0.00)	0.15 (0.83)
ΔF_t	0.84 (0.02)*	0.84 (0.02)*	0.80 (0.00)*
ΔF_{t-1}		−0.40 (0.00)*	0.04 (0.31)
ΔF_{t-2}		−0.19 (0.00)*	0.06 (0.13)
ΔS_{t-1}		0.23 (0.00)*	−0.06 (0.00)*
ΔS_{t-2}		0.13 (0.00)*	−0.08 (0.00)*
$\boldsymbol{\varepsilon}_{t-1}$		−1.33 (0.00)*	0.09 (0.33)
C	-	-	44.64 (0.00)*
ARCH	-	-	0.08 (0.00)*
GARCH	-	-	0.91 (0.00)*
Adj. R^2	0.47	0.49	0.47
Log-likehood	−18436.39	−19507.90	−18019.10
ARCH LM	31.42 (0.00)*	31.70 (0.00)*	0.86 (0.3545)

Note: *p*-Values are included in parentheses.
*Significance at the 1% and 5% levels, respectively.

However, the ARCH-LM test detects heteroskedasticity as well as the model's inability to capture the long-run relationships between SOYA- spot and JSE BEAN futures prices. Using an ECM corrects this, improving accuracy and dynamics representation.

The findings derived from the ECM reveal that the hedge ratio remains consistent, mirroring the hedge ratio calculated through the straightforward OLS estimate presented in Table 2. The determination of the lag length was guided by the AIC and SIC, favouring the use of four lags. Although the adjusted-R^2 value of 0.49 exhibits an improvement, it remains elusive to surpass the 80% threshold indicative of high effectiveness. Moreover, while the log-likelihood value exhibits a decrease to 19,507.90 in comparison to the OLS estimates, indicating a better model fit, the persistent presence of heteroskedasticity is affirmed through the ARCH-LM test.

The EC-GARCH model (Table 2) has a hedge ratio of 0.80, which is lower than the preceding two models. Elevated log-likelihood (−18,019.10) and adjusted-R^2 (0.47) confirm previous findings. Both the ARCH and GARCH parameters are significant ($p = 0.00$), indicating that volatility persists. The cumulative value of the coefficients for the ARCH and GARCH parameters ($0.084761 + 0.914151$) approximated unity, signifying a high degree of persistence in conditional variance shocks (high persistent volatility). GARCH outperforms ARCH in terms of forecasting during episodes of increased volatility. Notably, $\lambda_S = -1.19$ and $\lambda_F = -1.19$, imply that the JSE BEAN- futures price (F_t), adjusts more rapidly that JSE SOYA-spot price S_t to the prior deviations from the long-term equilibrium.

4.2 Hedge effectiveness

Evaluation of hedge effectiveness in these three models using the application of the "R^2 analogue method" (Juhl, Kawaller, and Koch 2012). This method compares the hedge portfolio relative to the unhedged position, and then deducts this ratio from one, with greater ratios indicating lower effectiveness. The hedge effectiveness results are outlined in Table 3 and show that hedge ratios and -effectiveness measures differ across models. The OLS model has a hedge ratio of 0.84 and a corresponding hedge effectiveness of 0.47, implying that approximately 47% of the overall variations in portfolio returns are mitigated through the hedging process. Similarly, the ECM has a hedge ratio of 0.84,

Table 3. Estimated hedge ratios and hedge effectiveness.

Model	Hedge ratio	Hedge effectiveness
OLS	0.84	0.4691
ECM	0.84	0.4910
EC-GARCH(1,1)	0.80	0.4692

Source: Compiled by author.

albeit with a sightly dismissed hedge effectiveness of 0.49 (49% of the overall variations in portfolio returns are mitigated through hedging). The EC-GARCH model, on the other hand, displays a slightly lower hedge ratio of 0.80, but it remains a hedge effectiveness level comparable to the OLS model at 0.47. This shows that, despite a slight loss in ratio, EC-GARCH controls risk as efficiently as OLS. The findings of Table 3 suggest that there is no single model consistently providing the highest hedge effectiveness for each commodity, highlighting the need to carefully consider the model choice when estimating an MVHR. Despite the absence of a clear superior model, the primary objective of assessing the effectiveness of cross-hedging with the BEAN contract for soybean producers in the South African market has been confirmed. Although no model outperforms another, the results affirm that BEAN can be effectively utilised as a cross-hedge instrument. Subsequently, the upcoming section on back-testing will further validate the accuracy of using BEAN as a cross-hedge to SOYA.

One notable constraint of this study is the efficiency of the JSE BEAN contract in providing hedging solutions solely at parity levels within South Africa. While the results show that the JSE BEAN contract provides hedging against immediate price risks, it is less successful at mitigating price changes between parity levels. This might explain the relatively low R^2-values obtained across the models. This indicates that while the models may anticipate price changes to some extent, they do not fully represent the intricacies of structural price adjustments within the market. This limitation necessitates the authors to provide a disclaimer stating that, while the JSE BEAN contract is a useful instrument for managing price risk at a static level, its usefulness declines when dealing with dynamic shifts between parity levels.

Future research could focus on enhancing the hedging models to account for structural price movements between parity levels. Different econometric models or adding additional variables to the existing models might better capture these dynamics and may provide deeper insights.

4.3 Back-testing

This section presents the results of a back-testing analysis conducted on the JSE BEAN and JSE SOYA contracts, aimed at evaluating the JSE BEAN performance as a potential cross-hedging tool during periods when the local soybean price approached or fell below export parity price levels. While similar results were anticipated for import parity levels, this aspect could not be tested. Table 4 presents the results of the Three-segment strategy, a hedging alternative with short futures contracts during the production season. According to the Dreyer (2020) process, the crop is divided into three equal portions to be marketed with short futures sales: one-third during planting (October to December), one-third post-pollination/flowering (February) and the final third during the harvest season (April to May). The strategy uses the averages of the futures prices for each respective period. The table below shows the financial results of this strategy for each production season, detailing the performance of the JSE BEAN compared to the JSE SOYA as a cross-hedging tool.

Table 4. Comparative three-segment strategy results.

Production year	Realised JSE BEAN price	Realised JSE SOYA price	BEAN performance relative to SOYA
2011	R3 484.65	R3 484.65	Performed at par
2012	R3 773.39	R3 625.44	Outperformed
2013	R4 888.83	R4 717.33	Outperformed
2014	R5 258.22	R5 625.58	Underperformed
2015	R4 159.65	R4 906.38	Underperformed
2016	R5 235.96	R6 300.42	Underperformed
2017	R5 042.98	R5 719.68	Underperformed
2018	R4 763.44	R4 704.15	Outperformed
2019	R4 603.04	R4 737.84	Underperformed
2020	R5 269.91	R6 070.88	Underperformed
2021	R7 225.63	R7 991.65	Underperformed
2022	R8 468.43	R8 306.41	Outperformed

Source: Compiled by author.
Calculations are available upon request from the author.

The study demonstrated a consistent trend in the performance of the JSE BEAN contract relative to the JSE SOYA contract, particularly under certain market conditions. Notably, the BEAN contract outperformed the SOYA contract in instances where the local soybean prices traded at or below export parity price levels. This indicates that the BEAN contract is more effective as a cross-hedge during seasons with ample supply, which tends to drive local prices closer to or even below export parity levels. However, as local soybean prices neared import parity levels, the JSE BEAN contract did not retain its outperformance, showing its limited usefulness in such market conditions. These findings highlight the JSE BEAN contract's viability as a cross-hedging instrument under specific market conditions, offering insight for traders and farmers planning to mitigate price risk when logistical constraints negatively affect the local soybean price. The practical application of the JSE BEAN contract has not been evaluated. Future research can aim to determine whether there exists sufficient liquidity in the JSE BEAN contract to be considered as cross-hedging instrument. Although the author acknowledges that liquidity is currently a challenge, it is anticipated that this may improve in the near future.

5. Conclusions

The study investigated the effectiveness of the BEAN contract for cross-hedging SOYA price risk exposure. It employs OLS regression, ECM and EC-GARCH (1,1) for comparative hedging performance analysis. The traditional use of OLS regression is primarily illustrative, with the ECM being a more effective model due to its incorporation of long-term relationship of the variables. Determining an accurate cross-hedge, optimal hedging ratio and appropriate cross-hedging instrument are critical aspects. An EC-GARCH, considering conditional volatility, characteristics of commodity returns, improves the model fit. However, despite the endorsement of advance models over OLS in some research, this research study finds that no model consistently outperforms others in generating an optimal hedge ratio through comprehensive simulation.

The results obtained from the backtesting approach show a pattern of BEAN outperforming SOYA during times when the local price traded closer to or below export parity price levels, suggesting that BEAN can be used as a cross-hedge instrument for SOYA. This approach can assist with the management of price risk, by careful analysis and risk management are necessary to make effective hedging decisions. Additionally, changes in the correlation between BEAN and SOYA prices should be monitored closely to fine-tune the hedging strategy.

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Data Availability Statement

The data that support the findings of this study are derived from public domain resources and are available in SE downloadable files: SAFEX/PriceHistory/Physically Settled Grain Contracts at this link https://clientportal.jse.co.za/downloadable-files?RequestNode=/Safex/PriceHistory/Physically%20Settled%20Grain%20Contracts and in JSE downloadable files: SAFEX/PriceHistory/Cash Settled Soft Commodities at this link https://clientportal.jse.co.za/downloadable-files?RequestNode=/Safex/PriceHistory/Cash%20Settled%20Soft%20Commodities The following source can be added to the data: (JSE, 2023b and JSE, 2023c).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Ankirchner, S., G. Dimitroff, G. Heyne, and C. Pigorsch. 2012. Futures Cross-Hedging with a Stationary Basis. *Journal of Financial and Quantitative Analysis* 47, no. 6: 1361–1395.

Adams, Z., and M. Gerner. 2012. Cross hedging jet-fuel price exposure. *Energy Economics* 34, no. 1: 1301–9.

AFMA (Animal Feed Manufacturers Association). 2023. AFMA industry statistics. https://www.afma.co.za/industry-statistics/ (accessed October 19, 2023).

Anderson, T.G., and T. Bollerslev. 1998. Answering the sceptics: Yes, standard volatility models do provide accurate forecasts. *International Economic Review* 34, no. 9: 885–905.

Anderson, R.W., and J.P. Danthine. 1981. Cross hedging. *Journal of Political Economy* 89, no. 6: 1182–96.

Asteriou, D., and S.G. Hall. 2021. *Applied econometrics*. 4th ed. London: Red Globe Press.

Aven, T. 2016. Cross-Hedging as a Risk Management Strategy in Commodity Trading. *Journal of Commodity Markets* 12, no. 1: 34–50.

Baillie, R.T., and R.J. Myers. 1991. Bivariate GARCH estimation of the optimal commodity futures hedge. *Journal of Applied Econometrics* 6, no. 2: 109–24.

Barndorff-Nielsen, O.E., and N. Shephard. 2004. Econometric analysis of realized covariation: High frequency-based covariance, regression, and correlation in financial economics. *Econometrics* 72, no. 3: 885–925.

Barndorff-Nielsen, O.E., P.R. Hansen, A. Lunde, and N. Shephard. 2011. Multivariate realised kernels: Consistent positive semi-definite estimators of the covariation of equity prices with noise and non-synchronous trading. *Journal of Econometrics* 162, no. 2: 149–69.

Barrera, G., A. Cañón, and J.C. Sánchez. 2020. Managing Colombian farmers price risk exposure with electrical derivatives market. *Heliyon* 6, no. 12: e05713. doi:10.1016/j.heliyon.2020.e05713.

Behm, J. 2013. The application of different ARCH/GARCH-models before and after the financial crisis. BsocSc diss., Uppsala University. https://urn.kb.se/resolve?urn = urn:nbn:se:uu:diva-204236.

Benninga, S., R. Eldor, and I. Zilcha. 1983. Optimal hedging in the futures market under price uncertainty. *Economic Letters* 13, no. 1: 141–5.

Berghöfer, B., and B. Lucey. 2014. Fuel hedging, operational hedging and risk exposure – evidence from the global airline industry. *International Review of Financial Analysis* 34, no. 1: 124–39.

Bieroth, C.W. 2010. Cross-hedging performance of wholesale beef in live cattle futures contracts revisited. PhD diss., Kansas State University, Manhattan.

Bollerslev, T. 1986. Generalized autoregressive conditional heteroscedasticity. *Journal of Econometrics* 31, no. 3: 307–27.

Bradburn, M.J., T.G. Clark, S.B. Love, and D.G. Altman. 2003. Survival analysis part II: Multivariate data analysis – An introduction to concepts and methods. *British Journal of Cancer* 89, no. 3: 431–6.

Brinker, A.J., J.L. Parcell, and K.C. Dhuyvetter. 2007. Cross-hedging distillers dried grains: Exploring corn and soybean meal futures contracts. https://ageconsearch.umn.edu/record/37567/ (accessed March 23, 2023).

Brinker, A.J., J.L. Parcell, K.C. Dhuyvetter, and J.R. Franken. 2009. Cross-hedging distillers dried grains using corn and soybean meal futures contracts. *Journal of Agribusiness* 27, no. 1: 1–15.

Brooks, C. 2002. *Introductory econometrics for finance*. Cambridge: Cambridge University Press.

Brooks, C., R.J. Davies, and S.S. Kim. 2007. Cross hedging with single stock futures. *Assurances et Gestion des Risques* 74, no. 4: 473–504.

Buhr, B.L. 1996. Hedging Holstein steers in the live cattle futures market. *Review of Agricultural Economics* 18, no. 1: 103–14.

Chang, E.C., and K.P. Wong. 2002. Cross-Hedging with Currency Options and Futures. *Journal of Financial and Quantitative Analysis* 37, no. 4: 555–574.

CEC (Crop Estimate Committee). 2002. Summer Crops (2001/02): Final Area Planted & Crop Production Figures. https://www.sagis.org.za/cec_reports_2002.html (accessed August 25, 2024).

CEC (Crop Estimate Committee). 2023. Summer Crops (2023): Area Planted & Final Production Forecast. https://www.sagis.org.za/cec_reports_2023.html (accessed August 25, 2024).

Cecchetti, S.G., R.E. Cumby, and S. Figlewski. 1988. Estimation of the optimal futures hedge. *Review of Economics and Statistics* 70, no. 4: 623–30.

Clark, E., J.-B. Lesourd, and R. Thiéblemont. 2001. *International commodity trading*. Chichester: John Wiley & Sons.

DALRRD (Dept. of Agriculture, Land Reform and Rural Development). 2021. A profile of the South African soybean value chain. http://webapps1.daff.gov.za/AmisAdmin/upload/Soyabean%20profile%202021.pdf (accessed March 31, 2023).

Dreyer, F.A. 2020. Analysing white maize hedging strategies in South Africa. PhD thesis, North-West University, Potchefstroom.

Delouche JC, Matthens R.K., Dougherty GM and Boyd, A.H. 1973. Storage of seed in sub-tropical and tropical regions. *Seed Sci Technol*, 1: 633–692.

Eaker, M.R., and D.M. Grant. 1987. Cross-hedging foreign currency risk. *Journal of International Money and Finance* 6, no. 1: 85–105.
Ederington, L.H. 1979. The hedging performance of the new futures markets. *Journal of Finance* 30, no. 1: 157–70.
Elam, E., and W. Donnell. 1992. Cross hedging cattle rations using corn futures. *Texas Journal of Agriculture and Natural Resources* 5, no. 1: 13–20.
Elam, E.W., S.E. Miller, and S.H. Holder. 1986. Simple and multiple cross-hedging of rice bran. *Journal of Agricultural and Applied Economics* 18, no. 1: 123–8.
Engle, R. 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica: Journal of the Econometric Society* 50: 987–1007.
Erickson, B., T. Hubbs, A. Miller, and C. Dobbins. 2009. Changing Input Costs and Grain Prices: Implications for Crop Selection and Management. https://ag.purdue.edu/commercialag/home/paer-article/changing-input-costs-and-grain-prices-implications-for-crop-selection-and-management/ (accessed June 26, 2023).
Fernando, J., and S. Anderson. 2022. Cross Hedge: Meaning and Examples of Trading Strategy. https://www.investopedia.com/terms/c/crosshedge.asp (accessed July 9, 2023).
Figlewshi, S. 1984. Hedging performance and basis risk in stock index futures. *Journal of Finance* 39: 657–69.
Finnerty, J.D., and D. Grant. 2002. Alternative approaches to testing effectiveness under SFAS No. 133. *Account Horizon* 16, no. 2: 95–108.
Franken, J., and J. Parcell. 2011. Cross-hedging fishmeal: Exploring corn and soybean meal futures contracts. *Aquaculture Economics & Management* 15, no. 1: 71–81.
Gayatri, S., N. Kumar, and P. Singh. 2023. Impact of Futures Trading Restrictions on Spot Market Dynamics: Evidence from India. *Journal of Financial Markets* 15, no. 3: 45–67.
Geyser, J.M. 2013. *Short and long of futures markets: SAFEX, grain hedging and speculation*. Krugersdorp: Kejafa Knowledge Works.
Ghosh, A. 1993. Hedging with stock index futures: Estimation and forecasting with error correction model. *Journal of Futures Markets* 13: 743–52.
Ghosh, A., and R. Clayton. 1996. Hedging with international stock index futures: An intertemporal error correction model. *Journal of Financial Research* 19, no. 4: 477–91.
Glen, J., and P. Jorion. 1993. Hedging for international portfolios. *Journal of Finance* 48, no. 5: 1865–86.
Guo, B., Sun, L., Jiang, S., Ren, H., Sun, R., Wei, Z., Hong, H., Luan, X., Wang, J., Wang, X., Xu, D., Li, W., Guo, C., and Qiu, L. J. 2022. Soybean genetic resources contributing to sustainable protein production. TAG. Theoretical and applied genetics. *Theoretische und angewandte Genetik* 135, no. 11: 4095–4121.
Hamilton, J.D. 2020. *Time series analysis*. Princeton, NJ: Princeton University Press.
Hashim, D.A., and V. Shunmugam. 2009. Can hedging fly airlines to safety in volatile ATF markets? *Economic & Political Weekly* 44, no. 7: 23–5.
Hayenga, M.L., and D.D. DiPietre. 1982a. Cross hedging wholesale pork products using live hog futures. *American Journal of Agricultural Economics* 64, no. 1: 747–51.
Hayenga, M.L., and D.D. DiPietre. 1982b. Hedging wholesale meat prices: Analysis of basis risk. *The Journal of Futures Markets (pre-1986)* 2, no. 2: 131.
Hieronymus, T.A. 1977. *Economics of futures trading for commercial and personal profit*. 2nd ed. New York, NY: Commodity Research Bureau, Inc.
Hill, J., and T. Schneeweis. 1981. A note on the hedging effectiveness of foreign currency futures. *Journal of Futures Markets* 1, no. 4: 659–64.
Hsu, Y.C., and A.P. Chen. 2014. A clustering time series model for the optimal hedge ratio decision making. *Neurocomputing* 138: 358–70.
Iyer, T. 2022. *Cryptic connections: Spillovers between crypto and equity markets*. Washington, DC: International Monetary Fund.
Junttila, J., J. Pesonen, and J. Raatikainen. 2018. Commodity Market-Based Hedging Against Stock Market Risk in Times of Financial Crisis: The Case of Crude Oil and Gold. *Journal of Commodity Markets* 12, no. 1: 34–50.
Johansen, S. 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society* 59, no. 6: 1551–80.
Johnson, L.L. 1960. The theory of hedging and speculation in commodity futures. *The Review of Economic Studies* 27, no. 3: 139–51.
JSE (Johannesburg Stock Exchange). 2023a. Grain Futures and Options. https://www.jse.co.za/grain-futures-and-options (accessed July 9, 2023).
JSE (Johannesburg Stock Exchange). 2023b. JSE Downloadable Files: SAFEX/PriceHistory/Physically Settled Grain Contracts. https://clientportal.jse.co.za/downloadable-files?RequestNode = /Safex/PriceHistory/Physically%20Settled%20Grain%20Contracts (accessed August 4, 2023).
JSE (Johannesburg Stock Exchange). 2023c. JSE Downloadable Files: SAFEX/PriceHistory/Cash Settled Soft Commodities. https://clientportal.jse.co.za/downloadable-files?RequestNode = /Safex/PriceHistory/Cash%20Settled%20Soft%20Commodities (accessed August 4, 2023).

Juhl, T., I.G. Kawaller, and P.D. Koch. 2012. The effect of the hedge horizon on optimal hedge size and effectiveness when prices are cointegrated. *Journal of Futures Markets* 32, no. 9: 837–76.
Kim, H., J. Lee, and S. Park. 2015. Cross-Hedging Strategies in Commodity Markets: Evidence from Crude Oil and Agricultural Products. *Journal of Commodity Markets* 8, no. 2: 123–135.
Koskosidis, A., Khah, E.M., Pavli, O.I. and Vlachostergios, D.N. 2022. Effect of storage conditions on seed quality of soybean (Glycine max L.) germplasm. *AIMS Agric Food* 7, no. 2: 387–402.
Koopman, S.J., B. Jungbacker, and E. Hol. 2005. Forecasting daily variability of the S&P 100 stock index using historical, realised and implied volatility measurements. *Journal of Empirical Finance* 12, no. 3: 445–75.
Liccardo, G. 2013. The effects of derivatives trading on stock market volatility and market efficiency: Some evidence from European markets. In *Asset pricing, real estate and public finance over the crisis*, eds. A. Carretta, and G Mattarocci, 25–37. London: Palgrave Macmillan.
Lien, D., and Y.K. Tse. 1999. Fractional cointegration and futures hedging. *Journal of Future Markets* 19: 457–74.
Lien, D. 1996. The effect of the cointegration relationship on futures hedging. *Journal of Future Markets* 16: 773–80.
Maitra, D., M. Ur Rehman, S. Ranjan Dash, and S. Hoon Kang. 2022. Do cryptocurrencies provide better hedging? evidence from major equity markets during COVID-19 pandemic. *The North American Journal of Economics and Finance* 62: 101–776. doi:10.1016/j.najef.2022.101776.
Markopoulou, C.E., V.D. Skintzi, and A.P.N. Refenes. 2016. Realized hedge ratio: Predictability and hedging performance. *International Review of Financial Analysis* 45 no. 1: 121–33.
McDonald, M.B., 1999. Seed deterioration: physiology, repair, and assessment. *Seed Sci Technol* 27:177–237.
Miao, H., S. Ramchander, T. Wang, and D. Yang. 2017. Role of index futures on China's stock markets: Evidence from price discovery and volatility spillover. *Pacific-Basin Finance Journal* 44: 13–26.
Miller, S.E. 1982. Forward pricing feeder pigs. *Journal of Futures Markets* 2, no. 1: 333–40.
Miller, S.E. 1985. Simple and multiple cross-hedging of mill feeds. *Journal of Futures Markets* 5, no. 1: 21–8.
Mitchell, J.B. 2010. Soybean futures crush spread arbitrage: Trading strategies and market efficiency. *Journal of Risk and Financial Management* 3, no. 1: 63–96.
Mongi, A., and H.A. Dhouha. 2016. Do structural breaks affect portfolio designs and hedging strategies? international evidence from stock-commodity markets linkages. *International Journal of Economics and Financial Issues* 6, no. 1: 252–70.
Morrell, P., and W. Swan. 2006. Airline jet fuel hedging: Theory and practice. *Transport Reviews* 26: 713–30.
Mun, K.C., and G.E. Morgan. 1997. Cross-hedging foreign exchange rate risks: The case of deposit money banks in emerging Asian countries. *Pacific-Basin Finance Journal* 5, no. 2: 215–30.
Naeem, M.A., S. Farid, F. Balli, and S.J. Hussain Shahzad. 2021. Hedging the downside risk of commodities through cryptocurrencies. *Applied Economics Letters* 28, no. 2: 153–60.
Nekhili, R., and J. Sultan. 2022. Hedging bitcoin with conventional assets. *Borsa Istanbul Review* 22, no. 4: 641–52.
Nelson, C.R., and C.I. Plosser. 1982. Trends and random walks in macroeconomic time series: Some evidence and implications. *Journal of Monetary Economics* 10: 139–62.
Nordier, J.P. 2021. Identifying possible misspecification in South African soybean oil future contracts. PhD diss., University of Pretoria, Pretoria.
Olson, E., A. Vivian, and M.E. Wohar. 2019. What is a better cross-hedge for energy: Equities or other commodities? *Global Finance Journal* 42: 100417.
Pennings, J.M.E., and M.T.G. Meulenberg. 1997. Hedging risk in agricultural futures markets. In *Agricultural marketing and consumer behaviour in a changing world*, ed. B. Wierenga, A. van Tilburg, K. Grunert, JB.E.M. Steenkamp, and M Wedel, 125–45. Boston, MA: Springer.
Penone, C., E. Giampietri, and S. Trestini. 2021. Hedging effectiveness of commodity futures contracts to minimize price risk: Empirical evidence from the Italian field crop sector. *Risks* 9, no. 12: 213. doi:10.3390/risks9120213.
Pirrong, C. 2014. *The economics of commodity trading firms*. Houston: Trafigura.
Ran, J. 2007. Cross-Hedging Effectiveness in Emerging Markets: The Case of Agricultural Commodities. *Emerging Markets Finance and Trade* 43, no. 4: 56–72.
Rahman, S.M., S.C. Turner, and E.F. Costa. 2001. Cross-hedging cottonseed meal. *Journal of Agribusiness* 19, no. 2: 163–71.
Ranganathan, T., and U. Ananthakumar. 2014. Market efficiency in Indian soybean futures markets. *International Journal of Emerging Markets* 9, no. 4: 520–34.
Raucci, G.L., R. Lanna, F. da Silveira, and D.H.D. Capitani. 2019. Development of weather derivatives: Evidence from the Brazilian soybean market. *Italian Review of Agricultural Economics* 74, no. 2: 17–28.
Refinitiv. 2023. Commodities - Agriculture data for BEAN and SOYA. [Dataset]. Refinitiv Tick History – PCAP.
Roche, J.S. 2020. Success criteria for commodity exchanges. *African Journal of Agricultural and Resource Economics* 15, no. 2: 127–39.
Rout, B.S., N.M. Das, and K.C. Rao. 2021. Functional effectiveness of commodity futures market: A comparative assessment of agricultural and metal commodities. *Paradigm* 25, no. 1: 42–60. doi:10.1177/09718907211023594.
SAGIS (South African Grain Information Service). 2023. Historic Hectares & Production Info. https://www.sagis.org.za/historic%20hectares%20&%20production%20info.html (accessed May 4, 2023).

SAGL (South African Grain Laboratory). 2022. Soybeans Reports. https://sagl.co.za/soybeans/reports/ (accessed October 19, 2023).

Samal, L., and S.K. Das. 2023. Hedging Effectiveness and Influential Direction Between Spot and Futures Market of Aluminium: An Evidence from India. *Business Perspectives and Research* 11, no. 1: 94–111. doi:10.1177/22785337221148537.

Stein, J.L., B.A. Goss, and B.S. Yamey. 1961. The simultaneous determination of spot and futures prices. *The Economics of Futures Trading* 51: 1012–25.

Susilo, D., S. Wahyudi, I.R.D. Pangestuti, B.A. Nugroho, and R. Robiyanto. 2020. Cryptocurrencies: Hedging opportunities from domestic perspectives in Southeast Asia emerging markets. *Sage Open* 10, no. 4: 2158244020971609.

Tan, M. 2002. *Managing aviation fuel risk: Emerging market's airline companies perspective on the international arena*. City: South Bank University, Centre for International Business Studies. http://www1.lsbu.ac.uk/cibs/pdf/25-02.pdf (accessed December 3, 2023).

Tsay, R.S. 2005. *Analysis of financial time series*. Hoboken, NJ: John Wiley & Sons.

USDA (United States Department of Agriculture Foreign Agricultural Service). 2021. South Africa: Oilseeds and Products Annual. https://www.fas.usda.gov/data/south-africa-oilseeds-and-products-annual-6 (accessed February 7, 2023).

Van der Linde, K. 2023. Productivity growth in the South African soybean industry:2001–2021. PhD diss., Stellenbosch University, Stellenbosch.

Van der Vyver, A., U. Barnard, and J.P. Nordier. 2022. Identifying possible misspecification in South African soybean oil futures contracts. *Agrekon* 61, no. 1: 80–93.

Van der Vyver, A., J. Nordier, and B. Verwey. 2018. Insufficient SA soybean crushing capacity influences export market. NWK Arena, Mei-June: 19–22.

Van Zyl, J.C., N. Vink, J. Kirsten, and D. Poonyth. 2001. South African agriculture in transition: The 1990s. *Journal of International Development* 13, no. 6: 725–39.

Vukina, T., and J.L. Anderson. 1993. A State-Space Forecasting Approach to Optimal Intertemporal Cross-Hedging. *American Journal of Agricultural Economics* 75, no. 3: 563–573.

Viatte, G. 2001. Adopting technologies for sustainable farming systems: An OECD perspective. In *Adoption of technologies for sustainable farming systems Wageningen Workshop Proceedings (Vol. 14)*, ed. G Viatte, 14–23. Paris: OECD.

Vink, N. 2003. *Macroeconomic and sector policy changes in South African agriculture, 1996-2002.* FAO Project on the Roles of Agriculture in Developing Countries, Food and Agricultural Organisation of the United Nations. Rome, Italy.

Vink, N., and S. Schirmer. 2002. South African Agriculture in the Period 1970–2000. In *The Decline of the South African Economy*, edited by S. Jones, 51–67. London: Routledge.

Vikhe, A.C. 2016. Effect of storage conditions on seed quality of soybean and impact of seed production area. *International Journal of Advanced Research* 4, no. 12: 2032–2038.

Voora, V., Larrea, C. and Bermudez, S. 2020. Global market report: Soybeans. Winnipeg, Manitoba: International Institute for Sustainable Development.

Writefull. 2024. *Writefull Revise.* https://libguides.nwu.ac.za/az/writefull (accessed June 18, 2024).

Wei, Y., Y. Wang, and D. Huang. 2011. A copula–multifractal volatility hedging model for CSI 300 index futures. *Physica A: Statistical Mechanics and its Applications* 390, no. 23-24: 4260–72.

Woo, C.-K., I. Horowitz, and K. Hoang. 2001. Cross hedging and forward-contract pricing of electricity. *Energy Economics* 23: 1–15.

Zainudin, A.D., and A. Mohamad. 2021. Cross hedging with stock index futures. *The Quarterly Review of Economics and Finance* 82, no. 1: 128–44.

Zhang, L. 2011. Estimating covariation: Epps effect, microstructure noise. *Journal of Economics* 160, no. 1: 33–47.

Zheng, S., and Z. Wang. 2013. Pricing efficiency in the Chinese NGM and GM soybean futures market. *China: An International Journal* 11, no. 3: 48–67.