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**TESTING FOR WEAK-FORM EFFICIENCY IN SOUTH AFRICAN FUTURES
MARKETS FOR WHITE AND YELLOW MAIZE**

By

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GOD IS GREAT

ABSTRACT

Testing for Weak-Form Efficiency in South African Futures Markets for White and Yellow Maize

By
Motlatjo B. Moholwa

Agricultural marketing policy in South Africa has moved from a fully regulated marketing environment to a more open and transparent system. The demise of the Maize Board in 1996 created a need for South African maize producers to give more attention to price risk management. Commodity futures markets should be efficient to play the most effective role in price risk management. This study tests for weak-form efficiency in the South African Futures markets for white and yellow maize by examining the predictability of daily futures price changes.

The results suggest that futures price changes for both white and yellow maize are partially predictable from past price information. The implication is that past price information does contain additional information that could be used to forecast the future price once the current futures price is known. But when taking into account brokerage costs and the time value of money, out of sample predictive performance of the model indicates that trading decisions based on the direction of predicted futures price changes do not lead to profitable trades for either crop. Hence, the evidence suggests there is no strong support for weak-form inefficiency in South African futures markets for white and yellow maize. The results further suggest that there is no trend in market efficiency over time for white and yellow maize futures markets in South Africa.

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1. INTRODUCTION

1.1 Background

South African agriculture has a long history of government intervention, reaching a watershed in approximately 1980 with a series of laws, ordinances, statutes and regulations affecting all aspects of agriculture (Kirsten and van Zyl, 1996). Since the mid-1980s, agricultural policy has been characterized by deregulation and market liberalization. Vink (1993) argues that deregulation of the agricultural sector started outside agriculture in the late 1970s when the financial sector was extensively liberalized following the publication of the De Kock Commission report¹. The most immediate effect on agriculture came from changes in the external value of the Rand and in the interest cost of farm borrowing.

The Marketing of Agricultural Products Act No. 47 was passed at the end of 1996. Agricultural marketing has since moved from a highly regulated environment to a more open and transparent system. For example, in the past maize prices were determined by the Maize Board. The Maize Board set producer prices and acted as a single channel marketer. But from 1996, with the abolition of the Maize Board, the maize market has been free from statutory intervention. Prices are now determined by the interaction of supply and demand. The deregulation of agricultural markets in South Africa implies that farmers now compete in a more open global trading environment. While this implies better access to export opportunities, it also implies that farmers have

¹ Commission of inquiry into the monetary system and monetary policy in South Africa, RP 70/1984.

to be competitive in domestic, regional, and international markets.

The demise of the Maize Board has created the need for South African maize producers to give more individual attention to managing price risk. While producers may feel they have some influence on yields through their decisions, prices are beyond their control. It has been argued that prices of primary products are often highly volatile, particularly in comparison to manufactured goods (Newbery and Stiglitz, 1981). This implies price risk because agricultural production decisions are generally made on the basis of expected prices and costs six months or more before harvest, allowing time for substantial changes in prices.

Agricultural futures markets serve several important functions, such as risk management for farmers, traders, and food processors, price discovery, and forward pricing (Sheldon, 1987). Futures trading is one mechanism for managing the effects of price risk resulting from the production, marketing and purchase of a commodity (Wang and Ke, 2003). The deregulation of agricultural markets in South Africa led to the establishment of a futures market for agricultural products which was opened in January 1995. The new Marketing of Agricultural Products Act in South Africa has created an environment in which farmers, traders and processors are able to react positively to transparent prices which are market related (SAFEX, 2004). White and yellow maize futures contracts were listed in 1996 have grown enormously in recent years. Wheat, sunflower seed, and soybean contracts were introduced in 1997, 1999 and 2002, respectively.

The physically settled beef and potato contracts have since been delisted due to inactivity (SAFEX, 2004). Overall growth continues to be encouraging as the exchange now trades on average 200,000 tons of maize contracts a day. Over 1.8 million contracts have been traded since 1995 with the bulk of the trades arising from white

maize contracts. The percentage of physical deliveries are on the decline. The implication is that the futures exchange is being used as a hedging facility and not as a pure delivery mechanism (SAFEX, 2004).

The study of market efficiency in agricultural commodity futures is important to both the government and to producers in South Africa. From the government policy perspective, an efficient market implies an efficient alternative to market interventions, such as price stabilization policies. For producers, it provides a reliable forecast of spot prices in the future and allows them to effectively manage their risks in the production and marketing process. Futures markets should be efficient to play the most effective role in risk management and price stabilization (Aulton, *et al*, 1997). The informational content of futures prices has important implications for the resource allocation decision of agents in the food chain (Sheldon, 1987).

Determining the nature of the relationship between futures price movements over time becomes critical in understanding and managing market price risk for a given commodity (Fortenbury and Zapata, 1993). There is a dearth of research in South Africa on the efficiency of agricultural commodity futures, probably because the Agricultural Marketing Division began trading futures only in mid-1996. Wiseman *et al.* (1999) tested the efficiency of the South African futures market for white maize using cointegration tests for the periods 1997 and 1998. Their results suggested that the white maize futures market was not efficient in 1997, but that market efficiency improved in 1998, which they argued could be evidence of a market learning process and a progression towards efficiency. Hence, it becomes interesting to determine whether there has been progression towards efficiency in South African futures markets for agricultural commodities. This study is an attempt to fill this gap and contribute to knowledge concerning this important issue.

1.2 Objectives of the study

The goal of this study is to test for efficiency in South African Futures markets for white and yellow maize over the period 1999-2003. Maize, especially white maize, is one of South Africa's most important crops, used as a staple food by millions of people in Southern Africa. Yellow maize is also the most important ingredient in feed rations for dairy, beef, poultry and egg production. Maize is produced in most parts of South Africa, but the major areas of commercial production are situated in the Free State, North West, and Mpumalanga Provinces.

Maize contributes approximately 42% to the gross value of field crops, and the average annual gross value of maize for the past five years amounts to 8,406 million Rand (National Department of Agriculture, 2004). Maize in South Africa is planted mainly between mid-October and mid-December. Its marketing season commences on May 1 and ends on April 30 the following year. Tests for efficiency should indicate whether or not nationally traded maize futures contracts are efficient for risk management and price discovery in white and yellow maize markets in South Africa. The specific objectives of the study are:

- (a) to determine whether daily futures price changes for white and yellow maize are predictable from past price information;
- (b) if they are predictable, then to determine whether trading decisions based on the direction of predicted futures price changes could lead to profitable trades; and
- (c) to determine whether these markets exhibit a trend towards increased efficiency over time.

1.3 Outline of the Paper

The remainder of the study proceeds as follows. Section 2 outlines the methodology of the study. The empirical results are presented in section 3. Section 4 summarizes the results of the study and draws relevant conclusions as well as providing a discussion of limitations and suggestion for future research.

2. METHODOLOGY

2.1 Market Efficiency

The Efficient Market Hypothesis (EMH) postulates that an asset price reflects all known information so that it is impossible to make speculative trading gains using publicly available information (Fama, 1970). It has been conventional to assume that market equilibrium can be expressed in terms of zero expected returns on assets such as futures contracts (Aulton, *et al.*, 1997). Given returns Y_{t+1} conditional on the information I_t reflected in current prices, then this implies,

$$E(Y_{t+1}|I_t) = 0 \quad (1)$$

A sequence of returns is then a “fair game” with respect to a sequence of information. Equation (1) could be described as a no arbitrage condition because it implies no unexploited profit opportunities for informed traders.

It is common in practice to distinguish between weak, semi-strong, and strong-form efficiency, with the distinction being based on the definition of information. Tests for weak-form efficiency rely on information embodied in past prices and tests for semi-strong efficiency typically use information on prices and other publicly available relevant market information (Hansen and Hodrick, 1980; Garcia, *et al.*, 1988). Tests for strong-form efficiency are based on all types of information, including private insider information. Weak-form efficiency is the most widely tested, and will be the basis of the analysis in this study.

Tests of futures market efficiency have traditionally been based on regressions of the observed spot price at time t on the futures price maturing at time t but observed i periods before contract maturity. The goal is to test how well futures price at $t-i$ predicts Spot (cash) price at t . There is lack of spot price data on most agricultural commodities in South Africa, even though there are hundreds of spot prices negotiated every day throughout the country (Gravelet-Blondin, 2004). This is because there is no

established price reporting system in the country. In the past SAFEX used to phone around and calculated the so-called “spot price” but have not done so for the past five years. Due to this lack of data, only futures prices are used to test market efficiency in this study. The rationale here is that if the futures market is efficient, then past futures price changes should have no significant information for predicting current futures price changes.

2.2 The Model

Tests for weak-form efficiency have been based on the so-called random-walk model, a special extension of the “fair game” process generating expected returns (Aulton, *et al.*, 1997). One might argue that the expected value of any futures price $F_t(T)$ quoted at t for delivery at T will be conditional on past realised prices $F_{t-1}(T)$, $F_{t-2}(T)$, ..., $F_{t-n}(T)$, where T represents the contract maturity month. Denote this conditional expectation:

$$E[F_t(T)|F_{t-n}(T), n > 0] = g[F_{t-1}(T), F_{t-2}(T), \dots] . \quad (2)$$

$F_t(T)$ will be a Martingale series if the function $g(\dots) = F_{t-1}(T)$,

$$E[F_t(T)|F_{t-n}(T), n > 0] = F_{t-1}(T) . \quad (3)$$

Equation (3) states that the expected value of a futures price, based on the information set $F_{t-n}(T)$ for $n > 0$ is equal to the last period price $F_{t-1}(T)$. Granger and Morgenstern (1970) indicate such a martingale will obey the model,

$$f_t(T) = \mu + f_{t-1}(T) + u_t \quad (4)$$

where $f_t(T)$ = logarithm of daily futures price observed at day t for maturity in period T , $f_{t-1}(T)$ = logarithm of daily futures price observed a day prior to t , but again with identical maturity date T , μ = a constant, and u_t = an error term.

It is common in the statistical analysis of the prices of financial securities, including futures contracts, to apply a logarithmic transformation to the data (Fortenbury and Zapata, 1993). Aulton, *et al.* (1997) give a number of reasons why it is desirable to use the logarithmic transformation of the future price series:

- (a) a logarithmic transformation will often succeed in stabilizing the variance of the observed series;
- (b) futures prices are positive valued and a lognormal futures price process cannot have a negative realization for futures prices;
- (c) a typical futures price series is non-stationary and requires a logarithmic transformation if it is to conform closely to an integrated process of order one, $I(1)$; and
- (d) by applying the logarithmic transformation to the two series we are more likely to find cointegration when it exists than by analysing the untransformed data series.

The efficiency test involves first testing the futures price series $f_t(T)$ for a unit root. If the $f_t(T)$ series is $I(1)$ then it is logical to impose differencing and test the joint hypothesis that $\delta_1 = \dots = \delta_k = 0$ in:

$$\Delta f_t(T) = \gamma + \sum_{i=1}^k \delta_i \Delta f_{t-i}(T) + \varepsilon_t \quad (5)$$

where $\Delta f_t(T)$ = daily changes in the logarithm of futures price observed at day t for maturity in period T , $\Delta f_{t-i}(T)$ = lagged daily changes in logarithm of futures price observed i periods prior to t , but again with identical maturity date T , γ and δ_s = coefficients, and ε_t = an error term.

If $f_t(T)$ is $I(1)$, then $\Delta f_t(T)$ and $\Delta f_{t-i}(T)$ are $I(0)$ (Pindyck and Rubinfeld, 1981;

Baillie, 1989). Additional lagged differenced terms are included in equation (5) to make sure that the error term is white noise, rather than autocorrelated. A process is said to be a white noise if its elements have zero mean, constant variance, and uncorrelated errors across time (Hamilton, 1994:P. 47). The standard distribution assumptions would then apply to the parameter estimators obtained by applying OLS to (5).

The notion of an unbiased or weak-form efficient futures market, under rational expectations and risk neutrality, is consistent with the null hypothesis that $\delta_1 = \dots = \delta_k = 0$, ε_t uncorrelated in equation (5). This ensures that past price information does not contain information that could be used to forecast future price changes. It embodies the notion that the market instantaneously and fully reflects available information in past prices and that agents are efficient information processors.

2.3 Data

Daily white and yellow maize settlement futures price for March, May, July, September and December contracts were collected directly from SAFEX. These are the five main hedging months on SAFEX. Settlement price is the last price for a futures contract on any trading day. Each contract month is introduced a year in advance and expires on the eighth last business day of that contract month. For example, the March 2003 contract expired on March 19, 2003. Data is collected over the period 1999–2003.

The Data set for each contract month is taken from the first business day of the month immediately after the introduction of that contract until the last business day of the month prior to the month of expiry. For example, for the March 1999 contract, data is taken from the first business day in April 1998 to the last business day of February 1999.

Data sets were pooled over the period of study according to each specific

contract month. For example, March contract data for each year were pooled over the period 1999-2003. But testing for weak-form market efficiency for the March contract (for example) using equation (5) requires first differencing of the data set. It was, therefore, necessary to compute first differences as well as a given number of lagged difference terms for each year's March contract prior to pooling of the data over the period of study to maintain data matching. This ensures that all price differences are computed using prices for the same contract; and lagged difference terms of a specific contract will always be associated with the same contract. The number of lagged difference terms computed is fifteen. This number was chosen to ensure that more than enough lagged difference terms would be available to implement the efficiency test with a very flexible lag structure.

The contract months of May, July, September, and December were pooled in a similar way. In summary, we have ten data sets in this study, five for each crop corresponding to five main hedging months on SAFEX.

3. EMPIRICAL RESULTS

3.1 Unit Root Tests

Many commodity prices, at least when sampled at high frequencies, appear to contain stochastic trends or unit roots (Ardeni, 1989; Baillie and Myers, 1991; Goodwin and Schroeder, 1991; Goodwin, 1992). The Dickey-Fuller (DF) and Phillips-Perron (PP) tests are common methods for testing unit roots, and are used here. Dickey-Fuller is

appropriate for a series generated by an autoregressive process of order one, AR(1). If, however, the series follows an AR(p) process where $p > 1$, the error term in the standard DF test will be autocorrelated. Autocorrelated errors will invalidate the use of the DF distribution, which is based on the assumption that the error term is white noise.

The augmented Dickey-Fuller (ADF) test includes additional lagged difference terms to account for this problem (Dickey and Fuller, 1981; Gujarati, 1995; Townsend, 1998). In order to test whether additional lagged difference terms are needed, the Ljung-Box Q-statistic is used and is formulated as follows:

$$Q = N(N + 2) \sum_{k=1}^m \left(\frac{\hat{r}_k^2}{N - k} \right) \quad (6)$$

where \hat{r}_k is the estimated autocorrelation coefficient, k is a given lag, m is the total number of lags and N is the sample size. Q is asymptotically Chi-squared (χ^2) distributed with m degrees of freedom. If the value of the Q -statistic exceeds the value in the $\chi^2(m)$ table, we can reject the null hypothesis of no significant autocorrelation at the appropriate significance level.

The logarithm of daily white and yellow maize futures prices were tested for a unit root using the augmented Dickey-Fuller test in the following model:

$$\Delta f_t(T) = \alpha + \rho f_{t-1}(T) + \sum_{i=1}^k \lambda_i \Delta f_{t-i}(T) + v_t \quad (7)$$

where α , ρ , λ_i = coefficients and v_t = an error term. The null hypothesis is:

$H_0: \rho = 0$ (Non-stationary or unit root)

$H_1: \rho < 0$ (Stationary or no unit root).

To test the significance of the estimated ρ coefficients, the augmented Dickey-Fuller unit root test computes the tau statistic (τ) for each estimated coefficient, in exactly the same way as a student's t statistic is calculated. But the estimated τ values

do not follow the same distribution as student's t. The statistical significance of the estimated τ values must be assessed by comparing them with critical values derived for the τ distribution tabulated in Dickey and Fuller (1981). If the estimated τ value is less than the critical value in absolute terms, then the null hypothesis of the existence of unit root cannot be rejected.

Phillips and Perron (1988) propose an alternative non-parametric method of controlling for autocorrelation in the error term when testing for a unit root. The PP method estimates the non-augmented DF test equation and modifies the t-ratio of the coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic (Eviews, 2002). The non-augmented Dickey-Fuller test equation is the same as that of the augmented Dickey-Fuller test, except that additional lagged difference terms are excluded. The PP test is based on the statistic:

$$Z_t = t_\rho \left(\frac{\gamma_0}{f_0} \right)^{1/2} - \frac{N(f_0 - \gamma_0)(\text{Se}(\hat{\rho}))}{2f_0^{1/2}S} \quad (8)$$

where ρ = coefficient estimator, t_ρ = the t ratio of ρ , $\text{Se}(\hat{\rho})$ = coefficient standard error, S = standard error of the test regression, N = sample size, γ_0 = error variance and f_0 = an estimator of the residual spectrum at frequency 0. However, it has been documented in the literature that the Phillips-Perron test suffers from severe size distortions when there are negative moving-average errors (Phillips and Perron, 1988; DeJong, *et al*, 1992). To evaluate the robustness of the results this study uses both ADF and PP tests for testing a unit root.

The result of Augmented Dickey-Fuller and Phillips-Perron tests for a unit root for the logarithm of each contract months' futures price series are presented in Table 1. If the two tests reinforce each then we can have more confidence in the results. The critical value for τ_c and Z_t at the 5% level of probability is -2.86 . Since the estimated τ

and Z_t values are less than 2.86 for all contracts months, the null hypothesis of the existence of unit root cannot be rejected. So, as expected, all logarithms of daily futures price series have unit roots. This is the characteristic property of many futures price series, especially when sampled at high frequencies, because futures prices are speculative prices and so should not be mean reverting. Given that all logarithms of daily futures price series are $I(1)$, it is then logical to impose differencing and test for predictability of futures price changes using equation (5).

3.2 Efficiency Tests

Having established the order of integration for the logarithm of the futures price series, it is now appropriate to impose differencing and test for the predictability of the changes in each series through the joint hypothesis that $\delta_1 = \dots = \delta_k = 0$ in equation (5). For each crop, equation (5) was estimated for each of the hedging months. The number of lagged difference terms included in equation (5) was chosen to ensure that there was no significant autocorrelation in the error term. The lag length was chosen for each equation separately by starting with the first lagged difference term and then testing for autocorrelation in the error term. If there is a significant autocorrelation in the error term, then the second lagged difference term is added. The process of including the additional lagged difference terms is continued until there was no significant autocorrelation in the error terms. The Q-statistic is calculated (see equation (6)) to test the null hypothesis that there is no significant autocorrelation in the error term. The Q test results indicate that there is no significant autocorrelation in the error terms at the 5% level of significance.

F-test statistics were used to test the joint null hypothesis of no predictability for both crops and are presented in Table 2. All of the estimated F statistics for white and

yellow maize for all contracts months are very high with very low p-values. Hence, the joint null hypothesis of market efficiency is rejected in all cases at almost any significance level. The implication is that past price information can be used to forecast future daily price changes. Hence, the results consistently suggest South African futures price changes for white and yellow maize are predictable.

The F-test used to test the joint null hypothesis of no predictability of futures price changes for both crops is based on the assumption that the residuals are normally distributed. If the normality assumption is violated the classical tests of significance such as F-tests will be inappropriate (Koutsoyiannis, 1977). In order to test whether the residuals are normally distributed, the Jarque-Bera (JB) statistics is used and is formulated as follows:

$$JB = N(S^2/6 + K^2/24) \quad (9)$$

where N is the sample size, S is the skewness and K is the kurtosis of the standardized residuals from equation (5). The JB statistic is asymptotically Chi-squared (χ^2) distributed with 2 degrees of freedom. Tests for normally distributed residuals results are also presented in Table 2. All estimated JB statistics are very high with low p-values. Hence, the null hypothesis of normally distributed residuals is rejected in all cases at almost any level of significance. The implication is that the efficiency test results obtained using the F-tests should be interpreted with caution.

3.3 Out of Sample Forecasting Evaluation

While the statistical significance of weak-form market inefficiency in the South African futures markets for white and yellow maize has been investigated using in sample testing, an important additional issue is to determine whether the prediction

model has strong out-of-sample predictive performance. In each case, one-third of the sample is withheld for out-of-sample forecasting (approximately one year in advance for all cases) because forecast errors are likely to be higher at longer forecast horizons (Irwin, Gerlow and Liu, 1994).

Efficiency tests for the model using just the first two-thirds of the data for each of the contract months, for white and yellow maize, are presented in Table 3. All of the estimated F statistics for white and yellow maize for all contract months remain very high with very low p-values. Again, the joint null hypothesis is rejected in all cases at almost any significance level. The implication is that past price information can be used to forecast future daily price changes, and so the previous results are robust to the new restricted sample period. Tests for normally distributed residuals results for the prediction model are also presented in Table 3. The null hypothesis of normally distributed residuals is again rejected in all cases at almost any level of significance except for the September and December contracts for white maize.

Out of sample forecasts are computed updating with new data as it becomes available but without model re-estimation. Computing forecasts with a once-off estimated model is more convenient than re-estimating the data every time another observation becomes available. To determine whether the prediction model has strong out-of-sample predictive performance that can be turned into profitable trades we need a trading rule. A trading rule in this case is defined as follows: If the prediction model predicts a negative futures price change then a contract will be sold, otherwise a contract will be bought. This implies that if the prediction model predicts a negative futures price change and the actual futures price change is, say negative R5/ton, then R5/ton will be recorded as a trading gain. And if the futures price change is positive R3/ton then R3/ton will be recorded as a trading loss. All trades are assumed to be held

for one day. Then the position is liquidated and a new position is taken out based on the updated one-day forecast.

The Client brokerage or trading costs for white and yellow maize futures at SAFEX for the forecasting period was 0.25 Rand/ton. A round trip brokerage fee of 0.50 Rand was then subtracted off every trade taken out. To take into account the time value of money trading gains and losses were discounted using 13% as opportunity cost of capital (OCC). The choice of this discount rate was informed by the fact that the average interest rate during the forecasting period was 13% per annum as reported by South African Reserve Bank (SARB). Discounted trading gains and losses are summed over the forecasting horizon for each of the contract months, for white and yellow maize, to determine whether trading decisions based on the direction of predicted futures price changes could lead to profitable trades. If the sum of trading gains and losses over the forecasting horizon for each of the contract months is positive, then trading decisions based on the direction of predicted futures price changes could lead to profitable trades. The implication will be that the prediction model has strong out-of-sample predictive performance and that this predictive performance can be turned into a profitable trading rule.

Table 4 presents out-of-sample predictive performance results for each of the contract months, for white and yellow maize. In all cases the sum of trading gains and losses over the forecasting horizon is negative. The implication of the results is that trading decisions based on the direction of the predicted futures price changes would not lead to profitable trades out of sample. Hence, the prediction model does not have a strong out of sample predictive performance and this is consistent weak-form efficiency in South African futures market for white and yellow maize.

3.4 Trend Towards Efficiency

New agricultural futures markets may be weak-form inefficient in their early stages of development and exhibit a process of adjustment towards efficiency over time. Statistical evidence of predictability of futures price changes and out-of-sample profitability of the model in this study have been established using pooled data from 1999 through 2003. The process of determining whether white and yellow maize futures markets in South Africa exhibit a trend towards improved efficiency over time involves first testing for the stability of parameter estimates across years. If there is parameter stability, then there would be no trend in market efficiency.

By pooling the data, it is assumed that the model parameter estimates are stable from one period to the other. An important issue now is to test the validity of this assumption. The stability of regression parameter estimates is tested using the standard likelihood ratio F-test, which uses the sum of squared errors with and without imposing the restrictions being tested. To test the assumption that the model parameter estimates are stable from one period to the other, we start with the null hypothesis that the regressions are identical and see whether or not we can reject this. Consider the regression models

$$\Delta f_t(T) = a_0 + \sum_{i=1}^k a_i \Delta f_{t-i}(T) + m_t \quad \text{for period 1} \quad (10)$$

$$\Delta f_t(T) = b_0 + \sum_{i=1}^k b_i \Delta f_{t-i}(T) + n_t \quad \text{for period 2} \quad (11)$$

where a_s and b_s are coefficients, and m_t and n_t are error terms.

We then estimate equation (10) and (11) using ordinary least squares separately.

There are no restrictions imposed on the parameters. The unrestricted sum of square residuals (ESS_{UR}) is obtained by adding the error sums of squares of the individual equations. The number of degrees of freedom is the sum of the numbers of degrees of freedom in each equation, that is $(N_1 - k) + (N_2 - k) = N_1 + N_2 - 2k$. N_1 and N_2 are sample sizes for period 1 and period 2 respectively, and k is the number of parameters in each equation. The joint null hypothesis is $a_0 = b_0$ and $a_i = b_i$. Assuming that the null hypothesis is true, then equation (10) and (11) reduce to

$$\Delta f_t(T) = a_0 + \sum_{i=1}^k a_i \Delta f_{t-i}(T) + m_t \quad \text{for both periods} \quad (12)$$

We then estimate equation (12) using ordinary least squares. Since there are restrictions imposed on the parameters, error sum of squares obtained here is the restricted error sum of squares (ESS_R). The appropriate F statistic with k restrictions and $N_1 + N_2 - 2k$ degrees of freedom is

$$F_{(k, N_1 + N_2 - 2k)} = \frac{(ESS_R - ESS_{UR})/k}{ESS_{UR}/(N_1 + N_2 - 2k)} \quad (13)$$

If the value of the F statistic exceeds the theoretical value of F at the given level of significance and degrees of freedom, then we reject the null hypothesis of stability of regression parameter estimates.

Pooling of the data will be appropriate if the null hypothesis is true, otherwise the results obtained earlier will need to be re-evaluated on a contract by contract basis. F statistics obtained from testing the joint null hypothesis of the stability of regression parameter estimates across years for white and yellow maize are presented in Tables 5

and 6 respectively. In the case of white maize the joint null hypothesis is accepted for July, September and December contracts but rejected for March and May contracts. In the case of yellow maize the joint null hypothesis is rejected only for May contract. The results indicate that there is parameter stability for the period 1999-2002 for white maize March and May contracts, but there is parameter instability for the period 2002-2003. In the case of the yellow maize May contract there is also parameter stability for the period 1999-2002, but parameter instability for the period 2002-2003.

The implication of these results is that there is no trend in market efficiency over time for white maize July, September and December contracts, and yellow maize March, July, September and December contracts (because there is no parameter instability). However, we also found that there is some evidence of parameter instability over time for white maize March and May contracts and yellow maize May contract. So it is natural to ask whether these contracts have become more efficient in the latter part of the sample.

The logarithm of the March and May futures price series for each crop is examined for a unit root using ADF and PP tests. The results of both ADF and the PP unit root tests for both white and yellow maize are presented in Table 7. The critical values τ_c and Z_t at the 1% and 5% level of probabilities are -3.43 and -2.86 respectively.

As expected the results suggest the existence of unit root in each of the logged futures price series, except for the white maize 2003 March contract. It is then logical to impose differencing and test for the predictability of futures price changes using equation (5). Efficiency tests are conducted for March and May hedging months for white maize and May for yellow maize to determine whether there is a trend towards increased market efficiency over time.

Tests for trend towards increased market efficiency results for white maize

(March and May contracts) and yellow maize (May contract) are presented in Table 8. Efficiency tests for white maize indicate statistical evidence of predictability of futures price changes for the periods March 1999-2002, March 2003, May 1999-2002 and May 2003. The results suggest that there is no trend towards reduced predictability of price changes over time for the white maize futures market in South Africa. The results for yellow maize also indicate statistical evidence of predictability of futures price changes for the periods May 1999-2002 and May 2003. The implication of the results is that there is no evidence of a trend towards reduced predictability of price changes over time for the yellow maize futures market in South Africa.

4. SUMMARY AND CONCLUSIONS

4.1 Summary of the Study

Agricultural marketing policy in South Africa has moved from a highly regulated marketing environment to an open and more transparent system. The demise of the Maize Board in 1996 has created a need for South African maize producers to give more attention to managing price risk. Commodity futures markets should be efficient to play the most effective role in price risk management. The Agricultural Markets Division (AMD) was established in January 1995 as a division of the South African Futures Exchange. White and yellow maize were listed in 1996. Given that there is a dearth of research in South Africa on the performance of agricultural commodity futures, this study has examined the predictability of daily futures price changes for white and yellow maize for five main hedging months for the period 1999-2003.

The results suggest that daily futures price changes for both white and yellow maize are partially predictable from past price information. The implication is that past price

information does contain additional information that could be used to forecast the future price, once the current futures price has been included. But when taking into account brokerage costs and the time value of money out-of sample predictive performance of the model indicates that trading decisions based on the direction of predicted futures price changes would not lead to profitable trades for white and yellow maize. This is consistent with market efficiency in South African futures markets for white and yellow maize. The results further suggest that there is no any indication of change in market efficiency over time for white and yellow maize futures markets in South Africa.

4.2 Limitations and Suggestions for Future Research

The most serious limitation of this study is unavailability of spot price data on white and yellow maize. There is a need in South Africa for the establishment of a price reporting agency. This agency should be responsible for spot price data collection for agricultural commodities in various local markets in the country. This will facilitate efficiency tests for agricultural commodities futures markets with respect to various local markets in the country, as well as provide a range of other benefits.

It is important to note that the assumption of normality in residuals was violated in most cases in this study. Hence, the efficiency tests results obtained should be interpreted with caution. It must also be noted that the trading rule evaluated for out of sample predictive performance of the model is arbitrary, and the results are only for one year (and without parameter updating). Extending to longer forecasting horizon might change the results of no trading gains. Another limitation of this study is the assumption that market participants are risk neutral in testing the weak-form efficiency hypothesis. Given the results from this study, one may try alternative empirical test of market efficiency that allows for a non-zero risk premium.

With the introduction of soybean futures contracts in 2002, research opportunities exist for testing the efficiency of other agricultural commodities traded on SAFEX. Agricultural commodities currently traded on SAFEX, with the exception of white and yellow maize, are wheat, sunflower seed and soybean. The South African currency is highly volatile, especially in the past five years. Hence, another area of research might be to determine the impact of exchange rate volatility on the performance of futures markets for agricultural commodities in South Africa.

APPENDIX

Table 1: ADF and PP unit root test statistics for white and yellow maize logarithmic futures prices

Contract	White maize τ statistic	Yellow maize τ statistic	White maize Z_t statistic	Yellow maize Z_t statistic
March	-0.99	-1.25	-0.98	-1.30
May	-1.09	-1.05	-1.21	-1.01
July	-1.00	-1.05	-0.98	-1.03
September	-1.14	-1.24	-1.12	-1.22
December	-1.28	-1.38	-1.26	-1.36

Notes: (1) Critical value: $\tau_c = -2.86$ at 5% level of probability

(2) Critical value: $Z_t = -2.86$ at 5% level of probability

Table 2: Efficiency tests

	White Maize		Yellow Maize	
Contract	F statistic	Q statistic	F statistic	Q statistic
March	$F_{(1, 1027)} = 118.23$ (0.000) JB = 22.38 (0.000)	Q (1) = 0.21 Q (3) = 2.92 Q (6) = 8.30 Q (12) = 18.96	$F_{(1, 985)} = 59.78$ (0.000) JB = 46.54 (0.000)	Q (1) = 0.20 Q (3) = 5.04 Q (6) = 6.73 Q (12) = 18.19
May	$F_{(1, 1022)} = 93.27$ (0.000) JB = 25.85 (0.000)	Q (1) = 0.21 Q (3) = 2.89 Q (6) = 5.47 Q (12) = 10.23	$F_{(2, 1012)} = 27.16$ (0.000) JB = 60.30 (0.000)	Q (1) = 0.02 Q (3) = 4.77 Q (6) = 6.04 Q (12) = 13.11
July	$F_{(4, 1021)} = 17.59$ (0.000) JB = 15.84 (0.000)	Q (1) = 0.00 Q (3) = 0.01 Q (6) = 3.31 Q (12) = 20.28	$F_{(8, 1015)} = 10.39$ (0.000) JB = 24.85 (0.000)	Q (1) = 0.13 Q (3) = 0.11 Q (6) = 0.20 Q (12) = 13.95
September	$F_{(8, 993)} = 13.95$ (0.000) JB = 7.67 (0.022)	Q (1) = 0.08 Q (3) = 0.09 Q (6) = 0.12 Q (12) = 16.71	$F_{(2, 998)} = 16.73$ (0.000) JB = 2342.01 (0.000)	Q (1) = 0.02 Q (3) = 1.44 Q (6) = 2.91 Q (12) = 17.96

December	$F_{(1, 1014)} = 11.33$	$Q(1) = 0.04$	$F_{(2, 1012)} = 12.83$	$Q(1) = 0.05$
	(0.001)	$Q(3) = 3.12$	(0.000)	$Q(3) = 1.09$
	$JB = 54.48$	$Q(6) = 6.18$	$JB = 59.08$	$Q(6) = 2.81$
	(0.000)	$Q(12) = 16.94$	(0.000)	$Q(12) = 7.46$

Notes: (1) The estimated model for each contract month is $\Delta f_t(T) = \gamma + \sum_{i=1}^k \delta_i \Delta f_{t-i}(T) + \varepsilon_t$ and the

joint null hypothesis being tested is $\delta_1 = \dots = \delta_k = 0$

(2) Figures in the parenthesis below F and Jarque-Bera (JB) statistics are P values

(3) Q-statistic critical Values: $\chi^2(1) = 3.84$, $\chi^2(3) = 7.81$, $\chi^2(6) = 12.59$ and

$\chi^2(12) = 21.00$ at the 5% level of probability

Table 3: Efficiency tests for out-of-sample forecasting

	White Maize		Yellow Maize	
Contract	F statistic	Q statistic	F statistic	Q statistic
March	$F_{(1, 684)} = 48.21$	$Q(1) = 0.15$	$F_{(1, 656)} = 12.66$	$Q(1) = 0.00$
	(0.000)	$Q(3) = 3.63$	(0.000)	$Q(3) = 2.46$
	$JB = 21.24$	$Q(6) = 5.50$	$JB = 58.42$	$Q(6) = 4.34$
	(0.000)	$Q(12) = 14.93$	(0.000)	$Q(12) = 7.61$
May	$F_{(1, 681)} = 33.78$	$Q(1) = 0.15$	$F_{(2, 673)} = 11.71$	$Q(1) = 0.02$
	(0.000)	$Q(3) = 3.50$	(0.000)	$Q(3) = 3.13$
	$JB = 29.97$	$Q(6) = 4.12$	$JB = 99.66$	$Q(6) = 5.82$
	(0.000)	$Q(12) = 5.65$	(0.000)	$Q(12) = 11.81$
July	$F_{(2, 681)} = 20.87$	$Q(1) = 0.00$	$F_{(2, 680)} = 21.48$	$Q(1) = 0.02$
	(0.000)	$Q(3) = 1.36$	(0.000)	$Q(3) = 4.32$
	$JB = 12.58$	$Q(6) = 2.41$	$JB = 30.42$	$Q(6) = 5.49$
	(0.002)	$Q(12) = 9.80$	(0.000)	$Q(12) = 9.06$
September	$F_{(2, 665)} = 41.38$	$Q(1) = 0.00$	$F_{(1, 665)} = 36.81$	$Q(1) = 0.22$
	(0.000)	$Q(3) = 0.48$	(0.000)	$Q(3) = 4.46$
	$JB = 3.57$	$Q(6) = 3.32$	$JB = 18.93$	$Q(6) = 6.57$
	(0.168)	$Q(12) = 16.21$	(0.000)	$Q(12) = 12.89$

December	$F_{(2, 673)} = 22.58$ (0.000) JB = 2.37 (0.306)	Q (1) = 0.00 Q (3) = 0.14 Q (6) = 3.90 Q (12) = 8.72	$F_{(2, 673)} = 23.45$ (0.000) 42.58 (0.000)	Q (1) = 0.01 Q (3) = 1.35 Q (6) = 2.60 Q (12) = 7.22
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Notes: (1) The estimated model for each contract month is $\Delta f_t(T) = \gamma + \sum_{i=1}^k \delta_i \Delta f_{t-i}(T) + \varepsilon_t$ and the

joint null hypothesis being tested is $\delta_1 = \dots = \delta_k = 0$

(2) Figures in the parenthesis below F and Jarque-Bera (JB) statistics are P values

(3) Q-statistic critical Values: $\chi^2(1) = 3.84$, $\chi^2(3) = 7.81$, $\chi^2(6) = 12.59$ and

$\chi^2(12) = 21.00$ at the 5% level of probability

Table 4: Out of sample predictive performance

Contract	White Maize Trading Gain/Loss (Rand/ton)	Yellow Maize Trading Gain/Loss (Rand/ton)
March	-90.05 (69.74)	-89.54 (63.32)
May	-89.82 (69.00)	-92.10 (65.43)
July	-102.20 (55.51)	-100.92 (56.46)
September	-105.83 (47.41)	-117.13 (34.64)
December	-145.62 (4.95)	-136.58 (15.17)

Note: Figures in the parenthesis are trading gains/losses without client brokerage costs and discounting

Table 5: Tests of the stability of regression parameters across years 1999-2003 for white maize

Contract	1999 & 2000	2000 & 2001	2001 & 2002	2002 & 2003
March	$F_{(2, 402)} = 2.71$	$F_{(2, 402)} = 1.20$	$F_{(2, 406)} = 2.15$	$F_{(2, 410)} = 4.71^*$
May	$F_{(2, 407)} = 2.54$	$F_{(2, 397)} = 2.31$	$F_{(2, 400)} = 1.49$	$F_{(2, 406)} = 5.02^*$
July	$F_{(5, 399)} = 2.81$	$F_{(5, 398)} = 1.64$	$F_{(5, 399)} = 0.77$	$F_{(5, 398)} = 1.99$
September	$F_{(9, 388)} = 1.60$	$F_{(9, 387)} = 1.65$	$F_{(9, 395)} = 1.12$	$F_{(9, 368)} = 1.70$
December	$F_{(2, 404)} = 0.34$	$F_{(2, 405)} = 1.19$	$F_{(2, 412)} = 0.74$	$F_{(2, 394)} = 2.08$

Notes: (1) The estimated models for each column are $\Delta f_t(T) = a_0 + \sum_{i=1}^k a_i \Delta f_{t-i}(T) + m_t$ for period

1 and $\Delta f_t(T) = b_0 + \sum_{i=1}^k b_i \Delta f_{t-i}(T) + n_t$ period 2, and the joint null hypothesis being tested is

$a_0 = b_0$ and $a_i = b_i$.

(2) * denotes significant at the 1% level of probability.

Table 6: Tests of the stability of regression parameters across years 1999-2003 for yellow maize

Contract	1999 & 2000	2000 & 2001	2001 & 2002	2002 & 2003
March	$F_{(2, 394)} = 0.74$	$F_{(2, 363)} = 0.87$	$F_{(2, 372)} = 2.05$	$F_{(2, 410)} = 3.33$
May	$F_{(3, 397)} = 1.55$	$F_{(3, 403)} = 0.04$	$F_{(3, 403)} = 2.41$	$F_{(3, 396)} = 3.75^*$
July	$F_{(9, 395)} = 1.23$	$F_{(9, 390)} = 1.29$	$F_{(9, 385)} = 1.32$	$F_{(9, 384)} = 1.80$
September	$F_{(3, 397)} = 1.19$	$F_{(3, 396)} = 2.60$	$F_{(3, 412)} = 0.73$	$F_{(3, 392)} = 3.28$
December	$F_{(3, 398)} = 1.61$	$F_{(3, 399)} = 0.73$	$F_{(3, 410)} = 2.22$	$F_{(3, 393)} = 1.55$

Notes: (1) The estimated models for each column are $\Delta f_t(T) = a_0 + \sum_{i=1}^k a_i \Delta f_{t-i}(T) + m_t$ for period

1 and $\Delta f_t(T) = b_0 + \sum_{i=1}^k b_i \Delta f_{t-i}(T) + n_t$ for period 2, and the joint null hypothesis being tested is $a_0 = b_0$ and $a_i = b_i$.

(2) * denotes significant at the 1% level of probability.

Table 7: ADF and PP unit root test statistics for white and yellow maize logarithmic futures price series (1999-2003)

	White Maize				Yellow Maize			
	1999-2002		2003		1999-2002		2003	
Contract	τ statistic	Z_t statistic	τ statistic	Z_t statistic	τ statistic	Z_t statistic	τ statistic	Z_t statistic
March	0.75	0.68	4.16	5.36	-	-	-	-
May	0.30	0.16	1.80	2.17	-0.01	0.00	2.47	2.87

Notes: (1) Critical values: $\tau_c = -3.43$ and -2.86 at 1% and 5% level of probability respectively

(2) Critical value: $Z_t = -3.43$ and -2.86 at 1% and 5% level of probability respectively

Table 8: Trends towards increased market efficiency for white and yellow maize futures markets (1999-2003)

	White Maize				Yellow Maize			
	1999-2002		2003		1999-2002		2003	
Contract	F statistic	Q statistic	F statistic	Q statistic	F statistic	Q statistic	F statistic	Q statistic
March	$F_{(1, 818)} = 84.63$ (0.000) JB = 5.96 (0.051)	Q (1) = 0.28 Q (3) = 4.15 Q (6) = 9.74 Q (12) = 15.09	$F_{(4, 209)} = 7.81$ (0.000) JB = 15.91 (0.000)	Q (1) = 0.05 Q (3) = 0.19 Q (6) = 7.94 Q (12) = 19.77	-	-	-	-
May	$F_{(1, 817)} = 75.66$ (0.000) JB = 9.63 (0.008)	Q (1) = 0.33 Q (3) = 3.56 Q (6) = 5.13 Q (12) = 10.01	$F_{(2, 207)} = 11.00$ (0.000) JB = 9.23 (0.010)	Q (1) = 0.00 Q (3) = 0.05 Q (6) = 9.25 Q (12) = 10.60	$F_{(2, 815)} = 23.89$ (0.000) JB = 38.78 (0.000)	Q (1) = 0.00 Q (3) = 1.18 Q (6) = 3.34 Q (12) = 11.84	$F_{(4, 208)} = 5.48$ (0.000) JB = 11.28 (0.004)	Q (1) = 0.14 Q (3) = 0.21 Q (6) = 2.31 Q (12) = 9.96

Notes: (1) The estimated model for each contract month is $\Delta f_t(T) = \gamma + \sum_{i=1}^k \delta_i \Delta f_{t-i}(T) + \varepsilon_t$ and the joint null hypothesis being tested is $\delta_1 = \dots = \delta_k = 0$

(2) Figures in the parenthesis below F and Jarque-Bera (JB) statistics are P values

(3) Q-statistic critical Values: $\chi^2(1) = 3.84$, $\chi^2(3) = 7.81$, $\chi^2(6) = 12.59$ and

$\chi^2(12) = 21.00$ at the 5% level of probability

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