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PRICE DISCOVERY IN THE SOUTH AFRICAN WHITE MAIZE FUTURES MARKET

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Barry Strydom[1] and Kerry McCullough[2]

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Abstract

This study examines the price discovery process in the South African futures and spot markets for white maize. Engle-Granger and Johansen tests of cointegration are performed after which an Error Correction Model, Vector Error Correction Model and Impulse Response functions are formulated representing the long-run relationship between spot and futures prices for white maize. It is found that spot and futures prices for white maize are cointegrated and that price discovery occurs in the spot market. The paper concludes by discussing the policy implications of this finding.

Key words: price discovery, spot market, futures market, cointegration.

JEL Classification: C58, D53, G12, G13.

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1. INTRODUCTION

Financial derivatives tied to commodity markets, including futures, forwards, options and swaps, have been increasingly traded since their inception in response to an growing need to manage price volatility and the risks associated with unanticipated price changes (Mahalik, Acharya and Babu, 2009: 1). Futures contracts are a common instrument employed in this regard as futures markets and their associated instruments provide a number of important economic functions (Srinivasan and Bhat, 2009: 28-29). These functions include that they act as a tool for price risk management (Hasbrouck, 1995: 1175), they contribute to price discovery and portfolio diversification, and are used for hedging practices (Srinivasan and Bhat, 2009: 29). They are also used as a tool for speculation and liquidity, as a means to store a variety of commodities (Phukubje and Maholwa, 2006: 199).

Mahalik *et al*. (2009: 3) highlight that futures markets' ability to provide for price discovery and the transfer of risk are two of the most significant contributions these markets have made to the coordination of economic activity. More specifically, Hasbrouck (1995: 1175) identifies the key function of financial markets as that of price discovery, a view supported by Pavabutr and Chaihetphon, 2010: 457 who suggest that the efficiency of the price discovery process impacts directly on the efficacy of the hedging function and yet Andersen, Bollerslev, Diebold and Vega, (2007: 252) argue that the process of price discovery remains poorly understood. The question of price discovery is of particular interest in the context of futures markets where two prices, the futures price and the spot or cash price, are driven by the same underlying fundamentals. The prediction hypothesis described by Yang, Bessler and Leatham (2001: 281) suggests that futures markets provide the primary point for price discovery although they observe that the argument for the price discovery function of futures is far stronger for storable commodities (Yang*et al*., 2001: 282).

This paper tests the hypothesis that price discovery occurs in the futures market by examining the spot and futures price data for white maize contracts traded on the South African Futures Exchange (SAFEX). The white maize contract is used as it represents a storable commodity and is the largest and most important commodity traded on SAFEX by volume (SAFEX, 2008). Following Hasbrouck (1995) we employ the Engel-Granger and Johansen cointegration technique to model the long-term relationship between spot and futures prices. Employing both an Error Correction Model (ECM) and Vector Error Correction Model (VECM) we test the reactions of both spot prices and futures prices to short-run shocks and find evidence that in the market for white maize spot prices lead futures prices. This paper contributes to our knowledge of the South African futures market as no study of the agricultural commodity futures market to date has examined the issue of price discovery or has employed an ECM or VECM to examine the relationship between spot and futures prices. Our results have important implications for market participants who use futures prices as predictors of expected future spot prices.

2. PRICE DISCOVERY

A general description of price-discovery is simply the impounding of new information into a security's price (Choy and Zhang, 2010: 37; Hasbrouck, 1995: 1175). When two markets are linked, however as is the case between spot and futures markets on the same underlying commodity, then two prices exist which are driven by the same underlying fundamental information and the question then arises as to whether price changes in one market lead changes in the other. Yang *et al*. (2001: 280) and Kavussanos and Nomikos (2003: 203), for example, define price discovery in futures markets as the use of futures prices to determine

expectations of future cash market prices. The limitation of this approach is it *a priori* assumes that futures prices must lead spot prices when in reality the evidence regarding the informational role between spot and futures prices is mixed (Yang*et al*., 2001: 282). In the context of price discovery between markets a more appropriate definition might therefore be"…the adjustments to prices due to cross-market information flows" (Eun and Sabherwal, 2003: 551).

Pavabutr and Chaihetphon (2010: 455) state that in general, futures markets respond faster to new information than spot markets. The most common explanations provided for futures prices to lead spot prices is that transaction costs are lower in the futures market (Andersen *et al*., 2007: 254) and futures markets offer greater leverage making it easier for speculators to profitably exploit new information in the futures market (Pavabutr and Chaihetphon, 2010: 457). Kavussanos and Nomikos (2003: 225) make the point that limitations in short-selling typically exist in the spot market which makes the futures market more appealing for traders seeking to exploit new information. Wahab and Lashgari (1993: 712) thus conclude that leverage, transaction costs and possibility of short-selling make trading in stock index futures more attractive than trading in the market for underlying stocks. Stoll and Whaley (1990: 445) go further to argue that such trading moves futures prices first after which index arbitrage 'pulls' the stock prices to respond to deviations from the cost-of-carry relationship.

A significant number of empirical studies provide support for the assumption that futures prices lead spot prices (Hasbrouck, 2003: 2376). Stoll and Whaley (1990: 466) in comparing stock index and stock index futures markets found that although the effect was not completely unidirectional, futures prices led spot prices and that this phenomenon had grown stronger as futures markets had matured. Similarly, Pizzi, Economopoulos and O'Neill (1998) found that both three- and six-month stock index futures prices led the spot market by at least 20 minutes but some causation from the spot market to the futures market was also evident. Hasbrouck (2003: 2377) looked at U.S. equity index markets including Exchange Traded Funds (ETFs) and found that electronically traded futures contracts dominated price discovery with the exception of the S&P 400 index where the ETF provided substantial price discovery. Employing a GARCH approach on the HangSeng index market, So and Tse (2004: 904) found that the volatilities of the index and futures markets spilled over to each other but that the effect was stronger from the futures market to the index indicating that the futures market dominated in the price discovery process. Choy and Zhang (2010: 47) examining the Hong Kong market also found that stock index futures play a dominant role in price discovery although the relative importance of mini futures contracts had increased over time. They further concluded that since both regular and mini contracts traded on the same trading platform the leading role of regular futures contracts in price discovery was due to their relatively lower transaction costs (Choy and Zhang, 2010: 56).

Yang *et al.* (2001) used a standard cointegration technique to study price discovery in commodity futures markets across several commodities including both storable and nonstorable commodities. They found that nonstorability does not affect the existence of cointegration and as a result concluded that futures prices are useful in predicting future cash prices (Yang *et al*., 2001: 297). Kavussanos and Nomikos (2003: 204) also focussed on the issue of storability and investigated the price discovery process for a nonstorable underlying asset in the freight futures market. They found a long-term relationship between spot and futures prices with evidence that price discovery occurs mainly in the futures market. Tse, Xiang and Fung (2006: 1133) studied price discovery on several foreign exchange futures markets and found that the GLOBEX futures market dominates price discovery for the euro but that spot trades for the yen dominate both electronic and floor-traded futures. Pavabutr

and Chaihetphon (2010: 455) employed VECMs for the Indian gold futures market to show that both standard and mini futures contracts lead the spot price.

Whilst it is clear that many studies have found evidence to support the hypothesis that futures prices serve as the primary source of price discovery it is also evident that many of the studies reported mixed results with some evidence that price discovery also flows from spot to futures markets albeit to a lesser extent. Whilst less common, some studies, however, have also found results indicating that spot prices can lead futures prices, Wahab and Lashgaris (1993: 731), for example, found evidence of a feedback relationship between stock index and stock index futures markets but concluded that their results confirmed that the lead from spot to futures was more pronounced. Similarly, Leng (2002: 12) found for one of the sub-periods in their study that the spot price led the futures price. Chan, Chan and Korolyi (1991: 682) concluded that new market information disseminates in both markets and that both spot and futures markets perform important price discovery roles.

In South African studies of price discovery, Ferret and Page (1998: 86) found that "stock index futures price changes lead those of the underlying spot index by up to three days in reflecting new information." Price discovery studies employing a VECM include those by Fedderke and Joao (2001), Leng (2002) and Floros (2009). Fedderke and Joao (2001: 10-11) used the VECM to show that price discovery takes place in the futures market for Stock Index Futures, and in most cases it was found that emerging market crises did not affect these price discovery findings. Leng (2002: 11-14) used the VECM to comment on causality in the South African share index futures market through the examination of the various error correction terms. The spot price dependent and future price dependent series were shown separately. Leng (2002: 14-15) found that the point of price discovery changed during the time period examined, one particular period of crisis showed that the spot lead the futures markets, while the majority of the time it was showed that the futures lead the spot market. Floros (2009: 150-151) used both the VECM and an ECM-TGARCH model to describe short-run deviations from the long-run equilibrium, and further employed an impulse response function to examine the price discovery role of the Stock Index Futures Market in South Africa. Floros (2009: 158) found that there was evidence of bi-directional causality within this market.

Several suggestions have been presented in the literature to explain a finding that the spot price leads the futures price. Ferret and Page (1998: 73) suggested that changes in the spot market form part of the information futures traders use to make decisions, and so, changes in the spot price may influence futures traders and in turn affect futures prices. Srinivasan and Bhat (2009: 29) also speculated that it may indicate that speculative traders, who are seeking profit making scenarios, will prefer to use a commodities futures market due to flexibility in terms of investment strategies. Their movement away from the spot market would then result in the spot market having less noise trading and reduced informational asymmetries which would in turn improve market depth, market efficiency and liquidity resulting in the spot market being better positioned to react to news events first.

Leng (2002: 2) suggests that futures markets in developing markets may have less informational efficiency compared to more developed markets and that this may result in the price discovery process running from the spot to futures. That is, financial derivatives will be viewed as an 'unknown' in developing markets and will thus be used less frequently resulting in a less liquid, and consequently less efficient, market (Leng, 2002: 2).

3   DATA AND METHODOLOGY

3.1 Data

White maize futures have been traded in South Africa since 1996. The data used in this study consists of price data on white maize futures contracts traded on the SAFEX. These historical spot and futures prices were obtained directly from the SAFEX website (SAFEX, 2008). The white maize futures contract in South Africa has expiry dates in March, May, July, September and December which translates to either a two or three month interval between contracts.Starting with the May 1996 contract and ending with the May 2009 contract, each white maize futures contract had two data points collected. The first was each contracts maturity or spot price, and the second was the futures price quoted on each contract at 8 weeks prior to the contract's expiry. This was done in line with Beck's (1994: 251) recommendation of choosing a futures price that is less than or equal to the time interval being examined in order to reduce the possibility of introducing correlations into the sample as a result of overlapping data readings. In this manner a data set of 66 observations was compiled, with each observation consisting of a spot price and a futures price on a single contract. It is noted that the SAFEX quoted spot price is in fact derived from the SAFEX near-futures contract on white maize (post 1999) while prior to 1999 this spot price represents an aggregation of available silo spot prices around South Africa at the time. Such a measure is not available post 1999 and as such this SAFEX quoted spot price is the best possible spot price estimate of South Africa white maize cash prices available. Although the physical cash price would be preferable, it is not uncommon in the literature for a near-futures contract to be used as a spot price proxy[3]. Once the full spot price and futures price series were compiled, a natural log transformation was applied to the data in line with previous studies of this nature including Aulton *et al*. (1997); Fedderke and Joao (2001); Leng (2002); and Zapata *et al*. (2005).

3.2 Methodology

As the focus of this paper is to examine the price discovery process of the white maize futures market of South Africa, the methodology of this paper focuses on describing the procedures directly related to such. Price discovery should be present in a market which has a long-run equilibrium relationship, that is, in such a market the spot price, the futures price or a combination thereof will adjust to news events in order to maintain equilibrium. Such a long-run relationship is tested for by examining the spot and futures price series for cointegration. Cointegration requires that both series be non-stationary in level form and integrated of the same order and so both series must be tested for the presence of a unit-root. This is typically done by means of an Augmented Dickey-Fuller test or a Phillips-Perron test, both of which were employed in this study.

The relationship between spot and futures prices is described by a cointegrating relationship. Once it has been established that the data series are nonstationary the next step is to test if there is a cointegrating relationship between the two series. That is, it is only after the stationarity of the data is established, and it is found that both the series in question are nonstationarity processes, that the next step is to test for cointegration. This relationship is described by equation 1 below.

$S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$

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[3] See for example Auret and Schmidt (2008: 108), He and Holt (2004: 8), Geyser and Cutts (2007: 297), Wiseman, *et al.* (1999: 326) and Jordaan *et al*. (2007: 309).

Two approaches exist through which the presence of cointegration may be established namely the EG and Johansen's methods. Both approaches were used, not only corroborate a finding of cointegration, but also to generate the output required to formulate both an Error Correction Model (ECM) and Vector Error Correction Model (VECM).

3.2.1 Engle-Granger ECM

Brooks (2008: 338-339) discuss the ECM within the context of a two variable model where *yt* and *xt* are both I(1). This model can be represented in first difference form by the following equation:

$$\Delta y_t = \beta \Delta x_t + \varepsilon_t$$

The residuals obtained from the cointegrating equation will contain the short-run disturbances, that is, the error term captures the deviations from the long-run equilibrium. The ECM brings these extracted residuals into the model as an explanatory variable. Wang and Ke (2002: 8-10) show that a common method of detailing this relationship is to show that there exists a linear combination of S_t and F_{t-1} that is stationary with residuals that have a mean of zero, and this combination can be shown by the following equation:

$$\hat{e}_t = S_t - \alpha - \beta_{t-1}$$

Ferret and Page (1998: 76) point out that within an ECM there must be Granger causality in at least one direction. The lead-lag structure of a given relationship may be examined in the ECM by observation of the statistical significance and magnitude of both the error correction terms and the coefficients associated with lagged differenced forms of the dependent and independent variables.

In order for this to be observed, error correction models are formed in both directions, one with the spot price as the dependent variable, and the other with the futures price as the dependent variable. Ferret and Page (1998: 76) have the following to say on the interpretation of these relationships: "If the change in x_t is dependent, not only on past changes of itself, but also the equilibrium error and past changes of y_t then it can be said that y_t leads x_t." The ECM for a study such as this, which has two cointegrated log price series is captured in general form by the following equations (adapted from Alexander (1999: 5), Mahalik *et al.*, (2009:11)):

$$\Delta S_t = \alpha_1 + \alpha_S \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{11}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{12}(i)\Delta F_{t-1} + \varepsilon_{St}$$

$$\Delta F_t = \alpha_2 + \alpha_F \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{21}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{22}(i)\Delta F_{t-1} + \varepsilon_{Ft}$$

The first item to be considered when examining the ECM is the sign and significance of the coefficient estimates (Brooks, 2008: 345). The speed of adjustment coefficients α_S and α_F can be interpreted as the rate of change in moving towards equilibrium, they show how much of last period's disequilibrium has been corrected for. α_S and α_F should be statistically significantly different from zero in the presence of cointegration as this indicates that deviations from the long run equilibrium position are corrected for in the short run (Enders,

2004: 338). Alternatively, if α_S and α_F are both found to be statistically insignificant then it can be concluded that the spot price does not Granger cause the futures price. If only α_S is found to be statistically insignificant, a change in the current period's spot price does not respond to deviations from the equilibrium that occurred in the previous period.   If only α_F is found to be statistically insignificant, a change in the current period's futures price does not respond to deviations from the equilibrium that occurred in the previous period (Mahalik *et al.,* 2009: 11). Further, if the speed of adjustment coefficient is shown to be zero this indicates that the variable is weakly exogenous and thus does not respond to any variations from the long-run equilibrium (Enders, 2004: 368).

Alexander (1999: 5) also shows that in these equations above representing the ECM it should be found that, between α_S and α_F, there should be one positive value and one negative value, as this is the process through which disequilibrium is corrected for. The absolute values of these coefficients should not be too large, as they should indicate that there would be a convergence with the long run equilibrium (Enders, 2004: 338). A finding greater than 1 would indicate that more than 100% of the difference was adjusted suggesting that a shock causes the variables to move apart invalidating a finding of cointegration which would suggest an incorrectly identified model.

Being able to determine in which market the point of price discovery lies may be considered the pivotal finding in this model and determining this relies on being able to establish where new information is first reflected – the changed futures price or the changed spot price (Mahalik *et al*., 2009: 4).

3.2.2 Johansen's VECM

It was necessary to formulate the VECM in order to ensure that the EG ECM results were consistent, and that they had not been distorted by sample size. The Johansen's method of detecting cointegration results in a set of matrices that contain the information that allows a VECM to be examined.

Brooks (2008: 352) shows that once the rank of the long-run coefficient matrix [Π] formed with the Johansen method has been determined this matrix [Π] can be defined as the product of two matrices α and β so that $\Pi = \alpha\beta$. These matrices will have the following dimensions: $\alpha = (g \text{ x } r)$ and $\beta = (r \text{ x } g)$

Where:
r = the number of cointegrating vectors
g = the number of variables in the cointegrating equation

The matrices α and β can be defined as follows (Brooks, 2008: 352):

α = the matrix which gives the amount of each cointegrating vector entering into each equation of the VECM, these are also known as the adjustment parameters.
β = the matrix β contains and describes the cointegrating vectors.

Enders (2004: 323) states that if an equation has x nonstationary variables then there can be x-*1* linearly independent cointegrating relationships.   The equation being examined here

contains 2 nonstationary variables[4], spot prices and futures prices, and because of this, at most only one cointegrating relationship can exist (the rank of the matrix association with this efficiency study will be at most 1). As this study examines only two variables, spot and futures prices, it is thus an *a priori* expectation that, if these variables are found to be cointegrated and of the same order, they will display only one cointegrating vector.

If, in regard to the *a priori* expectation discussed above, the rank of this study is found to be equal to 1 and it is already known that *g* is equal to 2 then the following depiction of $\Pi = \alpha\beta$ can be given:

$$\Pi = \alpha\beta = \begin{pmatrix} a_{11} \\ a_{12} \end{pmatrix} (\beta_{11}\beta_{12})$$

In line with the method used by McKenzie *et al.* (2002: 487) and Lai and Lai (1991: 573), the model was then normalized with respect to S_t (the spot price) from the cointegrating regression. It was then possible to generate impulse response functions within the VECM to comment on causality within the market, as this provides an additional means of developing the findings regarding causality found under the EG ECM methodology. These impulse responses were generated and discussed after the VECM was presented, and both models, the VECM and the impulse response graphs, were used to comment on the price discovery process of this market. The Cholesky method of ordering was applied in line with the study by Floros (2009: 155).

In both the EG ECM and the VECM lag length is an important consideration, and it is necessary to consider the choice of lag length carefully (Enders, 2004: 363). Following Mahalik *et al.* (2009: 16) and Srinivasan and Bhat (2009: 35) the AIC and SIC criteria, were used to ascertain the appropriate lag length.

4. EMPIRICAL RESULTS

4.1 Tests of Stationarity and Cointegration

Augmented Dickey Fuller and Phillips-Perron tests were conducted to test for stationarity. It was established that both spot and futures prices were not stationary in level form but both become stationary in first-difference form showing that they are both I(1) series.

Cointegration between the two stationary series was then tested for under both the EG and Johansen's method. Both these approaches concluded that a long-run equilibrium relationship exists between spot and futures prices. The results of these tests may be found in appendix 1.

4.1 EG ECM

An EG ECM model was estimated in order to describe the short-run deviations from the long-run equilibrium that has been shown to exist due to the presence of cointegration. In this regard table 1 will demonstrate the ECM formed on the original cointegrating equation where the spot price is the dependent variable as shown in equation 1, while tables 2 and 3 will show the results of the ECM applied to the alternative direction of this relationship where the futures price is used as the dependent term represented in equation 2.

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[4] Assuming that the spot and futures price series are found to both be nonstationary series.

$$\Delta S_t = \alpha_1 + \alpha_S \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{11}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{12}(i)\Delta F_{t-1} + \varepsilon_{St} \tag{1}$$

$$\Delta F_t = \alpha_2 + \alpha_F \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{21}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{22}(i)\Delta F_{t-1} + \varepsilon_{Ft} \tag{2}$$

Due to the fact that the variables contained in equations 1 and 2 are all stationary the test statistics used in traditional VAR analysis are appropriate lag length can be examined with a *chi*-squared test and the assumption that all coefficients associated with the lagged terms are equal to zero can be examined with an *F*-test . Further, given that there is only one cointegrating vector, restrictions concerning the coefficient on the error term may be examined with a t-test (Enders, 2004: 338).

Table 1: EG ECM on the Cointegrating Equation
Dependent Variable: DLOGS
Included observations: 64 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005632	0.024384	0.230968	0.8181
EGECT(-1)	-0.610073	0.406092	-1.502304	0.1383
DLOGS(-1)	0.615672	0.365173	1.685974	0.0970
DLOGF(-1)	-0.124332	0.130093	-0.955721	0.3430

The coefficient of the error correction term, labelled EGECT(-1), is negative although it is only statistically significant at the 13% level. It should be noted, however, that Alexander (1999: 5) stated that between α_S and α_F, there should be one positive value and one negative value, as this is the process through which disequilibrium is corrected for. In finding that this value is negative it is necessary that the error correction term from equation 2 is found to be positive, this is observed in table 2While this term may not be significant this finding is not necessarily surprising because, what this suggests is that a shock to the futures price does not affect the spot price in the long run. In other words, this indicates that the spot market was not responsive to the previous period's disequilibrium and hence the spot market does not show evidence of short-run efficiency, where short-run efficiency would prevent any deviations from the long-run equilibrium relationship with the futures market (Leng, 2002: 11). This is supported by Mahalik *et al.* (2009: 11) who showed that when α_S is found to be statistically insignificant, this indicates that a change in the current period's spot price is not responding to last period's disequilibrium.

If one examines the coefficient associated with the lagged future price (DLOGF(-1)) it can be seen that this term is also statistically insignificant indicating that temporary shocks to the futures price do not affect the spot price. Alexander (1999: 6) shows that if the coefficient to the lagged futures price in equation2 is found to be insignificant then turning points in the futures market do not lead (come before) turning points in the spot market. In order for us to conclude that the futures market leads the spot market in this scenario the coefficient to the lagged futures price would need to be positive and highly statistically significant showing that lagged changes in the futures prices lead to positive changes in subsequent spot prices (Brooks, 2008: 345).

The only statistically significant result from this ECM is the coefficient of the lagged spot price, indicating that the spot return is in some way affected by its own lagged or past values (Leng, 2002: 12), not past futures prices. That is, the spot price is completely unresponsive to

changes in the futures price and it is only slightly responsive to changes in its own past values. This, and the findings that the futures market does not appear to lead the spot market suggests that the spot market leads the futures market in white maize over this time frame and hence that the spot market leads the futures market in the price discovery process.

A Granger pairwise test requires that both underlying series be stationary, however, Enders (2004: 333-334) discusses how comment can be made about Granger causality in an ECM framework. That is, if the lagged values of futures price do not enter the spot price dependent ECM equation (they are statistically insignificant) and the spot price does not respond to deviations from the long run equilibrium, in this instance the spot price will not be Granger caused by the futures price, *i.e.* the spot market will lead the futures market (Enders, 2004: 334).

In order to explore the possibility that the spot market leads the futures market the next step in this process is to examine equation 2 where the futures price becomes the dependent variable and the spot price, constant term and the cointegrating residuals are set as the exogenous variables.

Table 2: EG ECM Futures Price as Dependent Variable
Dependent Variable: DLOGF
Included observations: 64 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009500	0.008699	1.092018	0.2792
EGECT(-1)	0.511713	0.144879	3.532003	0.0008
DLOGS(-1)	0.514474	0.130280	3.948970	0.0002
DLOGF(-1)	-0.111978	0.046412	-2.412671	0.0189

It can be seen that in table 2 the error correction term (EGECT) is not negative, and is highly statically significant as expected in line with the discussion above, and in keeping with our expectations given Alexander's (1990: 5) observation on this matter that between α_S and α_F, there should be one positive value and one negative value. A finding that the coefficient to the error correction term is significantly different from zero is further proof of the underlying cointegrating relationship between this spot and futures market (Enders, 2004: 338). Enders (2004: 329) states that one of these coefficients must be non-zero for cointegration and error correction to exist. The fact that α_F is found to be statistically significant indicates that granger causality is present, and that a change in the current period's futures price is responding to deviations from the equilibrium that occurred in the previous period.

In order to more intuitively interpret these results the original cointegrating equation is adjusted such that the futures price becomes the dependent variable and the residual series from this equation is extracted. From this relationship, a new futures price dependent ECM is formed, this time with the residuals taken from the cointegrating equation, where the futures price is the dependent variable. In fact, if one examines Equation2, it can be seen that it is required that a residual series be obtained from the cointegrating relationship in which the futures price has been made the dependent variable, that is, there is a noted difference between ε_{St} and ε_{Ft}. This process was undertaken and the new residual series was tested for stationarity in the same manner as the original residual series was. An AEG test was used to confirm that this residual series was also stationary.

This final ECM relationship is shown in table 3.

Table 3: EG ECM with Futures Price as Dependent Variable with New Residuals.
Dependent Variable: DLOGF
Included observations: 64 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009825	0.008147	1.206051	0.2325
RESFUTDEP(-1)	-0.631315	0.135833	-4.647748	0.0000
DLOGF(-1)	-0.044576	0.047908	-0.930446	0.3559
DLOGS(-1)	0.411845	0.122619	3.358749	0.0014

The coefficient associated with the error correction term (RESFUTDEP(-1)) is negative and highly statistically significant. The sign of this coefficient is important due to the fact that it describes the movement of short run fluctuations back to the long run equilibrium. If the difference between the log spot and log future price is positive in one period then the spot price will decrease in the following period as a positive sign and a negative sign together result in an overall negative sign which is shown as a decrease in order to move back to an equilibrium position. V*isa versa*, when the difference is negative the association of the negative coefficient with a negative difference will result in a positive sign and hence an increase towards equilibrium (Brooks, 2008: 345-346).

In this instance a figure of -0.631315 is reported indicating that 63.1315% of the difference between actual spot prices and long-run spot price is eliminated in each period. This is in line with the statement by Enders (2004: 338) where he states that this term should not be too large in absolute terms.

The coefficients on the lagged spot price in the futures price dependent variable ECM (equation 2) in both versions of this particular ECM (futures price dependent Tables 2 and 3) are seen to be statistically significant. This indicates that turning points in the spot market will lead turning points in the futures market. The statistical significance of the lagged spot price term further indicates that shocks to the spot price will have a short run effect on the futures price. The positive sign of this coefficient indicates that the change will tend to move in the same direction as previous movements in the spot market (Ferret and Page, 1998: 85). This finding that the spot market leads the futures market in the South African white maize futures market is specified by the coefficient to the lagged spot price being positive and highly statistically significant which shows that lagged changes in spot price lead to positive changes in subsequent futures prices (Brooks, 2008: 345).

To summarise, the results of these ECM models indicate that the spot price leads the futures price, that is, the spot price granger causes the futures price. The futures price is shown to not cause the spot price, that is, there is unidirectional causality from the spot market to the futures market. Although the EG models have allowed for the short-run corrections towards the long-run equilibrium described by cointegration to be modeled the magnitude of these figures should be treated with caution due to the fact that a proxy for the spot price was used. Nevertheless, it is clear that a movement towards equilibrium is corrected for each period, And most importantly, that price discovery occurs in the spot market.

4.2 VECM

A number of different lag lengths were applied in order to evaluate the behaviour of the AIC and SIC figures so as to ascertain the most appropriate lag length (which will be seen where the SIC and AIC values are lowest), the results of which are presented below:

LAGS	AIC	SIC
1	–0.396694	-0.261764
2	–0.351674	-0.147566
3	–0.293822	-0.019353
4	–0.257651	0.088394
5	–0.197944	0.220925

It can be seen that the figures obtained for the use of one lag are the smallest, -0.396694 and -0.261764 respectively, in this model and due to this the VECM formed included one lag. Table 4 below gives the output for the Johansen's VECM, with the inclusion of one lagged term on both the spot and futures prices as indicated.

Table 4: Johansen's Vector Error Correction Model [1,1]
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
LOGS(-1)	1.000000	
LOGF(-1)	-0.991487	
	(0.02117)	
	[-46.8263]	
C	-0.067362	

Error Correction:	D(LOGS)	D(LOGF)
CointEq1	-0.288423	0.796795
	(0.47707)	(0.15280)
	[-0.60457]	[5.21464]
D(LOGS(-1))	0.355015	0.246676
	(0.43812)	(0.14032)
	[0.81032]	[1.75792]
D(LOGF(-1))	-0.119054	-0.054421
	(0.14019)	(0.04490)
	[-0.84926]	[-1.21207]
C	0.010477	0.010975
	(0.02467)	(0.00790)
	[0.42467]	[1.38895]

In line with the findings under the EG ECM it is observed that there is one positive and one negative error correction term (labelled CointEg1) suggesting the presence of a cointegrating relationship that contains a price discovery process. As in the EG ECM it is only the error correction term associated with the futures price dependent VECM, shown in the far right hand column, which is statistically significant.

The response to the shock will be shown as a positive speed of adjustment coefficient associated with the futures price, thus the error correction term from the Johansen's output above on the future price dependent output associated with D(LOGF) is 0.796795, that is, there is a nearly 80% adjustment to the futures price in response to a unit shock to the spot price. This is in line with the results of the EG ECM discussed previously, although the EG ECM indicated a smaller size response.

Mills (1999: 297-298) discusses the fact that interpreting causality within the VECM can be complicated; however, it is possible to test for causality within the VECM through the application of impulse response functions. It must be noted, however, that EViews does not generate confidence intervals for these findings, and due to this the impulse response functions need to be read together with the results of the VECM and those obtained from the EG ECM. The impulse response functions on this VECM are shown in Figure 1 below.

Figure 1: Impulse Responses

These graphs show what happens within the model when a shock is applied to the equation in question. For example, the top left-hand graph shows how the spot price responds if there is a unit shock to the spot price. The response of spot prices to previous shocks is non-zero, indicating that the spot price is influenced by its own past values. If a shock is applied to the futures price it can be seen in the top right-hand graph shows that spot prices are unaffected by changes in futures prices as the response line remains close to zero. The bottom right-hand graph shows that futures prices are only slightly affected by their own past values. The bottom left-hand graph gives a clear indication that futures prices respond to changes in the spot price. If a shock is introduced to the spot price, the response of futures prices to this shock is evident in the response line climbing rapidly to a level above zero. From these impulse responses it can be seen that the spot market leads the futures market, and so this finding has been confirmed through the use of both the EG ECM and the Johansen's VECM. The first purpose of estimating this VECM model has been served in that its results coincide with those found under the EG approach. Both the VECM, and its associated impulse responses, and the EG ECM's show that it is the spot market that leads the futures market.

5. CONCLUSION

This study set out to test for price discovery between the spot and futures markets for white maize in South Africa. EG and Johansen tests for cointegration between spot and futures prices were conducted and it was established that cointegration exists between the two markets. An ECM and VECM were then formulated to model the equilibrium relationship between the two series of price data. It was found that it is the spot market which leads the futures market for white maize, a finding that is different from previous South African studies of price discovery between spit and futures markets, which showed a changing lead or a two-way relationship. This study is the first to examine the price discovery process for an agricultural commodity.

Our result may be due to a number of factors. As was discussed earlier, internationally empirical studies have, on occasion, found situations where the spot market leads the futures market, and have shown that such a finding may indicate some level of inefficiency (Leng, 2002: 2), or it may simply be a comment on the underlying market in that perhaps the spot market, for whatever reason, is more liquid and attractive to investors (Srinivasan and Bhat, 2009: 29 and Ferret and Page, 1998: 73). These findings may be attributed to the use of a best

proxy cash price rather than a true cash price. Furthermore, and potentially most likely, these results may be influence by additional factors. South African white maize may be influenced by the trade behaviour of the CBOT. Our results indicate that further research is required to understand the price discovery process for agricultural commodity futures in South Africa, specifically though the application of CBOT futures prices into this analysis..

These findings have a number of implications for market participants. At a very simple level these results show that price discovery is present which in turn suggests that information is being assimilated in prices and that these prices, in the long-run, tend towards equilibrium. However, given that the studies results point to the spot market being the point of price discovery, price changes in the spot market should be carefully observed as these are seen to lead changes in the futures market. Farmers, commodity traders, regulators and policy makers should therefore exercise caution in using futures prices to predict likely future cash prices whilst speculators in agricultural futures contracts should consider the potential of profitably employing spot prices in their trading strategies.

APPENDIX 1

º The estimated Phillips-Perron test statistic shown in the table above is smaller in absolute terms than the corresponding critical values in both instances hence the null hypothesis of nonstationary data and the presence of a unit root *cannot* be rejected.

* The value of these calculated *tau* figures displayed in the table above are smaller in absolute terms than the associated critical values in all instances and so it may be concluded that the null hypothesis that the series are nonstationary and do contain a unit root *cannot* be rejected.

º In both sets of results it can be seen that the estimated *tau* value is now much larger, and is in fact greater than the associated critical values in absolute terms. As the absolute value is greater than the critical value in both series in FDF, the null hypothesis that the first difference of the spot and futures price series contains a unit root is rejected and it is concluded that both the spot and futures series are integrated of the first order (Jordaan, Grove, Jooste and Alemu, 2007: 312).

Engel-Granger Cointegration
EG Test
-7.504342*

ˣIn all instances, the estimated t-statistic of -7.504742 is higher than the associated critical values at the 1% level of between-4.592 and -4.4441, indicating that the residual series from the cointegrating equation described in equation 1 is indeed stationary, indicating that a long-run cointegrating relationship exists between spot and futures prices.

	Johansen's Cointegration	
	Trace Test	Maximum Eigenvalue Test
No Cointegrating Relationships	34.88917	30.99011
At most 1 Cointegrating Relationship	3.899062$^\Delta$	3.899062$^\Delta$

$^\Delta$ The results show that both these tests agree that it is unlikely that the rank of this equation will be zero, and both show that the rank of this matrix will at *most* be equal to 1. IN the table above the $^\Delta$ indicates a statistically significant result. That is, these tests resulted in the same conclusion, namely, the rank is definitely not zero and so 1 cointegrating equation must exist between the spot and futures price series indicating the presence of a long run cointegration relationship.

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