academicJournals

Vol. 7(26), pp. 2603-2614, 14 July, 2013
DOI: 10.5897/AJBM12.1310
ISSN 1993-8233 © 2013 Academic Journals
http://www.academicjournals.org/AJBM

African Journal of Business Management

Full Length Research Paper

Price discovery in the South African White maize futures market

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Accepted 16 July, 2013

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

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

INTRODUCTION

Maize accounts for more than 60% of the total harvested area of annual food crops in eastern and southern Africa (Langyintuo et al., 2010). The Human Sciences Research Council describes maize as "…the best single indicator of food security in the [South African] region (de Klerk et al., 2004). In Africa, it accounts for between 22 to 25% of the staple consumption of starch and provides the single largest source of calories; 31% in South Africa, 43% in Zimbabwe and in excess of 50% in Lesotho, Malawi and Zambia (Smale et al., 2011). Expenditure on maize can represent up to 20% of low-income consumers' income in South Africa (Traub and Jayne, 2008). Rapid increases in food prices, particularly that of white maize, have highlighted the issue of fluctuations in food prices and their impact on poor communities (Watkinson and Makgetla, 2002; Smale et al., 2011) and in particular the volatility of futures prices as a driver of these increases (de Klerk et al., 2004).

For governments concerned with food security, price instability of maize acts as an invitation to actively attempt to stabilize prices although the cost-benefit relationship of these efforts is open to debate (Smale et al., 2011). An alternative approach is to rely on markets to coordinate production and marketing of agricultural commodities (Smale et al., 2011). This discussion is of particular relevance in South Africa which has a well-developed futures market, the South African Futures Exchange (SAFEX), trading contracts on several agricultural commodities including maize (Sitko and Jayne, 2012) and which since 1997 has deregulated its agricultural commodities market forcing farmers to adopt new methods of trading, primarily through using SAFEX (Monk et al., 2010). As a result, maize prices are now entirely set by market forces with SAFEX's near futures

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JEL classification: C58, D53, G12, G13.

contract providing a market determined indication of "spot" prices at the Randfontein silo (Traub and Jayne, 2008).

The importance of commodity futures markets is widely acknowledged in the literature as futures prices represent an important variable observed by several market participants, including farmers, processors, consumers, traders and policy makers (Chhajed et al., 2012; Mahalik et al., 2009). A well-functioning agricultural commodity futures market provides a number of benefits, the most important being price discovery and risk management as these allow for more efficient resource allocation, improved productivity, liquidity and transparency (Chhajed et al., 2012). While the importance of futures markets is well established, the increased use of these derivatives has promoted comment on the possible negative effects of futures trade, such as excessive speculation (Peri et al., 2013).

Mahalik et al. (2009) 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) identifies the key function of financial markets as that of price discovery, a view supported by Pavabutr and Chaihetphon (2010) who suggest that the efficiency of the price discovery process impacts directly on the efficacy of the hedging function. Andersen et al. (2007), however, 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 et al. (2001) 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).

It has been argued that one of the factors responsible for the surge in food prices experienced globally in 2008 was increased speculative trading in futures markets for basic agricultural commodities (West, 2008; Grynberg and Motswapong, 2009). In addition, Watkinson and Makgetla (2002) argue that inaccurate and incomplete market information impacts the maize price on SAFEX and that speculation in maize futures can cause prices to inaccurately reflect market fundamentals. Jordaan et al. (2007) further find that the volatility of the price of white and yellow maize was substantially higher than that of other crops traded on SAFEX. Kirsten (cited in de Klerk et al., 2004) however, found that the retail price of white maize is less volatile than the futures price while Behar (2011) goes even further to suggest that the futures price is at best no more effective for farmers as a price discovery mechanism than the old Maize Board price and possibly even less meaningful.

Given the importance of maize as a staple food product in Africa and the impact that price fluctuations have on consumers, an improved understanding of the price discovery process in the maize market is of great practical importance for market participants, regulators, policy makers and consumers. This paper thus tests the hypothesis that price discovery occurs in the maize 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 techniques 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.

PRICE DISCOVERY

A general description of price discovery is simply the impounding of new information into a security's price (Choy and Zhang, 2010; Hasbrouck, 1995). 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) and Kavussanos and Nomikos (2003), 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 that 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) although Peri et al. (2013) and Pavabutr and Chaihetphone (2010) observe that in general, the literature on price discovery finds that the futures market leads the spot market.

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) and futures markets offer greater leverage making it easier for speculators to profitably exploit new information in the futures market (Pavabutr and Chaihetphon, 2010). Kavussanos and Nomikos (2003) 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) 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.

A significant number of empirical studies provide support for the assumption that futures prices lead spot prices (Hasbrouck, 2003). Pizzi et al. (1998) find that both three- and six-month stock index futures prices lead the spot market by at least 20 min, but some causation from the spot market to the futures market is also evident. Hasbrouck (2003) looks at U.S. equity index markets including Exchange Traded Funds (ETFs) and finds that electronically traded futures contracts dominate price discovery with the exception of the S&P 400 index where the ETF provides substantial price discovery. Yang et al. (2001) use a standard cointegration technique to study price discovery in commodity futures markets across several commodities including both storable and nonstorable commodities. They find that nonstorability does not affect the existence of cointegration and as a result conclude that futures prices are useful in predicting future cash prices (Yang et al., 2001). Kavussanos and Nomikos (2003) also focus on the issue of storability and investigate the price discovery process for a nonstorable underlying asset in the freight futures market. They find a long-term relationship between spot and futures prices with evidence that price discovery occurs mainly in the futures market

Employing a GARCH approach on the Hang Seng index market, So and Tse (2004) find that the volatilities of the index and futures markets spill over to each other, but that the effect is stronger from the futures market to the index, indicating that the futures market dominates in the price discovery process. Choy and Zhang (2010) examining the Hong Kong market also find 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 conclude that since both regular and mini contracts trade on the same trading platform, the leading role of regular futures contracts in price discovery is due to their relatively lower transaction costs (Choy and Zhang, 2010). Pavabutr and Chaihetphon (2010) employ VECMs for the Indian gold futures market to show that both standard and mini futures contracts lead the spot price. Peri et al. (2013), using cointegration techniques, find that the market plays the dominate role in price discovery between spot and futures for both Corn and Soybeans.

Chhajed et al. (2012), however, examine spot and futures prices on nine different agricultural commodities on the Indian exchange and find that there is a noticeable difference in the price discovery process between different commodities, and that most of the commodities show bi-directional feedback. Tse et al. (2006) study price discovery on several foreign exchange futures markets and find 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.

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 some studies report mixed results with some evidence that price discovery also flows from spot to futures markets albeit to a lesser extent. Whilst less common, certain studies have found results indicating that spot prices can lead futures prices, Wahab and Lashgaris (1993), for example, find evidence of a feedback relationship between stock index and stock index futures markets, but conclude that their results confirm that the lead from spot to futures is more pronounced. Similarly, Leng (2002) finds for one of the sub-periods in his study that the spot price leads the futures price. Chan et al. (1991) conclude that new market information disseminates in both markets and that both spot and futures markets perform important price discovery roles.

In South African studies, Ferret and Page (1998) find 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) use the VECM to show that price discovery takes place in the futures market for Stock Index Futures and in most cases find that the emerging market crisis did not affect these price discovery findings. Leng (2002) uses 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 are shown separately. Leng (2002) finds that the point of price discovery changes during the time period examined, one particular period of crisis shows that the spot leads the futures markets, while the majority of the time it shows that the futures lead the spot market. Floros (2009) uses both the VECM and an ECM-TGARCH model to describe short-run deviations from the long-run equilibrium, and further employs an impulse response function to examine the price discovery role of the Stock Index Futures Market in South Africa. Floros (2009) finds that there is 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) suggest 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 speculate that it may indicate that speculative traders, who are seeking profit making scenarios, will prefer to use a commodities futures market due to its 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) 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).

Behar (2011) analyses price discovery and risk management before and after the deregulation of the maize board in South Africa in 1996. He finds little evidence to suggest that farmers respond to higher expected prices in the case of both the Maize Board and subsequent SAFEX futures price and concludes that the futures price is not as effective a tool of price discovery as was the Maize Board price. Consequently he suggests that the futures price should be dealt with cautiously given the number of additional factors which may influence the price discovery decisions made on the expected price. Behar (2011) further finds that price risk has increased since deregulation, and that this risk influences farming decisions but that there is evidence that SAFEX has assisted farmers to manage price risk despite greater price volatility.

DATA AND METHODOLOGY

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 eight weeks prior to the contract's expiry. This was done in line with various authors recommending 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 (McKenzie et al., 2002; Aulton et al., 1997). 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 African white maize cash prices available (Traub and Jayne, 2008). 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[1]. 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).

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 as follows:

$$S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t \qquad \ldots(1)$$

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 to 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).

Engle-Granger ECM

The residuals obtained from the cointegrating equation, shown by Equation 1, 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. Ferret and Page (1998) 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) 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

[1]See for example Auret and Schmidt (2008), He and Holt (2004), Geyser and Cutts (2007), and Jordaan et al. (2007).

leads x_t." The ECM for a study such as this, which has two cointegrated log price series, is captured in the following equations (adapted from Alexander (1999) and Mahalik et al. (2009)):

$$\Delta S_t = \alpha_1 + \alpha_S \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{11}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{12}(i)\Delta F_{t-1} + \varepsilon_{St} \quad (2)$$

$$\Delta F_t = \alpha_2 + \alpha_F \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{21}(i)\Delta S_{t-1} + \sum_{i=1} \alpha_{22}(i)\Delta F_{t-1} + \varepsilon_{Ft} \quad (3)$$

The first item to be considered when examining the ECM is the sign and significance of the coefficient estimates (Brooks, 2008). 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). 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). 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).

Alexander (1999) 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). 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).

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.

Enders (2004) 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, assuming that the spot and futures price series are both found to be nonstationary series, 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.

In line with the method used by McKenzie et al. (2002) and Lai and Lai (1991), 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 further comment on causality within the market. 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 formulating the impulse response functions in line with Floros (2009).

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). Following Mahalik et al. (2009) and Srinivasan and Bhat (2009) the AIC and SIC criteria were used to ascertain the appropriate lag length.

EMPIRICAL RESULTS

Tests of stationarity

Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests were conducted to test for stationarity. The data order was then examined with the ADF test on the price series in first difference form. The results for these tests are shown in Table 1.

It was observed that the estimated Phillips-Perron test statistic shown in the table above was smaller in absolute terms than the corresponding critical values (at the 1% level this tests critical value is -4.105534, and at the 5% level it is -3.480463) in both the spot and futures series, hence the null hypothesis of nonstationary data and the presence of a unit root *could not* be rejected. The ADF test displays the calculated *tau* figures in the table above, and it was seen that these are smaller in absolute terms than the associated critical values (at the 1% level the critical ADF test value is -3.536587 while at the 5% level it is -2.907660) in all instances, and so it was concluded that the null hypothesis that these series are nonstationary and do contain a unit root *could not* be rejected.

The final column of Table 1 shows the results of running the ADF test on the spot and futures price series after FDF had been applied. In both sets of results it was observed that the estimated *tau* value became larger, and was in fact greater than the associated critical values (as listed in the ADF test in the paragraph above) in absolute terms. As the absolute value was 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 as rejected and it was concluded that both the spot and futures series were integrated of the first order. It was thus established that both spot and futures prices were not stationary in level form, but both become stationary in first-difference-form showing that they were both I(1) series.

Tests for cointegration

Cointegration between the two stationary series was then

Table 1. Unit root tests and testing for data order.

Series	Testing for a unit root		Testing for data order
	Phillips-Perron	Augmented Dicky-Fuller	ADF (First Difference Form)
Spot price	-2.752166*	-1.739859*	-7.719992*
Futures price	-2.754108*	-1.840648*	-7.458547*

*indicates statistical significance

Table 2. Johansen's cointegration: Trace and maximum eigenvalue tests.

	Trace test	Maximum eigenvalue test
No cointegrating relationships	34.88917	30.99011
At most 1 cointegrating relationship	3.899062*	3.899062*

* indicates statistical significance

Table 3. EG ECM on the cointegrating equation.

Dependent variable: Spot price series				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Intercept	0.005632	0.024384	0.230968	0.8181
Error Correction Term	-0.610073	0.406092	-1.502304	0.1383
Spot Series (1 lag)	0.615672*	0.365173	1.685974	0.0970
Future Series (1 lag)	-0.124332	0.130093	-0.955721	0.3430

* indicates statistical significance

tested for under both the EG and Johansen's methodologies. For the EG test performed on the residuals of equation 1, the estimated t-statistic of -7.504742 was 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 was indeed stationary, and that a long-run cointegrating relationship existed between spot and futures prices.

The results in Table 2 show that both the Trace Test and Maximum Eigenvalue Test agreed that it was unlikely that the rank of this equation would be zero, and both show that the rank of this matrix was at *most* equal to 1. In Table 2, *, indicates a statistically significant result. Both tests thus resulted in the same conclusion, namely, the rank was definitely not zero and so 1 cointegrating equation existed between the spot and futures price series which indicated the presence of a long-run cointegration relationship. Both approaches thus concluded that a long-run equilibrium relationship existed between spot and futures prices.

Engle-Granger Error Correction Model (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 3 demonstrates the ECM formed on the original cointegrating equation, where the spot price is the dependent variable as shown in equation 2, while Table 4 shows 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 3.

Due to the fact that the variables contained in Equations 2 and 3 are all stationary, the test statistics used in traditional VAR analysis are appropriate and 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).

The coefficient of the error correction term is negative although it is only statistically significant at the 13% level. It should be noted, however, that Alexander (1999) states 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 4.

Table 4. EG ECM futures price as dependent variable with new residuals.

Dependent variable: Future price series				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Intercept	0.009825	0.008147	1.206051	0.2325
Error correction term from futures dependent equation	-0.631315*	0.135833	-4.647748	0.0000
Futures series (1 lag)	-0.044576	0.047908	-0.930446	0.3559
Spot series (1 lag)	0.411845*	0.122619	3.358749	0.0014

* indicates statistical significance

While 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). This is supported by Mahalik et al. (2009) who show 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 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) shows that if the coefficient to the lagged futures price in equation 2 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 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).

The only statistically significant result from this ECM is the coefficient of the lagged spot price, indicating that the spot price is in some way affected by its own lagged or past values (Leng, 2002), 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. A Granger pairwise test requires that both underlying series be stationary, however, Enders (2004) 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, that is, the spot market will lead the futures market. The finding 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 price discovery occurs in the spot market rather than the futures market.

In order to explore the possibility that the spot market leads the futures market, the next step in this process is to examine Equation 3 where the futures price becomes the dependent variable and the spot price, constant term and the cointegrating residuals are set as the exogenous variables. That is, a new futures price dependent ECM was formed, this time with the residuals taken from the cointegrating equation, where the futures price was the dependent variable. If one examines Equations 2 and 3, 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}. 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 is shown in Table 4.

The coefficient associated with the error correction term from the futures price as the dependent variable equation 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. Vice 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). 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.

The coefficients on the lagged spot price in the futures price dependent variable ECM (Equation 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

Table 5. Lag length criteria tests.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-11.63515	NA	0.005401	0.454505	0.524316	0.481812
1	103.3404	218.4536*	0.000134*	-3.244681*	-3.035247*	-3.162760*
2	105.1321	3.284638	0.000144	-3.171068	-2.822011	-3.034533
3	108.0728	5.195363	0.000149	-3.135761	-2.647080	-2.944611
4	109.6961	2.759506	0.000162	-3.056535	-2.428232	-2.810772
5	111.0224	2.166349	0.000178	-2.967413	-2.199487	-2.667035
6	113.3506	3.647467	0.000189	-2.911686	-2.004136	-2.556693

*indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

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). 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).

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.

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, the results of which are presented next in Table 5.

It was observed that the figures obtained for the use of one lag were significant under various tests applied and due to this the VECM was formed included one lag. Table 6 gives the output for the Johansen's VECM, with the inclusion of one lagged term on both the spot and futures prices as indicated.

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

The response to a price shock would 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 the error correction term in the Change in LOGFUTURES column was 0.796795, that is, there was 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.

As it is possible to test for causality within the VECM through the application of impulse response functions, these are shown in Figure 1.

These graphs show what happens within the model when a shock was applied to the equation in question. For example, the top left-hand graph shows how the spot price responds when there was a unit shock applied to the spot price. The response of spot prices to previous shocks was non-zero, indicating that the spot price was influenced by its own past values. If a shock was applied to the futures price it can be seen in the top right-hand graph that spot prices were unaffected by changes in futures prices as the response line remains close to zero. The bottom right-hand graph shows that futures prices were only slightly affected by their own past values. The bottom left-hand graph gave a clear indication that futures prices responded to changes in the spot price. If a shock was introduced to the spot price, the response of futures prices to this shock was evident in the response line climbing rapidly to a level above zero. From these impulse responses it was observed that the spot market led the futures market, and this finding had been confirmed through the use of both the EG ECM and the Johansen's VECM. Both the VECM, and its associated

Table 6. Johansen's Vector Error Correction Model.

Standard errors in ( ) & t-statistics in [ ]		
Cointegrating equation component	**Cointegrating equation**	
Log Spot Price	1.000000	
	-0.991487	
Log Futures Price	(0.02117)	
	[-46.8263]	
Intercept	-0.067362	
Error correction component	**Change in LOGSPOT**	**Change in LOGFUTURES**
	-0.288423	0.796795*
Error correction terms	(0.47707)	(0.15280)
	[-0.60457]	[5.21464]
	0.355015	0.246676
Change in LOGSPOT(1lag)	(0.43812)	(0.14032)
	[0.81032]	[1.75792]
	-0.119054	-0.054421
Change in LOGFUTURES(1lag)	(0.14019)	(0.04490)
	[-0.84926]	[-1.21207]
	0.010477	0.010975
Intercept	(0.02467)	(0.00790)
	[0.42467]	[1.38895]

* indicates statistical significance

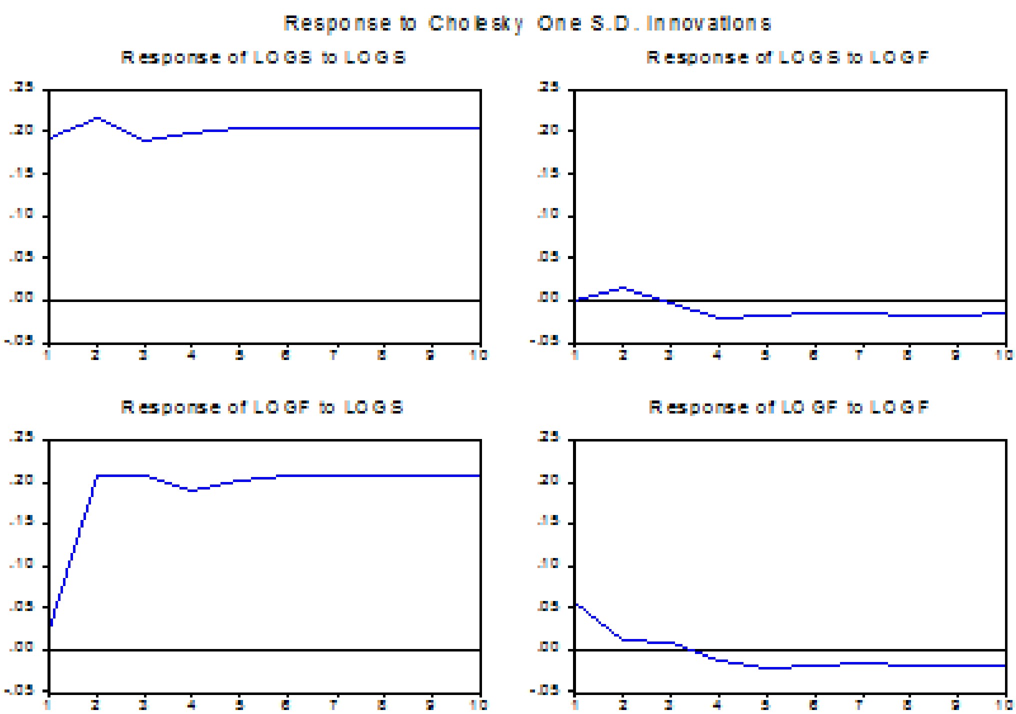

Figure 1. Impulse responses.

impulse responses, as well as the EG ECM's indicated that it was the spot market that led the futures market for white maize during this period.

Policy implications

Governments are naturally concerned with the volatility of the domestic maize price and the volatility of futures prices is often seen as being responsible for this volatility (de Klerk et al., 2004). Price instability may consequently tempt authorities to attempt to stabilise prices (Smale et al., 2011), Watkinson and Makgetla (2002) for example, recommend an investigation of the South African futures market and how its impact on actual prices can be controlled. Our finding that the spot market actual leads the futures market, however, indicates that speculation in futures markets is not the main cause for volatility in spot prices. This supports de Klerk et al.'s (2004) argument that in practice it is unlikely that price manipulation in the futures market will be able to distort spot prices and that both consumers and farmers benefit from the shift to a market-driven pricing policy. It further strengthens Smale et al.'s (2011) recommendation for policy makers to encourage the development of market-based systems through regulation and investing in transport, storage and information systems which will support market efficiency.

As discussed in earlier, theoretically, due to the benefits of leverage and lower transaction costs, one would expect the futures market to lead the spot market. Our finding that in effect price discovery in the spot market leads the futures market may be indicative of shortcomings in the South African futures market for white maize which is inhibiting its effectiveness. Sitko and Jayne (2012) have highlighted the challenge of attracting sufficient interest from farmers, wholesalers and processors in African commodity exchanges. Even in South Africa, Monk et al. (2010) and Jordaan and Grové (2007) describe the reluctance of South African farmers to use derivatives to manage their price risk.

Jordaan and Grové (2007) identify several reasons for this reticence including investment in human capital, lack of personal capacity and distrust of the market driven by bad experiences and the belief that it is characterised by too much speculation and manipulation. Seghal et al. (2012) identify similar concerns inhibiting the use of commodity futures trading in India. As already noted, if speculators move from the spot market to the futures market it may increase the noise trading in the futures market (Srinivasan and Bhat, 2009) and lack of trust in futures markets in developing countries may reduce their liquidity and efficiency (Leng, 2002). Despite the growth of SAFEX our results indicate that there is still room for improvement in SAFEX's marketing of its products to farmers. Pannell et al. (2008) observe that if a farmer has to incur learning costs as a result of inexperience trading futures or is concerned about the hedging process they may not consider the benefits worth the effort. Our findings thus support Monk et al.'s (2010) conclusion that more must be done to educate farmers about the benefits of hedging in order to lower their learning costs and lack of confidence. SAFEX, government agencies and farming associations all have a potentially valuable role to play in this process.

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. This finding is different from previous South African studies of price discovery between spot and futures markets, which showed a changing lead or a two-way relationship. This study, however, is the first to examine the price discovery process for an agricultural commodity traded on SAFEX.

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). Santos (2009) however, argues that a finding that a price discovery process exists indicates at least some level of market efficiency. Alternatively, this result may simply reflect the characteristics of the underlying market, indicating that the spot market, for whatever reason, is more liquid and attractive to investors (Srinivasan and Bhat, 2009; Ferret and Page, 1998). Given that trade volumes for white maize futures in South Africa have been steadily increasing over the time frame examined, insufficient liquidity in the futures market as an explanation for a finding of spot prices leading futures prices may, however, not be appropriate in this instance. An additional possibility is that the market for 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. The existence of a price discovery process between the two markets is suggestive of a degree of efficiency within these markets. However, given that the study's 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. Further development of the futures market for maize, with its contingent benefits for price discovery and risk management requires further effort from government, SAFEX and farming associations to improve farmers' education regarding these products and to improve the market structure for maize in order to reduce the perceived threat of price manipulation.

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