

UNIVERSITY OF KWAZULU-NATAL

**TESTING THE EFFICIENCY OF THE
SOUTH AFRICAN FUTURES MARKET
FOR WHITE MAIZE:
1996-2009**

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of the requirements for the degree of
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DECLARATION

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ABSTRACT

Agricultural commodity futures markets provide an important price discovery function and are important tools in risk management. The efficiency of futures markets for agricultural commodities is, therefore, an important issue for participants in the agricultural sector who rely on futures contracts to manage price risk and to assist in planning. Tests of market efficiency in futures markets typically address the relationship between spot and futures prices through the application of cointegration techniques. This study follows international practice by employing the Engel-Granger and Johansen's tests in this regard. Spot and futures prices of white maize are found to be cointegrated. Although cointegration is a necessary step towards identifying an efficient market, it alone is not enough to make any strong conclusions in this regard.

Error correction models (both the Engle-Granger ECM and Johansen's VECM) were then formed in order to more fully describe the long-run relationship identified through the presence of cointegration. Both models found that short-run periods of disequilibrium are corrected for, thus maintaining a long-run cointegrating equilibrium. Further, it was shown that there is a price discovery process in this market, and it is the spot market which leads the futures market in this regard. In order to comment on whether or not the futures market is efficient two parameters need to hold true. Firstly, that futures prices are unbiased predictors of upcoming spot prices; and secondly, that there is a zero risk premium in the market. These restrictions were applied and it was shown both these restrictions hold, which suggested that a finding of weak-form market efficiency could be drawn.

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1. INTRODUCTION

1.1 Background to Study

In South Africa, along with the rest of Africa and many other parts of the globe, the most obvious function of agricultural activities is to provide food for the millions of people that live below the poverty line and who suffer from malnutrition and hunger (Lyne, Hendricks and Chitja, 2009: 1-2). The agricultural sector is thus optimally positioned to help alleviate these problems as well as to address the global issue of food shortages through the optimisation of crop production and distribution (Lyne *et al.*, 2009: 1). Current issues of rising and volatile prices, especially commodity prices for fuel and basic foods such as maize and wheat, are often spoken of in the media as being an issue that needs urgent attention. As prices rise so are all persons affected, as these rising prices diminish the purchasing power of their incomes. These issues associated with unreasonable price volatility, as well as regular comment on the problems associated therewith, suggest that commodity markets are behaving in an inefficient manner where the underlying asset is either not being utilised correctly, or other market forces are causing inflated prices, perhaps due to profit related trade behaviour.

An example of such a news report was printed in The Economist on 18th April 2008. This article by Edward West, entitled, "Scramble to defuse world food price crisis" stated that the cause of rising food prices may be attributed to a number of factors including, "increased demand from fast-growing countries such as China and India, rising production costs like the price of fuel, shrinking resources such as the availability of land and water, and *sharply increased speculative trading* of all globally traded commodities." Items such as rising costs are an obvious link to associated higher food costs, but this mention of the effect of speculative activity within a given market adds another dimension to this problem. Speculation by some is seen as a necessity for efficient market functionality; however, any excessive speculation of the market may also be argued as causing the problem of rising commodity costs.

The blame for rising food prices has been laid on speculators by more than one source, for example, in the USA, the New York Times newspaper presented an article written by Diana B. Henriques on June 13, 2008 entitled: "Crackdown urged on speculation in commodities markets." The following is taken from this article: "...financial speculators ... are being

blamed for high gasoline prices, soaring grocery bills and volatile commodity markets ... This escalating rhetoric against speculators is starting to worry people with ... knowledge about how commodity markets work. Because without speculators...these markets simply do not work at all..." This article continues into an examination of why commodity futures markets specifically are being blamed as the vehicle of rising prices in current times. It is given in this report that speculators are the only "voluntary" market players in commodity futures markets, as other traditional participants, "the so-called commercial players ... have to be there [to control the risks they are exposed to through price changes]."

The New York Times article speaks of all commodities in general, however, the effect of many of these general commodities, such as the price of fuel, are also input costs to the production, transport and distribution of basic food goods. It makes sense that rising costs of other commodities such as fuel may be the reason that agricultural commodity prices are rising (as fuel is an obvious input cost in farming activities), however, it may also be that inefficiencies within the agricultural commodity itself are the cause of these pricing inefficiencies. "If properly managed, agriculture can have a positive impact on poverty alleviation, food security, rural-urban population distribution and the environment" (Lyne *et al.*, 2009: 2 citing Fraser *et al.*, 2003). Agricultural commodities thus form an integral part of the economy of all countries, although in developing, labour intensive, nations their role is most apparent in the provision of basic foods and low-income related employment opportunities. The distribution and availability of these goods in response to demand and supply market conditions is especially significant in light of these factors.

The importance of these markets functioning effectively may also be highlighted by recent events such as food riots in a number of countries such as India and around Africa; and, recently in South Africa, with the strike in July 2008 by COSATU in reaction to rising prices (Kharsany, 2008: para 1). These events demonstrate that the effect of price behaviour, especially increasing prices, are of great importance to all people and, in particular, to those living on base-level wages who are consequently the most affected.

In South Africa, the National Agricultural Marketing Council (NAMC) provides the average price movement on a basket of foods they monitor. In the period from March 2006 to March 2007 an increase of 7.58% was noted, and certain items in the basket increased by much more than this, for example, super maize meal by 24.98% and frozen chicken by 33.84% (NAMC Media Release, 2007: 3-4). From April 2007 to April 2008 the price of the basket

continued to increase, with a conclusion to the 2008 report that a large part of that increase can be attributed to the price of grain products (NAMC Media Release, 2008: 1). The choice of maize as the focus of this study has a clear significance in the face of these issues, especially as maize is a core agricultural commodity in both its primary and refined forms. Maize is used for human and animal consumption in domestic and international locations and, due to the number of people that rely on this staple good, the functionality of this market is of particular importance in light of the needs this market serves.

Speculative trade may be considered a positive influence within a market environment due to the tendency of speculators, through increased trade, to increase market liquidity, smooth out seasonal fluctuations, decrease price variability and in general serve to increase social welfare. There are, however, those that suggest that speculative trade negatively affects a market environment as these traders are seen to conduct themselves in a manner that leads to a destabilisation of prices and increased price variability, consequently leading to a decrease in social welfare (Marshall, 1989: 72).

The optimisation of the functionality of futures markets, which are a key part of the trade and distribution of agricultural products, is therefore vital as this would enable the supply and demand of goods to become more effective at meeting the requirements of its market participants, and thus potentially avoiding some of the real world scenarios described above. Financial derivatives tied to commodity markets, including futures, forwards, options and swaps, have been increasingly traded since their inception on both an international and domestic setting in response to an increasing need to manage price volatility and the risks associated with unanticipated price changes (Mahalik, Acharya and Babu, 2009: 1). Futures contracts are common instruments 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 are used as tools for price risk management (Hasbrouck, 1995: 1175); they contribute to price discovery, portfolio diversification and are used for hedging practices (Srinivasan and Bhat, 2009: 29); they are used as a tool for speculation and liquidity, as a means to store a variety of commodities; and, as a means to reduce volatility and uncertainty of investments, sales and purchases (Marshall, 1989: 52-54; Phukubje and Moholwa, 2006: 199).

This variety of functions arises from the fact that futures markets developed in order to meet the requirements of a wide range of people from manufacturers and retailers to brokers and traders in the supply chain of various goods (Teweles and Jones, 1987: 29), including agricultural products such as maize. In fact, early studies that examined futures markets were almost exclusively based in agricultural markets (Dagan, 2002: 1). The behaviour of the spot market for a given commodity has been shown to be influenced by the behaviour of market participants trading in the futures market and due to this it becomes important to understand how spot and futures markets for a commodity interact with one another (Srinivasan and Bhat, 2009: 29).

When a market is functioning at a level where it can effectively meet risk management and price stabilization roles then it may be referred to as being efficient (Moholwa, 2005: 3). In this context, 'efficiency' refers to the markets' ability to perform its functions; the details of which are described in more detail later in this study. The level of efficiency prevalent in the market often defines the interaction between spot and futures markets. The reason for this is that, in the instance of there being only a spot market any news that affects the associated asset will be incorporated into that spot markets price, however, when both spot and futures markets for a commodity exist that same information will need to be reflected in both the markets tied to that asset (Mahalik, *et al.*, 2009: 2).

Efficiency essentially comments on how quickly information is reflected into prices (Mahalik, *et al.*, 2009: 2) and, when viewed in the context of the above-mentioned functions, it can be seen that the speed with which news is assimilated into the market will affect the effectiveness of the various market functions. For example, if true price discovery is present, this indicates that news is incorporated into both spot and futures market instantaneously ensuring that futures prices can be used to accurately forecast upcoming spot prices. If, however, news takes some time to be reflected in prices, future spot price predictions would become unreliable – a problem for those using these predictions to control and monitor their risk exposure.

It is thus important to be able to assess the efficiency of futures markets in order to judge how effectively they perform their functions. If market efficiency is found to be present in a given market the implication of this finding is that market participants cannot use historical spot and future prices in order to earn abnormal profits. A market that is found to be efficient would exhibit true price discovery where information on upcoming spot prices can

be extracted from the price of a futures contract for the same commodity (Srinivasan and Bhat, 2009: 29).

This function of price discovery allows for futures markets to be used as a tool in aiding decisions made today, in view of the prices expected to prevail at a future date. Correct and efficient futures pricing improves the potential for successful hedging practices within the market, which in turn reduces the risks that producers and other risk-minimising market participants face. To give an example, a farmer needs to choose between a number of available crops and plant the one(s) that are believed will have the best return at the time of harvest and sale. The more efficient the futures markets for those crops are, the better equipped the farmer will be to make an informed planting decision. Increased market efficiency results in a more reliable and accurate means of decision making for supply-side/producer market participants. This would mean that the futures market is efficient and will already include all the information that is available in historical prices.

A finding of this nature will indicate to these participants that using their resources in a bid to 'beat the market' will not be successful. Efficiency implies that no trading gains can be realized so, for investors and traders, findings of efficiency may mean that other commodities that do not exhibit this characteristic are more appropriate for their purposes of identifying profit making opportunities. The conclusions and findings of efficiency studies may affect the trading behaviour of market players including speculators and hedgers; and will affect the way in which farmers and other participants directly related to the market make their decisions based on futures prices. Findings of efficiency, or lack thereof, may be used by policy controlling bodies to implement policies aimed at achieving efficiency.

Commodity futures market efficiency is of importance to both the public and private sectors (Aulton, Ennew and Rayner, 1997: 408). Market efficiency becomes increasingly relevant to agricultural commodity futures markets where it is a key management component for market suppliers and producers from a pricing and forecasting point of view. The government too has an interest in the findings of efficiency studies. This is due to the fact that an efficient market reduces the necessity of governmental intervention, such as price stabilising policies, within the market. Studies that find for or against market efficiency may help guide governmental policy in these markets.

Futures markets are also used as a primary resource for containing the instability of prices and output that arise from normal production and procurement of commodities (Aulton *et al.*, 1997: 408). Further, international import/export activities are also affected by the reliability of these markets and thus findings for or against efficiency have far reaching implications (Wang and Ke, 2002: 3). In light of recent price volatility and claims that they were as a result of speculative activity distorting prices, a study on the efficiency of the white maize market is appropriate.

1.2 Research Problem and Objectives

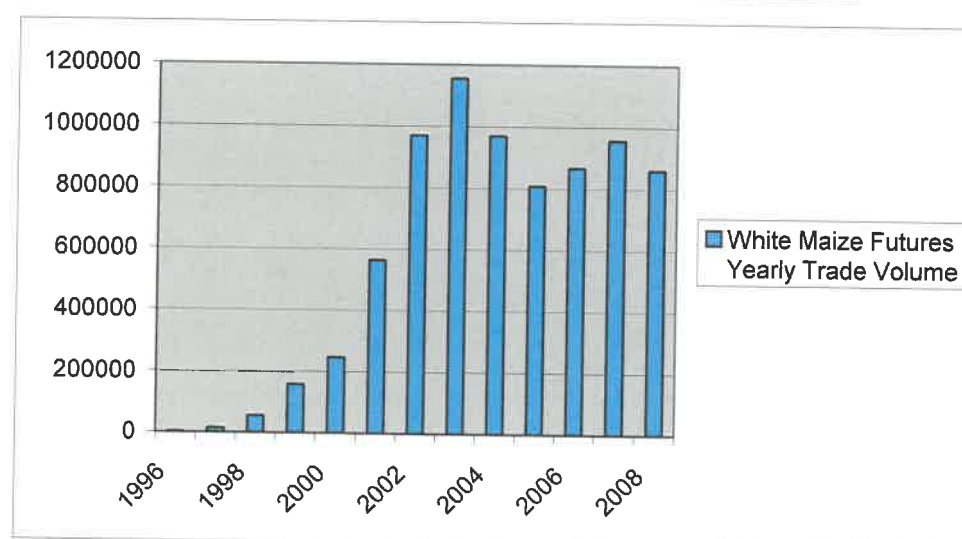
This study falls into the broad category of the testing of market efficiency. An efficient market is one in which the price of a futures contract contains all relevant information that market participants need in order to utilize the said financial instrument for risk control purposes (He and Holt, 2004: 2). When this definition is examined in more detail it becomes apparent that there are a number of important subsections that need to be individually addressed in order to analyse and understand the efficiency of a market environment. If a market is found to be efficient this has two key implications, firstly it suggests that historical prices will not help market participants formulate upcoming price predictions and so the market would be a place of true price discovery, where futures prices give an accurate idea of what prices will be present in the market in the future. This function allows for futures markets to be used as a tool in aiding decisions made today. Secondly, correct and efficient futures pricing improves the potential for successful hedging practices within the market, which in turn reduces the risks that producers and other risk-minimizing market participants face.

The study of market efficiency is relatively new within the South African context, mainly because this country's futures market is still a developing one. South African agricultural futures contracts, especially in contrast to international agricultural commodity markets, are relatively new, having faced many fewer years of operation than major international markets in similar products. While the South African Maize Futures Contract has been traded since 1996, maize (known as 'Corn' in the USA) was first traded in Chicago as a futures contract in the mid 1800's (TKFutures, 2010, para3). As such, there is merit in examining the issue of efficiency at this present time, so as to provide both current information on this market, and to further supplement and develop the relatively small literature base that is presently available.

This is supported by Aulton *et al.* (1997: 409) who highlight the merits of readdressing efficiency studies in light of market and communications advancements, as well as when there are improvements in technical testing techniques, that is, they suggest that the passage of time allows for a period of market learning, which may potentially result in a trend towards market efficiency. This effect is anticipated due to the fact that, prior to the disbandment of the Maize Board in 1996, the price of maize was not set by market forces of supply and demand, but rather by the Maize board itself (Moholwa, 2005: 1). Before this date, there was a high level of governmental and legislative involvement in South African maize markets and in the setting of maize prices, while after this date a more open and free market evolved into which maize futures contracts were introduced (Moholwa, 2005: 1).

Since 1996, when the South African agricultural commodity futures market was established, trading volume on white maize has increased significantly. To demonstrate the increase in the volume of maize traded in South Africa the following figures were obtained: in 1996 a total number of 3343 maize futures contracts were traded, while in 2007 a sum of 1224806 maize futures were traded (SAFEX, 2008c). This represents an increase of 36537.93% in total maize contracted (both white and yellow maize). In the graph below the trade volumes on the *white* maize futures contract are reported. In 1996 only 2179 contracts were traded throughout the year, however, in 2008 a total of 859837 contracts were traded. The highest volume of trade in white maize futures was reported in 2003 where 1155492 contracts were traded (SAFEX, 2008c).

Figure 1-1: White Maize Futures Contracts Trade Volume 1996 to 2008



Source: Data sourced from SAFEX (2008c)

In terms of expectations of increased liquidity, for example: if market trade volumes increase then so too should market liquidity and efficiency improve (Pennings and Meulenberg, 1997: 297), and recent market developments, such as the problem of rising food prices, there is an indication that studies of this nature provide a number of valuable insights for a variety of market participants. Further, from the point of view of previous literature available, at present only four papers have been written that deal with the efficiency of the South African commodity futures market, and although these are examined in full in chapter three, a brief summary follows.

The first of these was a Masters Thesis (Wiseman) and subsequent article by Wiseman, Darroch and Ortmann. in 1999, which covered market information for 1997 and 1998. The second was an Honours level thesis by Nikolova that revisited this topic in 2003 and covered the market prices from 1997-2002. The third was a study done as part of a Masters program by Moholwa in 2005 where the weak-form efficiency of white and yellow maize in South Africa was tested. The most recent study was the one by Phukubje and Moholwa in 2006; however, these authors did not examine the white maize market focusing instead on wheat and sunflower seeds contracts. Due to the small data sets and absence of certain statistical methods (the most important of these being the exclusion of an error correction model) from these studies, there is definite value in the reexamination of this particular futures markets efficiency using a more extensive data set and additional statistical techniques. Further, this will be the first South African efficiency study to use the historical spot prices provided by SAFEX, as this is a relatively new feature provided by SAFEX. In contrast, data for earlier studies was obtained from a number of different sources, or through the application of the convergence property (this is discussed in detail in chapter two). Given recent concerns regarding volatile commodity prices plus the availability of improved price data, an expanded study of the market efficiency for white maize is justified.

1.2.1 Core Research Problem

The core research problem of this study is presented below:

- To test whether or not the futures market for white maize is efficient.

1.2.2 Additional Research Objectives

In a continuation of the points discussed in the previous section, a statement of the key objectives to this study can now be summarized in the following set of statements. Beyond testing for market efficiency, the following are additional goals of this study:

- To test the spot price and the futures price individually for stationarity.
- To test for cointegration between spot and futures prices for white maize.
- To describe the relationship between the spot and futures market in terms of both long-run and short-run behaviour.
- To comment on the presence of a price discovery relationship in the South African futures market for white maize.
- Although not directly related to the core research problem, if possible the point of price discovery in the South African futures market for white maize will be found.

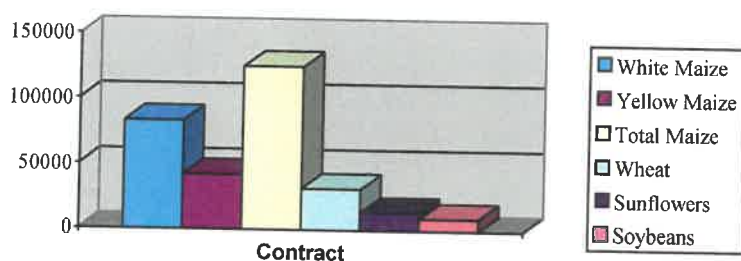
1.3 Scope and Method of Study

This study will be limited to an examination of the South African agricultural commodity futures market, with specific reference to the futures contracts on white maize. In terms of time frame, the scope of this study will cover most of the period that this market has been functional; it excludes only the last few contracts of 2009 and those that have expired in 2010 as the data set was finalized mid-2009. This results in a sample period spanning from 1996 until mid-2009.

The decision to limit this study to the examination of maize futures contracts is justified by the fact that if any level of efficiency is going to be found, theory suggests that this is more likely to occur in liquid and highly traded assets (Pennings and Meulenberg, 1997: 297). Results from thinly traded markets may reflect a lack of trading opportunities rather than an absence of price discovery or other market efficiencies (Fedderke and Joao, 2001a: 3). In the South African commodity futures markets, white maize contracts are the most traded (SAFEX, 2008b), and consequently most liquid, which makes them the appropriate choice for this study. The relative importance of a futures contracts can be distinguished by the level of liquidity and trade volume that the contract experiences.

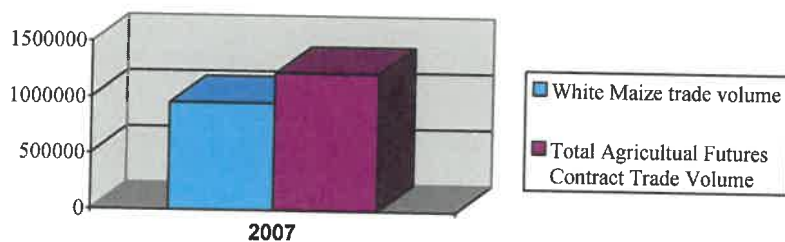
In South Africa, the Agricultural Products Division incorporates six main future contracts that are traded at present, these are namely: white maize, yellow maize, second grade maize, wheat (traded since 1997), sunflower seed (traded from 1999), and soybean (traded from 2002). In terms of yearly volumes, trade in white maize accounted for the majority (956026) of the 1224806 contracts that were traded in 2007, and in every year since the introduction of maize contracts white maize has formed the significant portion of total maize futures trade (SAFEX, 2008c). These trade statistics are given in Figure 1-2 below. To demonstrate this further, in August of 2008 a total of 180104 futures contracts were traded on agricultural products on the South African Commodity Futures Market, of these trades, 125112 were white (83034) and yellow (42078) maize contracts in comparison with 9433 contracts on soybeans, 13855 contracts on sunflowers and 31704 on wheat contracts. A brief look at volume data shows that maize is consistently traded at higher levels than other agricultural commodities (SAFEX, 2008c). These figures are presented in Figure 1-3 below.

Figure 1-2: Comparison of Trade Volumes by Contract in August 2008



Source: Data Obtained from SAFEX (2008c).

Figure 1-3: Comparison of Trade Volumes by Contract for the Year 2007



Source: Data Obtained from SAFEX (2008c)

In addition, South Africa is the largest producer of maize in the Southern African Developing Community (SADC) and SAFEX is the largest futures exchange for white maize in the world (Auret and Schmitt, 2008: 104), hence its performance is of particular relevance. South Africa is also unique in that SAFEX trades both white and yellow maize, whereas most other commodity futures exchanges only trade yellow maize (Auret and Schmitt, 2008: 105). SAFEX is also the largest maize (white and yellow) futures exchange in Africa (Auret and Schmitt, 2008: 105).

This study will be a quantitative investigation, which will employ a wide range of statistical methods specifically designed for the examination of time-series data sets. The statistical study begins with tests on the data for the presence of stationarity through the application of unit root tests to the individual time series. Cointegration techniques, namely the Engle-Granger and Johansen's methods, are used whereby the residuals of the equation representing the relationship between spot and future prices are extracted and then tested for the presence of a unit root. The relationship between spot and futures prices is examined in order to determine if a cointegrating long run equilibrium relationship exists between these two variables. Once the presence of a cointegrating relationship between these variables is ascertained, an error correction model is then applied individually within each cointegration methods. For the Engle-Granger technique an error correction model is formed, while in the Johansen's framework a vector error correction model is derived. These models are used in order to explain the short run deviations from the long run equilibrium found through the occurrence of a cointegrating relationship, and to analyze whether price discovery is present, and if so, is the point of price discovery the spot or the futures market.

Establishing that a market is efficient requires firstly that the spot and futures prices display a cointegrating relationship, and secondly that certain restrictions on that relationship are present. In order to ensure that a finding of cointegration is correct both the Engle-Granger and Johansen's methods are applied, while in the second stage of efficiency testing it is the vector error correction model which is utilized in order to run the necessary restrictions. An introduction to some of these terms is presented in chapter 2, while the literature review of chapter 3 shows how these methods have been employed by previous studies. Chapter 4 then describes these measures fully in the explanation of this study's methodology.

Once these tests have been performed, possible extensions to the key research problem of this study will be examined. Although these aspects are not part of the question of whether or

not the South Africa futures market for white maize is efficient or not, some of the models that are used in making such comment have additional applications. For example, the error correction models used to test part of the efficiency statement may also be used to comment more fully on the presence and nature of the price discovery process within a given market. Although this aspect is not part of the key research problem, as the underlying models are already being used it makes sense to extract as much information about this market as possible. These extensions are discussed more fully later in the dissertation.

Comments earlier suggested that it is a popular comment to tie rising food prices to the behavior of the market, specifically to speculators within a given market. A finding of efficiency or lack of efficiency may possibly be linked to the behaviour of speculators so as to draw usable conclusions with regard to the South African agricultural commodity futures market. Efficiency is often attributed to the presence of sufficient speculative activity within a market, in contrast however; speculation is often blamed for rising prices. It was shown that rising prices in other commodities may be the root of rising prices in other commodities, especially in terms of rising input costs. If a commodity market is found to be efficient then this would possibly indicate that the search for the cause of rising prices may be found elsewhere, if however a market is found to be inefficient the behavior of that markets participants may be called into question. This study has the potential to provide useful conclusions to guide policy makers regardless of whether or not these market participants' actions are deemed to be price stabilizing or not.

Finally, the findings of efficiency or lack thereof may have additional considerations in the context of a developing market such as this one. Kaminsky and Kumar (1990: 671) speak of two potential costs that commodity future markets have within developing countries. The first is that there may in fact exist a risk premium in these markets that may be demanded by investors in order to compensate them for the potential of volatility in the future spot price. The second cost arises when the futures price is not an unbiased predictor of future spot prices, this in turn suggests that information relevant to the market is not being incorporated as well as it could be, resulting in the potential for additional costs being associated with trading in the market (Kaminsky and Kumar, 1990: 671). This highlights the importance of this type of investigation in developing countries, and in part explains the relevance of this study within a South African context.

1.4 Plan of Dissertation

The purpose of this section is to provide an outline of the content of each of the chapters of this dissertation. Chapter one is aimed at presenting the background upon which the topic of this study is founded. This background information leads into the presentation of the research problem addressed, as well as briefing the reader on other key objectives of this investigation. A brief discussion on the methodology and extent of the study as well as a summary of each chapter is provided in order to give a practical guideline to the content and nature of the document as a whole.

Chapters two and three comprise the literature review of this study. Chapter two discusses the theory behind futures markets. The theoretical foundations of futures markets including pricing relationships and the theory of 'efficiency' are examined, as well as the implications of efficiency for all futures markets and then specifically for commodity futures markets. Chapter two thereafter specifically focuses on testing for efficiency in futures markets in order to provide a framework for understanding the literature presented in chapter three. Chapter three contains a review on previous empirical research testing for the efficiency of futures markets from, firstly, an international setting, and then from a South African perspective.

Chapter four presents the methodology employed in this study in order to test the efficiency of the South African futures market for white maize. This chapter firstly explains the data requirements and the data manipulations performed in order to arrive at the sample set used in this study. Secondly, the methodology employed is described together with the reasoning and theoretical foundations behind the choice of these methods. The results and analysis of the processes described in chapter four are then presented in chapter five. Finally, chapter six provides the conclusions to this study, including the implications the findings have for various market participants. As part of this chapter, suggestions for further research in line with, and/or stemming from this dissertation are suggested, and the limitations of this study are highlighted and discussed.

The bibliography and appendices follow the final chapter.

2. THE CONCEPT OF EFFICIENCY

2.1 Introduction

The literature on the structure and organization of an efficient market is extensive and includes a wide range of topics. This chapter is aimed at examining some of the key components related to efficiency studies. The first area discussed is that of the pricing of futures contracts. The theory relating to futures pricing has a direct relationship to efficiency studies both from a theoretical and statistical viewpoint.

A description of an efficient market, as well as the Efficient Market Hypothesis (EMH), is introduced after the discussion on pricing relationships, following which the nature of efficiency in futures markets and commodity futures markets is investigated. The latter part of this chapter reviews the roles that market participants play in a futures market, highlighting some theoretical associations speculators have with market efficiency.

2.2 Pricing Futures Contracts

If one were to purchase a commodity in a cash market, the item traded would be that commodity, however, in a futures market the item traded is the futures contract and not the actual commodity that underlies the contract (Dagan, 2002: 14). In any given futures market the terms of the futures contract are all contained in the contracts terms, the underlying commodity and volume thereof, as well as the delivery date(s) and location are all predefined by the contract itself (Dagan. 2002: 10 and 14). This use of set terms is characteristic of a futures market, that is, the futures market is seen to be a more liquid and standardised form of the less formal market for forward contracts given the fact that, in contrast to forward contracts, futures contracts are depersonalised, they are guaranteed by the futures exchange the contract is offered on, margins and clearing-houses are used, and the contracts are traded on public platforms (Brown and Reilly, 2009: 730).

Although futures contracts are seen to be standardized financial instruments, the one aspect of these contracts that is *not* set at a constant level is the current trading price of the contract (Blank, Carter and Schmiesing, 1991: 16). Futures prices are determined from available market information such as expectations of the supply and demand of the underlying commodity in a domestic and international setting (Geyser and Cutts, 2007: 295-296), and

due to this the futures trading price will fluctuate as news enters the market (Dagan, 2002: 16).

It is expected that the spot price of an asset will converge with the futures price as the expiration or delivery date of the contract approaches (this process is known as the 'convergence property', and this occurs regardless of the underlying asset of the contract (Dagan, 2002: 41). If this were not the case then arbitrage opportunities would exist. In fact, the futures and spot prices are forced to converge by market participants trading in futures in order to attain profits (Blank *et al.*, 1991: 85). This can be more simply explained by saying that the difference between the spot and future price of a futures contract will become smaller and smaller as the time of the contract's maturity date approaches. According to Lofton (1997: 132) this difference essentially becomes zero during the period that delivery is to be enacted.

Blank *et al.* (1991: 69) continues this discussion on the convergence property by stating that futures prices reflect expected spot price changes, so if new information enters the market then the futures price on a given contract should adjust to reflect this. When market data is difficult to obtain, the theory of convergence theory allows the maturity futures prices to be linked to the spot prices prevalent at that contract maturity, and this theory may be applied by studies where historical price information was not readily available. Dagan (2002: 41) also shows that, because this behaviour is widely expected by the market, it will influence the relationship between spot and futures prices throughout the contracts' life.

The price of a futures contract, as well as the spot and expected future spot rates, is an important component of any market efficiency statement due to the fact that efficiency studies use the relationship between spot and future prices to infer the state of efficiency present within a given market (Santos, 2009: 6). The law of one price is the foundation of commodity market price relationships; this theory demonstrates that all other prices on a commodity, through a process of price adjustment for storage, transport and processing costs, are related to the spot price (Blank *et al.*, 1991: 64).

Cox (1976: 1216), citing Telser (1958: 1967), explains that the price of a futures contract can be described as representing the average expectations of the spot price that is likely to exist at that future date, and in the case of storable commodities these expectations will factor in the potential costs of storing that commodity from the time of contract purchase to time of

contract sale or contract delivery. When the market price being described includes a relationship between present time and some future date then the idea of efficiency becomes more complex as it will become necessary to consider these additional factors such as storage or interest expenses. Marshall (1989: 51) provides an explanation for this phenomenon by showing that futures contracts bind the purchaser for some amount of time and consequently, at the very least, there will be some time related constraint present.

When examining the pricing of futures contracts it should be noted that commodities will generally fall into one of two categories, they will either be a commodity that can be stored until contract delivery, or one that need not be stored to contract delivery (Dagan, 2002: 37). Further, commodities that are described as storable are usually subdivided further into those that are affected by seasonal demand and supply (for example agricultural commodities such as maize or wheat), and those that are not, such as precious metals (Dagan, 2002: 37-38).

It is noted by Hudson (2007: 86) that products that are storable are subject to two price effects as a result of their storability. Namely, due to the existence of the product in storage facilities, which helps smooth out any demand inconsistencies, the price of that commodity should be lower than if no such facility existed. Secondly, when the current supply of the commodity is relatively large, the demand for that good for storage will also increase with an increase in current demand for the good, which should lead to an increase in the current price of the commodity greater than what would be expected if a storage facility was not available. The overall result on the prices of storable commodities is a reduction, but not elimination, of price volatility (in comparison to the level of variation that would be expected if stores were not available). In addition, the storage function further provides a link between supply and demand in both spot and futures markets (Hudson, 2007: 86).

The nature of the commodity being traded through a futures contract, especially in terms of its storability, is one feature that has been clearly included into a well-defined model of the pricing relationship between spot and futures prices, namely: the cost-of-carry model, which is also known as the spot-futures-parity theorem, or the theory of storage. This model is acknowledged to be the dominant model of pricing futures contracts associated with storable commodities (Dagan, 2002: 38) and it was provided by Working (1949: 1254-1255). This theory focuses, not on the relationship of risk transference between hedgers and speculators as do the ideas of normal backwardation and contango (discussed later), but rather on the inter-temporal price relationship where the spot and future price are related through the net

cost of carrying a commodity through time. Marshall (1989: 241) explains that this model captures, "the cost of carrying a stored commodity forward in time." Being able to calculate the carry cost allows for futures contracts to be fairly priced, that is, the fair price will be that which under normal circumstances prevents arbitrage opportunities arising (Van Zyl, Botha and Skerrit, 2006: 394).

In the context of agricultural commodity futures, where the time difference can be described as two different delivery dates – one now and one in the future (Working, 1949: 1256), the basis (or cost of storage) that arises from holding the commodity through this period of time needs to be understood too. "The terms cost of carry (or 'carrying charges'), 'basis', 'spread', and 'theory of storage' are interrelated" states Dagan (2002: 41). The relationship between the spot price and futures price will depend on this cost (Working, 1949: 1256). The basis (cost of storage) will change throughout the life of a given contract due to changes in any of a number of factors such as availability and cost of transportation; availability of storage; the price and availability of substitutes; and, the price expectations with regard to prices in the spot and futures markets (Blank *et al.*, 1991: 81).

The cost of storage (or carrying cost or carrying charge) is related to four components, namely: (1) the physical costs of storing a commodity such as warehousing fees; (2) transportation costs, (3) insurance costs, and (4) financing costs. Together costs (1) through (3) account for the physical costs of carry and, depending on the underlying commodity; these costs can be negligible (for example investing in share futures) or significant, for example for trade in live cattle. Financing costs may refer to the rate incurred on borrowed funds, or the opportunity cost associated with not having used that money elsewhere (Dagan, 2002: 43).

Blank *et al.*, (1991: 74) suggests that there is also some adjustment for risk aversion on top of the physical costs of carry; and, the effect of the convenience yield. The risk aversion factor is related to those that hold inventory, when larger amounts of inventory are held these inventory carriers are taking on additional risks that should be compensated for with a risk premium (Ward and Dasse, 1977: 72). The specific inclusion of a risk premium was a major contribution from Keynes' work and this is discussed more fully below where different pricing relationships are detailed.

Dagan (2002: 43) has the following to say on convenience yield: the convenience yield refers to the advantage that may be gained from holding onto additional units of a commodity rather than keeping cash aside for purchasing said commodity at a later date. Advantages of this instance include the ability to meet unexpected demand in periods of a shortage in that commodity. As this advantage will only be realised in instances of insufficient supply, during normal market conditions this aspect gives no value to the holder, however, when supply decreases convenience yields to the holder will increase, that is, the theory of storage indicates that the convenience yield should have a negative relationship with inventory levels of the commodity (Fama and French, 1987: 56) and it follows then that this measure will be higher when there is a greater possibility of shortages existing in the future for a given commodity (Hull, 1998: 69). The presence of a convenience yield represents a positive value, the advantage of carrying a commodity through time, and due to this it is deducted from the overall cost of carry (Dagan, 2002: 43), that is, the convenience yield is subtracted from (it decreases the effect of) the physical costs and risk aversion factor to arrive at the net carry cost (Blank *et al.*, 1991: 74).

These items mentioned above together form the differential that is used to explain the variation between spot and future prices (Brenner and Kroner, 1995: 25). That is, the relationship between spot and future prices is affected by the value of the differential or basis. The basis is considered to be the principal measure through which spot and future prices are related (Blank *et al.*, 1991: 81), and for this reason the basis provides one of the components used in the statistical tests examining efficiency.

It has been established above that there is a relationship between spot and futures prices, and that changes in spot and futures prices should be related through the basis as described above. Given that this is so, there is call for the nature of this relationship to be examined in more detail. Earlier it was stated that the concept that the futures price should equal the expected spot price at maturity may be applied to all future contracts. The expected spot price will depend on the markets' expectations of demand and supply, and if the commodity is one that must be stored, those expenses would also be accounted for in this pricing relationship.

In general, if the futures price is increasing through time (earlier maturities have lower prices than later maturities) this is known as a positive carrying charge market and this difference represents the amount the market is willing to pay for the commodity to be stored (the price of storage). In contrast, if futures prices are decreasing as maturity increases this shows that the market associates a discount with commodity storage (there is more incentive for the commodity to be delivered sooner rather than later). This price pattern is known as an inverted market (Blank *et al.*, 1991: 70). In fact, Working's cost of carry model described earlier was derived in an effort to describe the seasonal behaviour of spot and futures prices for agricultural commodities, especially in the face of an inverted market (Dagan, 2002: 56).

There are three additional versions of expected price relationship within a futures market; the summary of these is taken from Brown and Reilly (2009: 772) and additional information is referenced in text as necessary. These pricing relationships are namely:

- (1) The *pure expectations hypothesis* holds that, on average, the futures price will equal the expected spot price and in this scenario the futures price will act as an unbiased forecast of upcoming spot prices;
- (2) *Normal backwardation* refers to a situation where the futures price is less than the expected spot price giving rise to a scenario where, 'a risk premium in the form of a lower contract price would be necessary to attract numbers of [traders].' This refers to the situation that arises when a positive carrying charge is present but the difference in price is insufficient to cover all relevant storage costs that would occur in that time frame (Blank *et al.*, 1991: 71). The theory of normal backwardation originated from Keynes (Dagan, 2002: 65), and his explanation for these price pattern anomalies is that hedgers must compensate speculators for the risks (such as price risk) that speculators assume when investing in futures contracts. This situation arises when hedgers going short in the market outnumber those hedgers going long, and thus a lower contract price is needed to attract more speculators into taking long positions (Brown and Reilly, 2009: 772 citing Keynes (1930) and Hicks (1939)).
- (3) A *normal contango* market refers to the opposite scenario where the futures price is higher than the expected spot price, signalling that it is the purchaser of the commodity who is hedging, for example the miller ensuring he can obtain maize in the future at a set price is willing to pay a higher futures price to reduce price uncertainty (Dagan, 2002: 65).

Relationships (2) and (3) speak of the idea of risk management and hedging strategies, while the cost of carry theory deals specifically with the relationship between spot and futures prices across time. These pricing relationships are not necessarily entirely separate, as the idea that the futures price should equal the expected spot price (given in (1) above) will apply to storable commodities too, that is, futures prices should be predictors of subsequent spot prices such that the futures price at time t equals the spot price forecast at time t such that $F_{t,T} = E_t(S_T)$ in both storable and non-storable commodities, that is, even in the presence of different carry costs associated with different assets the underlying principle of this relationship should remain true (Dagan, 2002: 38-39, 61). If the market has this information that it should be incorporated into prices and hedging behaviours.

The relationship between spot and future prices is thus an important one, firstly in the context of pricing models and secondly, in the testing for market efficiency. An understanding of the first will lend a deeper level of understanding of the latter. The actual calculation of futures prices is then a mathematical approach where the spot price is adjusted for the carry cost to arrive at the futures price and any deviation from this fair price will be seen as an opportunity to make additional profits (Van Zyl *et al.*, 2006: 395-397). This fair value may not be one exact figure due to the presence of certain market constraints such as transaction costs; however, there is a range that the fair value of a futures contract will fall within. Any movements of the price outside of these bounds will indicate the possibility of arbitrage opportunities. Within a more liquid market, and/or a market with lower transaction fees, this fair price range will be narrowed (Van Zyl *et al.*, 2006: 397). Hedging and other market activities may then be based on these prices.

2.3 The Efficient Market

Having examined the theory on pricing futures contracts above, and referring back to the introduction where it was stated that efficiency between spot and futures markets relates to how quickly information is reflected into both the spot and futures markets for a given commodity, the next relationship that needs to be considered is the concept of an efficient market. Markets are said to demonstrate efficiency if information available to market participants is fully incorporated into prices. This information can include numerous items, although some commonly cited examples are financial statements and company announcements such as declarations of earnings or takeover attempts (Firer, Ross, Westerfield and Jordan, 2004: 375).

The Efficient Market Hypothesis is one theory that attempts to answer the question of whether markets themselves, through the actions of an “invisible hand,” make optimal use of available information (Figlewski, 1978: 582). This theory essentially states that at any given time the price of an asset will fully reflect all available information (Leng, 2002: 2). According to Teweles and Jones (1974: 95) an efficient market occurs when a large number of equally informed and competitive market participants behave in a manner aimed at maximising their profits earned. In this type of market at any given time it is expected that all information, as well as any expectations of upcoming events, will be reflected in the quoted prices.

Marshall (1989: 261) gives an alternative description of efficiency in markets, namely:

“...a market is efficient if new information is fully ... reflected in price. ...this definition means that market prices adjust to new information rapidly and completely, and that these adjustments are, on average, correct so that the adjusted prices are market clearing.”

Most discussions regarding market efficiency begin with Fama’s 1970 article, “Capital Markets: A Review of Theory and Empirical Work” which introduced the Efficient Market Hypothesis and the concept that three sub-categories of efficiency exist, namely: strong-form, semi-strong form and weak-form efficiency. Fama’s article has been extensively debated and because of this, this study will deal mainly with the implications of Fama’s study to this particular study, such as addressing the question of which form of market efficiency to use and the implications of that choice in terms of statistical and empirical work. Fama (1970: 388) presents three forms of market efficiency, in which the classification of “information” is more clearly defined for each form.

Weak-form efficiency encompasses the scenario where current prices only reflect information that is contained in historical figures (that is, information that is readily available to all market participants). Within a semi-strong form efficient market, it is expected that prices reflect all published information that is clearly available to the public (Wang and Ke, 2002: 4). Fama’s (1970: 388) description is more in depth and describes this efficiency as including an observation of the rate at which prices adjust to other clearly available information (for example: company publications such as reports; or those from market periodicals such as the business news section of the Financial Mail).

The concept of strong-form market efficiency describes a scenario where asset prices reflect all possible information, including so called 'insider information' (Bodie, Kane and Marcus, 2003: 265). This means that prices are exactly as they should be, that is, they are fairly priced. These prices will only change when new events/news occur. Fama (1970:388) describes this type of market efficiency as market participant(s) having, "...monopolistic access to any information relevant for the formation of prices..."

The EMH, in all of its forms, is often used as the foundation of efficiency studies because, as Zulauf and Irwin (1998: 309) note, although there exists a considerable amount of literature to fuel the debate with regard to how deeply the EMH holds, it is still the foremost hypothesis applied in efficiency studies in order to judge and analyse market behaviour. Further, the question of whether or not a market is an efficient one is important. The reasons for this are examined next.

2.4 The Importance of Efficiency in Futures Markets

The reason that the term 'efficient market' is extensively covered in literature (a review of the literature on this topic is contained in chapter 3) is due to the fact that futures markets provide a number of important functions (Phukubje and Moholwa, 2006: 199) to market participants, certain of which require an efficient market environment for that function to be utilized at an optimal level. As this study examines the South African commodity futures market, the relevance of these market functions to commodity futures markets are discussed in more detail below.

Futures markets are used as a tool for the management of price risk for farmers, traders and food processors (that is, other market participants), as they aid in price discovery (Auret and Schmitt, 2008: 105) and they provide a means of price prediction (Phukubje and Moholwa, 2006: 199). Moholwa (2005: 2) states this more completely showing that market participants are also able to use futures markets for hedging practices; as a risk management tool; as a market for speculation and liquidity; as a means to store a number of different commodities; and as a means by which to reduce volatility and uncertainty of investments, sales and purchases.

Futures markets perform many functions, however, it is the roles of speculative trading, hedging and arbitraging activities that are seen as the most important (Fedderke and Joao, 2001a: 1 and Dagan, 2002: 22). 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 provided, 'to the coordination of economic activity.' Feng, Liu, Lai and Deng (2007: 1) state the same roles as being central, referring to price discovery and then to the hedging function of futures markets. As hedging is a risk transfer activity these are discussed together in 2.4.2 below.

Especially in developing markets, there are two main potential costs of using futures markets, the costs of a risk premium, and the potential costs of market failure when bias exists (Kaminsky and Kumar, 1990: 671). These authors discussed the fact that these costs are reflected in the functions futures markets provide to market participants. That is, the role of the futures market is a forecasting one where futures prices should indicate upcoming spot prices without bias (discussed in 2.4.1 below) and the risk premium is associated with the role that futures markets should provide as a method of risk diversification (discussed in 2.4.2). . "Price discovery is an information-based contribution made by futures markets, whereas hedging implies a transactional role for futures markets (Dagan, 2002: 23)

2.4.1 Price Discovery

Price risk is described by Phukubje and Moholwa (2006: 199) as the risk associated with the possibility that prices, costs and/or pricing relationships will change during the period of time that stretches from the starting point of when a decision is made to the ending point where the result of that decision is realised, for example decisions made before planting season for the time of harvest. The clearest example to show this is that a farmer chooses to plant certain crops now, and although he is able to ascertain the current price on that good, there is a risk involved that, by the time the produce is ready for market, the price of that good will have changed.

Mahalik *et al.* (2009: 3), Srinivasan and Bhat (2009:29) and Fedderke and Joao (2001a: 1) all state that price discovery is one of the most important roles that futures markets play. Price discovery is described by Hasbrouck (1995: 1175) as the behaviour of asset prices in response to new information, which can be further explained as the effect of supply and demand forces on asset price. Mahalik *et al.* (2009: 3-4) give two alternate definitions of

price discovery stating that, “price discovery refers to the use of futures prices for pricing [spot] market transactions or price discovery means that the futures price serves as [the] markets expectations of subsequent spot price.”

That is, in an efficient market the futures price will be the expected future spot price, and so in this instance, market participants are able to use futures prices as a forecast tool for the prices expected to prevail in the future. This allows market participants to make informed decisions with regard to price behaviour in the face of the markets expectations regarding upcoming supply and demand conditions (Dagan, 2002: 22). This role is also commonly referred to as the ‘informational role of futures markets’ (Dagan, 2002: 22). To return to the previous example of the farmer, prior knowledge with regard to price behaviour will enable the farmer to make optimal production and crop planting choices.

...To relate this concept back to the pricing relationship Mahalik *et al.* (2009: 4) discuss the fact that the implication of price discovery in a given market is that there exists an equilibrium price and that the process of price discovery within the market will describe how news events are transferred between the spot and futures prices. The presence of an equilibrium price as described by the price discovery role further implies that the futures and spot markets of a given commodity will have some short-run and/or long-run relationship. This has the additional implication that futures prices should be fair predictors of expected spot prices (Dagan, 2002: 23).

The presence of such a relationship suggests that should disequilibrium occur then one or both of these markets will adjust in order to bring the relationship back to equilibrium. The question of which market moves to correct the disequilibrium is a vital part of describing the price discovery function of this market (Srinivasan and Bhat, 2009: 29). Either the spot market or the futures market, or some bilateral combination of the two may correct for disequilibrium; and, although it is commonly cited that the futures market is the point of price discovery (new information is reflected here first), Mahalik *et al.* (2009: 4) state that this has not always been found to be so in empirical studies. Ferret and Page (1998: 73) present Wahab and Lashgari’s (1993) paper as one that found that the spot market might lead the futures market.

Srinivasan and Bhat (2009: 29) present the following discussion on the theory behind the futures market leading the spot market; and the spot market leading the futures market:

“The main arguments in favour of future market leads spot market are ... due to the advantages provided by futures markets ... higher liquidity, lower transaction costs, lower margins ...[etc]. Such advantages attract large informed traders and make the futures market to react first when market-wide information...arrives. On the other hand, the low cost of contingent strategies and high degree of leverage benefits in futures markets attracts larger speculative traders from a spot market to a more regulated futures market...this ultimately reduces informational asymmetries of the spot market by reducing the amount of noise trading and helps price discovery, improve overall market depth, enhance market efficiency and increase ... liquidity. This makes the spot market to react first when market-wide information ...arrives. Hence, spot markets lead futures markets. ... there exists a bi-directional relationship between the futures and the spot markets through the price discovery function.”

Ferret and Page (1998: 73) suggest another possible explanation for the spot market leading the futures market on a given commodity, namely that changes in the spot market may form part of the information that futures traders use to make decisions, and so, changes in the spot price may influence futures traders and in turn affect futures prices. Further, Leng (2002: 3) states that futures markets in developing countries and emerging markets may not display as high a level of informational efficiency as other more developed markets. Due to this it may result in the price discovery process running in a direction opposite to that expected, that is from the spot to futures instead of the more commonly cited futures to spot.

For a market to be efficient any possible information that will affect market prices must be immediately reflected in both spot and futures prices simultaneously resulting in a scenario where arbitrage opportunities will not be present (Srinivasan and Bhat, 2009: 29). It is due to this that a discussion on price discovery should be tied to any discussion on market efficiency, especially as the underlying statistical methods to determine one may be used to describe the other.

Inefficiency implies that there has been a mispricing of the futures contract relative to the spot price (Leng, 2002: 15). Further, in order for markets to fulfil their function as a point of price discovery it is necessary that the market be efficient (Antoniou and Holmes, 1996: 116). Yang, Bessler and Leatham (2001: 285) state that the importance of futures markets in this price discovery function may depend on the futures markets' relative efficiency. The details of market efficiency are expanded on in 2.5 below.

2.4.2 Risk Reduction

The transfer of risk, management of risk, or use of hedging activities, refers to market participants using hedging strategies within the futures market in order to shift price risk from themselves to other parties (Mahlik *et al.*, 2009: 3). "The terms 'hedging role/function' and 'risk-transfer role/function' are essentially synonymous and the analogy to 'insurance' is commonly made" (Dagan, 2002: 22).

The role that futures markets play in hedging activities is a varied and extensive one. According to Marshall (1989: 53) "hedging reduces the uncertainty involved with production, consumption and financing decisions...[and] such reduction improves the efficiency with which resources are allocated and utilized...[which] can lead to greater output of goods and services, lower prices and greater welfare for society as a whole." Futures markets initially played an important role in providing commodity buyers and sellers with a liquid market where, through the application of hedging activities, these market participants could decrease the amount of price risk faced (Blank *et al.*, 1991: 26).

The purpose behind any hedging activity is to reduce the risk faced by the hedger (Hull, 1998: 79), and as such, the ability of futures markets to provide a risk-reducing activity is an important one that draws a number of market participants that would not previously have engaged in this market to do so. The logical result of this behaviour is an increased number of futures trades that consequently improves market liquidity, which in turn theoretically improves the efficiency of the given market. From an agricultural point of view there are a number of factors that create risk for the suppliers (farmers) and hedging on an appropriate exchange may allow for a level of risk reduction.

Hedgers include individual persons and corporate entities that use future contracts in order to set a price for the asset required at some future point in time. This market participant is simply trying to protect against risk exposure from negative changes in the market. In fact, futures markets were originally designed in order to meet the requirements of hedgers (Hull, 1998: 6). Hedgers are willing to pass up opportunities to benefit from favourable price movements in order to have protection from unfavourable price movements, that is, farmers wish to set the price they will sell at and traders wish to set the price they will purchase at.

In South Africa the Agricultural Market Division of SAFEX has experienced a decrease in the number of futures contracts that are held through until delivery (SAFEX, 2008b), indicating that this market has moved away from being a meeting place of hedgers alone. The decrease in delivery contracts indicates an increased use of this market for speculative or profit seeking market participants. This phenomenon of increased trade volumes and speculative activity can be partly attributed to the fact that technological development enables a larger number of futures markets to exist. These in turn offer an increasingly wide variety of contracts, which further allow for an increasing number of trades on these futures to be made on a daily basis (Newbery, 1987: 291). Thus liquidity is an important factor in market efficiency and its usefulness in hedging activities.

2.4.3 Liquidity

In order for these markets to be used as a risk reduction tool, it is necessary to examine some of the characteristics that are required within a market environment for these activities to be able to occur. For the financial instrument itself, Roehner (2002: 66) identifies five core factors that are necessary for any financial product, including futures, to be successful in a market environment. These are: firstly, a high volume of trade in the product; second, the standardization of the product; third, for there to be significant profit making opportunities available; fourth, for the product to be supported by a secure and significant exchange, and; lastly, for the product to be tied to the trading behaviour of market participants.

Liquidity is one market characteristic that helps ensure that the above-mentioned activities can occur. Liquidity within futures markets is governed by a number of factors. Even certain contract specifications may affect the liquidity of a given futures contract, for example: contracts that are traded often will generally demonstrate greater liquidity than those that are infrequently used. A futures market may be described as a liquid one if market

participants are able to quickly buy and/or sell futures contracts without that market being unduly affected by price changes as a result of these transactions (Pennings and Meulenberg, 1997: 296).

The importance of market liquidity is highlighted by Pennings and Meulenberg, (1997: 296) where they state that hedgers face a higher level of liquidity risk (the risk of incurring additional transactions costs through being unable to move into (out-of) a futures position in order to either prevent losses or to maximise profits) when markets are thin/not sufficiently liquid. From a pricing perspective, thin markets are undesirable in that it becomes more likely that larger contract orders will disturb equilibrium prices.

Pennings and Meulenberg (1997: 297) provide two key points to consider, both of which are relevant to the South African setting of this study. Firstly, as the number of futures contracts traded increases the market becomes increasingly liquid; and secondly, they emphasise that the degree of liquidity experienced by the market is an important underlying component of market functionality. It follows that more liquid markets will be more likely to experience efficiencies than markets associated with thin trade. Aulton *et al.* (1997: 422) support this view stating that inefficiency is more likely to be present in markets that are illiquid with thin trade volume.

Another aspect to be addressed in examining market efficiency is to be able to determine where efficiencies are most likely to be present. Cox (1976: 1218) discusses the effect that the introduction of a formal futures market will have, namely: the costs of trading should decrease as the trading process is centralized and thus searching for and identifying other agents, as well as finding better offers becomes easier; and, contracts are easier to negotiate. Overall this should result in more people entering the market and this in turn results in more information being available.

All three of these roles are considered vital functions of a futures market; what still needs to be addressed is the fact that these functions work best when the underlying market is an efficient one, for this reason, the next section examines what is meant by an efficient futures market.

2.5 Efficiency of Futures Markets

In chapter one it was shown that futures markets will be different to purely cash markets in how new information is incorporated into prices, and it is because of this that the concept of market efficiency needs to be reexamined in the context of futures markets. In spot markets, efficiency implies that the underlying asset is correctly priced. In futures markets, however, the efficiency of futures market prices are more complex than straight spot prices due to the fact that there is a time component that exists between the spot and future price of a given asset, which must be accounted for. It was also highlighted in 2.4.1 above that one of the most important roles provided by futures markets is that of price discovery and that this role is tied together with market efficiency.

Yang *et al.* (2001: 281) speak of two main concepts that are addressed when looking at the relationship between futures and spot prices, namely: the unbiasedness hypothesis and the prediction hypothesis. The question of whether or not futures prices are unbiased predictors is covered by the unbiasedness hypothesis (Yang *et al.*, 2001: 281). The prediction hypothesis questions whether or not futures prices are fair predictors of future spot prices, that is, does the futures market enable price discovery and not the spot market.

Marshall (1989: 263) and Antoniou and Holmes (1996: 116) explain that when the EMH is applied to futures markets the implied relationship between spot and future prices, given the information available at that time, is that futures prices are unbiased estimators of expected future spot prices, thus making abnormal profits from speculative activities impossible to attain. In testing for efficiency one is looking at a joint hypothesis of the market being not only efficient but also unbiased (McKenzie and Holt, 1998: 1). A futures price will be both efficient and unbiased when a given futures price equals the expected upcoming spot price it is associated with (Santos, 2009: 2). It would be preferable to be able to test for unbiasedness separately, however, it is difficult to separate efficiency and bias (it is desirable for information to be unbiased for true efficiency).

Santos (2009: 6) further explains that due to the fact that this idea of unbiasedness requires both efficiency and risk neutrality, if an empirical study is unable to show that a given market is unbiased then it may be concluded that, "either the market is efficient and [market participants such as] ... traders are risk averse, or the market is inefficient (regardless of whether traders are risk averse)."

If weak-form market efficiency is assumed then the testing procedure is attempting to show that historical spot and future prices will not help market analysts to form opinions on future price expectations that would enable abnormal profits to be earned. That is, if the futures market is weak-form efficient and reflects all the information that is contained in historical prices, futures prices can be used to accurately predict *expected* future spot prices (Nikolova, 2003: 23).

If markets are semi-strong form efficient we would expect the same - that the futures price on a given contract would be an unbiased predictor of the spot rate that will prevail at that date. With semi-strong efficiency the testing process would be more narrowly defined as this efficiency form requires that *all* publicly available information be included in prices. From an empirical point of view, however, it makes sense to start with testing weak-form efficiency, and only if market efficiency is found under those conditions would it then appear logical to test a higher form. This is supported by Aulton *et al.* (1997: 410) who state that testing for weak-form efficiency is the most widely tested form of efficiency and an appropriate starting point for efficiency studies.

In terms of strong-form efficiency it is implied that the price of a futures contract is exactly what it should be as *all* information, including insider information, is incorporated (Fama, 1970: 388), the exhaustive nature of this efficiency form makes it rarely used in empirical work.

The core concept of efficiency does not change when applied to commodities: the commodity futures market will be efficient if futures prices take into account all available information (Kaminsky and Kumar, 1990: 672). A more exact definition of efficiency within commodity futures markets is provided by Wang and Ke (2002: 2-3) where they describe efficient commodity futures markets as markets in which the prices in the futures market provide efficient information to agents allowing them to formulate appropriate spot prices, this in turn removes the possibility that trading behaviour and/or trade techniques can be used to generate profits. The price that exists in this efficient commodity futures market will be the equilibrium price.

A finding of an inefficient commodity futures market may have some logical explanations. For example: Srinivasan and Bhat (2009: 29) discuss that there are many real world influences, which they refer to as, 'market frictions,' that may affect the relationship existing

between spot and future prices such as transaction costs, margin requirements and liquidity differences. Avsar and Goss cited in Bowman and Husain (2006: 65) suggest that findings of inefficient markets may be as a result of the given market being either, a young market in its initial development phase, or a market with thinly traded contracts.

Agricultural commodity futures have several characteristics that should be highlighted as the prices on these futures contracts are exposed to significant price variation in both domestic and international settings. Although it has been explained that controlling this variability in price is one of the functions of the futures market, for completeness sake a short discussion on some of the factors that may cause this volatility in the underlying asset are discussed.

This price volatility is explained in the following supply and demand terms by Geyser and Cutts (2007: 292). Agricultural goods are by nature subject to price fluctuations due to various short-run inelasticities in both supply and demand. Supply side influences can include the fact that these goods' yields are both relatively fixed in the short-term (for example most grains have only one harvest per annum) and that they are at risk of unpredictable weather behaviour. It is suggested by Murphy (1987: 640) that the seasonality of agricultural futures leads to a seasonal adjustment, or bias, in the price of these contracts.

On the demand side, there are a number of factors that may influence the demand for these goods (Auret and Schmitt, 2008: 107-109). Some possible explanations are that because many agricultural commodities cover basic food essentials, the subsequent demand for these products may be more likely to be sensitive to income or other changes than to changes in the underlying price of that good. The availability and cost of product substitutes will also influence price volatility (Geyser and Cutts, 2007: 295).

Maize, the agricultural commodity future focused on in this study, is a crop-based agricultural commodity (as opposed to an animal product such as live cattle/beef) and as such, the supply of this product will be seasonal in accordance with planting and harvest times (Geyser and Cutts, 2007: 292). In commodity markets especially, market liquidity is also affected by the choice of contract months (Geyser and Cutts, 2007: 295). This can be attributed to the fact that these products follow a cycle of harvest times; thus the choice of contract month is an important one in terms of how well the trade in that commodity will function (Nikolova, 2003: 5).

In examining the market for maize, the international influence in terms of imports, exports and the effect of the exchange rate, should be considered (Hudson, 2007: 86). Developing countries especially depend on the income that is generated from the export of commodities, and so the aim is to reduce excessive price changes (price risk) as much as possible in order to optimise export earnings (Kaminsky and Kumar, 1990: 670-671).

2.6 Testing Futures Market Efficiency

It is apparent thus far in chapter two that the concept of efficiency in futures markets contains two core ideas. The first being the relationship between the spot and futures prices, and the second being the implications of market efficiency. When one looks at the literature on this topic (this is done in detail in chapter three), it becomes apparent that in order to test a market for efficiency there is a fair amount of study-specific terminology that is employed.

Due to the fact that the next chapter presents a comprehensive literature review on this topic, the second half of this chapter will examine some of the specific terms and associated literature that are necessary for these theoretical concepts discussed above to be analyzed in a statistical study. Further, this part of chapter two will provide an appropriate reference point for the literature review given in three. It is necessary to highlight some common elements to this type of investigation, such as the interpretation of the efficiency model and hypothesis, the importance of stationarity in the underlying data set and the importance of cointegration between the variables in the data set. This is done in order to aide a fuller understanding of the literature review. As such, the remainder of this chapter will present the efficiency model and hypothesis, comment on the applications of that hypothesis, and speak on the nature of the underlying data set and associated issues.

2.6.1 The Efficiency Model and Hypothesis

McKenzie, Jiang, Djunaidi, Hoffman and Wailes (2002: 478) state the concept of efficiency as follows: if futures prices are unbiased predictors of expected spot rates (indicating an efficient market) then a spot price (S_t), regressed against some futures price before that contract's maturity (F_{t-1}), will show that the current futures price is expected to equal the spot price of that commodity at its maturity date. Although various studies of this nature use different symbols and notation (Lai and Lai, 1991: 567; Beck, 1994: 249; Aulton *et al.*,

1997: 411; He and Holt, 2004: 4; and Moholwa, 2005: 7), the efficiency statement remains the same.

In Carter's (1999: 232) extensive literature review on commodity futures markets theory he mentions the efficiency statement and efficiency parameter restrictions in the following form which will be followed in this study.

Written in mathematical notation this theory is expressed as follows:

$$S_t = \alpha + \beta F_{t-1} \quad \dots \text{Equation 1}$$

Where:

- α is the intercept term;
- β is the slope coefficient to the future price term;
- F_{t-1} is the future price of the commodity lagged backwards in time n weeks;
- S_t is the spot price of the commodity at time t

Written in an econometric notation (showing the inclusion of an error term) this theory is expressed as follows:

$$S_t = \alpha + \beta F_{t-1} + \varepsilon_t \quad \dots \text{Equation 2}$$

Where:

- ε_t is the random error term included in the econometric model in order to capture any variability in the data set which is not explained by the explanatory variables.

The pricing relationships described earlier in this chapter by the cost of carry model (where spot and futures prices are related to one another through the basis/carry cost) and the pure expectations hypothesis (where upcoming spot prices should be predicted by current futures prices) may be summarised in this mathematical form which shows that the spot price at time t should be equal to the futures price that existed $t-1$ periods ago. The basis or cost of carry which binds these series together is contained within the random error term. This representation can be used to examine the efficiency of a commodity futures markets as contained in the spot-futures pricing relationship.

The null hypothesis of the study for efficiency has two parts. The first is that there will be a cointegrating long run relationship between spot and futures prices as presented by equation 2. The second part of the efficiency hypothesis examines the cointegrating regression described in equation 2 and requires that the alpha and beta coefficients can be shown to take on the following characteristics, that is, within equation 2, $\alpha = 0$ and $\beta = 1$ (Lai and Lai, 1991: 569).

Although variations of these parameter restrictions exist (they are commented on in section 2.6.3 below), the version commonly applied to a pure interpretation of market efficiency (unbiased estimators and no risk premium) is stated in standard form follows:

$$H_0: \alpha = 0 \beta = 1$$

$$H_1: \alpha \neq 0 \beta \neq 1$$

These ideals of a zero risk premium and unbiased predictors can be seen to be related to the functions of the futures market described earlier where it was shown that risk reduction and price discovery are core functions provided in any futures market. Before going into detail on specific methods used in this study, it is necessary to expand on this efficiency statement, hypotheses and parameter restrictions in order to more fully understand the principles underlying the format of the econometric notation and associated restrictions.

As stated above the first step that needs to be addressed in studies such as these is whether or not the spot and futures prices in question are cointegrated. The presence of cointegration is the first requirement of market efficiency and due to this an introduction to the theory on this aspect is given in 2.6.2 below. The second requirement of market efficiency requires that the hypotheses presented above are proven to hold true, and so section 2.6.3 will examine the various applications and implications of these hypotheses. If these parameter restrictions are not met the market may not be efficient even if it has been shown through the presence of cointegration that spot and future prices move together over time.

2.6.2 Stationarity and Cointegration

Any investigation into futures market efficiency uses time-series data, that is, the data is taken at different dates within a give timeframe. In statistical analysis, of which this testing for cointegration is part of, the use of time series data has a number of unique effects that must be highlighted and considered before trying to explain the specific procedures related to cointegration testing. Thus, this section will discuss some of the implications and effects of using time series data specifically focusing on the concept of stationarity before the importance of cointegration is examined.

A stochastic, or random, process is known as a stationary process if both its mean and variance remain constant over time, and further that the covariance (or autocovariance) that exists between two time periods depends only on the lag between the two dates (Gujarati, 2003: 797). The covariance should not be dependent in any way on the time at which the covariance is calculated, that is, the mean, variance and covariance should produce the same results regardless of when they are measured (Gujarati, 2003: 797).

The reason that it is desirable that the data are stationary is that when nonstationary data sets (often seen in time series data) are regressed against each other, these regressions have the potential of resulting in a spurious regression (Gujarati, 2006: 493) where the results are misleading and potentially incorrect despite showing statistical significance (Greene, 1997: 844). Due to the fact that financial data sets are often nonstationary, regressions run on such data may find that there is some relationship between the variables when in fact they are independent, that is, one must be aware of the fact that one's results may be misleading (Greene, 1997: 844). Specifically, a spurious regression is one where traditional statistical measures no longer yield BLUE (Best, Linear, Unbiased and Efficient) results and so Ordinary Least Squares (OLS) parameters become meaningless (Gujarati, 2006: 509). This is clearly a significant problem that analysts must be aware of in order to prevent incorrect results and conclusions being drawn.

The importance of stationarity is highlighted by Lai and Lai (1991: 567) because "asymptotic distribution theory invoked to construct a test of the efficiency hypothesis relies critically upon it." If an incorrect assumption is made as to the stationarity of the series under examination, it is possible for standard statistical tests (such as the F-test) applied to

non-stationary series to be biased towards wrongly rejecting market efficiency (Lai and Lai, 1991: 567).

Earlier it was stated that for efficiency to be found not only do the parameter restrictions need to hold, but also the residual series needs to be shown to be a white noise process. A white-noise process is a type of stationary process that shows a mean of zero and which is uncorrelated over time (Banerjee, Dolado, Galbraith and Hendry, 1993: 12). Considering that a stationary process should have an unchanging mean, variance and covariance; an absence of these characteristics may indicate the presence of a trend, which may indicate that the data in question is nonstationary. A trend may contain both deterministic and stochastic elements (Enders, 2004: 229). A variable, which has a mean and variance that are time dependent, is said to show a stochastic trend (Gujarati, 2006, 501).

It is thus important to be able to identify the presence of a trend within a given data set due to the fact that, if the residual term is autocorrelated instead of being white-noise, the ideal of efficiency within the market in question is rejected. Market efficiency requires that the error term demonstrate these white noise properties, however, it is possible for the error term to simply be stationary, which is a weaker restriction than white noise, under cointegration testing as long as the parameter restrictions (discussed in more detail in chapter four) are met (Lai and Lai, 1991: 569).

Only once the stationarity of the data set has been established and proven then the next step is to address the question of cointegration. Should the series prove to be nonstationary, as is often the case with time series data sets, one must then test that a cointegrating relationship exists between the given series, because, without this cointegrating relationship there is a real possibility that the regression will be a spurious one (Gujarati, 2006: 499). Having discussed the implications of a data series being stationary or not, the next step is to examine how a cointegrating relationship is discovered.

Cointegration is used in order to ascertain if two series have a long run relationship, as a long-run relationship must first be established before the parameter restrictions, the second step in establishing whether or not a market is efficiency, can be applied. Recall that it was stated earlier that the first requirement of market efficiency is a finding of a long run cointegrating relationship between spot and futures prices. Granger (1986: 226) explains that the test for cointegration can be thought of as a pre-test that enables the econometrician to

avoid a scenario of incorrectly applying traditional OLS testing statistics to a spurious regression, which would lead to incorrect conclusions being drawn. It is the second stage of the efficiency test which specifically looks at the hypotheses presented above.

If it is found that spot and future prices are not cointegrated then the market cannot be efficient as a lack of cointegration indicates that there is no relationship between these prices. In contrast, if it can be shown that spot and futures prices are cointegrated then the first requirement of efficiency will have been met showing that there is a long run relationship between spot and future prices, potentially indicating that the market is unbiased (Brenner and Kroner, 1995: 33).

In examining the variables in a given data set for a cointegrating relationship it is already understood that the data series being used has proven to be nonstationary. Cointegration techniques are very important in these instances where the data is nonstationary, as cointegration is a statistical methodology that is able to account for nonstationarity in the data series (Lai and Lai, 1991: 568), that is, nonstationary data sets can be regressed on one another when a cointegrating relationship exists between them. Specifically, a regression is run between the nonstationary data sets, the spot price and the futures price, in order to examine the residuals of that regression. In this instance when the data are nonstationary the estimated residuals of the cointegrating regression can be tested for stationarity (cointegration procedures) and if found to be integrated of order zero the data set can be tested and meaningful results found despite the initial finding of nonstationarity due to the fact that, despite each variable being nonstationary their combination produces a stationary result (Enders, 2004: 175 and 320).

As it is required that spot and future prices are cointegrated (tied together) in order for the market in question to be found to be efficient, the behaviour of spot and future prices as well as the basis is relevant. Brenner and Kroner (1995: 25) discuss this phenomenon in more statistical terms:

“...the results of tests for cointegration between spot and ... future prices [as will be used in this paper] depend entirely on the time-series properties of the differential. If the differential has a stochastic trend then spot and...futures prices will tend to drift apart, and they would not be cointegrated. ... If the differential is stationary then spot and ... futures prices are tied together, and they would be cointegrated.”

What still needs to be addressed is which specific methods allow cointegration to be detected, and discussing why one method may be preferred to another. The specifics of the cointegration tests is discussed in this study's methodology, for now it is sufficient to say that if a long run relationship is shown to exist between spot and futures prices, the next step involves examining the implications of the parameter restrictions shown previously, once again the specifics of actually testing these restrictions and the models associated with these testing procedures is only examined in detail in chapter four. The purpose of 2.6.2 and 2.6.3 is to act as an introduction to the terminology used in the literature review of chapter three.

2.6.3 Applications and Implications of the Hypothesis

Once the first step of the efficiency test has been proven, namely that it is found that there is a cointegrating relationship between spot and futures prices the second stage then examines the hypotheses that $\alpha=0$ and $\beta=1$. When these parameter restrictions cannot be disproved during statistical testing the implication is that; firstly, the futures price is an unbiased predictor of the spot price and; secondly, that it is then accepted that the market is efficient. Relating this to the theory, a finding of market efficiency implies that market participants are able to effectively employ the two core functions that are provided within a futures market, these being the risk reduction role and the price discovery role. Recall that earlier in this chapter the essential roles of futures markets were commented on, the parameter restrictions are in effect testing whether or not those functions are being performed.

The efficiency statement's parameter restrictions require that, not only is the intercept α not significantly different from zero and that the slope coefficient β is not significantly different from one, but that the residuals (ϵ_t) from the regression are also white noise. This would indicate that market participants have rational expectations and that they charge no premium for risk ($\alpha = 0$) in the futures market (Lai and Lai, 1991: 567). The finding of a nonzero risk premium could be due to the market costs such as transportation, rather than due to

inefficiencies or market failure. In a broader interpretation, any indication that the market is not fully efficient implies that risk reduction/hedging role and price discovery role of the futures market may not be fully utilized by those wishing to incorporate these roles into their trading/farming/investment operations, and further implies that there may be abnormal profit making opportunities available to market participants such as speculators and other risk-seeking players.

Referring back to section 2.2, where the nature of the differential in the cost of carry model was discussed, it is understood that this differential refers to the elements that are captured in the error term ϵ . Transaction costs, in statistical analysis, would be an example of one such item captured within the error term. The effect of Keynes' work which discussed the risk transference behaviour of hedgers may be seen in the requirement that there is a zero risk premium. Thus it is seen that these two approaches to futures pricing are not necessarily mutually exclusive, the representation of the pricing relationship given in equation 2 captures both the idea that futures prices should predict upcoming spot prices, and the fact that a fully efficient market will have a zero risk premium.

Yang *et al.* (2001: 284-5) clarify the significance of the differential in the following discussion:

"The validity of the unbiasedness hypothesis testing...depends on the assumption that other components of cash¹ and futures price differentials (except interest cost) are stationary variables, as captured by the constant term $[\alpha]$ ². If those components that may be captured by $[\alpha]$ (e.g. transaction costs, storage costs...) are proportional to ...prices, parameter estimates of the cointegrating vector may be affected, thus influencing the unbiasedness test results. Also, the $[\alpha] = 0$ is not imposed for testing the unbiasedness hypothesis ...for two reasons. First, there may exist a constant risk premium that may be captured by $[\alpha] \neq 0$. Second, even assuming risk neutrality...the location difference between commodity cash and futures markets may imply certain transportation costs that can also be measured by $[\alpha] \neq 0$."

¹ Cash price is an interchangeable term with spot price.

² This is the constant term used within this study.

If the parameter restrictions are not met, three possible conclusions can be drawn, namely:

- (1) the market is inefficient;
- (2) there is a constant risk premium present in the market which results in biased future estimates but which does not necessarily show the market is inefficient; and,
- (3) that a risk premium that varies with time is present in the market causing bias to arise (McKenzie and Holt, 1998: 2).

From these statements above it becomes clear that more than one version of the parameter restrictions may be applied, as the restrictions may not hold at all, they may hold in full, or only part of the hypothesis may hold. Depending on the findings of a given study specific interpretations will be discussed. For example, Zulauf and Irwin (1998: 311) note that efficiency findings have an important relationship with the trading strategies that market participants employ. If $\alpha = 0$ and $\beta = 1$, futures prices are unbiased predictors of future spot prices and there will be no benefit to be gained from using a routine strategy. If, however, $\alpha \neq 0$ and $\beta = 1$ then certain strategies may be profitable so long as the risk factor varies over time.

Wang and Ke (2002: 7) show that they consider the restriction that $\beta = 1$ the more important of the two due to the fact that α may be non-zero even when the market is efficient. Due to this they advise that these restrictions be tested separately in order to increase the depth of information that can be extracted (Wang and Ke, 2002: 13). Zulauf and Irwin (1998: 310) state that there are in fact two approaches to testing this efficiency statement: the first is the version commonly used and displayed above where $\alpha = 0$ and $\beta = 1$, and the second allows testing a situation where there is a non-zero return to bearing risk (a random walk with drift) and this is tested with these parameters: $\alpha \neq 0$ and $\beta = 1$.

In order to test for these restrictions a long run cointegrating relationship must have been shown to exist, and it is from the results of the cointegration method(s) that these restrictions are applied and tested for statistical significance. The manner in which this is done is described in the methodology of this study in chapter four.

2.6.4 The Error Correction Model

There is one final model that needs to be introduced before moving onto the literature review, namely, the error correction model. Regardless of the specific method employed to examine these residuals, the use of cointegration methodology itself in studies such as this have a number of advantages: firstly, the results show how two markets have tended to a long-run equilibrium relationship; secondly, this methodology allows for short-run disturbances of the long-run equilibrium between the markets to be described; and lastly, the cointegrating vectors themselves show that a long-run equilibrium is present, and from these the error correction model is formed and this allows for the price discovery process between these markets to be described (Mahalik *et al.*, 2009: 8). In fact, a finding of cointegration means that there is a price discovery process occurring between the spot and futures markets for the asset in question (Mahalik *et al.*, 2009: 16). Thus a finding of cointegration allows for an error correction representation to be formed by which comment on the price discovery process may be made (Alexander, 1999: 5-6).

The ability for a cointegrating regression to be shown in an ECM form is often referred to as the, “granger representation theorem” although it should be noted that the converse is true: if it is possible to use an ECM the underlying equation must demonstrate cointegration (Charemza and Deadman, 1992: 154).

The ECM can be used following the application of either the the Engle-Granger method of detecting cointegration (discussed in detail in section 4.5.1), while in the application of the Johansen method of finding cointegration (discussed in section 4.5.2) it is the Vector Error Correction Model (VECM) that would be examined. Both the ECM and VECM allow for short run discrepancies in the long run efficiency equilibrium to be estimated. This allows for a deeper level of information to be taken from a study examining the efficiency relationship between spot and futures prices at is allows one to comment on how the market maintains/moves towards an equilibrium level.

Further, the analysis of this model not only allows for the short-run and long-run behaviours of a given data set to be commented on, but is also where the point of price discovery between spot and futures markets can be highlighted. Alexander (1999: 5) has the following to say on the error correction relationship:

“The mechanism which ties cointegration together is a ‘causality’, not in the sense that if we make a structural change to one series the other will change too, but in the sense that the turning points on one series precede the turning points in the other. The strength and directions of this ‘Granger causality’ can change over time, there can be bi-directional causality, or the direction of causality can change.”

If it is found that spot and futures prices are cointegrated, an implication of this discovery is that there must be causality in at least one direction (Mahalik *et al.*, 2009: 10). If it can be shown that there is an error correction relationship between the prices of the spot and futures market on a given asset then this will confirm that there is a price discovery process which is enabling this long-run relationship to exist (Mahalik *et al.*, 2009: 10). In contrast, if cointegration cannot be established then the implication must be that the futures market of that asset cannot be used for price discovery. Mahalik *et al.* (2009: 10) comments that the ECM not only allows for the price discovery function to be commented on but also shows the magnitude of any short-run disequilibrium and shows how much of an adjustment towards the long-run equilibrium is being made in the spot and/or futures markets. In her literature review, Alexander (1999: 5) points out that the ECM has become the prevalent tool for explaining the price discovery process, and Mahalik *et al.* (2009: 11) state that one justification for estimating an ECM is so that the price discovery process can be commented on. Given these statements, it would appear that efficiency studies that employ a cointegration methodology could make comment on the price discovery function of the underlying market too.

2.7 Conclusion

This chapter has dealt with the pricing of futures contracts and the idea behind, and importance of, efficiency in futures markets. Futures markets perform many functions, although those of price discovery and risk reduction are commonly cited as the most important of these roles. A market needs to be efficient for these functions to be optimally employed. To follow on from this theoretical discussion, chapter three will examine a review of the prevalent literature on testing for market efficiency.

3. FUTURES MARKETS EFFICIENCY

3.1 Introduction

The previous chapter explored the theory of market efficiency and the pricing of futures contracts. This chapter aims to create a bridge between the theoretical and statistical aspects of this study. Chapter two explored the general theoretical and methodological foundations of this study, while this chapter will go into more detail with regard to specific theory that relates to market efficiency by presenting an overview of existing literature on this topic. The details of previous papers on efficiency studies are presented in this chapter for two reasons. Firstly, this allows a review of the various methods of these studies to be conducted, and secondly it enables a comparison of the results of these studies to be examined.

Dagan (2002: 54-55) states that the literature on futures markets that pertains to the role of price discovery can be split into four core branches of empirical work, namely:

- (1) Studies examining the forward pricing efficiency of futures markets where spot and futures prices should reflect all available information so that futures prices are unbiased predictors of spot prices;
- (2) Studies which seek to comment on the presence of a risk premium in the futures market (the focus of Dagan's study);
- (3) Studies that examine the EMH using a variety of methods, including mechanical filters, trading rules, or the random walk model and martingale hypothesis; and,
- (4) Studies that have examined whether a given model is capable of making out-of-sample forecasts of upcoming spot prices more accurately than that of the prices given by the futures market

Dagan (2002: 54) further states that, in light of the wide range of literature on these topics, "the lack of consensus on the underlying process, as well as the determinants of futures prices, has led researchers to take a variety of approaches in developing models of futures contracts." Even if a study includes the word 'efficiency' in their title, the underlying paper may deal with a wide range of different topics (Dagan, 2002: 54), and it is thus necessary to extract a set of appropriate studies from a wide-ranging base of literature. The studies

reported here are aimed at detailing those that relate to efficiency in terms of the first research area mentioned by Dagan – where it is examined if futures prices are unbiased predictors of expected spot prices.

3.2 Efficiency Studies

From a statistical testing point of view there has been an important development in statistical methods that enables efficiency to be tested more extensively. Earlier studies (Leuthold (1972); Stevenson and Bear (1970); and Praetz (1975), cited in Carter (1999: 231), used methods such as applying filter tests to futures prices while others employed statistical techniques such as Workings “H” statistic (Brinegar (1970) cited in Carter (1999: 231). Cargill and Rausser (1975) cited in Carter (1999: 231) compared filter tests to statistical methods and found that statistical methods were more appropriate when testing for market efficiency. These topics generally fall under the third and forth categories mentioned by Dagan (2002: 54) above.

Kaminsky and Kumar’s 1990 study is a slightly more recent one, compared to those mentioned above, that also does not use cointegration methods. They test for unbiasedness by examining the relationship between the futures price and the resultant spot price at maturity to see if they are equal and were therefore forecast, ‘correctly.’ Essentially they were looking for excess returns, which should not be present if the futures price is a suitable tool for forecasting future spot prices (Kaminsky and Kumar, 1990: 673). Their weak-form tests showed some of the commodities they examined to be efficient, while others were not (Kaminsky and Kumar, 1990: 694-5). They suggested that a finding of inefficiency may be associated with the presence of a risk premium rather than with market failure.

These earlier methods have, however, been supplanted by the development of the statistical method of cointegration and studies employing variations of this approach thus form the basis for this literature review.

3.2.1 International Studies

3.2.1.1 Lai and Lai (1991)

Lai and Lai (1991) examined the use of cointegration tests for market efficiency soon after the introduction of the Johansen's methodology. They suggest that, in light of the EG method's inability to apply the necessary parameter restrictions, that Johansen's method be used to examine market efficiency (Lai and Lai, 1991: 568). They examined the relationship between five currencies against the US Dollar, namely: the British Pound, the Deutsche Mark, the Swiss Franc, the Canadian Dollar and the Japanese Yen (Lai and Lai, 1991: 571). They found that the five currency relationships were neither efficient nor did they display a zero-risk premium (Lai and Lai, 1991: 574).

3.2.1.2 Beck (1994)

Beck's 1994 study examined efficiency with the aid of cointegration in seven commodity futures markets, although this study did so without the assumption of no risk premium. The reason for this approach is that, Beck (1994: 250) argued that an assumption of no risk premium would indicate that market participants are risk neutral, an assumption which Beck describes in this paper as being, "neither theoretically defensible nor empirically plausible" (Beck, 1994: 249)

The first stage of his study tests for cointegration in the EG manner and states that at this point in testing a risk premium is allowed for as spot and futures prices can be cointegrated without imposing the parameter restrictions (Beck, 1994: 250). The presence of cointegration does not remove the possibility that the residuals display serial correlation; however, Beck shows that this can be accounted for with the error correction representation of this equation (Beck, 1994: 250).

An ECM was employed in order to compensate for the possibility that the residuals will contain serial correlation. Market efficiency within the ECM can be tested with a set of restrictions that allow for the presence of a risk premium. The results for these various contracts were mixed showing that all five of the markets examined were at times inefficient but none were consistently inefficient (Beck, 1994: 254 and 256). The conclusion to this study was that, when the ECM rejects unbiasedness it should be found that efficiency

is also rejected as the implication is that it is inefficiency rather than the presence of an unspecified risk premium that results in this rejection (Beck, 1994: 256).

3.2.1.3 Aulton, Ennew and Rayner (1997)

Aulton, Ennew and Rayner (1997) are an often-referenced source on market efficiency. Their study examined the agricultural commodities of wheat, pigmeat and potatoes within the UK market, using cointegration to test for market efficiency and to comment on the theory of unbiasedness. Their study gives a cointegrating relationship between an observed spot price against a previous period's futures price – they employ an 8-week lag (Aulton *et al.*, 1997: 414). The usual efficiency parameter restrictions are applied to this study, as well as the application of natural log form transformation to both spot and future prices.

They firstly established the presence of cointegration, and thereafter moved onto testing that spot and lagged futures prices cannot be used to forecast future spot prices by imposing a restriction that tested that the effect of these factors was insignificant within a distributed lag specification of spot on futures prices. The next stage, if lagged futures and spot prices do not contain additional information, is to then test for unbiasedness by imposing the restriction that $\beta = 1$. They suggested that if the residuals of the cointegrating equation are shown to be stationary then that is sufficient support for the hypothesis that that market is unbiased (Aulton *et al.*, 1997: 420). The results of their testing procedures showed that the wheat contract was efficient and unbiased, pigmeat was slightly inefficient but unbiased; and potato showed some inefficiency as well as bias (Aulton *et al.*, 1997: 421).

3.2.1.4 McKenzie and Holt (1998)

McKenzie and Holt presented a paper in 1998 that addressed market efficiency within five different agricultural futures contracts. Their paper used both EG and Johansen methods of detecting cointegration and then included an ARCH/GARCH model to further examine short-run price behaviour (McKenzie and Holt, 1998: 1, 4-5). Their cointegrating equation was given in standard form, and they argued that the standard parameter restrictions were needed for the testing of market efficiency. They also highlighted the fact that if two series are shown to be cointegrated then an ECM should be specified, especially as cointegration does not preclude the possibility of short-run inefficiencies (McKenzie and Holt, 1998: 2).

In performing the statistical method of this study they first established the presence of cointegration with the EG method, after which the Johansen technique was utilized in order to further investigate the properties of this finding. Both methods of detecting cointegration found all contracts examined displayed a long-run cointegrating relationship (McKenzie and Holt, 1998: 6). Both maximum eigenvalue and trace tests were performed to confirm that a null hypothesis of one cointegrating vector could not be rejected (McKenzie and Holt, 1998: 7).

The authors then tested the parameter restrictions individually, and then applied them together as a dual restriction. The contracts examined that could not reject the joint parameter restriction indicating an unbiased market were for live cattle, live hogs, corn and soybean meal (McKenzie and Holt, 1998: 7). The market for iced broilers was found to be biased in the long-run (McKenzie and Holt, 1998: 9). After this the ECM was formulated, and the finding of significant coefficients to the error correction term was seen as support for the finding of cointegration as an error correction representation can only be modelled in the presence of cointegration. Their results showed that four of the contracts they examined were both efficient and unbiased in the long run despite short-run inefficiencies indicated within the ECM (McKenzie and Holt, 1998: 9).

3.2.1.5 McKenzie Jiang, Djunaïdi, Hoffman and Wailes (2002)

McKenzie, Jiang, Djunaïdi, Hoffman and Wailes (2002) examined the US market for white rice futures for the presence of efficiency and unbiasedness using cointegration and error correction. They used the Johansen method to detect cointegration, and then used an ECM in order to examine short-run deviations from equilibrium. They also explained that the unbiasedness hypothesis applied in efficiency studies creates a stricter version of market efficiency than the weak-form of market efficiency presented by Fama (2002: 477-478). Their study used both the standard cointegrating regression and parameter restrictions. The results of this study showed evidence of efficiency and unbiasedness indicating that this particular market had the potential to be used as a price risk management tool and forecasting aid (McKenzie *et al.*, 2002: 492).

3.2.1.6 Wang and Ke (2002)

Wang and Ke performed their 2002 agricultural commodity futures market efficiency study on the Chinese futures markets for wheat and soybeans using the Johansen's technique for detecting cointegration. Within the application of the Johansen method, both the trace and maximum eigenvalue tests were used to determine the appropriate rank of the formulated matrix. Three versions of the parameter restrictions were then applied onto the cointegrating vector, each as a stand-alone restriction and then with both restrictions tested jointly.

Their results show a long-run equilibrium relationship in the soybean market with short-run inefficiencies despite the allowance for a risk premium and transportation costs. The wheat market was found to be inefficient, with possible causes of this being attributed to over speculation and/or governmental policies (Wang and Ke, 2002: 14-15).

3.2.1.7 He and Holt (2004)

He and Holt (2004) performed an analysis of the efficiency of three contracts on forest commodity futures traded on the Chicago Mercantile Exchange using a typical regression approach where spot prices are regressed against a constant term and the lagged future prices associated with that spot price. The standard hypothesis and parameter restrictions were applied to this equation for the determination of market efficiency.

Johansen's method was used in order to ascertain whether or not cointegration was present between spot and future prices, after which an ECM model was formulated in order to describe the short-run deviations from the long-run equilibrium. They discussed that one of the limitations of Johansen's method is its inability to examine short-run dynamics, and due to this, even when Johansen's is used an EG ECM should be used too (He and Holt, 2004: 7). Their results find no evidence of cointegrating long-run relationships, however, they do show that the GQARCH-M-ECM may be an important tool in explaining spot price changes through time (He and Holt, 2004: 13).

He and Holt (2004: 8) describe the GQARCH-M-ECM as having several advantages over the ECM as it is a more general expression of an ECM that allows for a time-varying risk premium to be present in the data. This may result in superior forecasts (He and Holt, 2004: 8). The GQARCH-M-ECM results showed that there was no short-term varying risk

premium in these markets (He and Holt, 2004: 13). They also found that the markets examined did not demonstrate a cointegrating relationship, which implied that there was no long-run relationship between the markets examined (He and Holt, 2004: 13).

3.2.1.8 Zapata, Fortenbery and Armstrong (2005)

Zapata, Fortenbery and Armstrong in 2005 examined price discovery in world sugar futures and spot markets. Studies within the sugar futures market are relatively new. They discussed the fact that the price discovery function of futures market depends on whether the changes in the futures price affects spot prices or *visa versa* stating that previous literature has shown that the usual scenario is for futures to lead the spot markets, although the opposite may occur (Zapata *et al.*, 2005: 6). This study investigated sugar futures traded on the New York exchange.

Zapata *et al.* (2005: 12-13) employed an ADF test for detecting a unit root and Johansen's method was used to show that cointegration was present, after which they used a model that shows the rate at which prices reflect market information, known as the Garbade-Silber model. The ECM was then formed in order to examine short run effects, and the question of causality addressed through the application of impulse response functions. This study examined a split data set to examine whether basis risk had increased in recent years; this was tested by calculating separate volatilities and then applying a F-test.

This study does not specify any conclusions with regard to efficiency, but does show that within this market the futures price leads the spot price, and that the presence of cointegration can be seen as an indication that this futures contract on sugar could be used to decrease the overall market price risk spot market participants are exposed to (Zapata *et al.*, 2005: 16).

3.2.1.9 Santos (2009)

In 2009 Santos tested the futures contracts for wheat, corn and oats traded on the CBOT at two different times, 1880 to 1890 and then 1997 to 2007. He applied the standard hypothesis and associated restrictions, and showed that a finding that two series are cointegrated demonstrates that at the very least that the relationship was efficient in the long-run (Santos,

2009: 6). Further tests were then applied to test for unbiasedness (test the parameter restrictions) and then to quantify the short run behaviours (Santos, 2009: 6).

Unit roots were tested for with the ADF test, and then cointegration was demonstrated using with Johansen's trace test (Santos, 2009: 8-10). An ECM was then modelled in order to determine the short run characteristics of the relationship. Santos (2009: 7) also suggested using a measure of relative efficiency modelled on the work of Kellard *et al.* (1999) with which to determine the difference between efficiencies at two different times.

Findings of cointegration in the wheat market at both dates showed that long run and short run efficiency existed, and that both current and 1880-1890 eight-week series were unbiased. Efficiency was similar for wheat at both time periods. The results for corn and oats were mixed, and overall it was concluded that contracts at both current and past times were mostly efficient (Santos, 2009: 10-11).

3.2.3 Summary of International Efficiency Studies

The studies below show those investigations into efficiency in markets outside of South Africa.

Table 3-1: Summary of International Efficiency Studies

<u>Author(s) (year), Title</u>	<u>Model, Data Hypothesis</u>	<u>Stationarity, Residuals Cointegration</u>	<u>ECM</u>	<u>Results</u>
Lai and Lai (1991) A Cointegration Test for Market Efficiency	$S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$	Unit root tested with ADF and Phillips-Perron EG can test efficiency but can't draw strong conclusions about α and β - suggest Johansen's method.	Cointegration present so parameters are tested with a likelihood ratio test in a VECM	Cant separate test of bias and efficiency Joint hypothesis of efficiency and no risk premium not supported
Beck (1994) Cointegration and market Efficiency in Commodities Futures Markets	Any form that says that F expiring in t+1 should equal S expected to prevail at t+1 $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$	Unit root tested for with ADF and Dickey-Pantula Uses EG for cointegration such that risk premium excluded and then ARCH	ECM used Used Wald test to apply restrictions.	Reject efficiency Compare tests for bias and efficiency...show implied inefficiency not bias.

Aulton, Ennew and Raynor (1997) <i>Efficiency Tests of Futures Markets for UK Agricultural Commodities</i>	$S_{t+1} = \alpha + \beta F_t + \varepsilon_t$ Natural log form $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ F_t taken 1 month before maturity, 1980-1993 UK futures market for wheat, pigmeat and potatoes. Mention link between liquidity trade volume and efficiency.	Unit root tested with Phillips-Perron and Dicky-Fuller Cointegration with EG Phillips-Perron test residuals for stationarity. Residuals examined for white noise. Introduced lagged terms to determine if past price information contains useful information	ECM not explicitly stated, restrictions applied to cointegrating parameters and then tested residuals for stationarity – if stationary conclude market is unbiased.	DW statistic used on cointegrating equation – First order autocorrelation is evidence of inefficiency Unbiasedness examined coefficients of the autocorrelation corrected regression Wheat efficient and unbiased, potatoes inefficient and biased, and pigmeat inefficient but unbiased.
McKenzie and Holt (1998) <i>Market Efficiency in Agricultural Futures Markets</i>	$S_t = \alpha + \beta F_{t-1} + \varepsilon_t$ Natural log form. $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ 5 contracts: cattle, hogs, corn, soybean meal and iced broilers. Data 1966 to 1995 (price observations taken bimonthly)	Unit root tested with ADF, the weighted symmetric test, and Phillips-Perron EG and Johansen's methods applied. Used AIC for choice of lag length. Once cointegration established Johansen's used for greater depth. Both maximum eigenvalue and trace tests applied.	ECM used, and the ECM also applied within an ARCH in mean and GARCH in mean framework.	Results show that live cattle, live hogs, corn, and soybean mean are both efficient and unbiased, however, iced broilers demonstrate bias in the long-run.
McKenzie, Jiang, Djinaidi, Hoffman and Wailes (2002) <i>Unbiasedness and Market Efficiency Tests of the US Rice Futures Market</i>	$S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Data 1986-1999 on 6 rice contracts traded per year. Variety of pricing dates used to test different dates for efficiency, and a pooled data set also created.	Unit root tested for with DF Johansen's methodology applied, normalisation against the spot price. Both Trace and Maximum Eigenvalue tests run.	Use variety of estimation tools but if I(1) and cointegrating then ECM most appropriate ECM Use Johansen's cointegration.	Used ECM and see market unbiased but small sample and there was evidence of bias in short run Tested for Weak Form efficiency, individual alpha and beta could not be rejected hence market inefficient although could be efficient with a risk premium
Wang and Ke (2002) <i>Efficiency Tests of Agricultural Commodity Futures Markets in China</i>	$\varepsilon_t = S_t - \alpha - \beta F_{t-1}$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Data 1998 to 2002 on wheat and soybean contracts (6 per year) on two separate markets. Futures price at 1w, 2w, 1m, 2m, 4m and 6m.	Unit root tested for with ADF AND Phillips-Perron Johansen's cointegration method applied, both trace test and maximum eigenvalue test used.	Not explicitly discussed, although the presence of along-run equilibrium is spoken of.	Restrictions of the null hypothesis applied individually and jointly. Soybeans found to be weak short-run efficient, while the wheat market is seen to be inefficient.

He and Holt (2004) <i>Efficiency of Commodity Futures Markets</i>	Mention that there are many versions of the efficiency statement, all are some version of: $S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Data 1996 - 2001 weekly prices. 3 contracts examined.	Unit root tested for with ADF Johansen's method applied to test for cointegration, optimal lag length determined with AIC criterion.	Both standard ECMs and then GQARCH-M-ECM applied. For the ECM the AIC criterion was used to determine lag length.	Restrictions applied within the Johansen's results. None of the contracts examined showed a long-run relationship, indicating that these markets (softwood lumber, oriented strand board and northern bleached softwood kraft pulp).are neither efficient nor unbiased.
Zapata, Fortenbery and Armstrong (2005) <i>Price Discovery in the World Sugar Futures and Cash Markets</i>	As stated with the Garbade-Silber model. Natural log transformation applied Data taken on sugar futures prices traded on the NYSE from 1990 to 2002	Unit root tested for with ADF Cointegration determined with Johansen's method A version of the Garbade-Silber model forms a combination of long-run and short-run dynamics to be examined. Impulse response functions also employed to check causality	ECM used Note that in a bivariate system the t-test is equivalent to a Wald test for parameter restrictions.	No specific conclusions regarding efficiency, shows futures price leads spot price. Cointegration an indication that a futures contract can be used to decrease overall market price risk faced by market participants Split data set examined with separate volatilities and F-tests to show hedging less effective after 1995.
Santos (2009) <i>Grain Futures Markets: What Have They Learned?</i>	$S_{t+h} = \alpha + \beta F_t + \varepsilon_{t+h}$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Examined wheat, corn and oats futures on CBOT 1880-1890 vs 1997-2007.	Unit root tested for with ADF Cointegration found with Johansen's Trace test Cointegration at least means long run efficiency	Applied ECM for short run disturbances, also VECM AIC used for lag length	Concluded that these contracts were all long run efficient, and that early markets were mostly efficient.

An examination of the table above provides some indicators applicable to this study. DF and ADF unit root tests should be presented in conjunction with the Phillips-Perron unit root test results; the use of an error correction model is almost always associated with cointegration studies whether it be an EG ECM or the VECM associated with Johansen's approach; and, the efficiency statement and parameter restrictions thereof may be written in different ways but the underlying principle remains the same.

It would appear that using both EG and Johansen's testing methods for cointegration, as well as in applying both an ECM and VECM, are not uncommon. This is attributed to this approach increasing the robustness and informational content of the results and it would

appear that the logical approach would be to use both methods in these types of studies. Finally, findings of efficiency and unbiasedness or lack thereof are dependent on the market in question and as such each case needs to be examined on its own specific characteristics.

3.3 Market Efficiency in South Africa

This chapter has so far provided an international background to the literature available on efficiency studies, before moving on to a discussion on South African studies there are some elements, however, that need to be considered in light of the specific characteristics of the South African Futures Market. The following section provides a brief history to the South African Futures Market before providing a review of the studies done within agricultural commodity markets within South Africa.

Recall that Pennings and Meulenberg (1997: 297) showed that increased trade will result in increased liquidity, and that the more liquid an asset the more likely it is to be associated with an efficient market. It follows then that a newly formed futures market will be less likely to show market efficiencies than an established one. This point becomes especially relevant in the context of this study with the emphasis being on South African Agricultural Commodity Futures. The history of this markets' development covers a small time frame when compared to some of the older exchanges worldwide. The first futures market in South Africa began in 1987 and was an informal one, a formal market was then introduced on the 10th August 1990 by the enactment of the Financial Markets Control Act of 1990 (SAFEX, 2008b)

The South African futures market made some significant adjustments in 1995 with the formation of the SAFEX Agricultural Markets Division and again in 2001 when SAFEX was purchased by the JSE where it became known as the SAFEX Agricultural Products Division of the JSE (SAFEX, 2008b).

For the first time in the history of futures trading in South Africa there is a well-established and freely functioning agricultural commodity futures market (Moholwa, 2005: 3). Prior to this, in the early 1990's, agricultural products were highly regulated commodities in South Africa. Since the maize board was dissolved in 1996, this liberalization has seen the agricultural futures market taking on a more important role in managing price risk for agricultural products.

Although beef contracts were the first contracts to be listed in 1995, it was the formulation of white and yellow maize contracts in 1996 that truly enabled this market to develop (SAFEX, 2008b). The listing of white and yellow maize contracts was a success in that trade volumes increased quickly allowing for price transparency to be achieved in the futures market, and for market participants to have an avenue through which to manage their price risk (SAFEX, 2008b). Although there have been a number of changes in the history of this South African market, recent years have seen a number of market, technical and economic developments, such as the introduction of option contracts on maize in 1998 and the fairly independent functioning of the AMD (Gravelet-Blondin, no date: 16), that has seen this market become more firmly established and increasingly utilized.

In South Africa higher trade volumes (refer to Figure 1-1) may be indicative of a more efficient system and thus there is value in re-addressing the efficiency of the maize futures contract on SAFEX as theory and logic would suggest that there is a greater chance that market efficiency might be present than in earlier studies performed in the 'new' market. A more established market may be considered to be nearing a time of maturity if a number of successive years of flourishing trade have been observed (Wang and Ke, 2002: 3).

This market development and increased trade volumes should theoretically allow for the functions that futures provide and perform to be realistically achieved within the South Africa futures markets framework. Before this can be tested, however, a review of current domestic literature on this topic will be examined.

3.3.1 South African Efficiency Studies

The study of market efficiency is relatively new within South Africa, mainly because this country's futures market is still a developing one, especially in comparison to major international futures markets. At present four papers have been written that deal with the efficiency of the South African agricultural commodity futures market. In addition, a study was performed on index futures by Ferret and Page in 1998; a study by Fedderke and Joao examined the relationship between the JSE All Share Index (ALSI) and its associated futures contract in 2001(a) and in a separate paper, also 2001(b), examined the relationship between the JSE ALSI 40 Index, the risk-free rate and transaction costs; and a paper by Leng in 2002 looked at efficiency and causality of the All Share 40 Index.

3.3.1.1 Wiseman, Darrock and Ortmann (1999)

The first of these commodity futures studies was a Masters Thesis by Wiseman, and subsequent article in the *Agrekon* journal by Wiseman, Darrock, and Ortmann in 1999 on same, which covered market data for the South African white maize spot and futures markets for the years 1997 and 1998. Wiseman *et al.*, 1999: 326 applied a cointegration methodology to a data set that was collected from various sources as at that point of time there was no central price reporting system available.

This study used the Augmented Dicky-Fuller to test for the presence of a unit root, and then followed the EG method for detecting cointegration. They did not include an ECM, however, they did formulate and test a model which included lagged futures prices in order to determine if these lagged values affected could be used to forecast spot prices (Wiseman *et al.*, 1999: 325). Further, they suggested that a finding that the residuals of the efficiency statement are stationary might be used as support for saying that the market is unbiased (Wiseman *et al.*, 1999: 325). These approaches, however, have not been commonly used.

They found that there was evidence of an inefficient market as past price data could be used in order to predict upcoming spot prices, although they did also conclude that there was evidence of unbiasedness in the 1998 contract due to the presence of cointegration between the variables (Wiseman *et al.*, 1999: 332).

3.3.1.2 Nikolova (2003)

The second South African study was an Honours level thesis by Nikolova that revisited this topic in 2003 and covered market prices for white maize from 1997-2002, which found that the market was inefficient, possibly due to a lack of liquidity (Nikolova, 2003: 36). This study highlighted that it had addressed a potentially serious shortcoming of the Wiseman article. The Wiseman study had used spot and future prices from the same period and had not converted their data with a natural log transformation. Nikolovas study had accounted for this in that the data set used was in natural log form and used futures prices that had been lagged back in time as recommended by other studies (Nikolova, 2003: 28).

This study applied the Dicky-Fuller tests for detecting unit roots (Nikolova, 2003: 33) and then tested for cointegration with the EG approach. This paper, however, did not use an error correction model nor did it attempt to comment on the effect of lagged prices due to a finding of no cointegration. Each year was individually examined for cointegration, rather than running the spot price series against the future price series in order to obtain a full residual series to then be examined as is common practice. It seems unlikely that this finding of no cointegration over this entire time frame was correct, as a test that covered the full period from 1997-2002 may have yielded different results, however, without the data source used this is difficult to verify.

3.3.1.3 Moholwa (2005)

The third South African study was done as part of a Masters program in Science by Moholwa in 2005 where the weak-form efficiency of white and yellow maize in South Africa was tested. This paper found that there was no strong support for weak-form efficiency for white or yellow maize when examining the predictability of daily price changes in the futures price (Moholwa, 2005: 20-21). Due to the lack of reported spot data on SAFEX this study was performed using only futures prices. This study used pooled data sets that contained observations on the price from the introduction of the contract until the last business day of trade in the month prior to the contract's expiry (Moholwa, 2005: 9-10).

Moholwa (2005: 13-14) used a forecasting framework as his mode of testing for predictability, and not the cointegration methodology, although Dicky-Fuller, Augmented Dicky-Fuller and Phillips-Perron tests were used to detect unit roots (Moholwa, 2005: 10-11) and it was concluded that the presence of a unit root (nonstationarity) could not be rejected.

Moholwa (2005: 21) concluded by stating that, although prices for both white and yellow maize appeared to be partially predictable – implying that price data did contain information which could be used to predict upcoming prices, once brokerage fees and the time value of money had been accounted for there was little to indicate that decisions made to predict upcoming changes in the futures prices would create any value for the trader in either maize market.

3.3.1.4 Phukubje and Moholwa (2006)

The most recent study was one by Phukubje and Moholwa in 2006; however, these authors did not examine the white maize market deciding instead to focus on wheat and sunflower seeds. They also faced the restriction that SAFEX did not quote historical price data (Phukubje and Moholwa, 2006: 203). The settlement prices on the contracts were collected from SAFEX, although the July and September contracts on wheat were excluded due to incomplete data obtained SAFEX (Phukubje and Moholwa, 2006: 203). These authors state in their conclusions that the biggest limitation of their study was the unavailability of spot price data, and mentioned the need that such a reporting agency be formed in South Africa (Phukubje and Moholwa, 2006: 211). Their prices were used in pooled data sets to which they applied Augmented Dicky-Fuller and Phillips-Perron unit root tests to detect for the presence of a unit root.

They then imposed a restriction of no autocorrelation in the error term in order to test if past information in the market could be used to forecast upcoming changes in the futures price, and then out-of-sample forecasting was used to determine if the model can be used to make profitable trade decisions (Phukubje and Moholwa, 2006: 206). If the error term is uncorrelated and the coefficient on the lagged daily change in the futures price is zero, this shows that historical prices do not contain any information that could be used in predicting upcoming price changes. This paper found that there was no strong support for weak-form efficiency for either wheat or sunflower seeds in the period 2000-2003 (Phukubje and Moholwa, 2006: 210-211). When examining the out-of-sample forecasting ability of the model, however, it was found that profitable trade decisions could not be made by examining past price information indicating weak-form market efficiency (Phukubje and Moholwa, 2006: 211).

All of these abovementioned efficiency studies were, however, constrained by limited data sets (to demonstrate: Wiseman (1999) used data from 1997-1998; Nikolova (2003) used 1997-2003 figures; Moholwa (2005) used 1999-2003 data; while Phukubje and Moholwa (2006) used figures from 2000-2003 (although this study used pooled data sets across contract months which resulted in a sample size of 8 for wheat, and 5 for sunflower seeds). Further, not one of these South African studies used an Error Correction Model despite the literature suggesting that cointegration and ECM's should be closely associated.

3.3.2 Other South African Efficiency Studies

Efficiency studies have been performed in other markets within South Africa, some of which are presented next. The need to use an ECM in conjunction with a finding of cointegration is made by Ferret and Page (1998: 81).

3.3.2.1 Ferret and Page (1998)

Ferret and Page (1998: 77) examined four different South African indices that had both spot and futures markets, namely the All-Share, All-Gold, Industrial, and Financial and Industrial Indices. This study examined the data sets for stationarity through the application of the DF and ADF tests, and the relationship between spot and futures prices was described in the standard form in order to test for a cointegrating relationship following which ECM's were formed (Ferret and Page, 1998: 78-84). They made the observation that within the cointegrating regression, although it is not possible to use the traditional t-test due to problems associated with the use of non-stationary data, it is possible to use the OLS results as a fair estimator of the coefficient associated with the futures prices (Ferret and Page, 1998: 80), this being the coefficient that efficiency requires to equal 1.

All four of these series were found to be nonstationary and the residual series from the cointegrating relationships were all shown to be stationary and thus cointegrated demonstrating a long-run relationship (Ferret and Page, 1998: 81). Within the ECM it was shown that none of these indices were fully efficient, and that information appeared to flow from the futures market into the spot market more strongly than the reverse (Ferret and Page, 1998: 85-86). Ferret and Page (1998: 88) suggested that these findings may have been attributable to market imperfections such as transaction costs, or from the fact that the spot and futures markets had different closing times which may have prevented traders from acting on price information in a timely fashion.

Two additional papers written in South African are relevant, Fedderke and Joao examined price discovery in the share index futures market of South Africa in 2001(a); and in 2002 Leng wrote a paper that revisited the concepts of efficiency and causality within the South African share index futures market.

3.3.2.2 Fedderke and Joao (2001a)

Fedderke and Joao (2001(a): 2) examined the relationship between the JSE All Share Index and the All Share Index futures contract in order to determine if price discovery took place in the spot or futures market. Their analysis used an unrestricted VAR model on daily data, which was changed into first difference form (Fedderke and Joao, 2001(a): 8). This paper is not included in the tabulated summary below due to its use of an alternative methodology to that of interest here. Fedderke and Joao (2001: 1) applied this unrestricted VAR model to intraday data taken at 2, 6 and 10 minute intervals in 1998, and then looked at end-of-day data from 1996-1998. They included lags using the AIC and Schwarz-Bayesian criterion and then used these lags to test if previous prices influenced upcoming prices (Fedderke and Joao, 2001(a): 10-11). They concluded that within this market the price discovery role was from the futures market into the spot market (Fedderke and Joao, 2001(a): 9).

3.3.2.3 Fedderke and Joao (2001b)

In 2001(b) Fedderke and Joao examined the relationship between arbitrage, cointegration and efficiency in financial markets, specifically the ALSI 40 Index, in the event of a financial crisis over the period 1996-1998 (Fedderke and Joao, 2001(b): 366 and 370). They included interest rates and transactions costs within their model and showed that an efficient market was one where risk-free returns are greater than opportunity and transaction costs, that is, there are no opportunities to make abnormal profits (Fedderke and Joao, 2001(b): 366-367).

The ADF test was used to detect if unit roots were present in the spot price, futures price and cost of carry variable (risk-free rate, dividend yield and transaction costs) (Fedderke and Joao, 2001(b): 377). The Johansen's method and vector error correction model, as well as Pesaran, Shin and Smith's (PSS) cointegration techniques were employed (Fedderke and Joao, 2001(b): 377).

With Johansen's both the trace test and maximum eigenvalue tests were used finding that there was a single cointegrating relationship between the variables, this was consistent with the PSS finding (Fedderke and Joao, 2001(b): 377 and 382). A finding of an error correction relationship and the impulse response to shocks confirmed that there was a long-run equilibrium in this market that was not affected by the emerging market crises of 1997 and

1998 (Fedderke and Joao, 2001(b): 379 and 382). They suggested that their results implied that the futures market acted as the point of price discovery (Fedderke and Joao, 2001(b): 383), but did not discuss in detail how this conclusion was reached.

3.3.2.4 Leng (2002)

Leng's paper examined the All Share 40 Index, and in this study the data set used was split into four subsections in order to examine if the Asian financial crisis had affected the efficiency and causality of this market (Leng, 2002: 1). The data was tested for unit roots using the ADF, Phillips-Perron and KPSS methods (Leng, 2002: 7 and 9-10), and cointegration was detected using the Johansen's trace test and maximum eigenvalue methods (Leng, 2002: 8).

The Johansen test showed that only one cointegrating vector was present and a VECM was formed (Leng, 2002: 10-14). The results suggested that this market was inefficient before the crisis, but that efficiency was increasing during the crisis. There was a long run equilibrium between the spot and futures markets, and that the futures market was more responsible for the maintenance of that equilibrium, that is, the futures market reacted to market news before the spot market (Leng, 2002: 15-16).

This finding is related to price discovery and suggested that the futures market responded first to market news which implied that traders could use the futures market as a point of price discovery, however, during the crisis period examined there was a period during which the spot market took on the price discovery role (Leng, 2002: 16).

3.3.3 Summary of South African Efficiency Studies

These studies are arranged in chronological order, and examine market efficiency in agricultural commodity futures traded on the South African futures exchange, as well as relevant studies in other South African futures exchanges.

Table 3-2: Summary of Efficiency Studies in South African Markets

<u>Author(s)</u> <u>(year), Title</u>	<u>Model, Data</u> <u>Hypothesis</u>	<u>Stationarity, Residuals</u> <u>Cointegration</u>	<u>ECM</u>	<u>Results</u>
Wiseman, Darroch and Ortman (1999) <i>Testing the Efficiency of the South African Futures Market for White Maize</i>	$S_t = \alpha + \beta F_t + \varepsilon_t$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Data not transformed Lagged futures price not used. Weak-form efficiency tested for	Unit root tested with ADF Cointegrating regression DW test to test for cointegration. Addition of lagged spot and futures terms used to test for past price influence, applied F-test. Examined residual series in detail, used JB statistic, and Whites heteroskedasticity test.	ECM not used	If lagged spot and futures prices are significant, reject weak-form efficiency. Evidence of stationarity in residuals supports hypothesis that $\beta = 1$ and that the market is unbiased. Found this market is inefficient, although some movement towards efficiency was noted.
Ferret and Page (1998) <i>Cointegration of South African Index Futures Contracts and the Underlying Spot Market Indices</i>	$S_t = \alpha + \beta F_t + \varepsilon_t$ Show that OLS results may be used to obtain a fair estimate of the β coefficient (should be close to 1)	Unit root tested for with AD and ADF Cointegration run simply to check residuals for stationarity	ECM employed Highlight cointegration should have ECM model too.	Cointegration found, ECM used to describe relationship. Market not fully efficient. Information flows from futures to spot market so futures market plays a role in price discovery.
Fedderke and Joao (2001b) <i>Arbitrage, Cointegration and Efficiency in Financial Markets in the Presence of Financial Crises</i>	Natural log transformation applied Efficiency model included a term for cost of carry as well as spot and futures prices	Unit root tested for with ADF Cointegration detected with Johansen's, trace and maximum eigenvalue tests as well as the Pesaran, Shin and Smith (PSS) cointegration technique.	VECM employed	Results indicated a long run stable relationship between these variables that was not affected by financial crises. Implied that the futures market was the point of price discovery.
Leng (2002) <i>The South African Share Index Futures and Share Markets: Efficiency and Causality Revisited</i>	Natural log transformation applied Traditional hypothesis not applied, rather the split data set was examined for changes in results	Unit root tested for with ADF, Phillips-Perron and KPSS Cointegration detected with Johansen's. Both trace and maximum eigenvalue tests used - state that the smaller the value of these statistics the more efficient the market	VECM employed	Results showed contract was inefficient before Asian crisis, but that efficiency improved during the crisis. Futures market seen to dominate spot market, equilibrium depending strongly on the futures market.

Nikolva (2003) <i>Testing the Efficiency of the South African Futures Market for White Maize from 1997-2002 Honours Thesis</i>	$S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$ $H_0: \alpha = 0 \beta = 1$ $H_1: \alpha \neq 0 \beta \neq 1$ Applied natural log transformation and included lagged futures price term	Unit root Dickey-Fuller test	ECM not used	Unbiased if cointegration exists Semi-strong form efficiency tested for.
Moholwa (2005) <i>Testing for Weak-Form Efficiency in South African Futures Markets for White and Yellow Maize Masters thesis</i>	Natural log form. $F_t = \alpha + \beta F_{t-1} + \varepsilon_t$ And then FDF $\Delta F_t = \alpha + \beta_i \Delta F_{t-1} + \varepsilon_t$ $H_0: \beta_1 = \dots = \beta_k = 0$ Tests a random walk model Observations of the lagged futures price from month after contract introduced to month before expiry. Data from 1999-2003 on white and yellow maize pooled into a total of 10 sets.	Unit root tests with DF, ADF, and Phillips-Perron Lagged terms introduced to determine if past prices can be used to determine upcoming prices. Q-statistic used to determine if residuals autocorrelated. JB used to determine if residuals normal. Efficiency examined by using forecasting not cointegration.	Not used	Examined trend towards efficiency by examining stability of the regressions parameters with an F-test –parameter instability may indicate underlying change – perhaps towards efficiency... Past price information found to influence daily futures prices – a finding of inefficiency, however, if brokerage costs and time value of money considered author suggested efficiency possible.
Phukubje and Moholwa (2006) <i>Testing for Weak-Form Efficiency in South African Futures Markets for Wheat and Sunflower Seeds</i>	H_0 : No predictability Used F test and hold out sample (1/3) for forecasting Natural log form Lag prices until AC removed: used Q-Statistic	I(1) therefore use: Unit root ADF and Phillips-Perron Error term checked to be 'white noise' (zero mean, constant variance and uncorrelated errors across time)	ECM not used	If unbiased or weak form efficient then past prices cannot be used to be used to forecast future prices. Weak form – random walk

The table above shows clearly that ECM's have not been employed in any of the South African efficiency studies in agricultural commodity futures, despite the fact that the paper by Ferret and Page in 1998 and Fedderke and Joao in 2001 (b) did so in line with international practices. Studies completed in other markets have used the ECM, and the relationship between cointegration and error correction is considered to be a close one, thus the inclusion of an ECM would appear internationally to be the generally accepted practice in studies such as this. Further, and in keeping with the conclusions to the international

section, unit root tests should include DF, ADF and Phillips-Perron calculations; a natural log transformation should be placed on spot and futures prices; and finally the efficiency statement and parameter restrictions are consistent with those suggested for use in the international papers.

3.3.4 Additional Studies in South Africa

This final section of the literature review is provided for completeness sake and is aimed at highlighting some of the additional studies undertaken within the South African market, within the context of examining agricultural commodity behaviour in areas other than efficiency testing. Although these studies are not directly linked to this study in terms of testing for efficiency, they illustrate the depth of literature in this market thereby supported the suggestion that more studies need to be performed within the South African agricultural commodity market in order to increase and deepen the understanding of the functionality and performance thereof.

3.3.4.1 Mashamaite and Moholwa (2005)

Mashamaite and Moholwa (2005) wrote a paper entitled "Price Asymmetry in South African Futures Markets for Agricultural Commodities." This paper examined white and yellow maize, as well as wheat and sunflower seeds. Price asymmetry refers to a type of price behaviour where upwards and downwards price movements are not equal, if price asymmetry is found this may indicate that the market is not weak-form efficient, forecasting models may be incorrect and that policy makers need to account for this behaviour when setting market procedures (Mashamaite and Moholwa, 2005: 424).

The commodities mentioned above were tested over daily and weekly prices using a dynamic price asymmetry model which tested whether or not the aggregate impact of past price increases and decreases have the same effect on current price changes (Mashamaite and Moholwa, 2005: 425-426). A natural log transformation was applied to the data, and all series were found to be nonstationary using both ADF and PP tests (Mashamaite and Moholwa, 2005: 427-428). Price asymmetry was tested for with the sum of coefficients test and the speed of adjustment test using a standard F test, however, of the four commodities, only wheat displayed price asymmetry by rejecting both of these tests and it was thus concluded to be inefficient in that past prices do affect current prices. The authors suggested

that testing for efficiency in these commodity contracts was needed (Mashamaite and Moholwa, 2005: 431-432).

3.3.4.2 Geyser and Cutts (2007)

Geyser and Cutts (2007: 291-292) examined the price volatility of the SAFEX maize price, showing that fluctuations in prices increase the risk that a higher price will be charged for a given commodity, as well as increasing the cost of using derivatives associated with that commodity for risk hedging practices. Many factors from both the supply and demand sides can affect price volatility. Maize traded on SAFEX is mainly affected by supply and demand on an international level, domestic supply and demand, and inventory levels, as well as the Rand-US Dollar exchange rate (Geyser and Cutts, 2007: 296).

Their study showed that the daily maize prices on SAFEX were more volatile than those on the Chicago market, and further that maize prices in South Africa were more affected by domestic inventory levels and weather effects than similar trades on the Chicago Trade floor (Geyser and Cutts, 2007: 303).

3.3.4.3 Jordaan, Grove, Jooste and Alemu (2007)

Jordaan, Grove, Jooste and Alemu, (2007: 309) wrote a paper on a similar topic entitled, "Measuring the Price Volatility of Certain Field Crops in South Africa using the Autoregressive Conditional Heteroskedasticity (ARCH) or Generalized ARCH (GARCH) Approach." This study examined the question of price volatility with the use of the GARCH approach, and further this study examined all five contracts on SAFEX, namely: white and yellow maize, wheat, sunflower seed, and soybeans.

Seasonal dummy variables for each month of the year were added in order to compare effects across the different months of the year and then the data was tested for stationarity with the ADF test (Jordaan *et al.*, 2007: 310-312). An ARIMA process was generated using the Box-Jenkins methodology to determine the explanatory terms after which the data was tested for an ARCH effect which shows whether volatility varies over time. When an ARCH effect was found the GARCH approach was then applied where the standard deviation (volatility) may vary over time (Jordaan *et al.*, 2007: 313-315).

The results of this study showed that white and yellow maize, and sunflower seeds, were considered riskier than wheat and soybeans (Jordaan *et al.*, 2007: 319-320). Specifically it was maize that was exposed to a large level of price risk. The study also showed that harvest time should be accounted for when making hedging or marketing strategies. The amount of volatility in white maize, yellow maize and sunflower seeds were shown to change over time. The authors suggested that the factors that influence volatility needed to be examined further (Jordaan *et al.*, 2007: 320-321).

3.3.4.4 Auret and Schmitt (2008)

In 2008, Auret and Schmitt (2008: 103) examined the South African white maize market from another perspective – they investigated an explanatory model of the white maize futures price. Their model included twelve independent variables including weather indicators, local and international supply and demand, export and import figures, and the Rand/Dollar exchange rate. They applied a natural log transformation to their data and used the ADF test for detecting unit roots.

This paper employed a multiple regressions analysis and examined how these variables were correlated with the white maize futures price (Auret and Schmitt, 2008: 116-118). Some of the tested variables were found to be highly correlated and due to this, the final pricing model included four of the original twelve independent variables (Auret and Schmitt, 2008: 129-130). That is, the white maize futures price was found to be related to the past/lagged white maize price, the weather (as measured by the Southern Oscillation Index), the import parity of white maize and the JSEAlsi40 over this period (Auret and Schmitt, 2008: 103, 120 and 127). Although not explicitly stated, this finding that past price information (prices from a year ago) may be used to comment on the upcoming futures price suggests that the market was not fully efficient, and further that some inference could perhaps be made on the price discovery function of this market.

3.3.4.5 Moholwa and Liu (2009)

Moholwa and Liu examined the effect of volatility in the Rand/US Dollar exchange rate on agricultural commodity futures markets in 2009. This study investigated the behaviour of the contracts for white maize, yellow maize, wheat and sunflower seeds traded on SAFEX, as well as the corn and wheat contracts traded on the Chicago Board of Trade (CBOT)

(Moholwa and Liu, 2009: 2). The importance of the exchange rate in relation to these contracts is due to the fact that increased exchange rate volatility results in increased uncertainty and hence increased risk, which may in consequence affect prices (Moholwa and Liu, 2009: 3).

This study examined each contract for price asymmetry and the volatility of the Rand/US Dollar exchange rate was measured through the use of GARCH, TACRH and EGARCH methods. It was shown that the Rand/US Dollar becomes more volatile in the face of bad news, and less so when information was positive. Further, it was shown that a more stable exchange rate would result in an improvement in the performance of these South African commodity markets (Moholwa and Liu, 2009: 21-22). This study therefore suggests that the behaviour of the exchange rate may also influence the price of agricultural commodity futures.

3.4 Conclusion

This chapter detailed a review of the literature on this topic from which two main points can be taken. The first is that there is a clear discrepancy between the methodology applied in an international context and a domestic context in that, the use of an Error Correction Model is commonly applied to international studies (and is in fact called for once a cointegrating relationship has been established), however, this model has not been used in agricultural market reviews in South Africa.

Secondly, the literature review, together with the introduction to the methodology of those studies in tables 3-1 and 3-2 above, has served as an introduction to the methods and models of this type of investigation, a discussion of these statistical methods and models will be presented next in chapter four.

4. METHODOLOGY

4.1 Introduction

The central issue to be addressed in this study is whether or not the futures market for white maize in South Africa is an efficient one or not. The importance and relevance of such findings has been highlighted in previous chapters, however, to reiterate - an efficient market is one that is able to accurately fulfil its functions, the most important of these are those of risk reduction and price discovery. Chapter three presented a summary of previous studies in market efficiency that allowed for a general overview of the statistical methods employed in these studies to be noted. This chapter is aimed at showing how these theoretical aspects are analysed within a statistical framework, it also provides the details and hypotheses of the relevant tests and models; and concludes with a summation of the methodology that this study will follow.

4.2 Research Problem and Hypothesis

The core research problem being addressed is examining whether or not the South African futures market for white maize is efficient. In order to test this research problem the relationship that exists between spot and futures prices may be written in an econometric notation and is expressed as follows:

$$S_t = \alpha + \beta F_{t-1} + \varepsilon_t \quad \dots \text{Equation 2}$$

An efficient market must firstly display a long-run cointegrating relationship between spot and futures prices as represented in equation 2, and secondly, the coefficients associated with the aforementioned equation must be shown to take on the following characteristics as stated in the hypotheses below:

$$H_0: \alpha = 0 \quad \beta = 1$$

$$H_1: \alpha \neq 0 \quad \beta \neq 1$$

4.3 Data

The data used in this study consists of price data on white maize futures contracts traded on the SAFEX. These historical spot³ and futures prices were obtained directly from the SAFEX website (SAFEX, 2008a). The data for futures and spot market prices are by definition time series in nature, as they are collected from different time periods. One set of observations – one spot price and one futures price – on each contract for each year was taken. The first set of observations are from the May contract of 1996 and the last observation in this study is from the May contract of 2009. The white maize futures contract in South Africa has expiry dates in March, May, July, September and December⁴ which translates to either a two or three month interval between contracts. The resultant data set contains a sample of 66 observations. Although this is not a small sample, it is also not exactly large – especially in the context of a study using time series data. It is partly due to this that more than one test is run on each subset of this methodology – to ensure that the results are robust even when examined under different sets of assumptions.

McKenzie *et al.* (2002: 478) state that there are two methods through which efficiency can be examined, one being the use of a pooled set of observations, the other being to test the different maturities separately. The latter is the approach taken here. It was seen in the literature review that there were a few studies that employed pooled data sets, however, the study by McKenzie *et al.* (2002: 478) explains that pooled data sets may increase the chance of the results concluding that a given market is inefficient due to problems from overlapping data. Further, the process of examining the different maturities separately appears to be a common approach in the literature.

The futures price was chosen at a time period of 8 weeks before the contract's maturity, and the spot price was taken at the contract's maturity. 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. Eight weeks (two months) fits the given guidelines of avoiding overlapping data observations, as it is equal to the smaller time

³ The reported spot price quoted by SAFEX is derived from the SAFEX near futures contract and does not reflect a cash market transaction per se, as such data is not readily available in South Africa. The spot price given by SAFEX, however, represents the best possible data available. Further, the use of such data as the spot price is not uncommon – see: 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).

⁴ See Appendix 1

interval between contracts. In the formula given in equations 1 and 2, this would indicate that the value for n is 8 weeks.

It was seen that the use of a natural log transformation is commonly employed in these studies, as can be seen in the papers by Aulton *et al.* (1997); Fedderke and Joao (2001b); Leng (2002; Moholwa (2005) and Zapata *et al.* (2005), amongst others. As such, once the full spot price and futures price series were compiled, a natural log transformation was applied to the data. From then on, unless otherwise stated, the statistical testing procedures are performed on the log transformed data.

The reason for this transformation is explained by Aulton *et al.*, (1997: 411) who showed that a natural logarithmic transformation to the data series is both a generally accepted practice and a logical step in analysing price data. A brief summary of their main points follows... Firstly, this logarithmic transformation can reduce the variance of the series; secondly, futures prices can only be positively valued (there is no negative bound) and so this process ensures that the data cannot have a negative range. Thirdly, these series tend to be nonstationary and this transformation allows an integrated stationary series to be the result, this is especially relevant as first differencing alone may not be enough to achieve a stationary series.

Aulton *et al.*, (1997: 411) citing Banerjee *et al.*, (1993: 199) use the above reasons to support using logarithmically transformed time series rather than the level form of the data. The core to their argument is that, "if the cointegration is actually between the levels of the variables some linear equilibrium relationship will exist between the logarithms whilst the converse will not hold.... by applying the logarithmic transformation...we are more likely to find cointegration when it exists..."

4.4 Testing for Stationarity

The first stage in the testing procedure was to examine both the spot price series and then the futures price series for stationarity. Although a number of formal unit root tests exist, as was seen in the literature review, the two that were most commonly employed were the ADF Test and Phillips-Perron (PP) tests, and consequently these tests were used in this study. It is noted, however, that Brooks (2008: 331) stated that the Kwiatowski, Phillips, Schmidt and Shin (KPSS) test should also be utilized when testing for a unit root. This test is actually a

test for stationarity (in opposition to the ADF and PP which are looking for nonstationarity) and so the consistency of these results with those of the ADF and PP tests will allow for increased confidence in the accuracy of the results. The specific application and interpretation of these tests are presented in 4.4.1-4.4.3 below.

4.4.1 Augmented-Dicky Fuller

The ADF test, an extension of the simple Dicky-Fuller (DF) test, allows for the inclusion of lags in order to break any serial autocorrelation that may be present. The problem with the DF tests is that they assume that there is no autocorrelation between the error term μ_t . This may not be true and hence the Augmented Dicky-Fuller (ADF) test is used to circumvent this potential problem and thus it is the ADF instead of the DF tests which are used. The purpose of this extension is to ensure that the results obtained are not skewed due to autocorrelation problems. This test works by enhancing the DF equations by the process of adding lagged values of the dependent term (the change in spot price or the change in futures price).

In order to test for a unit root, the following ADF tests were run on the stochastic time series S_t and F_t in order to be certain that each series is correctly and consistently labelled as either stationary or nonstationary.

$$\Delta S_t = \beta_1 + \beta_2 t + \gamma S_{t-1} + \alpha \sum \Delta S_{t-i} + \varepsilon_t \quad (\text{ADF}) \dots \text{Equation 3}$$

$$\Delta F_t = \beta_1 + \beta_2 t + \gamma F_{t-1} + \alpha \sum \Delta F_{t-i} + \varepsilon_t \quad (\text{ADF}) \dots \text{Equation 4}$$

The null hypothesis of the unit root tests, known as the unit root hypothesis, is that the coefficient tied to the lagged term (in these instances γ) will be zero, which is indicative that the given time series is nonstationary (Gujarati, 2006: 497), that is:

- $H_0: \gamma = 0$ indicates the presence of a unit root and thus nonstationary data.
 $H_1: \gamma \neq 0$ if the null is rejected we conclude that the data is stationary.

As this is a unit root process, it is the *tau* test and not the t-test that was used in order to determine significance because the t values of the estimated coefficients of these regressions do not follow the t distribution (an asymptotic normal distribution) even in large samples; the alternative measure used here is the tau (τ) statistic (or DF test). One reason for this is that

the t-test will only be valid if the time series under consideration is stationary (Gujarati, 2006: 498).

The *tau* test is interpreted as follows: should the computed *tau* value be greater in *absolute* terms than the critical *tau* value then the null hypothesis is rejected and it is concluded that the given time series is stationary. If the computed *tau* is smaller than the critical *tau* value then the null hypothesis cannot be rejected and it is concluded that the given time series is nonstationary.

Some data sets can be manipulated in order to create a stationary series. Time series data can be assumed to be integrated of order d , $I(d)$, that is, the data can be made stationary through d number of adjustments. Data that are already stationary are said to be $I(0)$, that is, integrated of order zero and no manipulation or differencing is required (Banerjee *et al.*, 1993: 11). If the data becomes stationary after First Difference Form (FDF) has been applied then that data set is known to be integrated of order one, $I(1)$, that is, after one adjustment/differencing the data displays stationarity. If a given process can be made stationary through differencing it is known as an integrated process (Banerjee *et al.*, 1993: 11). For this reason the ADF test is performed once more in FDF to ascertain which order of integration applies to each series in line with the approach used in Jordaan *et al.* (2007: 312). The reason that one is concerned with the order of the data, and not only the presence of stationarity or lack thereof, is due to the fact that the next step in this process, detecting cointegration, requires that the variables in the cointegrating equation are both integrated of the same order. In order to show that this is so the ADF test was run on both the spot and future price series, this time in first difference form (FDF).

The decision of how many lagged terms to include is guided by the fact that there should be a sufficient number of lag terms that the series will not suffer from correlation problems. Gujarati (2003: 817) suggests that the choice of lag number will need to be determined empirically. Enders (2004: 191-192) discusses various ways that lag length may be determined in the application of the ADF test, while warning that the inclusion of unnecessary lags decreases the power of the test due to its association with decreasing degrees of freedom. In practice more formal tests such as the AIC and SIC criteria are often used, as can be seen from the literature review, and due to this it is these more formal tests that were employed in this study.

4.4.2 Phillips-Perron

The Phillips-Perron (PP) test was run on each series individually in order to test for stationarity. The relevant equations (Leng, 2002: 7) are given below:

$$\Delta S_t = \beta_1 + \beta_{2t} + \gamma S_{t-1} + \varepsilon_t \quad (\text{PP}) \quad \dots \text{Equation 5}$$

$$\Delta F_t = \beta_1 + \beta_{2t} + \gamma F_{t-1} + \varepsilon_t \quad (\text{PP}) \quad \dots \text{Equation 6}$$

The PP test controls for serial correlation within a given series by making a correction to the t-statistic associated with the coefficient of interest γ so that any serial correlation in the residual series is accounted for (Leng, 2002: 7). This method takes the non-augmented DF test and then modifies the t-statistic in such a way that the serial correlation will not affect the asymptotic distribution of the test statistic (Moholwa, 2005: 12). The hypotheses associated with this test are the same as for the ADF test; however, the critical values used are not the same (Moholwa, 2005: 12), and thus those reported in the testing procedure are used in interpreting the following hypotheses:

$H_0: \gamma = 0$ indicates the presence of a unit root and thus nonstationary data.

$H_1: \gamma \neq 0$ if the null is rejected we conclude that the data is stationary.

The PP test is interpreted as follows: when the PP test statistic is greater in value than the test critical values then the null hypothesis is rejected and it is concluded that the given time series is stationary. If the PP test statistic is smaller than the critical values then the null hypothesis cannot be rejected and it is concluded that the given time series is nonstationary.

4.4.3 Kwiatowski, Philips, Schmidt and Shin Test

Brooks (2008: 331) states that the use of both unit root tests (such as the ADF and PP tests) in conjunction with stationarity tests, such as the KPSS test, is known as, 'confirmatory data analysis,' the aim of which is to ensure that the correct data description is decided upon. Enders (2004: 189) states the reason for this is that, 'unit root tests do not have much power in discriminating between ... unit roots close to unity and actual unit roots.' In order to overcome this Enders (2004: 189) and Brooks (2008: 331) suggest that the KPSS test is always used with unit root tests. The KPSS test reverses the unit root tests hypotheses and

instead has a null hypothesis which states that the data is stationary (Leng, 2002: 7). The hypotheses of the KPSS test are shown below.

$H_0: \gamma \neq 0$ indicates that the data is stationary and $I(0)$.

$H_1: \gamma = 0$ if the null is rejected we conclude that the data is non-stationary and contains a unit root, the data is $I(1)$.

When the calculated KPSS test statistic is less than the critical value it is not possible to reject the null hypothesis and it is concluded that the data is stationary. If, however, the KPSS test statistic is found to be greater than its associated critical value(s) then it will be possible to reject the null hypothesis and accept that the underlying data is nonstationary (Leng, 2002: 8).

Cheung and Chinn (1996: para5) state the following: "instead of viewing the tests as competing, the KPSS test results could be used to corroborate the information obtained from the ADF test." That is, the use of more than one method of detecting stationarity provides a level of confidence in the results when the utilized methods draw the same conclusions, and due to this all three of these test results were conducted.

4.5 Testing for Cointegration

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. Two nonstationary series can still display a long-run relationship as long as it can be shown that the regression of those variables results in a stationary residual series. That is, the initial stage of testing for cointegration is to run the cointegrating regression described in equation 2 in order to extract the residual series, as it is the residual series characteristics that one is interested in in this instance. Once the residual series has been isolated, the testing for cointegration begins. A finding of a cointegrating relationship is the first stage of an efficiency study in futures markets, this requirement must be met in order to continue to the second stage of the efficiency testing procedure where the studies hypotheses are applied.

Two main techniques exist that enable this cointegrating relationship to be tested, namely the Engle-Granger (EG) method and the Johansen method (Gujarati (2003), Brooks (2008) and Enders (2004)). There exists some debate, however, regarding which of these methods should be used. In order to understand the differences between these methods, the Engle-Granger method is examined first and is discussed in 4.5.1 below, after which Johansen's method is discussed in 4.5.2 below. A discussion of why one method may be preferred to another is then presented in 4.5.3.

4.5.1 Engle-Granger Cointegration

In brief, the EG method involves a three-step procedure to determine if two $I(1)$ variables are cointegrated and thus display a long-run equilibrium relationship. These steps are adapted from Enders (2004: 335-339).

Step 1: Cointegration requires that the two variables display the same integration order, that is, they must both be $I(1)$ or both be $I(x)$, therefore, the first step involves applying the augmented Dicky-Fuller (ADF) test in order to determine how many unit roots (if any) are present in a given variable. This has been discussed above; where it was shown that the stationarity of the spot and futures price series will be determined through the application of both the ADF and PP tests.

Step 2: Estimate the long-run relationship that exists between the variables in order to examine the behaviour of the residuals from the cointegrating relationship. If the residuals are stationary then it is accepted that a cointegrating relationship exists. Step two is discussed in more detail shortly so as to understand the specifics of this step in terms of statistical method and associated hypotheses.

Step 3: Use the residuals obtained in step 2 to estimate an Error Correction Model for these variables. This stage is examined fully under section 4.7.1.

As we are currently interested in testing for a long-run relationship as described by cointegration, step two is now described in detail. The tests associated with step two are known as the Engle-Granger (EG) and/or Augmented Engle-Granger (AEG) tests.

Firstly, the estimated residuals are taken from the regression run on equation 2⁵.

$$\hat{\varepsilon}_t = S_t - \alpha - \beta_{t-1} \quad \dots \text{Equation 7}$$

Where:

$\hat{\varepsilon}_t$ the estimated residuals obtained from the cointegrating equation.

Then the EG/AEG test is run where the residual series $\hat{\varepsilon}_t$ is tested for stationarity in line within the following equation:

$$\Delta \hat{\varepsilon}_t = \beta_1 \hat{\varepsilon}_{t-1} \quad \dots \text{Equation 8}$$

in order to examine the following hypotheses adapted from Enders (2004: 336):

$H_0: \beta_1 = 0$ and therefore $\hat{\varepsilon}_t = I(1)$, residuals are not cointegrated as they are nonstationary.

$H_1: \beta_1 \neq 0$ and therefore $\hat{\varepsilon}_t = I(0)$, residuals are cointegrated as they found to be stationary.

If the null hypothesis is *not* rejected then there is no cointegration (Brooks, 2008: 340). The reason for this is that if the residual term is found to show stationarity then it can be concluded that spot and futures prices have a long run equilibrium relationship, that is, they are cointegrated.

Although these unit root tests are similar to the DF and ADF tests (in that a series is being tested for the presence of a unit root and consequently for stationarity or lack thereof), in the context of testing for cointegration these tests are referred to as the Engle-Granger (EG) or Augmented Engle-Granger (AEG) tests. The EG and AEG tests are very similar to the DF and ADF tests, except that these tests are run on the estimated residuals of the regression, not on the results of the regression itself. Due to the fact that these tests are based on *estimated* residuals the DF and ADF tests are no longer appropriate and it becomes necessary to use values calculated by Engle and Granger are used rather than the DF and ADF critical values (Gujarati, 2003: 823).

⁵ This regression output can be seen in Appendix 2, Table A2-22.

4.5.2 Johansen's Cointegration

The second method of cointegration testing is known as Johansen's cointegration. The Johansen procedure can also be summarized into three main steps, these are adapted from Enders (2004: 362-366).

Step 1: The first part of step one is as for the EG method in that the underlying series must be examined for stationarity, and it is also necessary to check the variables to determine what order of integration they are, as variables need to be of the same order of integration to be cointegrated.

Step 2: As it is not possible to use OLS (it is necessary to use cross-equation restrictions on the matrix generated with the Johansen's process) alternate forms of the model are utilized in order to estimate the most correct model and accurately determine the rank of the associated matrix created in this method. There are two tests through which the rank of the matrix and thus cointegration is observed, namely the Trace test and the Maximum Eigenvalue test. The details of this matrix creation and the tests mentioned here are discussed in more detail shortly.

Step 3: This stage involves analysing the cointegrating vectors (taken from the original matrix) and speed of adjustment coefficients in order to examine any testing restrictions. This final step is discussed in detail in section 4.7.2 below.

The following discussion is aimed at more fully describing step two of this method, as this is where the presence or absence of cointegration is established. As was stated in step one, Johansen's methodology begins by examining a data set that has two or more $I(1)$ variables which are thought to potentially be cointegrated (Brooks, 2008: 35). Following this finding, Johansen's method defines a vector X as consisting of p variables which are integrated of order 1, otherwise shown as $I(1)$ (Yang *et al.*, 2001: 285). Note that this determination that the series is integrated of order 1 was established by using a second set of ADF tests, this time on the data in FDF. As this study has two variables, spot and futures prices, the discussion below will focus on demonstrating the use of Johansen's with a two-variable case.

Given the fact that $p = 2$ in this study, the vector X will be shown as follows:

$$X = [S \ F]$$

Where S denotes the spot price and F the futures price (Yang *et al.*, 2001: 285).

If S and F are shown to be cointegrated then a vector autoregressive (VAR) model with k lags may be described (Yang *et al.*, 2001: 285). From this VAR it is possible to construct the long-run coefficient matrix to which the test of cointegration is applied and from which the VECM is formed (Brooks, 2008: 350). This matrix consists of both cointegrating vectors and speed of adjustment parameters (Enders, 2004: 36). Johansen's method works through the construction of a matrix of the coefficients of a potentially cointegrating relationship. In order to test for cointegration it is necessary to establish the rank of the matrix in question. The rank of the matrix was determined by establishing how many of the characteristic roots (known as eigenvalues) were different from zero (Brooks, 2008: 350-351).

If the variables of a given model are not cointegrated the rank of the matrix will not be significantly different from zero; and for the matrix to have a rank of 1 the largest of the eigenvalues must be shown to be significantly different from one, while the remaining eigenvalues are shown to not be significantly different from zero (Brooks, 2008: 351). Brenner and Kroner (1995: 30) show that it is expected that natural logs of the spot and futures prices will tend to be cointegrated and will demonstrate the presence of a cointegrating vector of $[1; -1]$ between these prices.

There are two tests that can be used in order to test for cointegration under this method, known as the Trace test and the Maximum EigenValue test (Brooks, 2008: 351), both of which have a null hypothesis that the matrix has a rank of zero, which would indicate a lack of cointegration. The alternative hypothesis is that the matrix has at most a rank of 1, which would indicate that the variables in question are cointegrated. The literature review presented in chapter three showed that both these tests are often employed. The reason for this is that it is possible for these tests to produce conflicting results, and so the use of both ensures that the correct rank is identified (Enders, 2004: 354). As such, both of these tests were utilized in this study.

The Trace test examines the joint hypothesis that the number of cointegrating vectors is less than or equal to r against a general alternative that there will be more cointegrating vectors than r (Brooks, 2008: 351). The null hypothesis of this approach can be described as the scenario where the variables are not cointegrated and hence the rank of the matrix will be zero. The alternative hypothesis states that at least one or more of the cointegrating vectors will have a rank of greater than zero (Enders, 2004: 364). It is common practice to begin this procedure by testing that $r = 0$ (there are no cointegrating vectors contained within the matrix) and if this is rejected the possibility that $r = 1$ and then $r = 2$ in ascending order until a rank can be determined (Charemza and Deadman, 1992: 199).

The Maximum Eigenvalue test examines each eigenvalue individually and thus tests the null hypothesis that the number of cointegrating vectors is r in comparison to the alternative hypothesis that there exists $r + 1$ cointegrating vectors (Brooks, 2008: 351).

Both these tests use critical values from the Johansen statistic tables, although other more recent versions of these critical values are often employed in more recent studies, for example: the values provided by Hansen and Juselius in 1995 used by McKenzie *et al.* (2002: 487) or those provided by EViews where the values from MacKinnin-Haug-Michelis (1999) are used. If the estimated test statistic is greater than the associated critical value then the null hypothesis is rejected. The first of these tests would be that the null hypothesis is that there are no cointegrating vectors, if this is rejected then the null hypothesis becomes that there is one cointegrating vector, and if that is rejected the matrix is tested for two cointegrating equations and so on in a sequential manner until such a time that the null is no longer rejected and the rank of the matrix is thus determined (Brooks, 2008: 352). This procedure was undertaken using the MacKinnin-Haug-Michelis critical values as EViews was used to carry out these tests.

The final stage in testing for rank in this study was to examine the matrix under a number of different assumptions – no intercept and no trend; intercept with trend; intercept with trend with a linear data trend; intercept and trend with linear data trend; and, intercept and trend with a quadratic data trend. The Trace test and the Maximum Eigenvalue tests were applied under a full range of these assumptions in order to examine the sensitivity of these assumptions on the rank determination.

4.5.3 Engle-Granger vs. Johansen's Cointegration

It can be seen from the literature review that many previous studies of this nature used the EG procedure, although it is acknowledged that others (such as McKenzie *et al.*, 2002 and Lai and Lai, 1991) recommend the use of Johansen's method. According to Harris, McInish, Shoesmith and Wood (1995: 564) the EG method is preferred when two variables are being examined where there is only one cointegrating vector. Lai and Lai (1991: 569), on the other hand, suggest the use of Johansen's method, which involves testing the cointegrating equation's parameter restrictions with a likelihood ratio test. The reason they suggest this, is because the EG method is unable to make strong statistical inferences with regard to the parameter limitations. Recall that it is necessary for the parameter restrictions to be proven to hold if a market is to be declared efficient.

There are, however, a number of advantages of using the EG approach, these are given by Alexander (1999: 5) where she highlights that, especially in financial applications of cointegration techniques, EG may be preferred due to the fact that it is easily implemented; the criteria of minimum variance may be more appropriate in a risk management application than the maximum stationarity requirement of Johansen's; the dependent variable in these instances is often clearly defined; and, the potential problem of EG suffering from small sample size bias is rarely a problem with financial data, as data sets are usually large. It must be noted that this study has a sample size of 66, and as was discussed earlier, although not necessarily small, neither is it large in the financial data sense. This is one of the reasons why both approaches were followed in this study - to avoid the possibility of small sample size biasing the overall results.

Although it is a simple and logical approach, some problems with the EG method do exist. Brooks (2008: 342) gives a summary of some of the problems one encounters with the use of the EG method. Firstly, this method can only deal with one cointegrating relationship; however, in some instances more than one relationship may exist. Secondly, one needs to be aware of the possibility of simultaneous equation bias, where the direction of the relationship being tested could theoretically run in both directions and not just the one that has been tested. Alexander (1999: 4), however, states that this problem of simultaneous equation bias is usually more relevant to an equation that contains more than two variables.

The main problem that arises with the use of the EG model, and the one most commonly mentioned in the literature, is seen when testing the price relationship for efficiency or lack thereof. Brooks (2008: 342) states that when working with the EG method of cointegration testing it is not possible to test any hypotheses about the cointegrating relationship.

Charemza and Deadman (1992: 201) acknowledged that the Johansen method is often regarded as superior to the EG method due to the fact that the statistical testing procedures and the power of the cointegration test are seen to be superior. Alexander (1999: 5) suggests that the Johansen's method does not suffer from bias as much as the EG method, especially when there are more than two variables, and the Johansen's method is said to have more power because it finds the most stationary linear combination while the EG approach finds the minimum variance combination.

He and Holt (2004: 6) suggest that Johansen's method has a number of advantages over the EG method (as mentioned above), however, they do emphasise that there are some limitations to its use. The main problem associated with this method is the models' inability to test or examine short-run effects, which could include items such as transportation costs or changing risk premiums, however, another limitation of this method is that the parameters may not be identified. Further, although Johansen's technique is able to deal with some of the shortcomings of the EG method, its main disadvantage is that it can be more challenging to interpret these results, especially in situations where more than one cointegrating relationship is present. It was suggested by He and Holt (2004: 6) that the logical approach to overcoming this is to use the error correction representation described by Engle-Granger.

Charemza and Deadman (1992: 201) highlighted the fact that these two methods have different foundations, the most notable of these being that with the EG method the division between endogenous and exogenous variables is assumed and so it is possible that only one cointegrating relationship exists. In the Johansen method, due to its derivation from VAR modelling, there are no exogenous variables and so, in the case of a single equation the Johansen method may be more suited to be used as an explanatory tool for checking the division of endogenous and exogenous variables.

Heaney (1998: 188) supported the explanation given above. He explained that the use of a single equation method for testing may be inappropriate because the exogeneity of the variables described in the model that is tested using the EG method may be incorrect. As the

Johansen method does not assume that the variables in the cointegrating equation are exogenous this is seen as one advantage of Johansen's over EG. The use of the Johansen's method of detecting cointegration has one further commonly cited advantage over the EG method in that it allows for various restrictions on the variables involved to be examined. In fact, this reason is often cited for explaining why this method is used over the EG method in studies such as this.

Gonzalo and Lee (1998: 149) discuss some possible problems which may arise in the use of the Johansen method of detecting cointegration when there are, sometimes undetectable, deviations from $I(1)$. After a detailed discussion on these potential pitfalls, they recommend that both EG and Johansen techniques be used to test for cointegration in order to increase the robustness of the test results and to avoid any possible errors in interpretation. An alternate approach is to use the number of cointegrating vectors as the decision point on which model to use. Harris *et al.* (1995: 564) have the following to say on the decision between using EG or Johansen's: "EG's method has ... been shown to be the most appropriate for systems of only two variables with one possible cointegrating vector. In the ... case of several variables, the cointegration test by Johansen (1988) is preferred..."

Recall, however, that the main shortcoming of the EG approach is its inability to test the parameter restrictions. While it is evident that arguments can be made supporting the use of both the EG and the Johansen's approach, it should be noted that these approaches are not necessarily mutually exclusive. From a logical point of view this would suggest that the Johansen methodology be applied, in conjunction with the EG method, in order to be certain that there is in fact only one cointegrating vector.

This relates to Alexander's (1999: 5) discussion showing that the underlying statistical characteristics of these methods are different, thus, if both reach the same conclusions that may be considered further support for the findings. Once the number of cointegrating vectors is identified and confirmed the relative coefficients from both tests, if found to be economically sensible and similar, can be seen as support for the EG model applied (Charemza and Deadman, 1992: 201-202). From this approach both tests have already been estimated, so now using the Johansen's method to apply any necessary restrictions is a simply methodological extension. Thus the use of both methods in a study such as this one is appropriate for both the depth of information acquired, and the increased confidence in the results that is obtained.

It can be seen above that the two core methods of detecting cointegration each have its own advantages and disadvantages. In keeping with the approach used in testing for stationarity, and with the EG approach, both these tests were employed in order to ensure that the results obtained from two different models both reach the same conclusions – either that there is or is not a cointegration relationship between spot and futures prices. This approach is supported by Gonzalo and Lee (1998: 149).

4.6 Residual Series Characteristics

As noted previously, a finding of market efficiency requires three things; the first is that cointegration exists between the series being examined, the second being that the parameter restrictions hold, and the third being that the residual series from the cointegrating regression is shown to be a white noise process that has a normal distribution, constant variance and is not affected by serial correlation, that is, covariance between the variables is zero (Greene, 1997: 824). As the residual series is utilized in order to test for cointegration, the underlying nature of the residual series was examined after the presence of cointegration was established. In line with Aulton *et al.*'s (1997: 418-419) suggestions, the residuals were examined by utilizing the following tests, namely: (1) the Jarque-Bera (JB) test for normality of the residuals, (2) the Breusch-Pagan-Godfrey (BPG) test for heteroscedasticity, and (3) the Lagrange-Multiplier (LM) test for serial correlation in order to determine if such a white noise process is present. The specifics of these tests are presented below.

The JB test examines if the series follows a normal distribution, its null hypothesis is that the residuals are normally distributed (Gujarati, 2003: 148). The BPG test examines a given series for heteroscedasticity and tests the null hypothesis that the series in question is homoscedastic. A variable that has constant variance will be homoscedastic as opposed to being heteroscedastic with unequal variance (Enders, 2004: 108).

The LM test examines a series for serial correlation. The null hypothesis of this test is that there is no serial correlation in the variable being tested, and it is only when the test statistic exceeds the critical *chi*-squared value at a statistically significant level that the null is rejected (Gujarati, 2003: 473). Enders (2004: 338) states that a finding of serial correlation would indicate that lag lengths may be too short. Should a residual series demonstrate autocorrelation and is shown to not be a white noise process, such a finding would be a

violation of efficiency in that this would indicate that historical prices and the current futures price could be used to predict future spot prices (Aulton *et al.*, 1997: 410).

The residual series was examined before the ECM models were run, as a finding of cointegration needs to be paired with a finding of a white noise residual series before the rest of the efficiency test can be performed with confidence. Having conducted all three tests an ECM was then developed.

4.7 The Error Correction Models

Regardless of the method or technique used to detect cointegration, the final stage of an efficiency study is to formulate an ECM in order to detail relationship(s) contained within that cointegrating long-run equilibrium. Once the presence of a long-run relationship has been established through the methods described above, an explanation for any deviations from this equilibrium relationship needs to be formed. The ECM is the statistical tool that enables one to investigate the short-run deviations from this proven long-run relationship, and it is understood that the relationship between a finding of cointegration and the use of error correction is a very close one (Greene, 1997: 855).

This error correction relationship applies whether the EG method or the Johansen technique is used to qualify the presence of cointegration. Within the EG framework the immediate step after determining that cointegration exists is to formulate an ECM. That is, cointegration is the first step and then examining the relationship contained in that long-run equilibrium for causality and 'flows' through the formation of an ECM is the second step in the process (Alexander, 1999: 5). In the Johansen test, it is only once the cointegrating vectors have been described that a vector error correction model (VECM) is explained (Greene, 1997: 859). It was shown in the paper by He and Holt (2004: 8) that there are other versions of this ECM relationship, for example, their paper used a GQARCH-M-ECM that allowed for a time varying risk premium to be present. This approach was not followed in this study as a straight forward weak-form efficiency test is to be presented first, the underlying requirement of which is that the market demonstrates a zero risk premium. Following the findings from this weak-form efficiency test, allowances for changes in the underlying assumptions may be suggested in this study's conclusion.

He and Holt (2004: 6) suggest that the EG ECM is estimated even if Johansen's method is used to detect cointegration. This further justifies why both methods are included in the literature, because, as will be discussed shortly, the ECM allows for comment on the price discovery process – arguably the most important role performed by a futures market. An implication of the price discovery function is that spot and futures prices on a given asset will be related to one another in the short run and/or long run. Finding cointegration between these prices shows that an equilibrium relationship describing the price discovery process exists between the two, and that any movement away from that equilibrium will be corrected for by prices in either the spot and/or the futures market (Mahalik *et al.*, 2009: 5).

Both these models are estimated in order to ensure that there is increased confidence in these results. Recall that there has not yet been a South African study that has included this model (either the ECM or the VECM) and as such the comments arrived at from this particular testing procedure are of particular relevance. Both methods are described below in conjunction with the main interpretations and associated concerns of these approaches.

4.7.1 The Engle-Granger ECM

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

$$\Delta y_t = \beta \Delta x_t + \varepsilon_t \quad \dots \text{Equation 9}$$

If a long-run equilibrium exists this indicates that the variables in question are going to reach a point where they converge on their long-run values and thus reach a point where the equilibrium long-run value is no longer changing or moving. Hence, in the model above $y_t = y_{t-1} = y$ and $x_t = x_{t-1} = x$ while the differencing terms will equal zero $\Delta x_t = 0$ and $\Delta y_t = 0$ resulting in a model that completely cancels out. The ECM is able to overcome this problem by combining the first differenced terms with lagged terms (Brooks, 2008: 338).

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:

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

...Equation 7

An advantage of using the ECM is that it is able to overcome one of the problems associated with the use of the EG technique. It was mentioned previously that it may be possible for simultaneous equation bias to occur within the EG framework, that is, the direction of the relationship may not be able to be determined. 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)):

$$\Delta S_t = \alpha_1 + \alpha_s \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{11}(i) \Delta S_{t-1} + \sum_{i=1} \alpha_{12}(i) \Delta F_{t-1} + \varepsilon_{st} \quad \dots \text{Equation 10}$$

$$\Delta F_t = \alpha_2 + \alpha_f \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{21}(i) \Delta S_{t-1} + \sum_{i=1} \alpha_{22}(i) \Delta F_{t-1} + \varepsilon_{ft} \quad \dots \text{Equation 11}$$

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, it shows 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).

The following additional interpretation of the coefficients to the error correction term is taken from Mahalik *et al.* (2009: 11). If 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 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. 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.

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). 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.

Alexander (1999: 6) provides an explanation for the interpretation of the lagged values and the role of price discovery in this model:

"If the coefficients on the lagged [futures price] in the [spot price as the dependent variable] equation are found to be significant then turning points in [the futures market] will lead turning points in [the spot market]. That is, $[\Delta S_t]$ 'Granger causes' $[\Delta F_{t-1}]$ in the 'price discovery' relationship between spot and futures it is often found that futures prices lead the spot, but at times an ECM analysis shows that spot may very well lead futures price."

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).

It is necessary to test for the appropriate lag length to be employed in this particular scenario in order to determine whether or not it is even necessary to include lagged terms within the ECM for this regression (Enders, 2004: 346). Heaney (1998: 189) shows that there are

several approaches to selecting lag length: the method suggested by Sims (1980) (also recommended by Enders, 2004: 363), the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC). The ECM model was thus run from both directions, with an appropriate lag length determined through the application of these lag length selectors. A selection of this output can be seen in Appendix 2, Tables A2-19 and A2-20.

4.7.2 The Johansen's VECM

It has been discussed previously that for a market to be efficient spot and futures prices need to be cointegrated with one another, and most importantly that it is shown that there is a zero risk premium within that market, as well as it being shown that futures prices are unbiased estimators of upcoming spot prices. It was also noted that the main short comings of the EG ECM in these circumstances is that: firstly, it is not possible to apply tests to this model in order to examine the concepts of a zero risk premium and unbiasedness; and secondly, that the EG ECM is not ideal when the sample size is small. Hence, it was necessary to formulate the VECM in order to ensure that the EG ECM results were not distorted by sample size, and most importantly, so that comment may be made on the presence of a risk premium and unbiasedness within this market.

The Johansen's method of detecting cointegration results in a set of matrices that contain the information that allows a VECM to be examined and further allows for parameter restrictions to be placed on the matrices in order to test the efficiency statement fully.

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

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 $n-1$ linearly independent cointegrating relationships. The equation being examined here contains 2 nonstationary variables⁶, 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 our *a priori* expectations 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:

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

It must also be remembered that the cointegrating vector will not be identified until some arbitrary normalisation has been applied to the model, and within the statistical programme employed in this study, this normalisation is set equal to positive one (Quantitative Micro Software, 2007: 370). In the study by McKenzie *et al.* (2002: 487) these authors normalized with respect to S_t (the spot price) from the cointegrating regression. When running Johansen's model in EViews one must simply list the variable that one wishes to normalise against first – that is, the spot price must be the first listed variable – and in this manner the normalisation process will be against the spot price. This process was followed and is in line with the method used by McKenzie *et al.* (2002: 487) and Lai and Lai (1991: 573).

This VECM method of error correction may be affected by the choice of lag length, so it is necessary to consider the choice of lag length carefully (Brooks, 2008: 350 and Enders, 2004: 363). Charemza and Deadman (1992: 201) suggest that a simple way of overcoming this problem may be to examine both a small and large number of lags, and possibly using economic principles to justify one lag length over another should it make more sense to do

⁶ Assuming that the spot and futures price series are found to both be nonstationary series.

so from a logical and theoretical point of view. For example, in this particular instance a lag length over 10 would suggest that part of the current spot price may be affected by prices from over two years ago – theory would suggest that such a long lag would be unlikely and this could be used as justification for a shorter lag-length. Alternatively, Mahalik *et al.* (2009: 16) suggested using the AIC and SIC criteria, while Srinivasan and Bhat (2009: 35) suggested that the SIC criterion be used. These more formal lag length testing methods were employed in order to determine lag length.

Gujarati (2003: 851) shows that it is possible to examine the Akaike AIC and Schwarz SIC figures, in order to ascertain if the lag length used within the VECM is appropriate. The lower these values the better the model and thus one can examine these figures at different lag lengths and then choose the lag length associated with the smallest AIC and SIC figures. As long as these results do not contradict one another, it can further be shown that the model is not sensitive to the choice of lag length selector. This step is undertaken first, after which the VECM is modelled and examined.

Before moving onto the core objective of the VECM, applying the parameter restrictions, it is possible to use this model to make comment on the price discovery function of this market. Brooks (2008: 299, 360-362) show that impulse responses may be used to determine how a dependent variable responds to 'shocks' to each of the other variables within the model. In this way it becomes possible to use the VECM to comment on causality within the market, and provides an additional means of confirming the findings regarding causality found under the EG ECM methodology.

Impulse responses work by applying a unit shock to the error and the effect of this shock over time on each variable within the system is recorded and then reported. Brooks (2008: 299) gives the following rule: 'if there are g variables in a system, a total of g^2 impulse responses could be generated. In this instance the system contains 2 variables, spot and futures prices, and so it can be expected that 4 impulse responses ($2^2 = 4$) will be generated. Enders (2004: 338) states that after the VECM has been examined in terms of its speed of adjustment coefficients and other significant variables, then impulse responses should be employed in order to fully explain the relationship between the variables in that particular system. As such, 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).

Enders (2004: 372) states: "restrictions on the cointegrating vectors and/or the speed of adjustment parameters can be tested using the chi-squared statistics." These restrictions affect degrees of freedom, if the restriction that $\alpha=0$ is applied then the likelihood ratio test applied to that restriction will have a *chi*-squared distribution with 1 degree of freedom; while a joint restriction of $\alpha=0$ and $\beta=1$ will have a *chi*-squared distribution with 2 degree of freedom (Enders, 2004: 366). The use of this method allows for comment to be made on the parameter restrictions that need hold for the market to be shown to be both unbiased and efficient. McKenzie et al. (2002: 487-488) point out that cointegration is showing a long-run relationship and as such, the restrictions placed on that model comment on the long-run efficiency and unbiasedness of the market.

Restrictions may be placed on the coefficients of the cointegrating equation by applying restrictions to the VECM estimates generated in EViews. This programme uses the following description of this spot-futures price relationship where it is possible to place restrictions on the variables in the VECM as follows: $B(r,1)*LOGS + B(r,2)*LOGF$ (Quantitative Micro Software, 2007: 371-372).

Brenner and Kroner (1995: 30) show that it is expected that natural logs of the spot and futures prices will tend to be cointegrated and will demonstrate the presence of a cointegrating vector of $[1; -1]$ between these prices. That is, it is required that $B(r,1) = 1$ and that the $B(r,2)$ coefficient (shown as β in equation 2) is shown to be equal to -1. The reason for the coefficient associated with the futures price being tested at -1 rather than +1 is due to the fact that, once these variables are both made endogenous (and are thus on the same 'side' of the equation), if the spot coefficient remains positive it must mean that the futures coefficient keeps the same value but becomes negative.

Only if a restriction is found to be statistically significant does EViews produce a LR statistic to show the significance of such a result. This test uses the *chi*-squared distribution and the statistic is used to show the significance of those restrictions that are found to be binding (Quantitative Micro Software, 2007: 373). A joint test, as described above, will use two degrees of freedom while an individual test would use one degree of freedom in the *chi*-squared test. If the test statistic is greater than the *chi*-squared critical value then the null

hypothesis will be rejected, that is, if the test statistic is greater than the critical value and the associated p -value is very small, one would conclude that the restrictions do not hold (Brooks, 2008: 375). If, however the opposite is true and a large p -value is obtained one can conclude that the restrictions set do hold.

The remaining parameter restriction requires that the constant term in the cointegrating equation be shown to equal zero, that is, $\alpha = 0$. EViews does not allow for a direct restriction on the constant term to be applied, as was done on the variables within the model as shown above. It is still possible, however, to estimate the VECM in such a way as to be able to comment on the value of the constant term.

When running Johansen's method of cointegration there are a number of different assumptions that may be applied, and as the interest in this instance is with the constant term of the cointegrating equation specifically, a VECM was formed with the assumption that *there is a constant term in the cointegrating equation, but not in the VAR* (shown as the VECM) as this is the term of interest. This VECM was then examined with special focus on the confidence interval and t-statistic that are generated with this models' output where, specifically, it is the t-statistic associated with the constant term that is of interest.

The critical values for this t-test were taken from Brooks' (2009: 617). The critical values fall between 1.6706 and 1.6669 (60 and 70 degrees of freedom respectively at the 5% level) or between 1.2958 and 1.2938 (60 and 70 degrees of freedom respectively at the 10% level). A larger calculated t-value than the critical value is evidence that the null hypothesis is rejected (Gujarati, 2003: 131). That is, a reported t-statistic smaller than these critical values would indicate that it is not possible to reject the null hypothesis that the constant term in the cointegrating equation is equal to zero. Alternatively, if it is found that the reported t-statistic is greater than these critical values the null hypothesis of a zero risk premium will be rejected.

The restriction that $\beta = 1$ was thus examined and presented first, by using the parameter restrictions described above and determining if a LR statistic was produced for those results. Following this, the requirement of a zero risk premium was examined. The results of this VECM and associated comment on these parameter restrictions are presented and discussed in chapter five. Note that restrictions were only applied in the Johansen's methodology once the VECM had been modelled.

4.8 Summary of Methodology

The diagram that follows summarises the methodology that will be used in this study:

Figure 4-1: Methodology

Stage 1: Testing for Stationarity of the Individual Series

Spot Price

1. Change to Natural Log Form
2. Test for Unit Root with ADF and PP
3. Test for Stationarity with KPSS

Futures Price

1. Change to Natural Log Form
2. Test for Unit Root with ADF and PP
3. Test for Stationarity with KPSS

Stage 2: Testing for Cointegration between Spot and Futures Prices

EG Approach

Run Cointegrating Regression

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

to extract Residual Series

$$\hat{\varepsilon}_t = S_t - \alpha - \beta F_{t-1}$$

Then test residuals for stationarity with AEG/EG.

Johansen's Method

1. Use Trace Test and Maximum Eigenvalue test to determine correct rank.
2. Examine rank of the Johansen's matrix under different assumptions

Test Residual Series for white noise process:

1. The JB test
2. The BPG test
3. The LM test

Stage 3: Estimating the Error Correction Representation and Associated Findings

EG ECM

Run EG ECM from both directions, and comment on Granger Causality within ECM



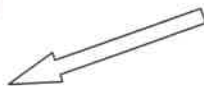
Use findings from above to comment on price discovery process

VECM

Create VECM in order to confirm EG findings and confirm EG ECM findings on Granger Causality with Impulse Responses.



Apply restrictions that $\alpha=0$ and $\beta=1$ to ascertain if long-run efficiency and unbiasedness hold.



4.9 Conclusion

This chapter has provided a description of the methodology that this study followed giving the relevant equations, notations and other information necessary for the understanding of the results of this study. The next chapter will present the findings of the testing procedures described above, as well as discussing the relevance, meaning and interpretation of the estimated results.

5. RESULTS AND ANALYSIS

5.1 Introduction

Now that both the literature and statistical method of efficiency studies have been discussed, this chapter will carry out the analysis described in chapter four above.

5.2 Unit Root Tests

In order to conduct the unit root tests, the relationship between spot and futures prices, as described by equation 2, was run in order to extract the residuals that result from that regression.

5.2.1 Augmented Dicky-Fuller Tests

The ADF tests were applied in order to overcome the limitation of the usual DF tests, which all assume that there is no autocorrelation in the error term. This ADF test enhances the previous DF tests by including lagged values of the dependent term into the testing equation.

These equations were presented in chapter four, however, for ease of reference they are repeated below:

$$\Delta S_t = \beta_1 + \beta_{2t} + \gamma S_{t-1} + \alpha_i \Sigma \Delta S_{t-i} + \varepsilon_t \quad (\text{ADF}) \dots \text{Equation 3}$$

$$\Delta F_t = \beta_1 + \beta_{2t} + \gamma F_{t-1} + \alpha_i \Sigma \Delta F_{t-i} + \varepsilon_t \quad (\text{ADF}) \dots \text{Equation 4}$$

The term of interest is the coefficient associated with the lagged spot price term, labelled as LOGS(-1) in the spot price output in table 5-1 and 5-2 and the lagged futures price term labelled LOGF(-1) in the futures price output shown in table 5-3 and 5-4. As was stated in chapter four, the lag length is determined through the application of the AIC and SIC criterion. Both these criterion suggested that a lag was unnecessary, however, these tests were run both without a lag (showing the SIC finding of no lags) and then with 1 lag in order to ensure that lag length did not affect the results. This was further checked by manually selecting a variety of lag lengths and confirming that, regardless of lag length applied, the results remained the same in both series. A selection of these results is shown in Appendix 2, tables A2-1 and A2-4, and then A2-6 and A2-9.

The ADF tests displayed in tables 5-1 through to 5-4 show the results when both a constant term and a trend term were included. The tests were run with both the inclusion and exclusion of a trend variable. In every case the result was a finding that a unit root was present. These additional results are presented in appendix 2 labelled A2-2 and A2-3 for the spot price series and A2-7 and A2-8 for the futures price series.

Table 5-1: ADF on Spot Price Data with 1 Lag.

Null Hypothesis: LOGS has a unit root
Lag Length: 1 (Fixed)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.010182	0.2819
Test critical values: 1% level	-3.536587	
5% level	-2.907660	
10% level	-2.591396	

Table 5-2: ADF on Spot Price Data with no Lag.

Null Hypothesis: LOGS has a unit root
Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.739859	0.4067
Test critical values: 1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

Table 5-3: ADF on Futures Price Data with 1 Lag.

Null Hypothesis: LOGF has a unit root
Lag Length: 1 (Fixed)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.856242	0.3506
Test critical values: 1% level	-3.536587	
5% level	-2.907660	
10% level	-2.591396	

Table 5-4: ADF on Futures Price Data with No Lag.

Null Hypothesis: LOGF has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.840648	0.3580
Test critical values: 1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

The estimated τ statistic for the γ term on the spot price series is -2.010182 with the inclusion of one lag and -1.739859 without a lagged term; while for the future price series these values are calculated to be -1.856242 with one lagged term and -1.840648 with no lag included. The value of these calculated τ figures are smaller in absolute terms than the 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. The results using one lag concur that both the spot and future price data sets are nonstationary.

Following the approach of the Jordaan *et al.* (2007) study this test was performed again, this time with the data in FDF, applied to the level form figures (using the price data without a natural log transformation), and these results are presented below in tables 5-5 and 5-6. It was, however, confirmed that the same conclusion was reached with the log-form data and the results of these tests are shown in table A2-5 and A2-10 in appendix 2.

Table 5-5: ADF on Spot Price Data (level) in First Difference Form

Null Hypothesis: D(SPOT) has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.719992	0.0000
Test critical values: 1% level	-3.536587	
5% level	-2.907660	
10% level	-2.591396	

Table 5-6: ADF on Futures Price Data (level) in First Difference Form

Null Hypothesis: D(FUTURE) has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.458547	0.0000
Test critical values: 1% level	-3.536587	
5% level	-2.907660	
10% level	-2.591396	

In both sets of results it can be seen that the estimated *tau* value is now greater than the critical values in absolute terms (-7.719992 for spot prices and -7.458547 for futures prices). Recall that if it is shown in FDF that the null hypothesis that there is a unit root is rejected, it is possible to conclude that the data is I(1). When the absolute value is greater than the critical value, the null hypothesis that the first difference of the spot and that of the futures price contains a unit root is rejected and so it is concluded that both the spot and futures series are integrated of the first order (Jordaan *et al.*, 2007: 312). The application of first difference has thus resulted in a stationary series in both cases.

5.2.2 Phillips-Perron Tests

The next set of unit root tests run were the Phillips-Perron (PP) tests, the results of which are presented below. The associated equations were given in chapter four as equations 5 and 6, and are repeated below for ease of reference.

$$\Delta S_t = \beta_1 + \beta_{2t} + \gamma S_{t-1} + \varepsilon_t \quad (\text{PP}) \quad \dots \text{Equation 5}$$

$$\Delta F_t = \beta_1 + \beta_{2t} + \gamma F_{t-1} + \varepsilon_t \quad (\text{PP}) \quad \dots \text{Equation 6}$$

Table 5-7: PP on Spot Price Data

Null Hypothesis: LOGS has a unit root

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.752166	0.2201
Test critical values: 1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table 5-8: PP on Futures Price Data

Null Hypothesis: LOGF has a unit root

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.754108	0.2194
Test critical values:		
1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

The PP's tests on both the spot and future price series demonstrate estimated values that are smaller in absolute terms than their corresponding critical values. The spot series has an estimated PP statistic of -2.752166 while the 5% critical value is -3.480463, and the futures series has an estimated PP statistic of 2.754108 with the same 5% critical value as the spot series. When the estimated test statistic is smaller in absolute terms than the critical value the null hypothesis of nonstationary data and hence the presence of a unit root cannot be rejected.

The different forms of the PP test were examined, including the PP without trend or intercept, with only intercept, and then with trend and intercept (this is the result given above). Model description did not affect the finding of a unit root within both the spot and future price series as in all instances the calculated value was smaller than the critical values. The output of a selection of these alternatives is given in appendix 2, labeled as tables A2-11 to A2-16.

At this point a conclusion that both spot prices and future prices are nonstationary I(1) variables can be reached, however, in order to confirm this finding, the KPSS test was also performed.

5.2.3 KPSS Test

The KPSS test examines a null hypothesis of stationarity against an alternative hypothesis of nonstationarity (Enders, 2004: 189). That is, the hypotheses are reversed from those tested with the ADF and PP unit root tests. The results of the KPSS test on the spot price series is shown below in Table 5-9, while that on the futures price series is shown in Table 5-10 below.

Table 5-9: KPSS on Spot Price Data

Null Hypothesis: LOGS is stationary
 Exogenous: Constant
 Bandwidth: 6 (Newey-West using Bartlett kernel)

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.607109
Asymptotic critical values*:	
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 5-10: KPSS on Futures Price Data

Null Hypothesis: LOGF is stationary
 Exogenous: Constant
 Bandwidth: 6 (Newey-West using Bartlett kernel)

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.620538
Asymptotic critical values*:	
1% level	0.739000
5% level	0.463000
10% level	0.347000

In both the spot and futures price series it is shown that the null hypothesis of stationarity is rejected at the 5% level, as it can be seen that the KPSS test statistic is greater than the critical value at the 5% and 10% levels. Recall that the null hypothesis of stationarity is rejected and it is concluded that the data is nonstationary when the calculated test statistic is greater than its associated critical value (Leng, 2002: 8). At the 1 % level, however, the calculated test statistic is greater than the 1% critical value, so that it cannot be said that the data is not stationary at this level. Brooks (2008: 355) states that a rejection of the null hypothesis at the 1% level would be interpreted as a 'strong rejection'; however, these findings still find that stationarity is rejected at the 5% level. In other words, the findings of the KPSS test are shown to be inconclusive. Cheung and Chinn (1996: para5) stated that KPSS results may be used to confirm the results of the ADF test, however, as these results are only a rejection of stationarity at the 5%⁷ (rather than a strong rejection at the 1% level), further investigation is warranted. It is noted by Asvar and Goss (2000: 199) that such conflicting results in studies of this type are not uncommon.

⁷ 5% is a commonly accepted and appropriate level of statistical significance (Goldacre, 2009: 264).

Leng (2002: 9) and Avsar and Goss (2000: 199) suggest examining a graphical depiction of the underlying series in order to note visually which one of these findings appears most appropriate. This approach is explained by Leng (2002: 9) as a method through which to decide which set of results is more accurate due to the fact that differing results may be attributed to the different power properties of these three unit root tests, or may simply indicate that there were significant changes noted in the underlying market during the time period examined. As such, a line graph of the spot price series is shown below in Figure 5-1, while that for the futures price series is shown in Figure 5-2. The line running horizontally through these graphs represents the mean value of each series respectively.

Figure 5-1: Spot Price (Natural Log Form) with Mean Line

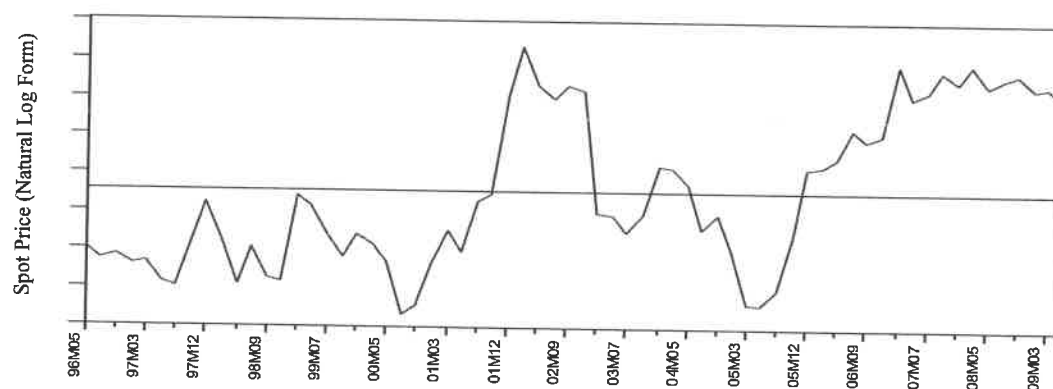
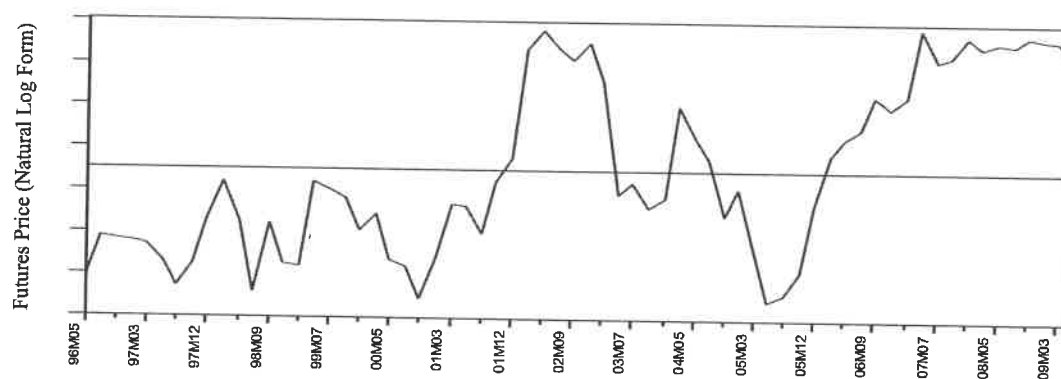


Figure 5-2: Futures Price (Natural Log Form) with Mean Line



Recall that a stochastic, or random, process is known to be 'stationary' if both its mean and variance remain constant over time, and further that the covariance (or autocovariance) that exists between two time periods depends only on the lag between the two dates (Gujarati, 2003: 797). Both these graphs can be seen to have shown an overall increasing trend over time, despite large movements which cross through the mean. These movements across the mean value may help explain why these contradictory results have been obtained. From

these figures it appears that the finding of nonstationarity in the underlying series is correct due to the evident upward trend overall which would indicate a less than constant mean and variance (ie non-stationarity), however, the finding of stationary series within the KPSS test may be as a result of these extreme observed price movements, or significant market changes during the period examined. The latter is possible given that the data series in question covers a time span of more than 10 years, a period of time which saw large increases in trade activity, as well as several global financial events such as the Asian crisis and more recent credit crisis.

It is also possible to examine a Q-test to assess if the autocorrelation in this series is equal to zero. If the calculated Q is greater than the critical Q taken from the *chi*-squared distribution then the null hypothesis that all the autocorrelation coefficients are zero is rejected and it is concluded that at least one of these observations will be non-zero and as such some autocorrelation is present indicating that the data set is nonstationary. The results of these correlograms (in which the Q-test is presented) are contained in appendix 2, tables A2-17 and A2-18. It was found that the calculated Q statistics for the spot series ranged from 53.843 to 184.44 while those for the futures price series ranged from 52.679 to 186.76. The critical value off the *chi*-squared distribution at the 5% significance level for a degrees of freedom (equal to the number of lagged terms) of 28 is 41.337 (Brooks, 2008: 207-208 and 621) and so the null hypothesis is rejected as at least one of the autocorrelation coefficients is non-zero indicating that autocorrelation is present and hence the spot and futures data sets are nonstationary. This is confirmed by the *p*-values which are all zero indicating that the null hypothesis can be rejected with 100% confidence. Brooks (2008: 210) states that only one autocorrelation coefficient needs to be statistically significant to result in a rejection of the hypothesis that all autocorrelation functions are equal to zero.

The ADF test and the PP test have both shown that the spot and futures price series appear to be nonstationary. Although the KPSS results were less conclusive, it was shown that this test rejected the null hypothesis that the underling series were stationary at the 5% level. In order to try and account for the inconclusive results of the KPSS test a visual inspection of these series was undertaken, as well as an examination of the autocorrelation functions of these series, which together demonstrated, through the presence of an upward trend and unequal movements around the mean, as well as a finding that there was autocorrelation present, that the spot price and futures price series are both nonstationary processes.

Literature in international and domestic settings shows that results finding both stationary and nonstationary series occur on occasion. Srinivasan and Bhat (2009: 34) found that all the banking shares they examined were stationary series, and that this finding was consistent regardless of which form of the ADF and PP test was run. In South Africa, Auret and Schmitt (2008: 120) found that the variables thought to influence white maize prices were a combination of stationary and nonstationary series through the use of the ADF test. Aulton *et al.* (1997: 415) also found conflicting results using both the ADF and the PP tests. In contrast, Feng *et al.* (2007: 2) found that both the spot and futures prices examined with the ADF test were nonstationary. Leng (2002: 9) used the ADF, PP and KPSS tests and produced conflicting results: KPSS showed the presence of a unit root in all cases, while the ADF and PP tests rejected the presence of a unit root in some of the time frames examined. This examination of a selection of the results from unit root tests in previous studies shows that the results obtained here are in keeping with those found by previous studies that examined different time series for the presence or absence of a unit root.

5.3 Cointegration Tests

Now that it has been confirmed that the variables in this model are both nonstationary, the next step is to test for cointegration in order to determine if the linear combination of the two data series create a set of estimated residuals that are stationary. The regression of one nonstationary data set on another nonstationary data set is known as a cointegrating regression (Brooks, 2008: 319). Cointegration tests require that the residuals of the cointegrating regression be examined. For reference sake the output for the cointegrating regression itself is shown in appendix 2, table A2-22. This is the first step in testing for efficiency. As discussed in chapter four, first the EG and then the Johansen's method of detecting cointegration will be analysed.

5.3.1 Engle-Granger Results

Having shown that both spot and future prices are nonstationary variables integrated of the first order, the first method of detecting cointegration to be examined is that of the Engle-Granger method.

The null hypothesis of the EG and AEG test is that a unit root is present in the residuals that were extracted from the spot/futures price relationship stated in equation 2. The alternate hypothesis is that the residuals are stationary, and this is the desired result as the presence of stationarity in the residuals indicates that the relationship between two individually nonstationarity variables can still be expressed in such a way that meaningful results can be drawn. All three versions of this test (random walk, random walk with drift, and, random walk with drift and trend) on the residuals were run in order to be certain that the correct result is reached. Although all versions of these tests were performed⁸, all reached the same conclusion and hence table 5-11 shows only the AEG test performed on the residuals, when neither an intercept term nor a trend term are included.

Table 5-11: AEG Test on the Residuals from the Cointegrating Equation

Variable	Coefficient	Std. Error	t-Statistic
RES(-1)	-0.930132	0.123946	-7.504342

The choice of critical value is taken from the fact that there are two variables in this equation (spot price and futures price, the constant term is not considered to variable) and as the complete data set was used to obtain the residuals, the sample size is 65 observations after adjustments. The critical values presented above were taken from Enders' (2004: 441) summary of the appropriate values to use with the EG and AEG tests. The critical values below give two figures; the ones on the left indicate the critical values for 50 observations while the right-hand side values give the critical values for 100 observations. The critical values are as follows:

1% level	-4.592; -4.4441
5% level	-3.915; -3.828
10% level	-3.578; -3.514

In all instances, the estimated t-statistic of -7.504742 is higher than the critical value indicating that the residual series is indeed stationary, at a 1% level. This showed that the null hypothesis should be rejected and the conclusion reached that the residuals of this relationship are stationary.

⁸ The additional AEG results are presented in appendix 2, tables A2-19 and A2-20

5.3.2 Johansen's Results

The first stage of testing for cointegration under the Johansen's method is to determine what the rank of the underlying matrix is. In the same manner in which more than one version of the DF and EG tests exist, so too can various constant terms and/or trends be included in the equation tested for in the Johansen's methodology. The set of assumptions which are the most appropriate in this study, due to the cointegrating equation containing a constant term, are where, firstly, there is a constant term in the cointegrating equation but not in the VAR and these are tested for under the assumption that there is no deterministic trend in the data; and secondly, where there is a constant term in the cointegrating equation and in the VAR but no trend and this is tested for under the assumption that there is a linear deterministic trend allowed for in the data. The Trace and Maximum Eigenvalue tests are run under the set of assumptions which contain a constant in the cointegrating equation, in line with the efficiency statement shown in equation 2, in order to ensure they draw the same conclusions.

The tables below display the results of the Trace tests (tables 5-12 (a) and (b)), and the Maximum Eigenvalue test results (tables 5-13(a) and (b)) under these assumptions. Tables 5-12(a) and 5-13(a) show the results when the first set of assumptions are applied; tables 5-12(b) and 5-13(b) show the results when the second set of assumptions are applied. The critical values are taken from MacKinnon-Haug-Michelis (1999) (Quantitative Micro Software, 2007: 369-370).

Table 5-12(a): Trace Test, No Deterministic Trend

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None	0.383823	34.88917	20.26184	0.0003
At most 1	0.059104	3.899062	9.164546	0.4273

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Table 5-12(b): Trace Test, Assuming a Linear Deterministic Trend

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None	0.383744	34.54092	15.49471	0.0000
At most 1	0.054091	3.558987	3.841466	0.0592

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

The results above both show that for the hypothesis that there are no cointegrating vectors (a rank of zero) there is a very strong and statistically significant rejection of a zero rank. As a consequence, it is found at the 5% level of significance that there will be at most 1 cointegrating equation leading to a conclusion that the Johansen's matrix should have a rank of one.

Table 5-13(a): Maximum Eigenvalue Test, No Deterministic Trend

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.383823	30.99011	15.89210	0.0001
At most 1	0.059104	3.899062	9.164546	0.4273

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

Table 5-13(b): Maximum Eigenvalue Test, Assuming a Linear Deterministic Trend

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.
None	0.383744	30.98194	14.26460	0.0001
At most 1	0.054091	3.558987	3.841466	0.0592

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

The results for the tests above concur with the Trace tests presented in tables 5-12(a) and (b) as both these tests agree that it is highly unlikely that the rank of this equation will be zero, and both agree at the 5% level that the rank of this matrix will at *most* be equal to 1. That is, these tests resulted in the same conclusion, namely, the rank is definitely not zero and so 1 cointegrating equation must exist between LOGS and LOGF. This finding is in line with the statement from Enders (2004: 323) that, if the equation (as in this instance) contains 2 nonstationary variables then at most only one cointegrating relationship can exist (the rank of the matrix association with this efficiency study will be at most 1).

It is further possible for EViews to present a summary of the Trace and Maximum Eigenvalue tests run under the full selection of possible assumptions associated with Johansen's cointegration. This is the information presented in table 5-14 the aim of which is to confirm the findings above, and to examine how sensitive these findings are to the models' underlying assumptions.

Table 5-14: Summation of Johansen's Test Output

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	2
Max-Eig	1	1	1	1	2

Quantitative Micro Software (2007: 366-368) points out that in practice the tests specified by the second and sixth columns (no intercept, no trend; and, a quadratic scenario of intercept and trend) are rarely used, that is, this summary is a tool with which to ascertain how sensitive the analysis is to the assumptions of trend and intercept. The conclusions of columns 3, 4, and 5 (the most commonly employed variations of this methodology) all suggest that a finding of one cointegrating vector is the correct one, and overall it would appear that the rank should equal 1. The last column does, however, indicate that there is a small possibility that a rank of 2 could be reached. Mills (1999: 282-284), however, shows that the quadratic trend is in fact merely an additional test that has the unsatisfactory outcome that the nature of the trend will vary with the number of cointegrating vectors and it is due to this that the common practice is to only focus on those relationships which contain a linear trend.

The fact that both the Trace Test and the Maximum Eigenvalue tests indicate the presence of one cointegrating vector increases the confidence with which it can be concluded that cointegration is present between spot and future prices. Further, considering that both these tests, as well as the Engle-Granger test, separately reach the same conclusion it is possible to conclude that the first requirement of market efficiency has been met and thus it has been shown that there is a long-run cointegrating relationship between spot and futures prices.

Before moving onto the next section of this study, it is appropriate to show how the results obtained here relate to previous studies findings on cointegration. In South African studies of agricultural commodity futures markets, the Wiseman thesis and subsequent paper (1999: 329-330) found that the white maize contracts in 1998 were both cointegrated, however, the 1997 contract was not cointegrated, indicating further that market efficiency had improved from 1997 to 1998. Nikolova's 2003 study did not find nonstationarity in the underlying data and so never went on to check for cointegration, while the studies by Moholwa in 2005 and Phukubje and Moholwa in 2006 did not test for cointegration. The studies by Wiseman

et al. (1999) and Nikolova (2003) used small samples, and examined the early years of the white maize futures market where thin trade may account for their findings. Regardless, this study's finding that the white maize futures market showed cointegration for the entire period 1996-2009 is a clear development in the available literature on this particular market.

Internationally, McKenzie and Holt (1998: 6-7) used both the EG approach, as well as the Trace Test and Maximum Eigenvalue Test in showing that cointegration was present for all of the commodities they examined. Wang and Ke (2002: 12-14) used only the Trace Test and Maximum Eigenvalue tests in showing that while some of the soybean contracts they examined did demonstrate cointegration, some did not. Santos (2009: 9) used only the Trace Test to show that cointegration was present in all the contracts examined in his study. He and Holt (2004: 13) concluded that there was no cointegration in the contracts they examined. That is, results from previous studies show that a finding of a long-run cointegrating relationship itself is fairly common when the underlying data contains two nonstationary processes of sufficient length in time. In this aspect the results of this study are in keeping with those in an international setting.

The approach used here of examining both the EG and Johansen's methods is consistent with the literature, and is also in keeping with the general approach of this particular study in ensuring that the results obtained are correct and consistent regardless of the underlying model chosen. The first stage of efficiency, that there is a cointegrating relationship, has thus been established.

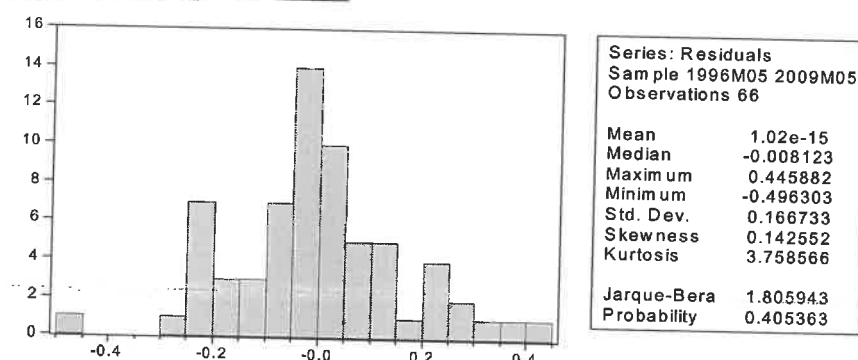
5.4 Residual Series Characteristics

Although a finding of cointegration is the first essential step, a finding of market efficiency also requires that the residual series be shown to be a white noise process. This residual series is that which is created under the EG approach when the cointegrating equation is run in order to extract the underlying residual series. In the EG approach this residual series is tested for stationarity, however, in this instance the same series is also tested for the presence of a set of characteristics which will indicate whether or not it can be considered a white noise process. Aulton *et al.* (1997: 418) suggest that the exact nature of the residual series should be examined in more detail in order to give more evidence towards a finding of efficiency or lack thereof. The following tests are examined: (1) the Jarque-Bera (JB) test

for normality of the residuals, (2) the Breusch-Pagan-Godfrey (BPG) test for heteroscedasticity, and (3) the Lagrange-Multiplier (LM) test for serial correlation

(1) Recall that the null hypothesis of this test is that the residuals are normally distributed. The JB statistic of 1.805943 is not statistically significant indicating that the null hypothesis cannot be rejected leading to a conclusion that the residuals are normally distributed.

Figure 5-3: Jarque-Bera Test



(2) The BPG test below shows that the residuals do not suffer from heteroskedasticity. In this instance the test results show that there is no statistical significance to the BPG test indicating that the null hypothesis of homoskedasticity cannot be rejected. That is, the residuals do not suffer from heteroskedasticity (unequal variance).

Table 5-15: BPG Heteroskedasticity Test

F-statistic	0.092798	Prob. F(1,64)	0.7616
Obs*R-squared	0.095560	Prob. Chi-Square(1)	0.7572
Scaled explained SS	0.123937	Prob. Chi-Square(1)	0.7248

(3) The LM test results are given below and these show that the presence of serial correlation within the residual series can be rejected as the null hypothesis that there is no serial correlation in the variable being tested cannot be rejected. The output below shows that the test statistics are not statistically significant and so the null hypothesis is not rejected and it can be concluded that the residuals do not contain serial correlation.

Table 5-16: Breusch-Godfrey Serial Correlation LM Test

F-statistic	0.332740	Prob. F(8,56)	0.9497
Obs*R-squared	2.994901	Prob. Chi-Square(8)	0.9347

It would appear from the results of these tests that the residuals of the relationship between spot and futures prices display the characteristics of a white noise process in that they are normally distributed and do not appear to suffer from heteroskedasticity or serial correlation. The presence of cointegration, as well as the finding that the residuals of the cointegrating relationship are a white noise process, is the first of the necessary conditions for efficiency to be found in a given market (Aulton *et al.*, 1997: 418), both of these characteristics have now been shown to exist in this data sample. These results also imply that there is an efficient price discovery function between spot and futures prices for white maize (Aulton *et al.*, 1997: 418).

Not all papers present the tests on the residual series characteristics; however, there is enough evidence in current literature to support the addition of these results to studies such as this. For example, in an international setting Santos (2009: 9) found that the residual series demonstrated white noise properties, a finding that the residual series is a white noise process in turn implied at least some level of short-run efficiency within this market. In South Africa, Phukubje and Moholwa (2006: 202-205) specifically examined the residual series for the presence of autocorrelation and found that there was no significant autocorrelation within that series, concluding that this was evidence of a white noise process. This supports the findings obtained here.

So far, the results have shown that, individually, spot prices and futures prices are nonstationary variables. Together these variables show a long-run cointegrating relationship with a residual series that was shown to be a white noise process thus meeting the first criteria for a market to be efficient. No comment, however, has yet been made on the restrictions that must hold in order for the market to be both efficient and unbiased. If this investigation was to end here, as previous South African studies in agricultural commodities have done, at most it could be stated that there is a long-run equilibrium between spot and futures prices on the white maize futures market.

South African studies in other domestic futures markets, however, have highlighted the need for an ECM to be formulated after a finding of cointegration is confirmed, and as such this is the next stage of this analysis. The core separation between this study and other South African studies of agricultural commodities begins now with the analysis of the ECM models and application of parameter restrictions, however, it is noted that these tests have been commonly applied in international practice.

5.5 Error Correction Models

5.5.1 ECM

The final stage of the EG methodology is to estimate an ECM model 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 5-17 will demonstrate the ECM formed on the original cointegrating equation where the spot price is the dependent variable as shown in equation 10, while tables 5-18 and 5-19 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.

$$\Delta S_t = \alpha_1 + \alpha_s \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{11}(i) \Delta S_{t-1} + \sum_{i=1} \alpha_{12}(i) \Delta F_{t-1} + \varepsilon_{St} \quad \dots \text{Equation 10}$$

$$\Delta F_t = \alpha_2 + \alpha_F \hat{\varepsilon}_{t-1} + \sum_{i=1} \alpha_{21}(i) \Delta S_{t-1} + \sum_{i=1} \alpha_{22}(i) \Delta F_{t-1} + \varepsilon_{Ft} \quad \dots \text{Equation 11}$$

Due to the fact that the variables contained in equations 10 and 11 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 (Enders, 2004: 338). 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 5-17: 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
R-squared	0.050211	Mean dependent var		0.013217
Adjusted R-squared	0.002722	S.D. dependent var		0.189839
S.E. of regression	0.189580	Akaike info criterion		-0.427546
Sum squared resid	2.156442	Schwarz criterion		-0.292616
Log likelihood	17.68148	Hannan-Quinn criter.		-0.374390
F-statistic	1.057311	Durbin-Watson stat		1.945882
Prob(F-statistic)	0.374024			

The coefficient of the error correction term, labelled EJECT(-1), is negative although it is only statistically significant at the 13% level. As 5% is a commonly acknowledged level of acceptance of statistical significance (Goldacre, 2009: 264), a level of 13% cannot be used to conclude statistical significance. 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 11 is found to be positive, this is observed in table 5-18.

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: 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.

A finding that the coefficient of one of the error correction terms (either α_S or α_F) is not statistically significantly different from zero, as indicated above, may indicate that the associated variable is weakly exogenous in that the variable does not respond to any disequilibrium present in the market (Enders, 2004: 333-334). This finding indicates that the spot price does not adjust to meet the long-run equilibrium between the spot and futures markets for white maize, and hence spot prices may be referred to as weakly exogenous.

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 equation 11 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 11 where the futures price becomes the dependent variable and the spot price, constant term and the cointegrating residuals as set as the exogenous variables.

Table 5-18 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
R-squared	0.879614	Mean dependent var		0.013378
Adjusted R-squared	0.873594	S.D. dependent var		0.190235
S.E. of regression	0.067635	Akaike info criterion		-2.488907
Sum squared resid	0.274473	Schwarz criterion		-2.353977
Log likelihood	83.64503	Hannan-Quinn criter.		-2.435751
F-statistic	146.1318	Durbin-Watson stat		1.946410
Prob(F-statistic)	0.000000			

It can be seen that in table 5-18 the error correction term $EGECT(-1)$ 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 if both the coefficients to the error term were statistically insignificant then there would be no granger causality between spot and future prices, that is, one of these coefficients must be non-zero for cointegration and error correction to exist. Mahalik *et al.* (2009: 11) shows that when the error term in the spot price dependent model is insignificant, the error term in the futures price dependent model should be highly statistically significant. That is, because α_f is found to be statistically significant this indicates that granger causality is present, and further suggests that a change in the current periods 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 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 Equation 11, 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. The AEG test confirmed that this residual series was also stationary; the result of this test is captured in Appendix 2 in table A2-21.

This final ECM relationship is shown in table 5-19

Table 5-19: 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
R-squared	0.893078	Mean dependent var		0.013378
Adjusted R-squared	0.887732	S.D. dependent var		0.190235
S.E. of regression	0.063741	Akaike info criterion		-2.607513
Sum squared resid	0.243776	Schwarz criterion		-2.472583
Log likelihood	87.44043	Hannan-Quinn criter.		-2.554357
F-statistic	167.0522	Durbin-Watson stat		1.921482
Prob(F-statistic)	0.000000			

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. *Visa 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).

The magnitude or numerical value of the error correction term shows the speed at which adjustments are made to move any disequilibrium towards the long-run state of efficiency and unbiasedness (McKenzie and Holt, 1998: 7). 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 (Burke and Hunter, 2005: 41-42). 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. A finding greater than 1, for example, would indicate that more than 100% of the difference was adjusted for which would in turn may perhaps suggest an event such as a market overreaction or possibly an incorrectly identified model.

The coefficients on the lagged spot price in the futures price dependent variable ECM (equation 11) in both versions of this particular ECM (futures price dependent Tables 5-18

and 5-19) 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 most important information that has been extracted deals with price discovery. It was shown in chapter two that price discovery is considered to be one of the most important functions performed by a futures market and being able to identify the point of price discovery as being in either the futures or spot market of a given commodity is an important one. The analysis above indicates that in the South African market for white maize over the period examined it was the spot market that performed this function.

There exists some literature on why this event may occur. Although these authors' discussions were presented in chapter two, as a point of reference now that it has been shown that the South African market for white maize is led by its spot market, some of the reasons for this finding are given below. Although this finding is not seen as often as the opposite (that the futures market leads the spot market), it is not the first study to identify this possibility (Alexander, 1999: 6). Leng (2002: 12) found that one of the periods examined had a spot leading futures scenario, and they cite the study by Wong and Meera in 2001 as another that found that the spot market leads the futures market. Ferret and Page (1998: 73) cite Wahab and Lashgaris' (1993) paper as also having found a spot leading futures scenario.

Srinivasan and Bhat (2009: 29) discussed that this finding 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 (Srinivasan and Bhat, 2009: 29) and hence the spot market leading the futures market. 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.

Leng (2002: 2) stated 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). As South Africa may be considered an emerging market and developing country, this could explain why such a result is observed. Santos (2009: 9), however, suggested that a finding that a price discovery process exists may indicate at least some level of market efficiency. Given that trade volumes for white maize futures in South Africa have been steadily increasing over the time frame examined, this suggestion of insufficient liquidity as an explanation for a spot leading futures finding may not be appropriate in this instance.

More detail is needed in order to fully comment on the efficiency of this relationship, and it is clear that the use of Johansen's VECM is necessary as it is in the VECM framework within which restrictions can be applied and examined in terms of statistical significance. As such, the next step is to estimate the VECM and apply the relevant parameter restrictions.

5.5.2 VECM

In line with Gujarati's (2003: 851) suggestion, 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 5-20 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 5-20: 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 (0.47707) [-0.60457]	0.796795 (0.15280) [5.21464]
D(LOGS(-1))	0.355015 (0.43812) [0.81032]	0.246676 (0.14032) [1.75792]
D(LOGF(-1))	-0.119054 (0.14019) [-0.84926]	-0.054421 (0.04490) [-1.21207]
C	0.010477 (0.02467) [0.42467]	0.010975 (0.00790) [1.38895]
R-squared	0.020452	0.899934
Adj. R-squared	-0.028526	0.894931
Sum sq. resids	2.224010	0.228144
S.E. equation	0.192527	0.061664
F-statistic	0.417572	179.8680
Log likelihood	16.69422	89.56106
Akaike AIC	-0.396694	-2.673783
Schwarz SC	-0.261764	-2.538853
Mean dependent	0.013217	0.013378
S.D. dependent	0.189839	0.190235
Determinant resid covariance (dof adj.)	0.000114	
Determinant resid covariance	0.000100	
Log likelihood	112.9603	
Akaike information criterion	-3.217508	
Schwarz criterion	-2.880182	

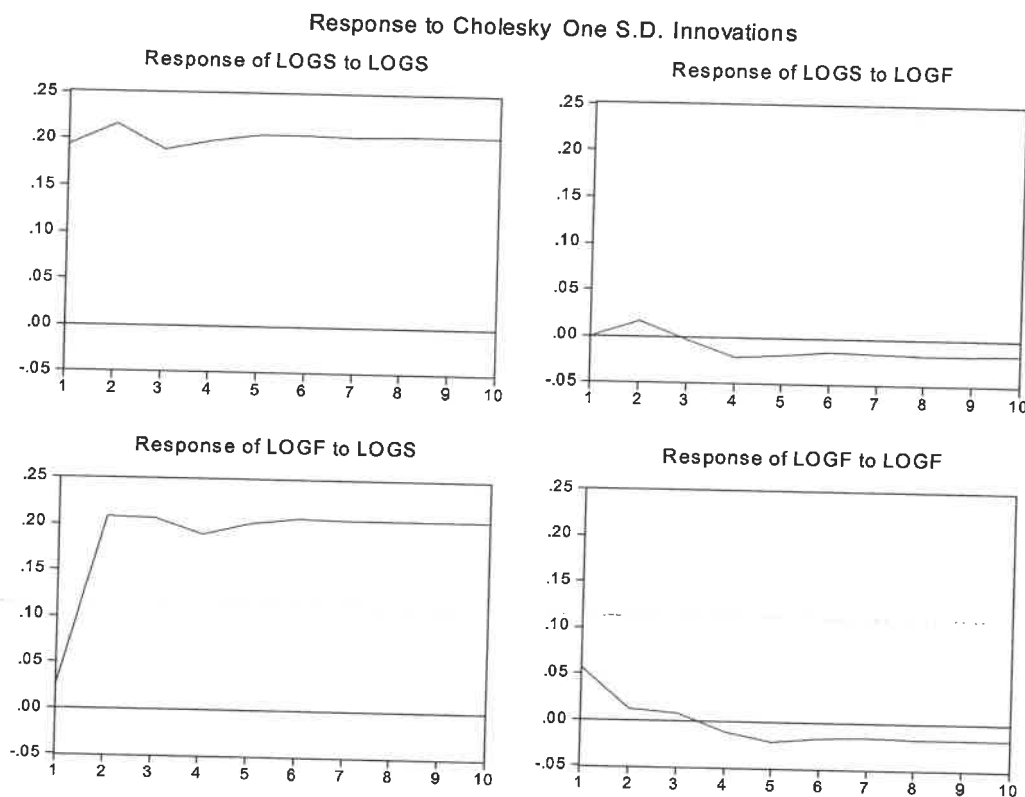
It should be noted that, when it is found that there is only one cointegrating vector, as is the case in this study, the EG method and the Johansen's technique will have the same asymptotic distribution (Enders, 2004: 357). In these scenarios it is not uncommon for the estimated ECM to be used to test restrictions on the speed of adjustment parameters with the usual t-test (Enders, 2004: 357). This implies that the significance of the error correction term above can be taken straight from the given t-statistic in the output above.

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 $D(\text{LOGF})$ 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 examine 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 VECM needs to be read together with these results and those obtained from the EG ECM. The impulse response functions on this VECM are shown in Figure 5-4 below.

Figure 5-4: Impulse Responses



The top left hand graph shows that the spot price is influenced by its own past values. The top right hand graph shows that spot prices are unaffected by changes in futures prices. 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. 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.

Before examining the final stage of this study – the parameter restrictions, the results of these ECM/VECM models in commenting on a price discovery process are compared with other studies that examined this aspect. In South Africa, efficiency and price discovery studies in markets other than agricultural commodities include those by Feddeke and Joao (2001b), Leng (2002) and Floros (2009), all of whom examined a VECM. None of the South African studies into agricultural commodities examined an ECM or a VECM.

Fedderke and Joao (2001b: 10-11) used the VECM to comment on price discovery not market efficiency, and to analyse the impact of shocks to the system. They showed 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.

This study has 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 discussed here, which showed a changing lead or a two-way relationship. This study's result may be due to a number of factors. As was discussed earlier, internationally based papers 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). It is thus necessary to examine the efficiency of this market in order to more fully comment on the implications of this finding that the spot market leads the futures market.

Although the findings on the ECM/VECM in this study have allowed comment to be made on one of the extra objectives of this study, price discovery, it must be highlighted that the core research problem still needs to be fully addressed. It has been established that there is a long-run equilibrium relationship between spot and futures prices, and that the residuals to that relationship have been shown to be a white noise process, however, the VECM can be further used to test the hypotheses of this efficiency study, namely that the futures price is an unbiased predictor and the market contains no risk premium. These restrictions are tested next.

5.6 Parameter Restrictions

As discussed previously, in order for a market to be shown to be efficient it needs to be shown that futures prices are unbiased predictors of upcoming spot prices so that market participants can effectively use the market for risk management and other decisions. A further more restrictive requirement is that the market contains no risk premium to trade. The findings of these restrictions, shown where $\alpha=0$ and $\beta=1$ in the cointegrating equation, are presented below.

Recall that the matrix formed under this method can be depicted very simply as $X = [S \ F]$. If we examine the original cointegrating relationship (and it has been established that there is only one of these cointegrating relationships) it is possible to see why a cointegrating vector of $[1; -1]$ between these prices is displayed below. In the original equation $S_t = \alpha + \beta F_{t-1,t} + \varepsilon_t$ the spot price is on the left hand side of the equation and is positive. When a matrix is formed both these variables are moved to the same 'side' of the equation, resulting in a positive spot coefficient but a negative futures coefficient. In order to test that $\beta=1$ the following restrictions are run: $B(1,1)=1$, $B(1,2)=-1$. This is testing that, given that the spot price coefficient is positive one (that is the spot price is unaffected) then the coefficient to the futures term must equal -1 for futures prices to be unbiased predictors of upcoming spot prices. The results of this test are shown below in table 5-21.

Table 5-21: Parameter Restrictions in Johansen's VECM. Testing $\beta=1$

Vector Error Correction Estimates	
Standard errors in () & t-statistics in []	
Cointegration Restrictions:	
B(1,1)=1, B(1,2)=-1	
Convergence achieved after 1 iterations.	
Restrictions identify all cointegrating vectors	
LR test for binding restrictions (rank = 1):	
Chi-square(1)	0.024428
Probability	0.875800

In this scenario the hypotheses are a joint restriction and thus the critical values were taken from the *Chi-squared* table with 2 degrees of freedom (Brooks, 2008: 130). Recall that in EViews a parameter restrictions output is only generated if the restriction is statistically significant. It can be seen that the *p*-value is 0.8758 and so these combined restrictions are supported by the data (Brooks, 2008: 374-375) and it can be concluded that there is a fairly strong indication that futures prices are unbiased predictors of spot prices.

It is still necessary to examine the constant term from this model. Although it is not possible within EVIEWS to apply a joint restriction which includes a restriction on the constant term, as was done on the variables within the model, it is still possible to estimate the VECM in such a way as to be able to comment on the value of the constant term. Earlier it was shown that Johansen's cointegration, as with many other tests, can be run under a number of different assumptions. As the interest, in this particular case, is specifically with the constant term, the VECM is formed under the assumptions that there is no data trend, although the test includes a constant term in the cointegrating equation (the item of concern here) but not in the VAR. In this manner it is possible to examine the possibility that $\alpha = 0$, as the output gives the confidence interval and t-statistic associated with the constant term. The results of this VECM are presented below in Table 5-22.

Table 5-22: Johansen's Vector Error Correction Model, Examining Constant Term

Vector Error Correction Estimates
Standard errors in () & t-statistics in []

Cointegrating Eq:	CointEq1
LOGS(-1)	1.000000
LOGF(-1)	-0.996943 (0.01902) [-52.4093]
C	-0.018414 (0.13134) [-0.14020]

The term of interest here is the constant term labelled "C". It can be seen that the constant term is shown with an associated t-statistic. Although this figure relate to the cointegrating regression the result can still be interpreted due to the fact that, in a spurious regression, one is concerned with wrongly rejecting a null hypothesis due to incorrectly inflated t-statistics (Brooks, 2008: 319-320). In this instance one is observing a very low t-statistic, and hence this low value may possibly be used with more confidence.

The critical values for the t-test here are taken from Brooks' (2008: 617). The critical values fall between 1.6706 and 1.6669 (60 and 70 degrees of freedom respectively at the 5% level) or between 1.2958 and 1.2938 (60 and 70 degrees of freedom respectively at the 10% level). A larger calculated t-value than the critical value is evidence that the null hypothesis is rejected (Gujarati, 2003: 131). The reported t-statistic is much smaller than any of these

possible critical values indicating that it is not possible to reject the null hypothesis that this term is equal to zero. There is thus evidence to suggest that the South African futures market for white maize does not contain a risk premium. Having examined these restrictions there is evidence that futures prices are unbiased predictors of upcoming spot prices and that the market displays a zero risk premium.

Before examining the final conclusions of this chapter, the results of these parameter restrictions are compared to results obtained in previous studies. An issue that must be highlighted before moving into a discussion of comparative results relates to the fact that existing studies of this nature use a wide variety of approaches and models in order to try and explain the dynamics of a given futures market. That is, the methodology of studies such as these is not consistent resulting in a wide range of approaches to testing for market efficiency. Some studies do not address the full long-run efficiency requirements; others examine the unbiasedness hypothesis but do not test for a zero risk premium; others will check the unbiasedness hypothesis and then apply restrictions aimed at detailing short-run market efficiency; while others try to overcome the limitation that it is not possible to test parameter restrictions under the EG methodology through the use of various other approaches.

For example, after discussing the unbiasedness hypotheses that $\beta=1$ the next step that Aulton *et al.* (1997: 413) and Wiseman *et al.* (1999: 325) utilized was to determine if the futures price contained all publicly available information needed to predict upcoming spot prices by running a regression containing lagged spot and futures prices against the exogenous spot price. If a highly statistically significant F value is obtained from this regression, it is concluded that the information held in historical prices has an effect on the spot price. This indicates that the market is not entirely efficient as there is information in historical spot prices that can be used to forecast spot prices in future periods. It was seen in the literature review that this approach is not commonly used, and it is the application of parameter restrictions, whether to test short-run or long-run market efficiency, that is the commonly accepted approach in these investigations.

As none of the South African papers into agricultural commodities have included an ECM/VECM it is necessary to look at more complete studies of market efficiency. The use of the EG ECM outside of commenting on price discovery becomes apparent as certain authors have applied restrictions within the EG ECM framework in order to comment on the level of *short-run* efficiency in a given market. Some of the findings from studies that discussed short-run market efficiency are presented here. Santos (2009: 9-10) is one who employed both the EG ECM and the VECM to show that wheat futures were short-run efficient, although mixed results were obtained for the corn and oats futures contracts. Authors such as McKenzie and Holt (1998) and He and Holt (2004) used the EG ECM, and then also employed an ECM modelled in an ARCH and GARCH framework and a GQARCH-M-ECM respectively. McKezie and Holt (1998: 9) used this ECM to show that the markets they examined were inefficient in the short-run, attributed to a varying risk premium, while the study by He and Holt (2004: 13) applied this ECM and concluded that there was no risk premium in the short-run.

The focus in this study, however, has not been on examining the short-run dynamics of this market, instead, comment is made on the *long-run* efficiency of this futures market as described by the original hypotheses of this study: that the cointegrating relationship must be shown to have a zero risk premium and the futures prices must be an unbiased predictor of upcoming spot prices. That is, it is appropriate to examine how the results from the application of the standard hypotheses shown in this study differ from results on long-run efficiency obtained in other papers. A selection of results from other studies that tested for $\alpha=0$ and/or $\beta=1$ are discussed below, as this is the methodology employed in this study.

Yang *et al.* (2001: 292-292) tested the unbiasedness hypothesis as above with $[1; -1]$ and found that the hog, oats, soybean and pork-bellies markets all had unbiased futures prices, while those for the live cattle and feeder cattle markets did not. They suggested that this finding would be more likely to be found in a long-run scenario. Yang *et al.* (2001:296-297) then went on to examine the price discovery role in more detail and did not specify testing for a zero risk premium. The paper by Feng *et al.* (2007: 4-6) followed a similar method to the Yang *et al.* paper, as it too showed that the market, in this case the electricity futures market, was unbiased.

McKenzie and Holt (1998: 5-9) found that, in their sample from 1966 to 1995, when the hypotheses were examined separately as $\alpha=0$ and then $\beta=1$ they could not be rejected, however, when these were applied as a joint restriction one of the markets, that for iced broilers, rejected the combined hypotheses at the 5% level, suggesting that the iced broiler market was biased. These authors went on to use the ECM to apply various short-run restrictions and finally concluded that the futures markets for live cattle, live hogs, corn and soybean meal were all efficient, being unbiased and without a risk premium in the long run, these all being markets that found the individual hypotheses to hold (McKenzie and Holt, 1998: 8-9). This approach was also similar to that taken in the paper by Antoniou and Holmes (1996: 122-123) who found that the FTSE-100 futures market was unbiased in the long run, although indications of short-run inefficiencies were attributed to a market risk premium. Lai and Lai (1991: 573-574) found that, although there was some evidence of unbiasedness in the market, overall the findings were inconclusive indicating either a violation of market efficiency, or the presence of an unidentified risk premium.

The finding in this study that the futures market for white maize is unbiased, and contains a price discovery function that is described within an ECM framework, is thus consistent with results obtained in studies in other markets. A finding of long-run market efficiency, although not as common as a finding that there is a risk premium in the market or some other inefficiency, is not unprecedented, although it does indicate a relatively high level of efficiency compared to the findings of the papers discussed above, with the exception of McKenzie and Holt (1998: 5-9). Although studies in various South African markets have not found evidence of market efficiency, the trend towards efficiency observed by Wiseman *et al.* (1999: 330) in the early years of the white maize futures markets operation, as well as the finding by Moholwa (2005) that a trend towards efficiency in this market between 1999 and 2003 was observed and further that, although the market was shown to be inefficient at that time, once market costs and the time value of money were considered the author suggested, but did not prove, that market efficiency may be possible. That is, these authors' earlier findings suggest that this conclusion of market efficiency over this entire period is appropriate. Further, this conclusion that the market is efficient implies that the finding that the spot market leads the futures market in this instance is not an indication of inefficiency, but rather suggests that the spot market is perhaps characterised by greater informational efficiency than the futures market.

5.7 Conclusion

Through the application of a variety of techniques, including graphical analysis, it was shown that both spot prices and futures prices can be described as nonstationarity series. Once this had been established the next stage of testing was to ascertain whether the first requirement of market efficiency held by a finding of cointegration between these two variables. Both the EG and Johansen's techniques were employed in order to be certain that the findings of cointegration or lack thereof were correct.

Cointegration was found to exist within this scenario regardless of model or method used and so it was possible to conclude with certainty that a long-run equilibrium relationship exists within the South African futures market for white maize. The presence of cointegration supported the theory of a weakly efficient market in that a long-run relationship implies that information is being relayed between futures prices and spot prices so that price discovery, to an unspecified degree, is taking place (Wiseman *et al.*, 1999: 324). It was further found that the residual series is a white noise process and as such an additional requirement of market efficiency was shown to be present.

Arguably the most important stage of this chapter involved specifying and interpreting an ECM model (associated with the EG method) and a VECM (associated with the Johansen's method). These models had not previously been employed in a South African study of this nature, and further, it was found that, despite the usefulness that the application of two forms of the ECM offer, this is more rarely presented in previous literature than the single ECM.

The reason both ECM's are offered is that it allows some important implications regarding the relationship between spot and futures markets to be examined; more specifically it allows comment on the point of price discovery, a vital market function, to be made. Both these error correction models were able to show that short-run disturbances of the long-run equilibrium, suggested by the present of cointegration, are being corrected for which in turn shows that there is a price discovery process between these markets. It was found that there was evidence in both the EG ECM and the Johansen's VECM to support the finding that there was price discovery in this market, over the period 1996 to 2009, and that it is the spot market which leads the futures market. This is an interesting finding given that most theory suggests that it should be the futures market that performs the leadership role. This is not, however, the first study to draw such a conclusion.

Next the necessary parameter restrictions for market efficiency were examined. It was found that there is evidence to suggest that futures prices are unbiased predictors of upcoming spot prices. This was done through the application of restrictions within the VECM. It was further possible to show that the restriction that $\alpha = 0$ holds, this finding, together with that above, indicating that there is evidence to suggest that the futures market for white maize in South Africa is weak-form efficient.

It was suggested earlier in the literature that a finding that the spot market leads the futures market could be taken as an indication that the market may not be fully efficient, although there have been studies which suggest several acceptable reasons that one may encounter such a finding in an efficient market. A finding that the spot market leads the futures market in the price discovery process does not preclude a finding of market efficiency per se, that is, the findings here of a spot lead price discovery process and a weakly efficient futures market are not necessarily contradictory terms. It indicates that new information is reflected in the spot market before the futures market, the test of market efficiency conducted in this study, however, measures whether the futures price is an unbiased predictor of the spot price that will occur in the future. It is possible that weak-form efficiency can exist, defined in this way, even if the spot price leads the futures price. This somewhat surprising result could, however, also be as a result of the spot price series used in this study being a 'best alternative' price series rather than a true 'free market determined' price series; and this issue represents an interesting area of further research.

To summarise, the South African market for white maize during the period 1996 to 2009 has been shown to be weak-form efficient due to the finding that there was a zero risk premium in the market during this period, and that, the futures price has served as an unbiased predictor of upcoming spot market prices.

6. CONCLUSIONS

6.1 Summary and Conclusions

Futures markets have been shown to perform many important functions for a variety of market participants. The most important of these functions are commonly cited as being those of price discovery (being able to rely on quoted price data to make investment decisions), risk reduction (being able to use this market to manage risk exposure through hedging activities) and liquidity (the market needs to be characterised by a certain level of liquidity in order for these functions to be of use). In order for market participants to be able to confidently use futures markets for price discovery and risk reduction purposes it is necessary for them to be able to assess the efficiency of the market in question as they require that the market be efficient, in that quoted prices continually reflect all relevant market information.

As the idea of efficiency is related to price information, and specifically the relationship between spot and futures prices, it was shown that the reason that spot and futures prices are related to one another across time is through the variable known as the differential, which contains additional price related information such as storage costs and transportation expenses. Two core theories related to the pricing of futures contracts were presented. The first was the theory provided by Working (1949), which specifically examined the costs involved with carrying a commodity through time (from the current time to the futures contracts maturity). The second was the theory of normal backwardation by Keynes, cited in Brown and Reilly (2009: 772), who suggested that variations in prices could be attributed to the risk transference relationship between hedgers and speculators, as hedgers must, in effect, compensate speculators for the risks they assume when trading in the futures market. These theories allowed comment to be made from a theoretical perspective, as well as forming the foundation from which the econometric notation of market efficiency is created. That is, the key issue is that they provide a theoretical justification why spot and futures prices should move together through time.

Market efficiency specifically refers to the ability of *prices* to reflect relevant information. How much and what types of information are detailed by Fama who presented three forms of market efficiency – weak-form, semi-strong form, and strong-form. From a testing point of view it was shown that weak-form efficiency, where current prices reflect all publicity

available information, is the logical place to start a test of market efficiency as it is would be possible to test a higher order of efficiency after weak-form efficiency is found to be present.

Before presenting the complete methodology that was to be undertaken in this study, an extensive literature review in both international markets and South African markets was presented in chapter three. By examining common elements which ran through these studies it was possible to use these summaries as motivation for the statistical methods presented in chapter four. Chapter four then discussed and presented a summation of this study's methodology, following which the results of the application of the method described in chapter four was presented in chapter five.

It was found through the application of the Augmented Dicky-Fuller and Phillips-Perron Tests that both spot and futures prices were nonstationary variables. The KPSS test for stationarity, however, only rejected *stationarity* at the 5% level. Due to the inconclusive findings of the KPSS tests, line graphs of each the variables were formed and examined. These graphs helped to explain the less than conclusive KPSS results. A clear long run upward movement was clearly observed indicating that the data was in fact nonstationary. Large and extreme price movement which crossed the mean line were noted, these extreme movements helped explain why the results were inconclusive as these large movements may indicate that the data was moving around a mean, rather than containing a trend. In addition to this, and in line with examining these series for stationarity, correlograms with their associated Q-statistics were formed in order to examine that the autocorrelation between each observation in the series was equal to zero. This null hypothesis was rejected, and due to this it was concluded that both spot and futures prices are nonstationary series.

Following this finding the residuals of the potential equilibrium relationship captured in equation 2 were extracted and tested for stationarity with the Augmented Engle-Granger test. This test found that the residuals of this relationship were stationary which in turn indicated that there exists a long-run equilibrium relationship between the two markets. In order to ensure that this conclusion of a cointegrating long-run equilibrium relationship between spot and futures prices was correct, and to further confirm that there was in fact only one cointegrating relationship (and not more) the Trace Test and Maximum Eigenvalue tests associated with the Johansen's method were run. These tests, as well as a diagnostic test on various potential combinations of these tests, all found that cointegration was present, and further allowed it to be concluded that there was only one congregating vector in this system.

The residual series was examined and it was confirmed that this series was a white noise process, thus showing that two of the requirements of market efficiency had been met, namely; that spot and futures prices were cointegrated and that the residual series followed a white noise process.

After a finding of cointegration and a white noise residual series were made, it was then possible to continue the methodology of an efficiency test by formulating an error correction model. This was done in both the EG framework (ECM) and the Johansen's method (VECM). Both these models supported the fact that a long-run cointegrating relationship exists between these variables. Further, and most importantly, they both concluded that there exists a price discovery process between these markets, and that, in contrast to commonly cited *a priori* expectations; it was the spot market that was found to lead the futures market in this regard. Comment on causality was made in the EG ECM by examining the statistical significance of the coefficients within various versions of the EG ECM's, while in the VECM, impulse response graphs were generated in order to visually comment on the nature of causality in this market. It was shown that there exists a price discovery process between the spot and futures markets for white maize in South Africa, and it is the spot market that is the point of price discovery.

As noted earlier there are a number of potential explanations for this discovery. While it had been suggested that this findings could indicate an inefficient market, there were a number of authors who provided valid reasons for this result that would apply within an efficient market. For example, if futures markets are used more by speculative traders the spot market would contain less noise trading and less informational asymmetries which could result in increased market depth, liquidity, and efficiency in the spot market causing the spot market to react first to news event. Further, during periods of uncertainty, such has been experienced in recent years with global events such as the Asian and financial crises, increased value may be given to more certain spot prices by traders of all descriptions.

These findings have a number of implications for various 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. Further, due 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.

The key research question that needed to be addressed, however, was to investigate whether or not the South African market for white maize was efficient over this time period or not. Market efficiency requires not only that the market be found to display a cointegrating long-run relationship, which further implies the existence of a price discovery function between the markets in question as shown within the ECM/VECM framework, but also requires that certain parameter restrictions are met. These restrictions were examined by applying a set of restriction to the estimated VECM model. A zero constant term (no risk premium) and a coefficient associated with the independent variable with a value of one are required. It was found that this constant term was statistically significantly equal to zero ($\alpha = 0$). Further, there was statistically significant evidence from the Johansen's methodology to show that $\beta = 1$. This indicated that the futures price had been an unbiased predictor of upcoming spot prices over this period. These findings indicated that the white maize futures market in South Africa displayed weak-form market efficiency during the period 1996-2009.

6.2 Limitations to Study

This study is limited in that it has only examined one of the agricultural commodities traded on SAFEX. In order to fully comment on issues that affect agricultural commodities (such as those of rising prices that were discussed in chapter one), the behaviour of this entire section of the market would need to be examined, as well as those markets that are key input costs in agricultural commodities, such as fuel. A unified approach will be necessary in order to fully comment on these issues.

Although it has been shown that the market is weak-form efficiency, it should be noted that a limitation of this study is that it has not continued on to test for higher orders of market efficiency. That is, the market is at least weak-form efficient, but stronger tests may indicate that semi-strong form efficiency or even strong-form efficiency is present. Further, it is noted that although these findings may be helpful in describing the market, they have not included a forecasting function, nor have they commented on what may cause future imbalances which would cause the market to move away from efficiency. These aspects would be of particular concern to traders in this market.

Although possible to use the spot prices quoted by SAFEX in testing for market efficiency, it would have been best to use actual cash prices. This is a limitation to the study, although it is noted again that the data used is the best option currently available.

Limitations related to the sample size of this study must be noted. Although a sample size of 66 is not small in the conventional sense, in terms of financial time series data it is not large (considering some financial time series can use daily data over a number of years). On occasion this makes model choice difficult. For example: the EG ECM is not recommended for small sample sizes, but as this sample size is neither small nor large a judgement call must be made. Although mentioned before, this is one of the reason why this study used both the EG and Johansen's methods.

One clear limitation of this study was the problem encountered in applying a three part restriction to the VECM described for the purpose of examining the parameter restrictions. Although it was shown, individually and within the same model and using the same data, that $\beta=1$ and then that $\alpha=0$, it would have added a deeper level of confidence in these results if it could have been shown that, when the spot price is set at one, as is common practice, that both the futures price is unbiased and that the constant term in that equation is equal to zero. Although not explicitly stated in other authors' research, it is a possibility that the reason the ECM is often employed to examine short-run market efficiency, and to not focus on the *dual* application of the long-run efficiency requirements of unbiasedness and a zero risk premium, could be attributed to similar problems being encountered by others. That is, it is seen in the literature that comment made on long-run unbiasedness is often combined with a discussion on short-run market efficiency or price discovery, rather than on long-run efficiency which combines the restrictions of unbiasedness and the zero risk premium.

The methodological limitation, and one that will be faced by any author on this topic, is the wide ranging and not necessarily consistent coverage of the topic. As can be seen from the literature review presented in chapter three, numerous techniques and methods are applied within very similar studies, and models that are quoted as being a necessity by some authors (specifically in this study mention is made of the ECM) are not even mentioned by others. Further, authors also inconsistently report the results of the application of certain models. For example, the ECM can be used to comment on the role of price discovery in a given market, but not all studies that use an ECM follow through its application to a comment on price discovery. Nor do all authors use the ECM to its full potential by showing the ECM modelled from both variables perspectives (individually making first the spot price and then the futures price the exogenous variable) in order to fully comment on the price discovery relationship. To summarise, it is believed that a more apparent common methodology would encourage further research into market efficiency both domestically and internationally.

6.3 Suggestions for Future Research

Although this study is able to address the issues of market efficiency and price discovery over the full data sample, the main potential for additional research in this topic specifically lies in examining how market efficiency and price discovery have changed and/or developed during this period. That is, there is room for more detailed commentary on the development of efficiency – if smaller time frames are examined, in effect cancelling out the first few years of ‘thin’ trade, would different periods of market efficiency be found? When did this market become efficient, especially considering that theory would suggest that the early years of thin trade in this market should not be efficient? Further, if possible to identify when the market first become efficient could that finding be linked to a particular event of market development that could then be used as guidance to other developing exchanges in improving their markets efficiency? Although it has been shown that the spot market leads the futures market over this entire timeframe, it would also be useful to comment on whether or not this has changed from time to time, in order to describe more fully the implications of this price discovery finding, especially considering that a finding that the spot market leads the futures market is not as common as the alternative. Further to this, it would be an interesting avenue of research to more fully examine the relationship between a spot lead price discovery process and market efficiency.

Analysing the price discovery process in the markets for yellow maize, wheat, soybeans and sunflower seeds are obvious potential topics for future research. To the best of the authors’ knowledge the application and associated interpretation of the ECM has not been applied to any of these markets. Further research relating to the use of an ECM could involve modelling the short-run efficiency of this and other markets within the ECM framework, as has been done by other authors.

Previous studies have mentioned the importance of being able to translate econometric findings into policy and/or trading tools. One avenue for future research in this regard is to investigate the creation of a trading strategy which would take advantage of the movements away from equilibrium which are described by the ECM and VECM models. A finding of periods of disequilibrium alone merely shows that there may be potential to make abnormal profits; modelling how to take advantage of such a finding remains a separate issue. The behaviour and nature of that risk premium at different points in time would be another aspect of a study that examined this suggestion.

The introduction to this study showed that there is some debate as to the relative costs and/or benefits that speculative trade provide within a given market. It is when a market is found to be inefficient that the question of speculations' effects may become pertinent, for one may further examine such a market in order to decide what such a lack of efficiency is attributable to. For example, one possible explanation would be that speculation has caused greater volatility in prices leading to instability and findings of inefficiencies. Other reasons, such as the presence of a varying market risk premium, are more commonly concluded by efficiency studies when inefficiency is found, as these reasons directly relate to the tested hypothesis. As this market has been indicated to be at weak-form efficient, it could be assumed that speculation here has had a stabilizing effect; however this cannot be commented on with any level of significance. As such, an area of potential research relating to this would be to try and determine exactly whether or not speculators within the agricultural commodities futures markets have a positive or negative effect on the core functions of the futures market.

From a statistical analysis point of view, developing a standardized approach to the examination of market efficiency and price discovery would encourage more research in this area. Some suggestions to this regard have been made in this study in the discussion on methodology and the results above. For example, when testing was performed in chapter five it was found that both EG and Johansen's techniques indicate that a long-run cointegrating relationship exists. It is suggested then that in future studies the approach of this study is taken whereby both tests are utilized in order to emphasize the appropriateness of the results and conclusions drawn. If the core problem being faced is that the EG method cannot account for more than one cointegrating relationship, then use Johansen's to determine that only one does exist. This confirmation can be used to show ones understanding of the underlying problems of the EG method. Once it has been ascertained that only one cointegrating relationship exist it would be possible to continue with the EG method and its associated ECM. If the problem is that the model being examined needs to have its parameters tested with statistical significance, then it would make sense to continue with the Johansen's method in order to be able to examine any limiting parameters in more detail. Although these comments would perhaps fall under a purely econometrical investigation, the findings would be of particular relevance to studies such as these.

6.4 Conclusion

The use of the ECM, as well as the findings related to price discovery in this market are two key areas that this study has contributed to the literature base and information available on the white maize futures market in South Africa. Due to the inclusion of the ECM/VECM methodologies it was possible to show that the point of price discovery within this market was in the spot market. The core advantage, however, to the inclusion of these models, in particular the VECM, was that it allowed the parameter restrictions of the original hypotheses to be examined, allowing for the key research question of this study to be addressed fully with measurable statistical significance.

There have been no studies in agricultural commodity markets in South Africa that have continued on from detecting cointegration to formulating an ECM/VECM, despite the fact that efficiency studies in other markets, both internationally and domestically, have detailed that these models belong together. In this manner, this study has not only described the level of market efficiency in the white maize futures market and detailed its price discovery function, but it has shown clearly that a finding of cointegration alone is insufficient to comment on these matters. The use of the ECM/VECM framework is vital to efficiency studies and it is hoped that this comment will be used in the future to increase the depth of knowledge and literature available on agricultural commodity markets in South Africa.

This study has showed that the South African futures market for white maize does not contain a risk premium and that futures prices are seen to be unbiased predictors of upcoming spot prices, allowing a final conclusion to be drawn that this market is weak-form efficient. This indicates that historical price information may not be used by market participants to make accurate predictions of upcoming prices, and that the key functions of a futures market of risk reduction and price discovery may be used by market participants with a fair level of confidence. In addition to this, it was found that the spot market leads the futures market in the price discovery function, indicating that market participants should closely monitor spot market changes as these have been shown to influence the prices set in the futures market.

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Appendix 1 - Contract Specifications for White Maize

Code	WMAZ
Underlying Commodity	Maize” means white maize from any origin, of the grade “WMI” as defined in the South African Grading regulations, that meets all phyto-sanitary requirements and import regulations, but is not subject to the containment conditions for the importation of genetically modified organisms
Trading Hours	09h00-12h00
Contract Size	100 Metric Tons
Contract Months	March, May, July, September, December All other calendar months are introduced 20 business days preceding the new month. Once the month is introduced it is traded in the same fashion as the 5 hedging months.
Expiration Date and Time	12h00 on the eighth last business day of the listed expiry month. Physical deliveries from the first business day to the last business day of expiry month.
Settlement Method	Physical delivery of Safex silo receipts giving title to maize in bulk storage at approved silos at an agreed storage rate
Quotations	Rands/ton.
Minimum Price Movements	Twenty cents per ton.
Initial Margin WMI	R10 000/contract up to first notice day. At extended price limits, requirements increased to R15 000/contract R15 000/contract up to expiry day. R30 000/contract up to last delivery day. R3 000/contract for calendar spreads.
Expiry Valuation Method	Closing futures price as determined by the clearing house.
Booking Fees Charges	Futures: R12.00/contract (incl VAT). Options: R6.00/contract (incl VAT). Physical delivery: R200.00/contract (incl VAT).
Maximum Daily Price Movement	R80/ton (R120/ton at extended limits)
Maximum Position limits	Position limits apply to White Maize as per Derivative Directives

Source: Adapted from JSE (2011)

Appendix 2 –Selected Additional Output from EViews

Table A2-1: ADF on Spot Price Data using the AIC Criterion for Lag Length

Null Hypothesis: LOGS has a unit root

Lag Length: 0 (Automatic based on AIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.739859	0.4067
Test critical values: 1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

Table A2-2: ADF on Spot Price Data Assuming Trend and Intercept

Null Hypothesis: LOGS has a unit root

Lag Length: 0 (Automatic based on AIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.574865	0.2929
Test critical values: 1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table A2-3: ADF on Spot Price Assuming No Intercept or Trend

Null Hypothesis: LOGS has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.421603	0.8017
Test critical values: 1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-4: ADF on Spot Price with Manual Lag Selection = 10

Null Hypothesis: LOGS has a unit root

Lag Length: 10 (Fixed)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.781734	0.3856
Test critical values: 1% level	-3.555023	
5% level	-2.915522	
10% level	-2.595565	

Table A2-5: ADF on Spot Price Data in First Difference Form

Null Hypothesis: D(LOGS) has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.167334	0.0000
Test critical values: 1% level	-4.107947	
5% level	-3.481595	
10% level	-3.168695	

Table A2-6: ADF on Futures Price Data using the AIC Criterion for Lag Length

Null Hypothesis: LOGF has a unit root

Lag Length: 0 (Automatic based on AIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.840648	0.3580
Test critical values: 1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

Table A2-7: ADF on Futures Price Data Assuming Trend and Intercept

Null Hypothesis: LOGF has a unit root

Lag Length: 0 (Automatic based on AIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.573199	0.2936
Test critical values: 1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table A2-8: ADF on Futures Price Assuming No Intercept or Trend

Null Hypothesis: LOGF has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.568697	0.8366
Test critical values: 1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-9: ADF on Futures Price with Manual Lag Selection = 10

Null Hypothesis: LOGF has a unit root
Lag Length: 10 (Fixed)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.626111	0.4627
Test critical values: 1% level	-3.555023	
5% level	-2.915522	
10% level	-2.595565	

Table A2-10: ADF on Futures Price Data in First Difference Form

Null Hypothesis: D(LOGF) has a unit root
Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.505173	0.0000
Test critical values: 1% level	-4.107947	
5% level	-3.481595	
10% level	-3.168695	

Table A2-11: PP on Spot Price Assuming No Intercept or Trend

Null Hypothesis: LOGS has a unit root
Exogenous: None
Bandwidth: 1 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	0.395945	0.7951
Test critical values: 1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-12: PP on Spot Price Assuming Intercept without Trend

Null Hypothesis: LOGS has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.855537	0.3510
Test critical values: 1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

Table A2-13: PP on Spot Price Assuming Intercept and Trend

Null Hypothesis: LOGS has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.752166	0.2201
Test critical values:		
1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table A2-14: PP on Futures Price Assuming No Intercept or Trend

Null Hypothesis: LOGF has a unit root
Exogenous: None
Bandwidth: 0 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	0.568697	0.8366
Test critical values:		
1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-15: PP on Futures Price Assuming Intercept without Trend

Null Hypothesis: LOGF has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.940452	0.3121
Test critical values:		
1% level	-3.534868	
5% level	-2.906923	
10% level	-2.591006	

Table A2-16: PP on Futures Price Assuming Intercept and Trend

Null Hypothesis: LOGF has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West using Bartlett kernel)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.754108	0.2194
Test critical values:		
1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table A2-17: Correlogram of the Spot Price Series

Included observations: 66

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
*****	*****	1	0.883	0.883	53.843	0.000
*****	*	2	0.743	-0.166	92.588	0.000
*****	.	3	0.631	0.058	120.98	0.000
*****	*	4	0.507	-0.154	139.58	0.000
****	.	5	0.390	-0.014	150.78	0.000
***	.	6	0.285	-0.058	156.86	0.000
**	.	7	0.195	-0.005	159.74	0.000
*	*	8	0.140	0.080	161.25	0.000
.	*	9	0.125	0.110	162.49	0.000
.	**	10	0.076	-0.213	162.94	0.000
.	*	11	-0.006	-0.152	162.95	0.000
*	.	12	-0.078	-0.072	163.46	0.000
*	.	13	-0.127	0.055	164.83	0.000
*	*	14	-0.145	0.112	166.64	0.000
*	.	15	-0.151	0.026	168.64	0.000
*	.	16	-0.160	-0.039	170.94	0.000
*	.	17	-0.148	0.022	172.94	0.000
.	.	18	-0.108	0.006	174.04	0.000
.	*	19	-0.045	0.135	174.23	0.000
.	.	20	0.009	0.042	174.24	0.000
*	**	21	0.082	0.232	174.91	0.000
*	*	22	0.121	-0.175	176.41	0.000
*	.	23	0.129	-0.125	178.16	0.000
*	.	24	0.154	0.011	180.68	0.000
*	*	25	0.143	-0.093	182.90	0.000
.	*	26	0.092	-0.066	183.85	0.000
.	*	27	0.053	0.076	184.18	0.000
.	*	28	0.047	0.112	184.44	0.000

Table A2-18: Correlogram of the Futures Price Series

Included observations: 66

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
*****	*****	1	0.873	0.873	52.679	0.000
*****	*	2	0.741	-0.095	91.135	0.000
*****	.	3	0.619	-0.027	118.43	0.000
*****	*	4	0.492	-0.102	135.95	0.000
*****	.	5	0.388	0.017	147.00	0.000
**	.	6	0.301	-0.010	153.77	0.000
**	.	7	0.228	-0.005	157.72	0.000
*	.	8	0.157	-0.061	159.62	0.000
*	*	9	0.120	0.089	160.76	0.000
.	*	10	0.064	-0.139	161.08	0.000
.	*	11	-0.024	-0.166	161.13	0.000
.	.	12	-0.089	0.007	161.79	0.000
.	.	13	-0.136	0.022	163.36	0.000
.	*	14	-0.148	0.100	165.24	0.000
.	.	15	-0.156	-0.055	167.39	0.000
.	.	16	-0.158	-0.018	169.62	0.000
.	.	17	-0.152	0.008	171.72	0.000
.	*	18	-0.110	0.147	172.85	0.000
.	*	19	-0.041	0.108	173.00	0.000
.	.	20	0.034	0.108	173.12	0.000
.	*	21	0.106	0.043	174.23	0.000
.	*	22	0.147	-0.069	176.44	0.000
.	*	23	0.150	-0.157	178.79	0.000
.	*	24	0.179	0.142	182.21	0.000
.	*	25	0.154	-0.186	184.79	0.000
.	.	26	0.110	-0.020	186.16	0.000
.	*	27	0.058	-0.129	186.54	0.000
.	*	28	0.044	0.141	186.76	0.000

Table A2-19: AEG Test on Residuals Assuming Trend and Intercept

Null Hypothesis: RES has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.549125	0.0000
Test critical values: 1% level	-4.105534	
5% level	-3.480463	
10% level	-3.168039	

Table A2-20: AEG Test on Residuals using the AIC Criterion for Lag Length

Null Hypothesis: RES has a unit root

Lag Length: 0 (Automatic based on AIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.504342	0.0000
Test critical values: 1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-21: AEG Test on NEW Residuals

Null Hypothesis: RESFUTDEP has a unit root

Exogenous: None

Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.612669	0.0000
Test critical values: 1% level	-2.601024	
5% level	-1.945903	
10% level	-1.613543	

Table A2-22: Cointegrating Regression

Dependent Variable: LOGS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.629992	0.345372	1.824097	0.0728
LOGF	0.910303	0.049944	18.22643	0.0000
R-squared	0.838467	Mean dependent var		6.913592
Adjusted R-squared	0.835943	S.D. dependent var		0.414848
S.E. of regression	0.168030	Akaike info criterion		-0.699512
Sum squared resid	1.806984	Schwarz criterion		-0.633159
Log likelihood	25.08390	Hannan-Quinn criter.		-0.673293
F-statistic	332.2029	Durbin-Watson stat		1.848347
Prob(F-statistic)	0.000000			