

**Measuring the volatility spill-over effects between
Chicago Board of Trade and the South African
maize market**

GERT J. VAN WYK

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE *MAGISTER COMMERCII IN RISK MANAGEMENT* AT THE
POTCHEFSTROOM CAMPUS OF THE NORTH-WEST UNIVERSITY

Supervisor: Dr André Heymans

July 2012

ACKNOWLEDGEMENTS

Ode to the reader: I have set out on a journey to find knowledge and instead I found myself gaining wisdom, finding that there is no greater achievement in life than to conquer oneself.

By experiencing this fundamental truth, I have proven to myself that I am.

I would like to thank Jesus Christ, my personal saviour and my friend, through whom all things are possible.

I would like to thank my wife, Denise, without whom I would be an empty vessel, eternally adrift on the sea of life; I love you dearly.

To my friend and supervisor, André Heymans, may we have many more adventures and may fortune favour us always!

My family and all my dear friends, thank you for all your love, support and for all that you have sacrificed for me over the years. Please know that each of you has a special place in my heart.

To Kobus Strauss (Senwes, SA), Christo Booyens (Senwes, SA), Wimpie Bouwer (Senwes, SA), Daniel Bobrick (HSBC, London, UK), Martin Crawley (Bank of New York, London, UK), Werner Rossouw (Silostrat, SA), Neel Rust (Senwes, SA), each of you took a chance on me at some point in my career and I can vividly recall each and every interview I had with you. You are collectively and individually the reason that I am the trader I am today. I am eternally grateful for all you have done for me, and it is my sincere hope that when our paths cross again that I will be able return the favour.

Last but not least, to Prof. Paul Styger, if you ever have the opportunity to read this document, please know that you inspire me to be more than what I am.

Gert J. van Wyk

2012

ABSTRACT

It is widely believed among South African agricultural market participants that the United States' corn price, as represented by the Chicago Board of Trade-listed corn contract, is causal to the price of white and yellow maize traded on the South African Futures Exchange. Although a strong correlation exists between these markets, the corn contract is far from causal to the South African maize price, as indicated by Auret and Schmitt (2008). Similarly, South African market participants believe that volatility generated in the United States corn market spills over to the South African market. Given the perceived volatility spill-over from the corn market to the maize market, market participants might inadvertently include a higher volatility component in an option price in the South African maize market than is necessary.

This study sought to quantify the amount of volatility spill-over to the South African white and yellow maize market from the United States corn contract. This task was accomplished by applying an Exponential Generalised Auto Regressive Conditional Heteroscedasticity model, within an aggregate shock framework, to the data. The findings indicated that the volatility spill-over from the United States corn market to the South African maize market is not statistically significant. This result suggests that volatility in the South African market is locally driven; hence, it should not be necessary for a South African listed option contract to carry an international volatility component in its price. It was also found that the returns data of the South African maize market is asymmetrically skewed, indicating that bad news will have a greater effect on the price of maize compared with good news.

Keywords: SAFEX, WMAZ, YMAZ, CBOT corn contract, GARCH, EGARCH agricultural commodities, trader, maize, volatility, volatility spill-over, options.

OPSOMMING

Suid-Afrikaanse deelnemers in die landboumark het die onwrikbare persepsie dat die Verenigde State se mielieprys, soos voorgestel deur die "Chicago Board of Trade"-gelyste mieliekontrak, oorsaaklik is tot die bepaling van die Suid-Afrikaanse wit- en geelmielieprys soos verhandel of Suid Afrikaanse Termynkontrak Beurs. Die persepsie spruit uit 'n sterk korrelasie wat tussen die twee markte bestaan. In realiteit is die Verenigde State se pryse nie oorsaaklik tot die Suid-Afrikaanse mielieprys nie, soos deur die navorsing gedoen deur Auret en Schmitt (2008), bewys is. Soortgelyk aan die persepsie, glo Suid-Afrikaanse deelnemers in die landboumark ook dat volatilititeit wat in die Verenigde State se mieliemark gegeneer word, oorspoel na die Suid-Afrikaanse mieliemark. Die persepsie kan daartoe lei dat markdeelnemers in Suid-Afrika 'n hoër volatilititeitskomponent in die Suid-Afrikaanse opsiepryse inprys as wat vereis word.

Hierdie studie het dus ten doel om die grootte van die volatilititeit wat na die Suid-Afrikaanse wit- en geelmieliemark, vanaf die Verenigde State se mieliemark oorspoel, te kwantifiseer. Die proses is gedryf deur gebruik te maak van 'n Eksponensiële Veralgemeende Outoregressiewe Kondisionele Heteroskedastisiteitsmodel binne 'n totale skok ("aggregate shock") raamwerk wat op die datastel toegepas is. Die bevindinge het getoon dat geen statistiese beduidende volatilititeit vanaf die Verenigde State se mieliemark na die Suid-Afrikaanse mieliemark oorspoel nie. Die resultaat dui daarop dat volatilititeit intern gedryf word en die prys van Suid-Afrikaanse opsiekontrakte dus geen internasionale volatilititeitskomponent behoort te dra nie. Dit is ook bevind dat die opbrengsdata vir die Suid-Afrikaanse mieliemark asimmetries verdeel word, wat toon dat slegte nuus 'n groter uitwerking op die prys het as goeie nuus.

Sleutelwoorde: SAFEX, WMAZ, YMAZ, CBOT mieliekontrak, GARCH, EGARCH, landboukommoditeite, handelaar, mielies, volatilititeit, volatilititeitsoorspoel effek, opsies.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
ABSTRACT.....	iv
OPSOMMING	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES	ix
LIST OF FIGURES	ix
Chapter 1: Introduction	1
1.1 Introduction.....	1
1.2 Volatility spill-over: A brief overview	2
1.2.1 Background to volatility spill-over	2
1.2.2 Defining volatility spill-over.....	4
1.3 Problem statement.....	4
1.4 Research aims and objectives	4
1.5 Research methodology.....	5
1.6 Chapter outline.....	5
Chapter 2: Maize Background to a global commodity	7
2.1 Introduction.....	7
2.2 Overview of the maize market.....	7
2.2.1 A brief history of maize	8
2.2.2 Corn in the US.....	9
2.2.3 Maize in South Africa	11
2.2.4 Conclusion.....	14
2.3 Maize price fundamentals	15
2.3.1 Maize price determinants	15
2.3.1.1 Supply and demand of maize	15
2.3.1.2 Weather	17
2.3.1.3 Secular trends	18
2.3.1.4 Government programmes and policy	18
2.3.1.5 Reports	18
2.3.1.6 Political influences	19
2.3.1.7 International news flows	19
2.3.1.8 Exchange rate fluctuations	19
2.3.1.9 Business conditions	20
2.3.2 Factors that influence the pricing of derivative contracts	21
2.3.2.1 The basis.....	21
2.3.2.2 Contango and backwardation markets	22
2.3.3 Conclusion.....	22
2.4 Futures exchanges.....	23
2.4.1 CME Group.....	23

2.4.2 SAFEX Commodity Derivatives Market	25
2.4.3 Exchange contract specifications	26
2.4.4 Conclusion.....	28
2.5 Conclusion	28
Chapter 3: Pricing of derivatives and volatility measurement.....	30
3.1 Introduction.....	30
3.2 Forward, futures and option contracts	31
3.2.1 Forward contracts	31
3.2.2 Futures contracts	32
3.2.3 Option contracts	34
3.2.3.1 Delta	37
3.2.3.2 Gamma	37
3.2.3.3 Theta.....	37
3.2.3.4 Vega	37
3.2.3.5 Rho	38
3.2.4 Conclusion.....	38
3.3 ARCH, GARCH and EGARCH models.....	39
3.3.1 ARCH model.....	41
3.3.2 GARCH model.....	42
3.3.3 EGARCH model	42
3.3.4 Volatility spill-over	46
3.3.4.1 Trade linkages	47
3.3.4.2 Financial linkages.....	47
3.3.4.3 Behaviour of market participants	48
3.3.5 Conclusion.....	48
3.4 Conclusion	48
Chapter 4: Volatility spill-over effects	50
4.1 Introduction.....	50
4.2 Volatility spill-over effect.....	50
4.2.1 Hamao <i>et al.</i> (1990).....	51
4.2.2 Lin <i>et al.</i> (1994).....	51
4.2.3 Koutmos and Booth (1995).....	52
4.2.4 Kanas (1998)	53
4.2.5 Ramchad and Susmel (1998).....	53
4.2.6 Ng (2000)	54
4.2.7 Collins and Biekpe (2003)	54
4.2.8 Baele (2005)	55
4.2.9 Piesse and Hearn (2005).....	55
4.2.10 Conclusion.....	55
4.3 Data and methodology	56
4.4 Empirical results	59

4.4.1 Granger causality.....	59
4.4.2 Aggregate shock model.....	61
4.4.3 Results of the empirical study	66
4.5 Conclusion	68
 Chapter 5: Conclusion.....	 69
5.1 Introduction.....	70
5.2 Aim of the study.....	70
5.3 Review of maize as a global commodity	71
5.4 Review of pricing of derivatives and volatility measurement	72
5.5 Review of the volatility spill-over effect	73
5.6 Conclusion	73
5.7 Recommendations for further research	74
 REFERENCES	 74

LIST OF TABLES

Table 1.1 Production of corn in the US (in million tonnes).....	9
Table 1.2 Corn production in the US per state for 2011/2012.....	9
Table 1.3 Maize production in SA (in tonnes).....	11
Table 1.4 Record number of futures contracts per month	12
Table 1.5 Hectares planted per province (in million tonnes).....	12
Table 1.6 Tonnes produced per province.....	13
Table 4.1 Descriptive statistics for Corn, WMAZ, and YMAZ (R/t).....	56
Table 4.2 Corn level data ADF unit root test.....	57
Table 4.3 WMAZ level data ADF unit root test	58
Table 4.4 YMAZ level data ADF unit root test	58
Table 4.5 Granger causality test between WMAZ and Corn returns.....	60
Table 4.6 Granger causality test between YMAZ and Corn returns.....	60
Table 4.7 EGARCH 121 AS model for Corn and WMAZ.....	64
Table 4.8 EGARCH 211 AS model for Corn and YMAZ.....	65

LIST OF FIGURES

Figure 2.1 Production of corn in the US (in million tonnes)	27
Figure 2.2 Corn production in the US per state for 2011/2012	27
Figure 2.3 Maize production in SA (in tonnes)	28

Chapter 1

Introduction

It would be foolish, in forming our expectations, to attach great weight to matters, which are very uncertain.

John Maynard Keynes

(1936:148)

1.1 Introduction

Increased globalisation has benefited economies around the world, with the increased interconnectivity between markets increasing the risk of volatility spill-over between markets (Boshoff, 2006:61). Volatility spill-over occurs when the volatility generated in a foreign market, owing to a crisis experienced in that market, affects the supply and demand dynamics of a stock or commodity in a local market. The volatility generated in the troubled foreign market effectively spills over to the local market, adversely affecting market prices of certain stock or commodity prices (Kaminsky *et al.*, 2003:3). Volatility spill-over can also be classified as contiguous and non-contagious. (Contagious effects is defined as an immediate transfer of volatility generated in one market and spilled over to the next market, while non-contagious effects are slower to take effect in outside markets and have a limited impact on the local market (Kaminsky *et al.*, 2003:2)).

The contagion effect, brought about through increased globalisation, has left local financial markets vulnerable to international volatility (Khalid & Rajaguru, 2005:8). The extent to which markets are interlinked will govern the degree of contagion and subsequently the level of volatility spill-over experienced between markets (Gonzalo & Olmo, 2005:5).

The three categories that govern the level of interconnectivity between markets and subsequently the level of contagion and volatility spill-over are the behaviour of market participants, and the financial and physical trade linkages that exist between countries (Boshoff, 2006:63). Arguably, the level of market interconnectivity and ultimately the level of volatility spill-over experienced between agricultural markets can be viewed as one of the

most important concepts for market participants¹ to gauge and understand in order to manage price levels accurately. The importance stems from the fact that the volatility in agricultural prices will eventually influence the level reserve food stock, especially if the volatility is experienced in a commodity that is deemed to be a staple food for that country. This dissertation will report on a study on measuring the level of volatility spill-over from movements in the United States corn price to the South African white and yellow maize prices.

This chapter will begin with a short literature review on volatility spill-over in section 1.2. This section will be followed by the description of the problem statement in section 1.3 and of the study's research aims and objectives in section 1.4. Thereafter, the study's methodology will be explained in section 1.5. Lastly, the chapter outline for the remainder of the dissertation will be provided in section 1.6.

1.2 Volatility spill-over: A brief overview

Volatility can be generated by the changes in the supply and demand fundamentals that govern the price of a stock² or commodity. Volatility can consequently be divided into a local and international derived component, with the latter experiencing the volatility spill-over effect (Collins & Biekpe, 2003:182). The greater the market integration between markets, the higher the risk of a large amount of volatility spill-over, effectively destabilising the local market as a result of factors influencing the foreign market. When a significant amount of volatility is spilled over between markets, this situation is referred to as "contagion" (Collins & Biekpe, 2003:182). It is, therefore, important for market participants to be able to gauge the level of volatility generated internationally, since it will directly affect the price of a tradable stock or commodity in the local market. This section will aim to elucidate the concept of "volatility spill-over". Section 1.2.1 will give a brief overview of the background to volatility spill-over, which will be followed by a short explanation of what volatility spill-over entails in section 1.2.2.

1.2.1 Background to volatility spill-over

¹ For the purpose of this dissertation, market participants will mainly include maize producers, speculators, arbitrage traders, millers, animal feed producers, governments, traders, option writers, importers and exporters.

² This dissertation will refer to equity shares as stocks.

In developing an understanding of the concept of "volatility spill-over" concept, it is necessary to revisit the basic finance theory, according to which the risk of return on a stock or commodity can be divided into a systematic and unsystematic risk component. The first type of risk cannot be diversified away and is the risk to which a stock or commodity is exposed by changes in the entire market (Marx, 2006:34). The systematic risk component can vary over time and when macro-economic changes occur that influence the value of a stock or commodity, these changes will increase or decrease the systematic risk component in the pricing of these assets (Reilly & Brown, 2003:244). The second type of risk, the unsystematic risk component, is the risk associated with a specific stock or commodity that can be diversified away and represents uncorrelated returns with the general market (Marx, 2006:34).

Building on these two types of risks, the Capital Asset Pricing Model (CAPM) specifies that beta should be utilised to quantify the risk associated with a stock or commodity (Sharpe, 1970:95). Beta represents a yardstick by which to measure systematic risk based on a stock or commodity's covariance with a market portfolio (Reilly & Brown, 2003:248). The beta measurement subsequently measures the extent to which a stock or commodity's price fluctuates over time compared with the rest of the market (Sharpe, 1970:91). If the price of a stock or commodity fluctuates extensively over time, compared with the rest of the market, that stock or commodity is considered a risky asset, since it is more volatile than the rest of the market. The greater the price movements of a stock or commodity, the higher the volatility of the stock or commodity will be.

Since volatility is an important input into the pricing of stocks and commodities, various studies have been conducted on quantifying the volatility spill-over effect between markets. Although many of these studies have been conducted on equity markets, the findings of these studies can be applied to commodity markets. These studies include Barclay *et al.* (1990), Hamao *et al.* (1990), Lin *et al.* (1994), Koutmos and Booth (1995), Kanas (1998), Ramchand and Susmel (1998), Ng (2000), Collins and Biekpe (2003), Beale (2003), and Piesse and Hearn (2005). (These studies will be discussed in more detail in chapter 4.) From the conclusions drawn from these studies, it is possible to establish a model to quantify the volatility spill-over effect from an international market to a local market. Once a market participant has quantified the effect of international volatility on the local market, he or she will be able to make better informed decisions with regard to hedging or speculative decisions.

1.2.2 Defining volatility spill-over

As explained in section 1.1, volatility spill-over is the amount of volatility that spills over from an international market to a local market. Markets that have close trade links, both physical and financial, will have a tendency to transfer volatility more rapidly than markets that do not have these links. Moreover, volatility spill-over theory indicates that the behaviour of market participants can also increase the level of the volatility spill-over effect between countries (Boshoff, 2006:61). The next section will outline the problem statement that is the subject of this dissertation.

1.3 Problem statement

The volatility spill-over effect from the United States corn (Corn) market to the South African white and yellow maize (WMAZ and YMAZ) market is not well documented. Notwithstanding this lack of documentation, it is widely believed by traders that the Corn price and the exchange rate are causal to the WMAZ and YMAZ price. It is also widely believed by market participants that the volatility generated in the Corn market is spilled over to the South African maize market, despite the lack of any distinct physical trade links between these two markets.

This study subsequently set out to determine whether any volatility is spilled over from the Corn market to the WMAZ and YMAZ markets, respectively. If this is indeed the case, South African market participants will pay a higher premium for option contracts³ in South Africa, owing to volatility generated because of international factors. The findings of this dissertation will provide South African market participants in the options market with valuable insight into the construction of the volatility component with regard to the pricing of options on the South African Futures Exchange (SAFEX).

1.4 Research aims and objectives

The aim of this dissertation is to supply South African market participants with deeper insight into the level and construction of the volatility spill-over effect caused by movements in the

³ An option contract is a contract that gives the buyer the right but not the obligation to buy (sell) a certain asset at a set price (strike price) on or before a certain date (Krugel, 2003:93).

Corn contracts traded on the Chicago Board of Trade on the WMAZ and YMAZ contracts traded on the Johannesburg Stock Exchange's (JSE) SAFEX Commodity Derivatives Market (referred to as SAFEX in this document). Moreover, this dissertation will aim to provide South African market participants dealing in option contracts with an explanation of the amount of volatility spill-over that should be priced into the local options price via the volatility input.

1.5 Research methodology

The research aims of this dissertation were attained through research in the form of a literature review and through empirical tests. The literature review that will be detailed in chapter 2 considers all the factors that may have an effect on a market participant's trading decisions, including the history of maize, the fundamental analysis and the derivative pricing methodology. For the empirical part of the study, which will be detailed in chapter 4, an aggregate shock (AS) model and an Exponential Generalised Autoregressive Conditional Heteroscedasticity (EGARCH) model were utilised to model the level of volatility spill-over from the Corn market to the WMAZ and YMAZ markets.

1.6 Chapter outline

Chapter 2 will investigate the history of maize and the spread of this commodity throughout the world. Following the section on the origins of maize, the focus will move to factors that may influence the price of maize. This will be done to clarify the fundamental factors that influence the price expectations formulated by market participants before they enter into a trade on an exchange. The fundamental pricing factors of maize will be included to provide a comprehensive overview of the process of forming a trading decision. The last section in chapter 2 will briefly examine the most important futures exchanges for the purpose of this study where maize is traded in the United States (US) and South Africa (SA).

Chapter 3 will examine the pricing of derivatives and the models constructed to measure volatility in markets. This chapter will start with a description of forward contracts, followed by futures contracts and then a discussion of option contracts. As part of the option-pricing model, volatility will be shown to be an important factor in pricing this type of contract.

Following on from the concept of volatility, chapter 3 will discuss the Auto Regressive Conditional Heteroscedasticity (ARCH) family of models, which are designed to measure volatility. Each model has certain strengths and weaknesses that will be explored in order to identify the most appropriate model for this study.

Chapter 4 will examine and present the descriptive statistical tests conducted on the market returns of corn and maize traded on the Chicago Board of Trade exchange and the South African Futures Exchange, respectively. The empirical results obtained and the interpretation and explanation of these results will subsequently be presented at the end of this chapter.

Chapter 5 will conclude with a summary of each chapter in relation to the aims of this study. This chapter will provide concluding remarks and recommendations for further study on volatility spill-over between the US corn and SA maize markets.

Chapter 2

Maize: Background to a global commodity

The divergence between expectations and outcomes provides the key to understanding history and I interpret financial markets as a historical process.

George Soros

(2003:18)

2.1 Introduction

Market participants form expectations about the futures⁴ price of a commodity based on the information available to them at any given time. It is therefore vital to understand the price drivers of the commodity that will be traded. In this section of the study, the focus will be on driving forces behind the prices of both SA maize and US corn. With insight into the fundamental workings of maize, the aim of this chapter will be to provide the reader with a clearer understanding of the interaction of both the WMAZ and YMAZ prices with the Corn price. This will provide the foundation to chapter 4, which will provide insight into the determination of price and volatility transmission before and during supply and demand shocks.

This chapter will start by providing an overview of the maize market by first giving a brief history of maize, followed by a market overview of the US corn and SA maize markets in section 2.2. Next, the fundamentals of the maize price will be discussed in section 2.3, starting with the maize price determinants, followed by other factors that determine the derivatives pricing of maize. Once the fundamentals have been discussed, the futures exchanges on which corn and maize are actively traded will be discussed in section 2.4, along with the contract specifications for corn and maize on each of these exchanges.

2.2 Overview of the maize market

⁴ A futures contract is a contract between a buyer and a seller for the delivery of a standardised amount of a specifically defined commodity at a specific price and delivery date in the future. These contracts are traded on formalised exchanges (Krugel, 2003:93).

Maize is the third largest global crop planted after wheat and rice (Abbassian, 2006:1). It is an important food crop and primarily used as a feed crop and a staple food source. Moreover, maize has also become popular for its industrial application, that is, the production of ethanol (Abbassian, 2006:3). The usage of maize has shifted away from purely human consumption and has become popular for animal feed and industrial usage. The feed component of the world usage figure accounts for 510.6 million tonnes and the balance is divided between human and industrial consumption, with the latter carrying a greater weight (USDA, 2011).

2.2.1 A brief history of maize

Although maize is currently considered a global agricultural commodity in the trading arena, it started as a wild grass several millennia ago (Salvador, 1997:2). Maize is believed to have been cultivated approximately 5 000 years ago for human consumption in the Central American country now known as Mexico (Salvador, 1997:2). The maize was grown as a wild grass referred to as "*teosinte*" and cultivated by the Meso-American natives (Abbassian, 2006:4). The modern-day term "maize" is believed to have been derived from the word "mahis", which means "source of life" for the Tanio people in the US, maize is known as corn. This word has its origin in the German word "korn", which refers to edible grass (Salvador, 1997:3).

Maize (corn) is not a perennial plant and must be replanted annually. The plant is highly adaptable, which helped its spread across the globe. In the fifteenth century, the Spanish, among other Europeans, expanded the cultivation of maize into North America, Europe, Asia and Africa (Salvador, 1997:2). Maize, over time, evolved into several hybrids, the most common of which includes dent (a field crop utilised in animal feed and human consumption and can be white or yellow), flint (grown in Central and South America) and sweet or green maize (Abbassian, 2006:4).

Maize, depending on the taste and colour, is grown in two broad groups: yellow and white. Yellow maize accounts for the bulk of the production worldwide, grown mostly in the Northern Hemisphere, where it is used mainly for animal feed and industrial usage (Abbassian, 2006:4). White maize is produced in the US, Mexico and SA, and requires more favourable growing conditions. This maize variant is generally considered a human food crop and as such normally carries a monetary premium to yellow maize, depending on local supply and demand conditions (Venter, 2011).

2.2.2 Corn in the US

The US is the principal consumer of maize, with 34% of its total production being used for animal feed (USDA, 2011). The US mainly produces yellow dented corn, which is utilised in feed for hogs, poultry and cattle (Hinebaugh, 1985:10). In addition to the animal feed component, the US utilises 37% of its maize supply in the production of ethanol (USDA, 2011). Table 1.1 shows the production of corn in the US from 1998 to 2011.

Table 1.1: Production of corn in the US (in million tonnes).

Year	Total
1998/1999	384 191
1999/2000	371 279
2000/2001	390 333
2001/2002	374 271
2002/2003	353 012
2003/2004	397 183
2004/2005	464 817
2005/2006	437 535
2006/2007	414 741
2007/2008	513 279
2008/2009	476 037
2009/2010	515 405
2010/2011	490 012
2011/2012	484 603
Average	433 335
Maximum	515 405
Minimum	353 012

Source: USDA (2011).

The production of corn, as shown in the table above, has been as high as 515 405 000 tonnes and as low as 353 012 000 tonnes, with an average of 433 335 000 tonnes produced per season. The enormity of the US crop can be put into context by comparing it to the total world production of maize, which the USDA pegs at 867 520 000 tonnes for December 2011 (USDA, 2011). Table 1.2 shows production of the corn crop in the US per state.

Table 1.2 Corn production in the US per state for 2011/2012.

State	Production	% of total production
Iowa	91 890 584	18.96
Illinois	76 153 266	15.71

Nebraska	59 839 208	12.35
Minnesota	48 186 310	9.94
Indiana	32 537 569	6.71
South Dakota	25 510 399	5.26
Wisconsin	20 660 274	4.26
Ohio	20 155 577	4.16
Kansas	16 928 197	3.49
Missouri	14 125 203	2.91
Michigan	12 818 188	2.65
North Dakota	8 877 461	1.83
Texas	7 027 170	1.45
Kentucky	7 004 337	1.45
Colorado	6 377 600	1.32
Pennsylvania	3 990 724	0.82
Tennessee	3 908 445	0.81
Mississippi	3 576 967	0.74
New York	3 099 828	0.64
Louisiana	2 976 213	0.61
Arkansas	2 810 868	0.58
North Carolina	2 582 534	0.53
Other states	2 580 566	0.53
Maryland	1 818 797	0.38
Georgia	1 735 337	0.36
Virginia	1 592 825	0.33
California	1 121 985	0.23
Alabama	1 010 968	0.21
Washington	950 735	0.20
Delaware	914 949	0.19
South Carolina	725 354	0.15
Oklahoma	724 369	0.15
New Jersey	403 521	0.08
Total	484 616 329	100.00

Source: USDA (2011).

From the table above, it is evident that Iowa, Illinois and Nebraska account for approximately 47% of the total production of corn in the US. Planting starts as early as 1 March in Texas and ends as late as 15 July in California, whilst harvesting starts around 15 July in Florida and ends around 10 December in Utah (USDA, 2010:9). Some of these planting and harvesting times overlap, because of the vast geographic area in which corn is produced

across the US. Corn is planted from the South to the North and harvested in a similar fashion (USDA, 2010:9).

Corn in the US is traded in cents per bushel. There are 54 pounds per bushel and 5 000 bushels per contract in a grade 2 yellow contract, which equates to 127 tonnes. Corn in the US is graded according to five grades: (a) grade 1: 56 pounds per bushel with a moisture content of 14%; (b) grade 2: 54 pounds per bushel with a moisture content of 15.5%; (c) grade 3: 52 pounds per bushel with a moisture content of 17.5%; (d) grade 4: 49 pounds per bushel with a moisture content of 20%; and (e) grade 5: 46 pounds per bushel with a moisture content of 23% (Abbassian, 2006:5). The grading of corn is important, since it not only measures the quality of the corn, but also provides a benchmark for exchange contract standardisation. Another exchange standardisation factor for corn is that the marketing season for the corn crop starts between 1 September and 31 August (CME, 2011).

2.2.3 Maize in South Africa

One of the few exceptions to the uses of yellow maize⁵ can be found in SA, where white maize is used as a staple diet for human consumption. Even though maize is the second largest crop produced in SA, after sugar cane, it is considered the most important grain crop because of its staple food status (DAFF, 2010:1). According to the SA National Crop Estimate Commission's (DAFF, 2011) final production figures for commercial summer crops for 2011, white maize production accounted for 58% of the maize crop production and yellow maize 42%. Table 1.3 shows the production of both white and yellow maize from 1998 to 2011 (NDA, 2011).

Table 1.3 Maize production in SA (in tonnes).

Year	White maize	Yellow maize	Total
1997/1998	5 209 200	4 373 000	9 582 200
1998/1999	4 459 500	2 744 000	7 203 500
1999/2000	4 601 000	2 860 000	7 461 000

⁵ Yellow maize can be used to produce food products, animal feeds, industrial products, fermentation and by products like industrial alcohol and ethanol (DAFF, 2010:1).

2000/2001	6 680 800	4 320 000	11 000 800
2001/2002	4 260 300	3 126 500	7 386 800
2002/2003	5 537 500	4 194 350	9 731 850
2003/2004	6 365 600	3 025 900	9 391 500
2004/2005	5 805 000	3 677 000	9 482 000
2005/2006	6 540 700	4 909 300	11 450 000
2006/2007	4 187 400	2 430 600	6 618 000
2007/2008	4 315 000	2 810 000	7 125 000
2008/2009	7 480 000	5 220 000	12 700 000
2009/2010	6 775 000	5 275 000	12 050 000
2010/2011	7 830 000	4 985 000	12 815 000
2011/2012	6 052 000	4 308 000	10 360 000
Average	5 739 933	3 883 910	9 623 843
Maximum	7 830 000	5 275 000	12 815 000
Minimum	4 187 400	2 430 600	6 618 000

Source: DAFF (2011).

White maize is mainly utilised in the production of speciality food products like maize meal, and yellow maize is primarily used for animal feed and industrial applications. Between 1998 and 2011, the average annual production of white maize in SA was 5.73 million tonnes, whilst yellow maize accounted for 3.88 million tonnes. Moreover, white and yellow maize combined accounts for the largest volume of futures trades that pass through SAFEX each year. The below table indicates records achieved on SAFEX.

Table 1.4 Record number of futures contracts per month.

Commodity	Futures contracts traded*	Traded in the month of	Record future contracts open interest*	At the end of the following month	Record tonnes delivered	In the following month
WMAZ	145 432	Jun-03	40 165	Aug-10	690 200	Jul-02
YMAZ	55 460	Jun-08	18 920	Oct-11	278 900	Sep-00

*One futures contract equates to 100 tonnes of maize.

Source: JSE (2011:10).

Maize is produced throughout SA, with the production in Mpumalanga, the North West and the Free State accounting for 82.62% of the tonnes produced and 87.47% of the hectares planted (DAFF, 2011). Tables 1.5 and 1.6 indicate the hectares planted and production in each of the nine provinces of SA.

Table 1.5 Hectares planted per province (in million tonnes).

Province	WMAZ	YMAZ	Total	%
Free State	595	395	990	41.73
North West	500	145	645	27.19
Mpumalanga	180	260	440	18.55
Gauteng	74	41	115	4.85
KwaZulu-Natal	39	42	81	3.41
Northern Cape	2	45	47	1.98
Limpopo	25	12	37	1.56
Eastern Cape	3	12	15	0.63
Western Cape	0.3	2	2	0.1
Total	1 418	954	2 372	100

Source: DAFF (2011).

Table 1.6 Tonnes produced per province (in million tonnes).

Province	WMAZ	YMAZ	Total	%
Free State	2 648	1 501	4 149	39.11
North West	1 850	522	2 372	22.36
Mpumalanga	918	1 326	2 244	21.15
Gauteng	385	185	569	5.37
Northern Cape	23	527	550	5.18
KwaZulu-Natal	220	242	462	4.35
Limpopo	125	51	176	1.66
Eastern Cape	11	60	71	0.66
Western Cape	2	14	16	0.15
Total	6 182	4 427	10 608	100

Source: DAFF (2011).

From the above two tables, it is clear that the most hectares are planted in the Free State and that this province produces the most maize when compared with the other eight provinces. It can also be seen that even though the North West plants 205 000 hectares more than Mpumalanga, the North West only yields 128 000 tonnes more maize than Mpumalanga. This indicates that the North West yields are lower than that of Mpumalanga. It can also be seen that a substantial amount of yellow maize is planted in the provinces situated in the east of the country as opposed to the west. Planting in all the provinces, from east to west, is heavily governed by weather conditions, in particular rain. For maize to complete its growing

cycle and mature, it requires 450 to 600 mm of water per season. It is estimated that for every 15 kg of maize produced, 1 mm of water is consumed; hence, each plant would consume 250 litres of water over its lifespan (JSE, 2010:10). This indicates that maize is sensitive to weather conditions and is a seasonal crop (JSE, 2010:10).

Maize in SA is planted in the summer months from October to December and harvested between May and August, with the bulk of the maize harvested between June and July. The maize is field dried and harvested at approximately 12.5% moisture content up to a maximum of 14% (JSE, 2010:10). Moreover, the maize produced in SA normally has a lower moisture content than maize imported from the US.

The moisture content of maize is also a standard used for grading maize in SA. There are three different grades of maize in SA, namely WM1, WM2 and WM3 for white maize, and YM1, YM2 and YM3 for yellow maize. The grading not only divides white from yellow maize, but also identifies the percentage of defective kernels, foreign matter, kernels of a different colour, maize with a musty, sour or unpleasant odour, and insect-infested maize (JSE, 2010:10). Grading is important in standardising futures contracts traded on SAFEX and for the storage of maize (i.e. trading a WMAZ future on the JSE will intrinsically represent a WM1 contract).

Maize can be stored for a period of two years if well fumigated against insects (JSE, 2010:10). Since it can be stored for such a long period, the marketing season for maize is between 1 May and 30 April of the following year; for example, maize produced in 2010/2011 will be marketed in 2011/2012 (JSE, 2010:10).

Both SA and the US are normally net exporters of maize, depending on local supply and demand conditions; however, SA imported 9 576 000 tonnes from the US from 1960 to 2011. The imports are not the norm but the exception, with 27.88% of the tonnes imported in 1983, 22.85% in 1991 and 20.08% in 1992 (USDA, 2011). This indicates that although the US is the larger of the two markets, direct trade in the physical commodity between SA and the US is sporadic at best.

2.2.4 Conclusion

This section has described the history of maize and focused on the fundamentals of maize, as well as the uses and production of this crop in the US and SA. Maize plays an integral role in the modern economy and, in addition to being a key industrial input, maize is used as an

important food source for both humans and animals. With regard to the use of maize, the US stands out as the largest producer and consumer of maize and maize products in the world, and as such influences the world market to a great extent. The SA maize market is very small in comparison, thus taking its lead from the US maize market. The next section of this dissertation will discuss the fundamentals that determine the price of maize.

2.3 Maize price fundamentals

The basic economic principal that governs the price of maize is supply and demand. Any decrease in the supply of maize should increase the price of maize and a subsequent increase in the supply level should decrease the price. Similarly, an increase (decrease) in demand will increase (decrease) the price of maize. The interaction between demand and supply will eventually even out at an equilibrium price level at which the market should clear (Bernstein, 2000:148).

Maize is mostly traded on futures exchanges throughout the world. A futures contract is in essence a contract that reflects the future value of maize, dependent on the day-to-day expectations of market participants with the information available at that time. The futures prices over time will converge into the spot or cash price of maize (JSE, 2010:23). Since futures prices are derived via market expectations, it is important to determine what drives the expectations of market participants.

The drivers of the expectations formed by market participants are the factors that influence the supply and demand of maize (Bernstein, 2000:148). This section will, therefore discuss these factors. The section 2.3.1 will focus on the factors that influence the supply and demand of maize, while the section 2.3.2 will discuss the factors that influence the derivative contract price of maize.

2.3.1 Maize price determinants

2.3.1.1 Supply and demand of maize

One of the major price determinants of the price of maize is the factors that determine the supply and demand at an international and local level. Since maize is traded across the globe, the exchange rate forms a pivotal factor in the price determination of maize. The exchange

rate influences the substitution effect between countries via import and export prices, which influences the supply and demand of maize in a country (Geysler & Cutts, 2007:296). The factors that influence the demand side are firstly the current population and the growth rate of the population, and secondly the availability of products that can substitute maize. The supply of maize is driven mainly by the availability of hectares for planting, technology, the production in previous years, the current year's production, imports, ending stock levels and weather conditions (Venter, 2011).

Since substitutes are part of the supply and demand conditions of maize, the supply and demand of the substitutes are also important. The demand for commodities may change over time as new technology drives the utilisation of these products. Demand can also be created artificially via the relationship between refined and raw products. An example of this is the relationship between soybean meal and oil (Geman, 2005:148).

Soybean meal accounts for 80% of the soybean and is primarily utilised in animal feed as a substitute for maize (Geman, 2005:148). The price of soybean meal is influenced by the availability of meal from oil-crushing activities, the price of fishmeal, the price of maize and size of livestock herds. Soybean oil is utilised for cooking and is in direct competition with canola, sunflower, palm and groundnut oil (Geman, 2005:149). Therefore, when the demand for soybean oil is relatively low and the soybean meal price is high, the processing of soybeans will continue, since the meal will be sold and the oil will be stored until the price of soybean oil rises to acceptable levels (Geman, 2005:149). This situation will lead to an artificial demand being created for oil by the storing of the soybean oil, a by-product of the production of soybean meal, the same principals are applicable to maize.

Another example of the creation of artificial demand is the relationship between white and yellow maize in SA. White maize can act as a substitute for yellow maize. The producers of animal feed and the owners of feedlots will substitute white maize for yellow maize when the white maize price falls below that of yellow maize. White maize, however, is rarely substituted by yellow for human consumption in SA, since it is deemed by the end-user as an inferior quality product to white maize (Venter, 2011).

The price of white and yellow maize is governed by the supply and demand for each of these commodities. The supply of maize can also be affected by technology. Technology mainly refers to the use of nitrogen-based fertilisers and farming implements utilised in the production and harvesting of the maize crop. Technology utilised in the production of maize

lowers the cost of production, thereby increasing profit margins, which motivates and enables increased production. Increased production increases the carry-in stock, which is the stock left over from the previous production season, which in turn will lower prices (Geman, 2005:143). (From the discussion above, it has become clear that supply and demand determinants for maize and its substitutes are reflected in the price formation of this commodity).

2.3.1.2 Weather

One of the most important supply side determinants is the weather. Weather patterns affect the supply of both local crop production and international imports. It also affects the surplus or deficit of the stock produced in the previous year. Higher levels of rainfall are associated with a higher supply of maize, and a lower level of rainfall is associated with a lower crop size (Kleinman, 2001:114). The level of rainfall is driven by weather patterns, which can be predicted by the Southern Oscillation Index (SOI). This index measures the sea-level temperatures in the central Pacific Ocean on a daily basis. Although the data in this format does not infer much in terms of the state of the climate, an effective indicator can be attained to establish the current long-term weather pattern, El Niño–Southern Oscillation (ENSO) and anti-ENSO (Australian Bureau of Meteorology), by converting it into a monthly or seasonal figure (ABM, 2011). The changes associated with an El Niño event are termed "ENSO", which includes such variables as changes in atmospheric pressure and rainfall patterns. The warm phase of the ENSO is referred to as "El Niño", which indicates the warming of the upper ocean in the tropical eastern Pacific Ocean over a five-month period (Hansen *et al.*, 1999:93). The El Niño effect results in increased cloud cover in the central tropical Pacific Ocean, below normal strength easterly winds and low or negative SOI values. These conditions are normally associated with general drier weather conditions in SA (ABM, 2011).

The colder phase of the ENSO, or anti-ENSO, is called La Niña and is associated with an extensive cooling of the central and eastern Pacific Ocean (Wang *et al.*, 1999:11071). This phase is characterised by an increase in cloud cover over the tropical region of Australia, Papua New Guinea and Indonesia (ABM, 2011). The La Niña phase tends to have above normal strength easterly winds across the Pacific Ocean and high positive SOI values. These conditions are normally associated with wetter weather conditions in SA (ABM, 2011).

The La Niña and El Niño weather patterns are important factors in the supply of maize across the world. In SA, an El Niño weather pattern is more likely to result in a dry year, whilst

good rainfall will persist in the Midwest US (Venter, 2011). Equally, wetter conditions will be experienced in SA during a La Niña year (Hoerling, Kumar & Zhong, 1997:741). The La Niña and El Niño effects are often utilised to explain commodity prices. All things being equal, a higher probability exists for high maize prices during an El Niño year and low prices for maize in a La Niña year for countries in the Southern Hemisphere like SA (Hansen *et al.*, 1999:102; Martin *et al.*, 2000:1479). It should be noted that for a good harvest the El Niño or La Niña effect is not the sole climatic determinant. Factors like favourable growing conditions and good soil moisture reserves are also necessary prior to the planting period (Venter, 2011).

2.3.1.3 Secular trends

The term “secular” refers to a long-term change in the demand and supply of maize. Changes that can affect supply and demand in the long-run include changes in geographic factors, demographic factors, long-term weather patterns, consumer tastes, government policy, new uses for the commodity, purchasing power changes, substitution and technology. When a market participant wishes to determine the future price of a commodity, all the factors that can influence a secular change to that commodity should be taken into consideration (Bernstein, 2000:159).

2.3.1.4 Government programmes and policy

The role of government and its policy on certain commodities can either increase or decrease the supply and/or demand for that commodity. For instance, the allocation of land might have a long-term effect on the supply of maize. The government can intervene in the land allocation process and institute tax incentives and price support mechanisms to stimulate the supply of maize and indirectly increase exports (Kleinman, 2001:114). Interventions by governments to control markets through regulation and incentives have for various reasons been largely unsuccessful over the long-run. Moreover, the introduction of trade agreements to open commodity markets will reduce the success rate of price-stabilising policies (Lence, 2002). The motivation for the implementation of government policies and legislation might be as a result of political issues removed from the actual commodity fundamentals and can subsequently have a major impact on the prices of commodities (Bernstein, 2000:158).

2.3.1.5 Reports

Reports are compiled by government and non-governmental organisations on the fundamentals that determine the supply and demand factors related to a commodity. These reports can play a pivotal role in the price formation of maize, since they can influence the expectations that market participants form about the direction that a market should take. Reports that can affect expectations about the level of futures prices include reports on wholesale prices, consumer prices, trade deficits, unemployment rates, money supply, crop progress, rainfall statistics, harvesting progress, planting progress and stock balance statements. Each of these reports can have varying effects on the price of maize at certain times periods in the year (Bernstein, 2000:159).

2.3.1.6 Political influences

Decisions made in both the global and local political arena, geared to influence the supply and demand of a commodity in a country, will have an impact on the price of that commodity. For example, if a political influence group puts pressure on the government of a country to support maize production through subsidies, this action can influence other countries to institute protectionism policies to avoid the importation of cheap maize from the first country. The protectionism policies might include tariffs and trade barriers to imports (Bernstein, 2000:159).

2.3.1.7 International news flows

Maize, being a commodity traded across the globe, is vulnerable to international news flows. News regarding a variety of topics can affect the price of maize in the local market. News of war, for example, might increase the stockpiling of maize, thereby decreasing the supply of maize and increasing the price of maize. With increased stockpiling due to a pending war, the possibility of lower exports from the stockpiling country also increases. The resulting effect will be that countries that are dependent on imports will experience a decrease in supply, which will increase the local crop price (Bernstein, 2000:161).

2.3.1.8 Exchange rate fluctuations

Currency fluctuation is an important consideration when determining the value of imported or exported maize. The importance of the exchange rate is directly related to the substitution value of local maize with international maize. When the exchange rate of a country is weak compared with others, imports into that country should be expensive compared with other countries with a stronger exchange rate. Similarly, a country with a stronger exchange rate

will be less competitive in terms of its exports to other countries (Bernstein, 2000:161). Moreover, the level of the exchange rate can have a direct influence on the inset cost of producing maize.

A vital input cost in the production of maize is the diesel price. The diesel price in SA is 90% correlated with the Rand price of Brent crude oil quoted in US Dollars. When the Brent crude oil price stays the same and the Rand devaluates against the US Dollar, the price of diesel will increase. A higher diesel price will increase the production cost of maize, hence increasing the total price that the producer of maize will be willing to accept for his or her maize (Venter, 2011).

In addition to the Rand price of Brent crude oil being an important price-determining factor of maize, it is also linked to the fertiliser price. Fertiliser is considered to be a major driver in the growth of maize yields across the globe. When the Rand appreciates against the US Dollar, producers will be able to purchase fertiliser at a lower price, hence decreasing the input cost of producing maize (Venter, 2011).

Similarly, when the Rand appreciates against the US Dollar, implements imported from the US will become cheaper to purchase by SA farmers. Cheaper implements will not only decrease the cost of production maize over time, but will also increase the productivity of producers, hence supporting future income potential for these producers (Venter, 2011).

Given the examples above of how currency fluctuation can influence inset costs and ultimately the price of maize, it is clear that the exchange rate of a country is an important factor in determining the price of maize.

2.3.1.9 Business conditions

Ultimately, supply and demand are governed by the prevailing business conditions in a country. The best-case scenario is consumers being willing to spend money in purchasing goods and services, and producers being willing to supply goods and services to consumers (Krugel, 2003:77). If unemployment increases, for example, consumers will be under pressure to cut spending, hence reducing demand for the products and services produced by producers. This will ultimately put prices under pressure. Similarly, when economic growth is high, unemployment is low and consumers will have more disposable income to spend on

goods and services. This situation will increase demand for products, increasing the general price for goods and services temporarily until supply is increased (Krugel, 2003:77), also when disposable income increases for a particular part of the population that consumed a certain product as a staple food, the demand dynamics for that product might change. A section of the population might choose to substitute their consumption of the traditional staple food for a more expensive food staple (Venter, 2011).

2.3.2 Factors that influence the pricing of derivative contracts

The futures price of maize eventually reflects the price at which buyers (representing the demand for maize) and sellers (representing the supply of maize) are willing to buy or sell the physical maize at a future date. The maize futures contract price thus reflects the demand and supply dynamics that govern maize prices. The current futures contract prices represent all the available market data and information at any given time (Krugel, 2003:77). The following section will elaborate on other factors that influence the pricing of derivative contracts. The relationship between the futures and cash prices of maize will be discussed first. This section will be followed by a discussion on the contango and backwardation market conditions.

2.3.2.1 The basis

The basis is defined as the difference between the spot and futures prices for maize at a specific location (Strong, 2002:420). The basis is calculated as follows (Kolb, 1997:63):

$$\text{Basis} = \text{Current cash price} - \text{Futures price} \quad (2.1)$$

The basis is divided into a carry and a value basis. The carry basis is defined as the theoretical futures price minus the spot price of maize, and is equal to the cost of carry. The value basis is the difference between the market price and the theoretical futures price (Watsham, 1998:88). The cash price of maize differs between locations; hence, it follows that the basis for maize will differ too. Volatility in the fluctuation of the basis can be ascribed to storage and transportation costs. The basis risk can, therefore, be described as the risk of instability in the cash price of maize because of the fact that storage and transportation costs can differ over time (Kleinman, 2001:21).

The basis can carry a negative or positive value, based on the relationship between the cash and futures prices of maize. When the cash price is lower than the futures price, the basis is negative, and when the cash price is higher than the futures price, the basis is positive (Kolb,

1997:64). When the basis is negative, the market is referred to as being "in contango", and when positive results in backwardation (Strong, 2001:419, 421). In theory, the cash and futures prices will converge to zero over time, where the cash and futures prices should be equal (Kolb, 1997:65).

2.3.2.2 Contango and backwardation markets conditions

When the cash price of the physical maize is lower than the futures price, the basis will move from negative to zero at expiration (Kolb, 1997:65). A market is referred to as being in contango when the nearby futures contracts are trading at a lower value than the prices of more distant futures contracts. Conversely, a market that is inverted will exist when the prices of the nearby futures contracts are higher than the more distant futures contracts. This situation is called backwardation and indicates that the cash price of maize will decrease from a positive value until it reaches zero at expiration (Kolb, 1997:65).

Apart from the relationship between futures and cash markets, there is also a relationship between nearby and distant futures contracts. This relationship is referred to as a calendar spread and is closely associated with the cost of carry, which will be explained under section 3.2.2. In addition to the calendar spread, there are three different types of spreads, the inter-commodity, inter-market and intra-commodity spreads, this will normally reflect markets expectations on supply and demand fundamentals differentiated between time, markets and grains (Strong, 2002:217).

In order to enter an inter-commodity spread, both a long and a short position should be held at the same time in two related commodities (Strong, 2002:217). An inter-market spread requires both a long and a short position in two different markets. Profit will be realised when the commodity can be purchased at a lower price than what it can be sold for on the futures market (Strong, 2002:218). An intra-commodity spread requires both a long and a short position in different futures months for the same commodity (Strong, 2002:218).

2.3.3 Conclusion

For a market participant to be successful, it is imperative that he or she be aware of all the fundamental factors that influence and determine the price of an agricultural commodity. This awareness includes knowledge of new technology, weather patterns, substitution products and the uses of the product and pricing models. With in-depth background into the fundamentals of maize, it becomes possible for the experienced market participant to make an

informed forecast regarding what the value of the traded commodity should be. Once a market participant has assessed the value of the commodity, it is possible to calculate whether the commodity is over- or undervalued. Now that a market participant is ready to enter a transaction, it is important to know where and how a trade can be placed in order to capitalise on the over- or undervalued commodity. Market participants effectively need a platform on which they can meet to transact on the market with each other. This platform is normally a formal exchange with set rules and regulations governing transactions. In the US, the exchange on which corn is traded is known as the Chicago Board of Trade (CBOT), which is a designated contract market owned by Chicago Mercantile Exchange Group (CME). In SA, the exchange on which maize is traded is known as the SAFEX Commodity Derivatives Market. The next section of this document will discuss the CME Group's CBOT futures and options exchange, followed by a discussion of the JSE's commodities exchange and the various exchange contract specifications.

2.4 Futures exchanges

Maize is traded across countries and across different time zones, moreover the bulk of maize trading around the globe is facilitated through an exchange. An exchange endeavours to standardise a commodity and package that commodity in a tradable contract. These standardised factors can include the asset class, contract size, delivery arrangements, settlement arrangements, quoting of prices, implementation of positions limits, price limits and various aspects that govern and ensure fair dealing among market participants (JSE, 2011). Once a commodity has been standardised and packaged by an exchange, market participants can take positions on the direction of the market. The risk of owning a commodity is transferred among the participants on the exchange depending on their view of the value of the commodity (Bernstein, 2000:53).

The following section will discuss the two commodity exchanges that facilitate transactions in the US and the SA grain markets, respectively. These exchanges are CBOT and the JSE's SAFEX Commodity Derivatives Market. Following the discussion of the exchanges, the contract specifications for Corn, WMAZ, and YMAZ will be listed.

2.4.1 CME Group

The development of CBOT and the Chicago Mercantile Exchange (CME) is closely linked, and these two exchanges eventually merged to form the CME Group in 2007 (CME, 2011). The exchanges now function as designated contract markets of the CME Group. The history of both CBOT and the CME will therefore be covered together, starting with the former.

CBOT is one of the oldest derivatives exchanges in the world and was established in 1848 (Watsham, 1998:7). In 1851, CBOT recorded the first forward contract on Corn. By 1865, grain trading was formalised by the development of a standardised futures contract, and the exchange required buyers and sellers to pledge a performance bond or margin for trades executed. In 1870, CBOT developed the now famous octagonal futures trading pit and began trading the grain complex, which included corn, oats and wheat (CME, 2011).

With the rapid expansion brought about by futures trading, CBOT constructed a new building in 1885 situated in La Salle Street and Jackson Boulevard in Chicago. In 1898, the Chicago Butter and Egg Board was established and would become the CME in 1919 (CME, 2011). With the establishment of the Chicago Butter and Egg Board and the growing popularity of futures trading, CBOT established the Board of Trade Clearing Corporation to guarantee deals in 1926. With the CBOT Clearing Corporation established, the popularity of futures contracts increased substantially. The popularity of futures contracts drove the CME to establish the first frozen foods futures contract in the form of the pork bellies futures contract in 1961 and later in 1964 established the first agricultural non-storable commodities futures contract in the form of a live cattle futures contract. Two years later, CBOT started to trade iced broilers and a year later it listed the first metals contract in the form of a silver futures contract (CME, 2011).

With the advent of the metals contracts, the natural progression was to introduce contracts on foreign currencies, which followed in 1972, and a year later CBOT launched an equity option contract on the Chicago Board Options Exchange. In 1975, CBOT launched interest rate futures contracts and futures on Government National Mortgage Association rates. Eurodollar futures were launched in 1981 by the CME and a year later futures contracts were launched on the S&P 500 Index. CBOT also launched option contracts on US Treasury bond futures in the same year (CME, 2011). As the trading environment evolved, providing market participants with ever more sophisticated trading contracts, so too did the technological environment in which these contracts were traded.

A major technological advancement was the introduction of the Globex trading system. The CME began development of Globex in 1987, which was the first electronic trading platform for futures contracts in the world, with the first electronic futures trades being made on the Globex platform in 1992. In 1997, the CME established the E-mini S&P 500 futures contract, which extended trading past floor trading hours. Weather contracts were also introduced in 1999 by the CME and in 2000 the CME memberships decided to demutualise and become a publicly traded exchange, listing shares on the New York Stock Exchange (CME, 2011).

The CME, being a publicly traded company and focusing on efficiency in its clearing activities in 2003, attracted the business of CBOT. This move from CBOT injected a substantial amount of capital into the CME, cementing its authority as a market leader with regard to derivatives clearing activities. The CME created history not only with its clearing activities but also with its electronic trading platform. In 2004, the CME Globex platform recorded its one billionth contract traded since the first trade in 1992 (CME, 2011).

In 2005, CBOT also demutualised its operations and became a publicly listed company, listing on the New York Stock Exchange. In 2006, the CME and CBOT agreed to merge into a single company and the merger was complete by July 2007. In 2008, the CME Group acquired the New York Mercantile Exchange, increasing the CME Group's market share to 90% of all futures contracts traded in the US (CME, 2011).

2.4.2 SAFEX Commodity Derivatives Market

In April 1987, Rand Merchant Bank Limited (RMB) established an informal futures market that offered five derivative contracts. The underlying assets traded on these futures contracts were equity indices and bonds. At that stage, RMB was the only futures exchange, clearing house and market maker in SA (JSE, 2011). In 1989, a group of twenty-one banks and financial institutions met to establish a formal futures exchange, SAFEX, and the Safex Clearing Company (JSE, 2011). In August 1990, the minister of finance officially opened the SAFEX for derivatives and SAFEX diversified its operations further in January 1995 by opening the Agricultural Markets Division (AMD).

The AMD commenced trading by listing its first commodity futures contract on the exchange in the form of a physically settled beef contract (JSE, 2011). The beef contract was shortly followed by a physically settled potato contract (JSE, 2011). However, owing to inactivity and low volumes traded on the contract, both the physically settled beef and potato futures

contracts were delisted. With the deregulation of the grain market, white and yellow maize contracts listed in 1996 and later proved to be responsible for the growth in contract volumes traded on the exchange (JSE, 2011).

In May 2001, SAFEX and JSE members agreed to a buyout of SAFEX by the JSE and SAFEX moved into the JSE building in August 2001. In 2010, SAFEX listed internationally referenced commodities in the form of a Corn contract, which was promptly followed by the addition of CBOT soybeans, soya oil, gold, platinum, West Texas Intermediate oil and Hard Red Winter wheat (JSE, 2011).

SAFEX currently (2012) offers option and futures contracts on white maize, yellow maize, wheat, sunflower seeds and soybeans, as well as various international contracts. Although other contract months exist, the December, March, July and September contracts are the most popular and most frequently traded on most commodities (JSE, 2011).

2.4.3 Exchange contract specifications

Since futures contracts are standardised contracts, it is important that the market participant be aware of what these specifications entail. This section will detail the corn and maize contract specifications traded on CBOT and SAFEX, respectively. This first figure will describe the Corn contract, followed by the WMAZ and YMAZ contracts, respectively.

Actual contract size	5,000 bushels	
Deliverable grades	#2 Yellow at contract price, #1 Yellow at a \$0.015/bushel premium #3 Yellow at a \$0.015/bushel discount	
Pricing unit	US cents per bushel	
Tick size	1/4 of \$0.01 per bushel (\$12.50 per contract)	
Main contract months	March, May, July, September & December	
Trading hours	CME Globex (electronic platform)	6:00 pm – 7:15 am and 9:30 am – 1:15 pm CST, Sunday–Friday

	Open outcry (trading floor)	9:30 am – 1:15 pm CST, Monday–Friday
Daily price limit	\$0.40 per bushel, expandable to \$0.60 when the market closes at limit bid or limit offer. There shall be no price limits on the current month contract on or after the 2 nd business day preceding the 1 st day of the delivery month.	
Settlement procedure	Physical delivery	
Last trade date	The business day prior to the 15 th calendar day of the contract month	
Last delivery date	The 2 nd business day following the last trading day of the delivery month	
Product ticker symbols	CME	ZC
	Globex (electronic platform)	C=Clearing
	Open outcry (trading floor)	C

Source: CME (2011).

Figure 2.1 Corn futures contract.

Actual contract size	100 tonnes	
Deliverable grades	WM1	
Pricing unit	Rand per tonne	
Tick size	R0.20 per tonne	
Main contract months	March, May, July, September & December	
Trading hours	JSE SAFEX	9:00 am – 12:00 am GMT+ 2:00, Monday–Friday
Daily price limit	R80 per tonne and R120 per tonne extended limits. There shall be no price limits on the current month contract.	
Settlement procedure	Physical delivery	
Last trade date	The 8 th last days of the expiry month	
Last delivery date	The last business day of the expiry month	
Product ticker symbols	JSE SAFEX	WMAZ

Source: JSE (2011).

Figure 2.2 WMAZ futures contract.

Actual contract size	100 tonnes	
Deliverable grades	YM1	
Pricing unit	Rand per tonne	
Tick size	R0.20 cent per tonne	

Main contract months	March, May, July, September & December	
Trading hours	JSE SAFEX	9:00 am – 12:00 am GMT+ 2:00, Monday–Friday
Daily price limit	R80 per tonne and R120 per tonne extended limits. There shall be no price limits on the current month contract.	
Settlement procedure	Physical delivery	
Last trade date	The 8 th last days of the expiry month	
Last delivery date	The last business day of the expiry month	
Product ticker symbols	JSE SAFEX	YMAZ

Source: JSE (2011).

Figure 2.3 YMAZ futures contract.

2.4.4 Conclusion

An exchange facilitates the buying and selling of a commodity or share by providing a platform for market participants to trade various innovative products, including derivatives. This facility provided by an exchange makes it easy for market participants to effect their views on the direction of the market. One of the most prominent exchanges in the commodities world is CBOT, which facilitates the trading of various important commodities, one of which is Corn. Since this study is based on the volatility spill-over effect between Corn, WMAZ, and YMAZ, with the last two being traded on the JSE's SAFEX, this section has covered the histories and contract specifications of the respective exchanges.

2.5 Conclusion

When trading a commodity, a market participant requires a good understanding of all the fundamental factors that influence the price of that commodity. This fundamental understanding into how a commodity, in this case maize, is priced and what determines fluctuations in the value of that commodity will determine the profitability of the decision by the market participant. Determinants of the price of maize and its supply and demand dynamics can be influenced by a variety of factors. The factors can be weather, supply and demand of substitute products, technology, news (both local and international), currency fluctuations, reports, government intervention, and international markets affecting domestic imports and export programmes. In addition to the fundamentals of maize markets, a market participant dealing in this commodity will need a good understanding of the pricing of a futures contract. The pricing of a futures contract will also have an effect on the price of

option contracts traded on the future. The next chapter will focus on the pricing of exchange-traded products and the influence of volatility on these products.

Chapter 3

Pricing of derivatives and volatility measurement

In a strict sense there isn't any risk – if the world will behave in the future as it did in the past.

Merton Miller

(cited by Du Toit, 2002)

3.1 Introduction

Once a market participant has formed a view about the value of a commodity based on the prevailing supply and demand fundamentals, that market participant is in a position to make a trading decision. As part of the trading decision, the market participant should decide on which exchange, if any, a trade will be placed. Once the market participant has decided on the commodity, the direction of the trade and the exchange on which the trade will be placed, that market participant must decide on the exchange products for example futures or options for placing the trade. Exchange contracts are standardised products and it is essential that a market participant acknowledge how these exchange contracts are priced, since this will influence the price at which exposure is gained in the market. There is a range of products, the three main groups being forward, futures and option contracts. The last two are exchange-traded products and the former is traded Over The Counter (OTC) (Epps, 2007:2).

The pricing of these contracts will ideally reflect a value that does not allow arbitrage. If a market moves out of sync, arbitragers will capitalise on the opportunity, closing down the arbitrage gap. Owing to the arbitrage factor, a market should more often than not move to a level at which arbitrage is effectively nullified (Epps, 2007:152). Other than the non-arbitrage theory of the pricing of a derivatives contract, various other factors can influence the price of that commodity. These factors include the time value of money, the volatility of prices and the storage cost of the underlying commodity (Epps, 2007:5). The longer the contract is priced into the future, given a contango market condition, the higher its value should be. This is a direct result of the funding cost of carrying a commodity into the future. Moreover, if the volatility of the commodity is relatively high, the risk of pricing a commodity far into the future should entail a higher price for that commodity. This is because the market will factor

into the price of a commodity, the risk of high volatility levels in the value of that commodity over time (Natenberg, 1994:60).

This chapter will aim to provide an overview of the pricing of the various types of contracts available to the market participant wishing to enter the maize market. The first section will discuss the pricing of forward contracts, followed by futures contract pricing and then option contract pricing. After the contract pricing has been discussed, the ARCH, GARCH and EGARCH models will be discussed in section 3.3, which will be used to model the volatility spill-over effects, following the model explanation, volatility spill-over will be discussed, along with the theories of crisis

3.2 Forward, futures and option contracts

It is important for a market participant to form an opinion of what the value of a stock or commodity trading on a market should be. It is equally important for a market participant to know how to price a derivatives contract before making a trading decision, since this factor can directly influence the value of the investment and the volatility thereof. This section will aim to provide insight into three commonly used products and their pricing methodologies. The first product that will be discussed is the forward contract, the second is the futures contract, and the third and most complicated of the three is the option contract.

3.2.1 Forward contracts

A forward contract is a contract between a buyer and a seller, the buyer is obligated to purchase a specific commodity, at agreed on quantity, at a predefined date in the future and at a predefined price and the seller is obligated to sell that commodity to the buyer (Krugel, 2003:93). The forward contract is tailored to the specific needs and circumstances as required and agreed on by the buyer and the seller. This type of contract does not need to adhere to contract specification rules, because it is not recognised by exchanges and is subsequently traded on an OTC basis, hence outside of a formalised exchange (Kolb & Overdahl, 2010:7).

Since forward contracts are not traded on formalised exchanges, these types of contracts are not subject to mark-to-market⁶ practices. This situation increases the risk of the counterparty

⁶ The practice of mark-to-market refers to the transferring of funds from one account to another at the end of each day, reflecting the daily profit and loss of a position as a result of the market movement (Krugel, 2003:93).

defaulting on the contract, making a forward contract vulnerable to credit risk.⁷ Given the large notional value associated with forward contracts, the majority of forward contracts are settled with the delivery of the physical commodity (Hull, 2002:34). When the price of the physical commodity is higher than the price of the forward contract at the maturity date, the buyer of the forward contract will realise a net profit. When the price of the physical commodity is lower than the price of the forward contract at maturity, the seller of the contract will realise a profit (Benhamou, 2007:27). The profit and loss dynamics between forward and futures contracts are fairly similar, even though there are fundamental differences between forward and futures contracts. The mathematics in the price calculation of these two products is fairly similar. The pricing of a futures contract will be discussed in the next section and is applicable to the price calculation of a forward contract.

3.2.2 Futures contracts

A futures contract is a contract between a buyer and a seller for the delivery of a standardised amount of a specifically defined commodity at a specific price and delivery date in the future. These contracts are traded on formalised exchanges (Krugel, 2003:93). The major difference between a futures contract and a forward contract is that the former is traded on formal exchanges and is standardised. The standardisation relates to the asset type, a set quantity of the asset, a set quality of the asset and a set maturity or delivery date (Valsamakis *et al.*, 1996:267). Given the standardisation of a contract, the profit and loss dynamics will remain the same over time. When the price of the physical commodity is higher than the price of the futures contract at the maturity date, the buyer of the futures contract will realise a profit. When the price of the physical commodity is lower than the price of the futures contract at maturity, the seller of the future will realise a profit (Benhamou, 2007:28).

In determining the price of a futures contract, the cost of carry is an important concept and represents the total cost of carrying a physical commodity from one date to the next (Kolb, 1998:69). The cost of carry consists of four basic components (Kolb, 1998:69):

- the funding cost of carrying a commodity into the future;
- the insurance cost;
- the storage cost; and

⁷ Credit risk (or default risk) refers to the risk that an obligation will not be honoured by the counterparty to the transaction (Krugel, 2003:93).

- the transportation cost.

The storage component refers to the actual warehousing of a commodity in a safe and secure location where the necessary precautions against insect infestation are taken. When a commodity is stored, it should also be insured against damage from water or overheating. The transportation charge is applicable when a commodity needs to be transported from one location to another and will be added as a cost component that increases the cost of carry (Krugel, 2003:93).

The cost of financing a commodity might vary from one market participant to the next, depending on his or her individual creditworthiness, hence making the cost of carry marginally different for most market participants (Dalton, 2008:114). This situation will also influence the fair value calculation of a futures contract among market participants. In order to prevent this, Falkena and Kok (2000) suggest the use of the prime interest rate to calculate the cost of funding of the physical commodity from one date to the next. In SA, the prime interest rate is derived from the repo rate set by the SA Reserve Bank; hence, the cost of carry of a commodity can be influenced by monetary policy.

The study of Falkena and Kok (2000) suggest only including the financing cost in the calculation of the fair value of a commodity, unlike Kolb (1998:7), who also included a storage cost component. Falkena and Kok (2000) utilise the following equation in determining the fair value of a futures contract for a commodity:

$$FVFC = P(1+r)^{t/365}, \quad (3.1)$$

where the *FVFC* factor equals the fair value of a futures contract that will expire in *t* days, utilising compound interest; *P* = the cash price of a commodity based on the start date for the calculation; *r* = the cost of funding the commodity; and *t* = the days to the settlement date.

Falkena and Kok (2000) further advise that the above equation be rewritten as follows:

$$FVFS = P(1+r)^{t/365}, \quad (3.2)$$

where the *FVFS* factor equals the fair value of a futures contract that will expire in *t* days, utilising a simple interest rate; *P* = the cash price of a commodity based on the start date for the calculation; *r* = the cost of funding the commodity; and *t* = the days to the settlement date.

Continuously compounded interest is utilised to calculate the fair value of a futures contract in equation 3.1, and simple interest is utilised in equation 3.2. Falkena and Kok (2000) suggest using a compounded interest rate in calculating the fair value of maize, since market funding rates are calculated in this manner and subsequently reflects the fair value calculation more accurately to reality.

3.2.3 Option contracts

An option contract is a contract that gives the buyer the right but not the obligation to buy (sell) a certain asset at a set price (strike price) on or before a certain date (Krugel, 2003:93). The buyer of an option contract pays an irrevocable premium for this right (Madura, 2000:66). The fact that the holder of the option contract has the right but not the obligation to buy or sell the underlying commodity provides the market participant with more flexibility compared with a forward or futures contract. As is the case with a futures contract, an option contract can provide a market participant with exposure to rising and falling prices. The former is provided through what is known as a call option and the latter a put option. A call option gives the buyer of the option contract the right but not the obligation to buy a commodity at a predetermined strike price at a set time in the future (Briys *et al.*, 1998:15). A call option will be profitable when the price of the underlying commodity is higher than the strike price at which the option was done at the expiry date. A put option gives the buyer of the option contract the right but not the obligation to sell a commodity at a specific strike price at a set time in the future (Briys *et al.*, 1998:15). A put option will be profitable when the price of the underlying commodity is lower than the strike price at which the option was done at the expiry date (Hull, 2002:168). When an option is profitable, it is referred to as being "in the money". Similarly, when an option is not profitable, it is referred to as being "out of the money". When the strike price and the price of the underlying commodity are the same as the market price, the option is referred to as being "at the money" (Hull, 2002:168).

In addition to call or put options, options can further be divided into two groups, American-style and European-style options. An American-style option can be exercised at any time, from the date of purchase up to the date of expiry, whereas a European-style option can only be exercised on expiry (Hull, 2002:261). The price models used to price an American- or European-style option will differ. It is, therefore, important that a market participant use the correct model in pricing an option. Various models exist to value and price options, these models include binominal option valuation models and the models created by John C. Cox,

Stephen A. Ross and Mark Rubinstein (Cox *et al.*, 1979:1). The most commonly used model used to value most options was created by Fischer Black, Myron Scholes and Robert Merton (Benhamou, 2007:79).

This model, now famously known as the Black–Scholes model, had its origins in 1973, when Black, then a 31-year-old independent finance contractor, and Scholes, a 28-year-old Assistant Professor of Finance at Massachusetts Institute of Technology and Robert Merton wrote a draft paper on an analytical model to determine the fair value of a European-style call option (Benhamou, 2007:79). Their paper was submitted to the *Journal of Political Economy* and the *Review of Economics and Statistics* to be published. Surprisingly, both of these journals rejected the paper and help was enlisted from Merton Miller and Eugene Fama at the University of Chicago, after which the paper was accepted by the *Journal of Political Economy*.

At the same time that the paper was accepted by the *Journal of Political Economy*, options on stocks began to be actively traded on organised exchanges. In 1975, the Black–Scholes model was widely adopted by the trading community. The success of the Black–Scholes option pricing model led to the Noble Prize being awarded to Scholes and Merton in 1997 (Black had unfortunately passed away; Benhamou, 2007:80). The Black–Scholes model will now be discussed in more detail.

The Black–Scholes model can be illustrated by three equations (Kolb & Overdahl, 2010:373)⁸:

$$c = SN(d1) - Ke^{-rt}N(d2), \quad (3.3)$$

where:

$$d1 = [\ln(S/K) + (r + \sigma^2/2)T] / \sigma\sqrt{T}, \quad (3.4)$$

$$d2 = d1 - \sigma\sqrt{T}, \quad (3.5)$$

and where:

c = the current option value, S = the current underlying asset price, $N(d)$ = the probability that from a standard normal distribution a random draw will be smaller than d , K = the strike

⁸ This equation will indicate the call option valuation, for information on the put option valuations, please refer to Kolb & Overdahl (2010)

price of an option, e = the natural logarithm's base value, r = the risk-free rate, T = the time left until option expiry, \ln = the natural logarithm, and σ = the standard deviation of the continuously compounded rate of return of the underlying commodity.

Equation 3.3 states that the price of an option is the difference between the expected value of the underlying commodity's price and the expected value of the option's strike price (Epps, 2007:259). In calculating the expected value of the underlying commodity and the expected premium for the option, probabilities are linked to the standardised normal distribution. The normal distribution function is utilised in describing the continuous random walk component of the underlying commodity (Natenberg, 1994:432):

The Black–Scholes model relies on the following assumptions (Kolb & Overdahl, 2010:373):

- The value of the underlying commodity follows a geometric Brownian motion⁹, with a constant drift factor and constant volatility.
- The model assumes that the market can accommodate the short selling¹⁰ of the underlying commodity.
- There are no limits to arbitrage.
- Trading in the underlying commodity is continuous.
- There are no transaction costs.
- There are no taxes.
- The underlying commodity can be traded in perfectly divisible units, that is, 1/100th of the underlying commodity can be purchased or sold.
- Borrowing and lending can occur at a constant risk-free rate.
- The underlying commodity pays no dividends.

From equations 3.4 and 3.5, factors that can affect the price of an option are as follows (Bodie *et al.*, 2002:699):

- the price of the underlying commodity;
- the strike price of an option;
- the volatility of the underlying commodity;

⁹ Brownian motion refers to the presumable random moving particles movement of particles suspended in fluid, liquid or gas. The Brownian motion formula is widely used to describe random movements in application to financial instruments (Bodie *et al.*, 2002:699)

¹⁰ Short selling refers to a practice where a commodity can be sold before it is owned (Krugel, 2003:93).

- the time to option expiry;
- the interest rate; and
- the dividend rate of the underlying commodity.

The degree to which the above factors influence the price of an option can be measured by what is referred to as "the Greeks". The Greeks are essentially partial derivatives and higher-order expressions derived from equation 3.3 (Kolb & Overdahl, 2010:373). The Greeks will be explained in the following sections.

3.2.3.1 Delta

The delta of an option measures the sensitivity of an option to small changes in the price of the underlying commodity. Delta is calculated as follows (Kolb & Overdahl, 2010:381):

$$\frac{\partial c}{\partial S} = N(d_1). \quad (3.6)$$

3.2.3.2 Gamma

The gamma of an option measures the sensitivity of the calculated delta's sensitivity to small changes in the price of an option. Gamma is calculated as follows (Kolb & Overdahl, 2010:381):

$$\frac{\partial^2 c}{\partial S^2} = \frac{N'(d_1)}{S \times \sigma \sqrt{T}}, \quad (3.7)$$

where $N'(d_1)$ is given by $N'(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$.

3.2.3.3 Theta

The theta of an option measures the sensitivity of an option's price to small changes in the time until maturity. Theta is calculated as follows (Kolb & Overdahl, 2010:381):

$$\frac{\partial c}{\partial T} = \frac{S \times N'(d_1) \times \sigma}{2\sqrt{\sqrt{T}}} - r \times K \times e^{-rT} \times N(d_2). \quad (3.8)$$

3.2.3.4 Vega

The vega of an option measures the sensitivity of an option's price to small changes in the volatility of the underlying commodity. Vega is calculated as follows (Kolb & Overdahl, 2010:381):

$$\frac{\partial c}{\partial \sigma} = S \times \sqrt{T} \times N'(d_1). \quad (3.9)$$

3.2.3.5 Rho

The rho of an option measures the sensitivity of an option's price to small changes in the interest rate. Rho is calculated as follows (Kolb & Overdahl, 2010:381):

$$\frac{\partial c}{\partial r} = K \times T \times e^{-rT} \times N(d_2). \quad (3.10)$$

From the above sensitivity measurements, it is clear that the price of an option can be influenced by a variety of factors. However, vega is the main option-pricing factor of importance for this study, since this Greek measures the sensitivity of an option's price to changes in volatility of the underlying commodity (Kolb & Overdahl, 2010:382). Since this Greek is used to price options, it is imperative for a market participant to know what the volatility spill-over effect, if any, from larger markets on the local underlying commodity will be. This will enable the market participant to price the derivative option contract more accurately.

3.2.4 Conclusion

With the advent of the derivatives market, various instruments have become available to market participants to execute their respective views on the direction of the market, whether for speculation, hedging or arbitrage. The mathematics in calculating the value of these instruments has become more complex and, owing to the increased complexity of the products available to trade, it is extremely important for a market participant to understand how these derivatives contracts are priced (Benhamou, 2007:3).

One of the important factors that influence the price of options is the volatility of the underlying stock or commodity (Benhamou, 2007:274). Owing to the pricing input that measures volatility in the Black–Scholes model, it is important for the market participant to quantify the volatility spill-over effect from larger markets to smaller markets on the

underlying commodity. This is important, since this volatility spill-over will ultimately influence the price of an option contract and the value of an investment made in the market. In order to quantify the volatility of a stock or commodity, various models have been created. The next section will discuss these models in more detail. As will be shown in chapter 4, these models were used to measure the level of volatility spill-over from the Corn contract to WMAZ and YMAZ contracts, respectively.

3.3 ARCH, GARCH and EGARCH models

One of the most important drivers of volatility and market price movements is news about the supply and demand fundamentals of a commodity (Daly, 2008:2379). The rapid succession of news flows about a certain event and how quickly the news is distributed among various news agencies and their respective clients provides a high frequency of data flow. This high frequency of news flows can exacerbate the volatility that occurs in the price and returns of a commodity or stock. The increased volatility after the release of certain news events leads to a phenomenon termed "volatility clustering" in the returns of the underlying commodity (Daly, 2008:2379). Volatility clustering during lower frequency news flows is mainly governed by macro-economic and institutional changes. During high frequency news flows, volatility clustering is governed by the volume of turbulence and trading pressures experienced by a specific stock, commodity, sector or market (Daly, 2008:2379).

In addition to the factors described above, Athanassakos and Robinson (1994), as well as Berument and Kiyamaz (2001), found that volatility is also affected by the "day of the week". It was found that the arrival rate of information in the market, be it a trading or non-trading day, has an effect on the returns measured on a stock or commodity. This effect is referred to as the "day-of-the-week" effect (Daly, 2008:2379).

Another factor that influences the level of volatility is the extent to which a company or commodity trading on an exchange is leverage. The higher the leverage of a company, the higher the level of volatility experienced in that futures contract. Conversely, the lower the leverage of company, the lower the level of volatility will be (Daly, 2008:2379). Leveraging can be deemed one of the most influential long-term volatility factors.

Factors that influence short-term volatility are firstly the level of sophistication with regard to the financial instrument utilised by market participants, for instance derivative contracts, as opposed to normal shares; secondly, the extent to which contrarian trades are placed by market participants; and lastly, the level of trading volume experienced on a stock or commodity contract (Daly, 2008:2379). Given the long- and short-term factors that influence volatility, it has been proven that volatility is positively correlated with economic recessions, high nominal interest rates and financial crises (Daly, 2008:2379).

Given the extent to which volatility encompasses the effect of various economic factors, the modelling and analysis thereof is crucial in quantifying a fundamental understanding of individual markets, stocks and commodities in an economy. In order to model volatility, Engle (1982) introduced the Auto Regressive Conditional Heteroscedasticity (ARCH) model. This model is excellent at capturing important features contained within economic data (Daly, 2008:2381). These features include the measurement of variance changes over time caused by positive autocorrelation in conjunction with the fat tails in unconditional distribution (Daly, 2008:2381). The ARCH model has become popular in financial modelling and has been used to examine the flow of information between countries, asset classes and markets (Daly, 2008:2381). The ARCH model has been used to model the time-varying conditional variance and risk premium contained within the term structure of interest rates, to measure inflation and to ascertain the relationship between the macro-economy and equity markets (Daly, 2008:2381).

The ARCH model uses the maximum likelihood estimation to estimate the conditional variance of an asset's returns (h_t), as opposed to the conventional method of standard-deviation modelling (Poon, 2005:37). In calculating the conditional mean, the ARCH model utilises information from a previous period, which is defined by a variable obtained randomly and can be represented as follows (Daly, 2008:2382):

$$m_t \equiv E[y_t | F_{t-1}] \equiv E_{t-1}[y_t], \quad (3.11)$$

where y_t represents the rate of return for a commodity from time $t-1$ to t , F_{t-1} represents the past information for a commodity variable up to time $t-1$, and E represents the expectations operator.

Market participants are familiar with the realised values of all the relevant commodity variables (F_{t-1}) in constructing their respective investment decisions at time t (Daly,

2008:2382). Their expectations about the volatility and returns can be given by the conditional expected value of y_t in equation 3.11, whilst the conditional variance of y_t can be given by F_{t-1} , and is represented in the equation below (Daly, 2008:2382):

$$\sigma_t^2 \equiv E_{t-1}[y_t - m_t]^2. \quad (3.12)$$

By utilising the conditional variance σ_t^2 , market participants will be equipped to make more precise forecasts on return variability (Daly, 2008:2382).

3.3.1 ARCH model

The ARCH model enables the modelling of the expectations of market participants with respect to expected returns, uncertainty and risk by accurately measuring variance in time series data. When conventional modelling methods are used, the variance of the error terms can be seen as a being constant or homoscedastic. In reality, volatility increases and decreases during certain periods, making it preferable to examine the conditional volatility of a data series. An ARCH model can model the conditional volatility of data and will enable the market participant to estimate the riskiness of an asset over a set period (Asteriou & Hall, 2007:250).

From the ARCH model description, $\sigma_t^2 = h_t$ and returns can be represented as $r_t = u + \varepsilon_t$, whilst $\varepsilon_t = \sqrt{h_t} z_t$, where $z_t \sim D(0,1)$ represents a white-noise component (Poon, 2005:37).

The practice z_t is extended by the conditional variance factor h_t (Poon, 2005:37).

Engle (1982:998) proposed the ARCH (q) procedure as taking the following form:

$$h_t = \omega + \sum_{j=1}^q \alpha_j \varepsilon_{t-j}^2, \quad (3.13)$$

where $\omega > 0$ and $\alpha_j \geq 0$ will warrant that h_t is a positive variance process (Poon, 2005:38).

Volatility persistence in financial markets, q , is likely to be of a higher order (Poon, 2005:38). In equation 3.13, h_t is known at time $t-1$, which indicates that a forecast is readily available (Poon, 2005:38). This forecasting model can be constructed by assuming $E[\varepsilon_{t+\tau}^2] = h_{t+\tau}$. The unconditional variance of r_t can be represented as follows (Poon, 2005:38):

$$\sigma^2 = \frac{\omega}{1 - \sum_{j=1}^q \alpha_j}. \quad (3.14)$$

The model is covariance stationary when the sum of the autoregressive variables is less than 1 (Poon, 2005:38).

3.3.2 GARCH model

A disadvantage of the ARCH model is that it is more of a moving average specification than an autoregression (Asteriou & Hall, 2007:260). In order to compensate for this shortcoming, Tim Bollerslev constructed a new model in 1986, which included a lagged conditional variance term as an autoregressive term (Asteriou & Hall, 2007:260). This new model is known as a Generalised Auto Regressive Conditional Heteroscedasticit (GARCH) model. Compared with the regular ARCH (q) model, the GARCH (p, q) model permits additional dependencies on the p lags for past h_t as indicated in the equation below (Poon, 2005:38):

$$h_t = \omega + \sum_{i=1}^p \beta_i h_{t-i} + \sum_{j=1}^q \alpha_j \varepsilon_{t-j}^2, \text{ and } \omega > 0, \quad (3.15)$$

given a GARCH (1, 1) model, where $\alpha_1 \geq 0$ and $\beta_1 \geq 0$ require that h_t carries a positive value, the unconditional variance can be represented by the following equation (Poon, 2005:38):

$$\sigma^2 = \frac{\omega}{1 - \sum_{i=1}^p \beta_i - \sum_{j=1}^q \alpha_j}. \quad (3.16)$$

The GARCH model is covariance stationary when $\sum_{i=1}^p \beta_i + \sum_{j=1}^q \alpha_j < 1$ (Poon, 2005:38).

3.3.3 EGARCH model

ARCH and GARCH models are successful at capturing various features of financial data; however, these models cannot capture the asymmetric effects¹¹ contained within data (Daly, 2008:2384). The unconditional returns have a propensity to exhibit fatter tails than represented under a normal distribution, are more skewed and carry a higher kurtosis (Daly, 2008:2384). In order to solve these shortcomings, Nelson (1991:350) created the EGARCH model. This model deals with excess conditional kurtosis in returns based on a generalised exponential distribution (Daly, 2008:2394). The Exponential Generalised Auto Regressive Conditional Heteroscedasticity EGARCH model reduces the restrictive features of the common GARCH model by explaining variation in the volatility of stock market returns.

The GARCH model created by Bollerslev (1986) was constructed from the basic ARCH model established by Engle (1982). Bollerslev (1986) converted the variance parameter (σ_t^2) to make it linear in lagged values of the error term $\varepsilon_t^2 = \sigma_t^2 z_t^2$. In order to appreciate the changes made by Nelson (1991) to the Bollerslev (1986) model, it is necessary to revisit the GARCH model equation.

The GARCH model is given by the following equation (Nelson, 1991:348):

$$\sigma_t^2 = \omega + \sum_{i=1}^q \beta_i \sigma_{t-1}^2 + \sum_{j=1}^p \alpha_j z_{t-j}^2 \sigma_{t-j}^2, \quad (3.17)$$

where the terms ω, α_j and β_i are not negative (Nelson, 1991:348). The change effected by Nelson's model to the GARCH model can be represented by the equation below and is known as the generalised autoregressive conditionally heteroscedastic in-mean (GARCH-M) model (Nelson, 1991:348):

$$R_t = a + b\sigma_t^2 + \varepsilon_t, \quad (3.18)$$

where σ_t^2 represents the conditional variance of R_t , which in turn enter the conditional mean of R_t . Where R_t is the return on a portfolio at time t , its required rate of return may be linear in its risk as calculated by the term σ_t^2 .

¹¹ Asymmetric effect is a market phenomenon where market volatility is higher in periods of downswings, than periods of upswings (Daly, 2008:2384).

Market participants utilising the new ARCH methodology with regard to explaining the variation in volatility are now able to calculate an asset's price by substituting the $\beta_i \sigma_{t-i}^2$ term recursively in equation 3.17, where σ_t^2 can be calculated by the following equation:

$$\sigma_t^2 = \omega^* + \sum_{k=1}^{\infty} \phi_k z_{t-k}^2 \sigma_{t-k}^2. \quad (3.19)$$

When the terms ω, α_j and β_i are positive, then the terms ω^* and ϕ_k will also be positive. The volatility clustering can be captured by setting the conditional variance equal to a constant in conjunction with a weighted average of positive values, constructed from past squared residuals (Nelson, 1991:349).

The ability of a GARCH model to capture volatility clustering enables the measurement of volatility patterns (Nelson, 1991:349); however, the GARCH model has important limitations. The difference between the EGARCH and the GARCH models is the assumption that good news and bad news have the same effect on volatility. A limitation of the GARCH model is that no difference between good news and bad news is distinguishable, whilst an EGARCH model will measure the asymmetric effect of good or bad news on volatility (Daly, 2008:2385). The GARCH model cannot measure the asymmetric effect of good or bad news event on volatility, whereas the EGARCH model can, hence making the latter model superior to the former (Nelson, 1991:349).

A second limitation of the GARCH model originates from the positive-value constraints on the terms ω^* and ϕ_k in equation 3.19. This limitation guarantees that the term σ_t^2 remains positive for all t periods with a probability of 1 (Nelson, 1991:349). These constraints entail that an increased z_t^2 term experienced in any period will subsequently lead to an increase in the term σ_{t+m}^2 for any $m \geq 1$, subsequently eliminating any random behaviour in the σ_t^2 process (Nelson, 1991:349). These positive-value constraints heighten the difficulty of estimating GARCH models (Nelson, 1991:349).

A third limitation of the GARCH model is the interpretation of the shocks to conditional variance (Nelson, 1991:349). For instance, if a shock to volatility lasts for an indefinite period, this situation can shift the whole term structure of the risk premium and will more than likely impact the investment level of long-lived capital goods (Nelson, 1991:349). When a process is stationary under a GARCH (1, 1) model, shocks may be constant in one norm

and vanish in another. This situation could lead to conditional moments of GARCH (1, 1) being exaggerated (Nelson, 1991:350).

For the term σ_t^2 to be seen as the conditional variance of ε_t , given all the relevant information at time t , it has to have a positive value with a probability of 1 (Nelson, 1991:350). A GARCH model can achieve this when the term σ_t^2 is a linear combination of positive random values (Nelson, 1991:350). Nelson's (1991:350) EGARCH model resolves the positive-only constraint by making the term $\ln(\sigma_t^2)$ linear in a number of functions of time and lagged z_t for a number of suitable functions. This method can be illustrated as follows:

$$\ln(\sigma_t^2) = \alpha_t + \sum_{k=1}^{\infty} \beta_k g(z_{t-k}), \quad \beta_1 \equiv 1, \quad (3.20)$$

where the terms $\{\alpha_t\}_{t=-\infty, \infty}$ and $\{\beta_k\}_{k=1, \infty}$ are non-stochastic, real and scalar sequences (Nelson, 1991:350). In order to accommodate an asymmetric relationship between volatility changes and returns, the value of $g(z_t)$ should be a function of the sign and magnitude of the term z_t . In order to achieve this state, the term $g(z_t)$ should be made into a linear combination of $|z_t|$ and z_t . This process can be illustrated as follows (Nelson, 1991:351):

$$g(z_t) \equiv \theta z_t + \gamma [|z_t| - E|z_t|], \quad (3.21)$$

$$z_t = \varepsilon_t / \sqrt{\sigma_t}. \quad (3.22)$$

The terms θz_t and $\gamma [|z_t| - E|z_t|]$ each carry a mean of zero (Nelson, 1991:351). The term θz_t estimates the sign effect of the innovation and the term $\gamma [|z_t| - E|z_t|]$ estimates the magnitude of the effect. If the z_t values are distributed symmetrically, the components of the model are statistically significant (Nelson, 1991:351). Across the range $0 < z_t < \infty$, the term $g(z_t)$ is linear in z_t with a slope of $\theta + \gamma$. Across the range $-\infty < z_t \leq 0$, the term $g(z_t)$ is linear with a slope of $\theta - \gamma$ (Nelson, 1991:351). Therefore, the term $g(z_t)$ allows for the conditional variance procedure $\{\sigma_t^2\}$ to react asymmetrically to a fall or rise in returns (Nelson, 1991:351).

If it is assumed that $\theta = 0$ and $\gamma > 0$, the innovation in $\ln(\sigma_{t+1}^2)$ would be negative (positive) when the size of z_t is smaller (larger) than its expected value (Nelson, 1991:351). If however the terms are $\theta < 0$ and $\gamma = 0$, the innovation in conditional variance will be positive (negative) when returns innovations are positive (negative; Nelson, 1991:351).

The EGARCH model is more adept at modelling the positive and negative excess returns than the GARCH model. This is because the GARCH model is subject to certain limitations as explained earlier (Nelson, 1991:351). The EGARCH model is preferable to the ARCH model, since the conditional volatility functions of the direction of innovations and the magnitude thereof can be measured (Samouilhan, 2006:250). The EGARCH model is also preferable to a GARCH model, since the GARCH model has difficulty in evaluating whether the shocks to variance are continuous. The EGARCH model allows the term $\ln(\sigma_t^2)$ to follow a linear process, whilst allowing stationarity to be easily verified (Nelson, 1991:351). When the shock to the term $\{\ln(\sigma_t^2)\}$ is sporadic and short, the term $\{\alpha_t\}$ can be removed, this would transform the term $\{\ln(\sigma_t^2)\}$ into a stationary process (Nelson, 1991:351). The process for transforming the model into a stationary process is the same as for the general linear process with finite innovation in the variance (Nelson, 1991:352).

This study, focuses on the volatility spill-over effect, subsequently an EGARCH model will be used within an Aggregated Shock (AS) model framework. Before the construction of the EGARCH model is discussed, it is important to understand volatility spill-over. The next section will explain volatility spill-over by detailing various theories relating to the importance of crisis transmission, trade linkages, financial linkages and the behaviour of market participants to volatility spill-over between markets.

3.3.4 Volatility spill-over

A stock or commodity may experience periodic bouts of volatility owing to news flows that can affect its supply and demand dynamics. The volatility of an international stock or commodity can influence the price at which stocks and commodities trade in other countries. The relationship that exists between the volatility of an international stock or commodity and of a local stock or commodity is known as the volatility spill-over effect.

Theories that aim to explain the volatility spill-over or crisis transmission seek to explain how a crisis in one country affects the market prices in another country. Chan-Lau *et al.*

(2004:390) state that a crisis can be transmitted much more quickly between countries that have strong financial and trade links than those that do not. Moreover, owing to strong market integration over time, price co-movements may occur in the markets of these countries. The level of market integration therefore can determine the level of contagion. There are two levels of contagion, contagious and non-contagious, the latter indicating low or no contagion (Boshoff, 2006:62). A contagious crisis can be defined as a crisis that occurs in a certain country and has an immediate impact on markets in other countries (Boshoff, 2006:62). A contagion subsequently implies that the collapse of one market could signal the collapse of others, whereas interdependence implies that no significant market impact between countries exists (Gonzalo & Olmo, 2005:5).

3.3.4.1 Trade linkages

Trade linkages refer to a real association between countries, where physical goods and services are traded and the values of the goods and service traded are determined by macro-economic factors (Pritsker, 2000:10). The local supply of a good or service can be significantly influenced by international factors. The supply and demand conditions of goods and services between countries that are closely linked can affect the export performance between countries when a crisis occurs (Boshoff, 2006:64).

3.3.4.2 Financial linkages

Through globalisation, financial companies have gained access to investment and broker international financial market transactions. This financial association between countries opened an additional conduit through which a financial crisis can spread between countries (Sbracia & Zaghini, 2003:2). For example, a local financial institution may become an important provider of credit to companies situated in another country. If an international company defaults on payments owing to a crisis, the local financial institution can be directly affected (Sbracia & Zaghini, 2003:4). It is frequently the case that a financial institution becomes an important global financier (Sbracia & Zaghini, 2003:5). The activities of these types of companies and their respective banking activities, both proprietary and client-driven transactions, can result in the sudden withdrawal and or injection of capital into or out of a country (Sbracia & Zaghini, 2003:8). These transactions are usually short-term transactions and occur relatively quickly, depending on the sophistication of the financial institution performing the intermediation (Sbracia & Zaghini, 2003:8).

When a crisis occurs, the flaws of the banking system become evident and are amplified by the international and domestic interbank market. The association that exists between banking institutions in various countries increases the possibility of contagion and the simultaneous collapse of companies across the globe (Sbracia & Zaghini, 2003:9), hence making the financial linkages between countries a very important factor in determining volatility spill-over.

3.3.4.3 Behaviour of market participants

The behaviour of market participants with regard to the way in which an investment decision is made may transmit volatility between markets (Van Rijckeghem & Weder, 2001:3). In the event of a crisis occurring in one country, market participants in another country may adjust their view of the local market and subsequently adjust portfolios and hedging strategies to avoid risk. This situation leads to prices of assets and commodities being traded lower in the country in which the crisis did not originate (Boshoff, 2006:65). The behaviour of market participants may transmit risk and volatility between countries that do not share common macro-economic risk factors, but may share risk factors with a third country (Pritsker, 2000:12).

3.3.5 Conclusion

The measurement of volatility is an important factor in determining the price of a stock or a commodity. A market participant needs to be well versed in quantifying the risk that an investment holds before entering a transaction. Various models have been created over time to quantify risk through volatility measurement. The models explained in this section are the ARCH, GARCH and EGARCH models, with the first two models having inherent constraints that fail to quantify volatility to the extent that this study requires. Consequently, the EGARCH model was used to quantify the volatility spill-over effect of Corn on WMAZ and YMAZ, respectively (as will be detailed in chapter 4). The EGARCH model has the inherent ability to not only quantify the volatility spill-over effect, but also determine the effect of good *and* bad news on volatility.

3.4 Conclusion

The evolution of the derivatives market brought about various means of exchanging risk via derivatives contracts. It is thus essential that market participants be able to understand the pricing of derivative contracts and know where and how to trade these contracts. The major products available to market participants are forward contracts (usually not traded on an exchange), and futures and option contracts (both usually traded on formal exchanges). An important input into the calculation of these contracts is the volatility of the underlying commodity. Owing to the importance of volatility in the pricing of derivatives contracts, it is very important for market participants to be able to quantify the level of volatility in a particular market.

In quantifying volatility, it is important for a market participant to determine the origin of the volatility. Volatility can originate through factors affecting the supply and demand fundamentals of a stock or commodity and through international market volatility spill-over effects. The EGARCH model enables an accurate quantification of the volatility spill-over effect and will be used in this study. Once a market participant knows what causes volatility, the decision-making process of that market participant is enhanced.

Various theories have been constructed to explain how and when volatility spills over from one market to the next. It has been proven that financial market integration, the physical trade of goods and services between countries and the behaviour of market participants plays an important role in volatility spill-over. The next chapter will aim to quantify the volatility spill-over from Corn to WMAZ and YMAZ, respectively.

Chapter 4

Volatility spill-over effects

Markets can remain irrational longer than you can remain solvent.

John Maynard Keynes

(cited by Du Toit, 2002)

4.1 Introduction

With markets becoming ever more integrated owing to deregulation and the ease with which funds can flow between markets, the study of volatility and the spill-over effect of volatility on integrated markets has become increasingly more important. The volatility spill-over effect occurs when volatility generated in one market generates volatility in the prices and returns of assets (including commodities) traded in other markets (Tanizaki & Hamori, 2009:28). Moreover, the trade of goods and services and the events that govern supply and demand for the goods and services between countries are driven by information, which in turn drives volatility and prices in various markets, (Tanizaki & Hamori, 2009:28, 29).

This chapter will aim to quantify the amount of volatility that is spilled over from the Corn market to the WMAZ and YMAZ markets. This will be accomplished by discussing the applicable studies in chronological order regarding volatility spill-over effects between markets in section 4.2. Following this section, a description of the data and methodology regarding this study will be provided in section 4.3. The chapter will conclude with a discussion of the empirical results in section 4.4.

4.2 Volatility spill-over effect

The volatility of returns as measured on financial and derivatives markets provides additional information on returns (Tanizaki & Hamori, 2009:28). Moreover, Ross (1989) found that volatility on returns provides valuable insights into the flow of information between markets. The rate of information flow between markets has also been found to be linked to the volatility of prices (Ross, 1989:16). Given this link, a growing number of studies have

emerged that aim to explain the conditional variance link between markets and, by implication, the spill-over effect of volatility between financial markets (Tanizaki & Hamori, 2009:29). An overview of the relevant studies regarding the transmission of volatility between markets will be given in the sections that follow.

4.2.1 Hamao *et al.* (1990)

Utilising a GARCH-M model, the short-run interdependent relationship that exists between price and volatility in three major markets, namely Tokyo, New York and London, was explored by Hamao *et al.* (1990). In this study, two major points were explored: firstly, how volatility in one market affects the observed volatility in other markets; and secondly, how the equity prices in one market affect the opening equity prices in other markets (Hamao *et al.*, 1990:282). The results of this study indicated that the volatility transference rate between New York and London was relatively weak compared with the transference rate experienced by Tokyo from New York and London, respectively (Hamao *et al.*, 1990:306).

4.2.2 Lin *et al.* (1994)

Lin *et al.* (1994:508) state that the integrated relationship that exists between financial markets is a result of financial contagion and interdependence. The study focused on the correlation between the volatility on the New York and Tokyo markets, and what market participants could learn from overnight price and volatility movements. Similar studies (Hamao *et al.*, 1990; Schwert, 1990; Susmel & Engle, 1994; King & Wadhvani, 1990; Neumark *et al.*, 1991; Becker *et al.*, 1992; Dravid *et al.*, 1993) identified four universal traits effecting contagion. These traits are firstly that volatility varies over time, secondly that price correlation increases in major markets during periods of high volatility, thirdly that the North American markets are causal to price movement in other financial markets, and lastly that lagged volatility and price spill-over effects exist in major markets (Lin *et al.*, 1994:507–508).

In their first model, Lin *et al.* (1994) considered intraday stock price movements; however, since the New York and Tokyo markets are not synchronised in terms of trading hours, the flow of information between these markets was important for the study. Lin *et al.* (1994) utilised the signal-extraction process introduced by King and Wadhvani (1990) to segment foreign and local information flows in order to establish causality. The signal-extraction process functions under the assumption that a portion of the observed price change is

extracted from the foreign price change. The extracted portion of the observed price change is a fraction of the total variance of returns resulting from the foreign price factor (Lin *et al.*, 1994:510). They implemented the signal-extraction process by deconstructing the close-to-close returns into day and overnight returns, whilst allowing time-varying volatility. The reasons Lin *et al.* (1994) state for allowing time-varying volatility are to capture firstly the volatility clustering phenomenon (periods of increased volatility), secondly the rate of information flow, which is related to volatility as indicated by Ross (1989), and thirdly expectations about information, which can lead to trading taking place as a result of the expectations. Expectations can deviate from reality and can lead to price changes over time when reality differs substantially from what was expected (Lin *et al.*, 1994:510).

In order to illustrate the volatility spill-over effect between financial markets, Lin *et al.* (1994) constructed a second model based on an AS model. The AS model adjusts for the day-of-the-week effect by adding dummy variables and expresses the local overnight returns as a function of the previous local return data point. This explains the practice of using the previous data point generated by the foreign market in order to determine opening prices (Lin *et al.*, 1994:535). Moreover, given the opening prices should fully reflect the flow of information from the foreign market, given an efficient market.

The the speed of information transfer between markets will drive the correlation of volatility measured between markets (Lin *et al.*, 1994:510). In order to test the adjustment speed with which market prices reacted to overnight foreign news flows, Lin *et al.* (1994) tested for lagged returns and volatility. In conjunction with the lagged returns and volatility tests, they also tested the performance of the AS model and signal-extraction model in measuring market participant's behaviour relative to the performance of a GARCH-M model, as utilised by Hamao *et al.* (1990) too (Lin *et al.*, 1994:511).

From the research conducted by Lin *et al.* (1994), the following conclusions were drawn. Firstly, it was found that cross market interdependency existed between the New York and Tokyo foreign daytime and local overnight returns and volatilities. Secondly, it was found that the Schwarz criterion did not provide sufficient evidence to prove that the signal-extraction model better explained the behaviour of traders in the Tokyo markets than other models. Thirdly, it was found that little evidence existed that implied that lagged spill-over effects existed between the New York and Tokyo markets.

4.2.3 Koutmos and Booth (1995)

Koutmos and Booth (1995), building on Hamao *et al.*'s (1990) GARCH-M model, used an extended multivariate EGARCH model to measure the volatility spill-over effect between the New York, London and Tokyo equity markets. Moreover, utilising earlier research by Nielsen (1991), who introduced a model to capture the asymmetric impacts of shocks on volatility, Koutmos and Booth (1995) explored a gap in research at that time: the possibility that the quality and quantity of news flows between markets could be an important determinant of the degree to which volatility spills over from one market to another (Koutmos & Booth, 1995:748).

By utilising the multivariate EGARCH model, the disadvantages of the univariate Nielsen (1991) model can be eliminated. The EGARCH model improves the efficiency of the test for cross-market spill-over effects, which eliminates problems with estimated regressors and allows for asymmetric impact of news flows, both for local and foreign markets (Koutmos & Booth, 1995:749). After adjusting for the probable asymmetric effects that affect volatility spill-over, Koutmos and Booth (1995:747) found volatility spill-over from New York to London and Tokyo, respectively, and from Tokyo to London. In addition, they found that secondary movement interaction was more likely to occur, thus increasing the spill-over effect between markets. These findings indicate that the markets in this study were more prone to react to bad news than good news, suggesting that volatility spill-over effects are asymmetrically skewed to foreign news (Koutmos & Booth, 1995:760).

4.2.4 Kanas (1998)

Kanas (1998) conducted a study on the volatility spill-over effects between three of the largest European markets, London, Paris and Frankfurt. This study was conducted in a similar fashion to the study by Koutmos and Booth (1995), in that Kanas (1998) utilised an EGARCH model that captures asymmetric effects of news and information flows. Kanas (1998:244) found evidence indicative of volatility spill-over from London to Paris and from Paris to Frankfurt, and observed bi-directional spill-over effects between London and Frankfurt. Kanas (1998:244–245) linked market interdependence and volatility spill-over effects to market deregulation, electronic trading and market capitalisation.

4.2.5 Ramchand and Susmel (1998)

Building on the research conducted by Kanas (1998), which indicated that volatility spill-over effects increased during periods of highly volatile price movements, Ramchand and

Susmel (1998) explored the relationship between volatility and correlation between markets within a conditional time- and state-varying framework. This study aimed to provide insight into how the correlation between markets changed during volatility regimes, particularly the time- and state-varying volatility and correlation between the US, Japan, UK, Germany and Canada, by utilising a switching ARCH model (Ramchand & Susmel, 1998:3–4). The research found that the correlation between the US equity market and other world markets increases by 2 to 3.5 times during periods of high volatility in the US (Ramchand & Susmel, 1998:1), suggesting that when a large market experiences increased volatility the correlation between markets will tend to increase.

4.2.6 Ng (2000)

Ng (2000) researched the volatility spill-over from the US to Hong Kong, Malaysia, Singapore, Korea, Taiwan and Thailand, respectively. Ng (2000:212) constructed a model that incorporated a localised shock, a regional shock (from Japan, for instance) and a foreign shock (from the US), allowing the unexpected returns generated on other regional markets to be measured. A GARCH (1,1) model was used to measure the regional and foreign shock and a maximum likelihood technique was utilised for the bivariate system (Ng, 2000:212).

Firstly, it was concluded that both regional and foreign factors drove volatility spill-over effects, but that foreign effects on a specific market were larger. Secondly, it was found that volatility was also driven by currency fluctuations, market liberalisation and the size of trades. Thirdly, it was concluded that even though foreign and regional volatility spill-over effects existed, these effects were less than 10% of the weekly variance in returns for Hong Kong, Malaysia, Singapore, Korea, Taiwan and Thailand combined (Ng, 2000:230).

4.2.7 Collins and Biekpe (2003)

Collins and Biekpe (2003) researched the volatility spill-over effect and contagion between African and international emerging equity markets. They utilised the adjusted correlation coefficient to measure the contagion and interdependencies between African and emerging markets. The Granger causality test was also utilised to gauge the directional relationship between African and emerging markets (Collins & Biekpe, 2003:192).

They concluded that out of the eight African markets included in the study, only SA and Egypt showed evidence of contagion during periods of high emerging market equity volatility (Collins & Biekpe, 2003:192). The Granger causality test indicated that most African markets

are isolated from their international counterparts, since no causal relationship could be gauged, other than between themselves (Collins & Biekpe, 2003:193). They also found that the interrelationship between African equity markets is a result of fundamental trade links between these African countries (Collins & Biekpe, 2003:193).

4.2.8 Baele (2005)

Baele (2005) expanded the research conducted by Ng (2000) by constructing a GARCH model. This model utilised regime-switching volatility spill-over to measure the scale and the time-varying characteristics of volatility spill-over effects between US equity markets, and aggregate of European equity markets, and thirteen Western European equity markets. The research found that the volatility spill-over effects between US and European markets were relatively high, with the bulk of the sensitivity experienced by the latter between 1980 and 1990 (Baele, 2005:31). With the introduction of the Euro, a single monetary system, most Western European markets experienced lower sensitivity to shocks generated in the US. It was also found that European shocks explained 15% of local variance and that the shocks originating from the US explained 20% of local variance between 1980 and 2001 (Baele, 2005:31).

4.2.9 Piesse and Hearn (2005)

Piesse and Hearn (2005) explored the volatility spill-over effect between Botswana, Kenya, Ghana, Malawi, Namibia, Mauritius, Zambia, SA and Zimbabwe. They utilised a univariate EGARCH model to measure the asymmetric impact of good and bad news flows on volatility. The research presented strong evidence that volatility was transmitted from SA and Nigerian markets to the rest of the region. The magnitude of the volatility spill-over effects was found to be a function of the strength of the trade links between the countries (Piesse & Hearn, 2005:49). It was further found that, owing to the asymmetric nature of the model, bad news had a greater effect on markets compared with good news (Piesse & Hearn, 2005:49).

4.2.10 Conclusion

The studies conducted by Hamao *et al.* (1990), Lin *et al.* (1994), Koutmos and Booth (1995), Kanas (1998), Ramchand and Sumel (1998), Ng (2000), Collins and Biekpe (2003), Beale (2003) and Piesse and Hearn (2005) predominately sought to explain the volatility spill-over effect generated and experienced on equity markets with great success. The same logic used in the aforementioned studies can be applied to quantify the volatility spill-over effects

generated between agricultural futures markets. Section 4.3 and 4.4 will aim to apply an EGARCH approach within an AS framework quantify the amount of volatility that is spilled over from the Corn market to the WMAZ and YMAZ markets.

4.3 Data

Building on the previous research conducted on volatility spill-over effects, this study pursues a better understanding of the relationship, information flows and integration between the Corn futures market and the WMAZ and YMAZ futures markets, respectively. In order to accomplish this goal, the returns of Corn, WMAZ, and YMAZ were tested to statistically determine the volatility spill-over effect between these markets. This section will start with a discussion of the data utilised for this study, followed by the research methodology.

The data used to test for the volatility spill-over effect between Corn, WMAZ, and YMAZ that are traded on CBOT and SAFEX Commodity Derivatives Market, respectively, was obtained from Thomson Reuters (Thomson Reuters, 2011). The data consists of daily (end-of-day) level data for the continuous futures prices for the period of 20 March 1997 to 20 August 2011 for Corn, WMAZ, and YMAZ and the Dollar–Rand exchange rate (Rand; Reuters, 2011). The data collected represents 3140 observations for Corn, WMAZ, and YMAZ and the Rand, respectively. Weekends and cross-market holidays were removed from the dataset, in order to represent all tradable data.

The Corn contract is traded in Dollar (\$) per bushel (Bu) and was subsequently converted to Rand per tonne (R/t) by multiplying the \$/Bu rate by the factor 39.3679 and the Dollar–Rand exchange rate (SAGIS, 2011). This conversion enables direct comparison between the Corn contract and the WMAZ and YMAZ contracts traded in Rand per tonne.

Before the empirical study was conducted, a number of statistical inference procedures were conducted. Table 4.1 presents the descriptive statistics for the returns of Corn, WMAZ, and YMAZ for the datasets used.

Table 4.1 Descriptive statistics for Corn, WMAZ, and YMAZ (R/t).

Futures price	Mean	Median	Max.	Min.	Standard deviation	Skewness	Kurtosis	Obs.
Corn	0.00043	-0.00030	0.11722	-0.10808	0.02181	0.19638	4.80048	3139

WMAZ	0.00040	0.00056	0.12405	-0.19628	0.02241	-0.60377	8.55283	3139
YMAZ	0.00040	0.00000	0.13142	-0.13081	0.02051	-0.25948	7.53596	3139

From the table above, it can be deduced that the variation in the returns for the period under review for Corn varied from a minimum of -0.10808 to a maximum of 0.11722. WMAZ varied from a minimum of -0.19628 to a maximum of 0.124053. YMAZ varied from a minimum of -0.13081 to a maximum of 0.131416. In addition, the formal method of volatility measurement is the standard deviation. This volatility measurement indicated that WMAZ futures market was the most volatile, followed by Corn and then YMAZ. The kurtosis on all three datasets was larger than 3, thus indicating that the returns on the futures markets are more peaked and have fatter tails than normal distributions. Corn has positively skewed returns and WMAZ and YMAZ both have negatively skewed returns data.

Further to the descriptive statistics, an important concept necessary for statistical inference regarding time series data is the level of integration. When a data series contains a unit root (integrated to the order of 1), the assumptions of the classical linear regression model are violated, resulting in spurious results in the t-test, F-test and R-squared values (Asteriou & Hall, 2007:295). In order to eliminate the unit root contained in a data series, it can be differenced once or more to achieve an integration order of 0, also indicated as I(0) (Asteriou & Hall, 2007:295). Utilising the augmented Dickey–Fuller (ADF) test the data variables were tested for the level of integration. The results of the ADF test conducted, as given in tables 4.2, 4.3 and 4.4, reveal that all the variables contain a unit root, hence the data is integrated to the order of 1 (I(1)).

Table 4.2 Corn level data ADF unit root test.

Null hypothesis		t-statistic	Prob.*
ADF test statistic		-0.715377	0.8410
Test critical values	1% level	-3.432246	
	5% level	-2.862263	
	10% level	-2.567199	

*MacKinnon (1996) one-sided p-values.

From table 4.2, it can be deduced that the Corn dataset at level data contains a unit root, since the null hypotheses cannot be rejected at the 95% confidence level.

Table 4.3 WMAZ level data ADF unit root test.

Null hypothesis		t-statistic	Prob.*
ADF test statistic		-1.117724	0.7110
Test critical values	1% level	-3.432244	
	5% level	-2.862262	
	10% level	-2.567199	
*MacKinnon (1996) one-sided p-values.			

From table 4.3, it can be deduced that the WMAZ dataset at level data contains a unit root, since the null hypotheses cannot be rejected at the 95% confidence level

Table 4.4 YMAZ level data ADF unit root test.

Null hypothesis		t-statistic	Prob.*
ADF test statistic		-0.934075	0.7778
Test critical values	1% level	-3.432244	
	5% level	-2.862262	
	10% level	-2.567199	
*MacKinnon (1996) one-sided p-values.			

From table 4.4, it can be deduced that the YMAZ dataset at level data contains a unit root, since the null hypotheses cannot be rejected at the 95% confidence level; hence, the data is integrated to the level of 1 (I(1)). In order for the variables to achieve I(0), the datasets were differenced once.

Following the transformation of the data to a I(0) form, a test for the presence of heteroscedasticity was performed. Heteroscedasticity refers to the distribution of the parameter estimate data points being equally distributed across the dataset. When the data points within the dataset are not distributed heteroscedastically, the ordinary least squares estimator can become inefficient, and hypothesis testing, t-statistics and F-statistics can become unreliable (Asteriou & Hall, 2007:116). White's test was utilised to test for

heteroscedasticity, the null hypothesis of heteroscedasticity was discarded and all the p-values were considerably lower than 5% level of statistical significance.

With the data converted to I(1) from I(0) via the log returns and differencing the data set once, the data was subjected to a Granger causality test to check causality. Following this, an EGARCH model was applied to measure the volatility spill-over effect. The data was tested for volatility spill-over effects for the entire period that SA maize is tradable, utilising the statistical models discussed in chapter 3 and the studies reviewed in section 4.2, in conjunction with several statistical procedures in E-Views 7 (QMS, 2009). The methodology and results of the empirical study will be discussed in the following section.

4.4 Methodology and results

Granger causality tests were the basis for early studies relating to volatility spill-over effects, since this approach captured the unidirectional spill-over effect from larger markets to smaller markets. Later models introduced ARCH and GARCH models, which made the study of conditional volatility possible across stock markets. These models not only modelled the conditional volatility, but also allowed for the volatility to be forecast into the future (Worthington & Higgs, 2004:2).

The first part of this section will discuss the Granger causality test performed to determine the level of integration between WMAZ, YMAZ, and Corn. This test provided an indication of whether volatility spill-over is present between Corn, WMAZ, and YMAZ. The second part of this section will discuss the AS model applied to model the conditional volatility and establish the level of volatility spill-over from the Corn market to the WMAZ and YMAZ markets respectively..

4.4.1 Granger causality

The Granger causality test indicates that a variable X in a time series Granger causes variable Y, providing that it can be proven that the X values present statistically significant information in relation to the future values of Y. Conservatively, the Granger causality test

entails the testing of the null hypothesis that χ_t does not Granger cause γ_t . This can be depicted by the use of the following two regressions (Asteriou & Hall, 2007:285):

$$\Delta\gamma = \sum_{i=1}^m a_i \gamma_{\gamma-i} + \sum_{j=1}^n b_j \chi_{t-j} + e_t, \quad (4.1)$$

$$\gamma = \sum_{i=1}^m a_i \gamma_{\gamma-i} + e_t, \quad (4.2)$$

where $b_i = 0$ for every i , assuming that all the disturbances are uncorrelated. The unidirectional causality from Corn to the WMAZ and YMAZ futures markets was tested, which means that for the Corn futures price to Granger cause the WMAZ and YMAZ futures price, the estimated coefficients on the lagged Corn futures prices must be statistically different from zero, and that the estimated coefficients on the lagged WMAZ and YMAZ futures prices must not be statistically different from zero (Gujarati, 2009:697).

In order to conduct the Granger causality test, the datasets were subjected to a Vector Auto Regression (VAR) model. An initial lag structure of 20 was selected and given the results, a lag structure with a p-value was selected, which was a lag structure of 1. Given this lag structure, the Granger causality test was performed on Corn and WMAZ and Corn and YMAZ.

Table 4.5 Granger causality test between Corn and WMAZ returns.

Null hypothesis	Obs.	F-statistic	Prob.
DIFFWMAZ does not Granger cause DIFFCORN	3137	1.16243	0.3129
DIFFCORN does not Granger cause DIFFWMAZ		117.250	0.0000

Table 4.5 presents the results of the Granger causality test between Corn and WMAZ futures returns. From the results, it can be deduced that the null hypotheses that Corn does not Granger cause WMAZ cannot be rejected at the 95% significant level. This suggests that volatility spill-over occurs from Corn to WMAZ.

Table 4.6 Granger causality test between Corn and YMAZ returns.

Null hypothesis	Obs.	F-statistic	Prob.
DIFFYMAZ does not Granger cause DIFFCORN	3137	2.68901	0.0681
DIFFCORN does not Granger cause DIFFYMAZ		127.941	0.0000

Table 4.6 presents the results of the Granger causality test between YMAZ and Corn futures returns. From the results, it can be deduced that the null hypotheses that Corn does not Granger cause YMAZ cannot be rejected at the 95% significant level. This suggests that volatility spill-over occurs from Corn to YMAZ.

The results from the Granger causality test indicate market integration between the WMAZ and YMAZ futures markets, respectively, and Corn futures market. Once the directional impact of the volatility spill-over effect had been established, the level of the volatility spill-over effect was determined by the application of an EGARCH-AS model.

4.4.2 Aggregate shock model

The Granger causality test quantified the direction of the spill-over effect, thus illustrating that the WMAZ and YMAZ futures markets, respectively, and the Corn futures markets are integrated. This section will discuss the AS model used to determine the level of volatility spill-over from the Corn futures market to the WMAZ and YMAZ futures market. The AS model followed a two-step method, in which the fitted values of e_t and σ_t^2 in equations 4.3 and 4.5 were calculated and subsequently substituted into equations 4.4 and 4.6.

The daily Corn futures returns of the AS model are specified by the following equation:

$$CDR_t = \alpha_1 + \beta_1 CDR_{t-1} + e_t, \quad (4.3)$$

where CDR represents the daily Corn futures returns for the period under review, whilst e_t captures the variables that affect the level of returns that cannot be unexplained by the autocorrelation of the current daily returns with the previous day's returns. Moreover, assuming efficient markets, e_t represents returns that cannot be anticipated based purely on the existing public information when futures trading is initiated at the beginning of each day. Once the daily Corn futures returns had been modelled, the domestic WMAZ and YMAZ futures returns were modelled.

The daily WMAZ and YMAZ futures returns on SAFEX over the same period t as the daily Corn futures returns were modelled by the following equations for WMAZ and YMAZ, respectively:

$$WMDR_t = \alpha_2 + \beta_2 WMDR_{t-1} + \phi e_t + \mu_t, \quad (4.4)$$

$$YMDR_t = \alpha_2 + \beta_2 YMDR_{t-1} + \phi e_t + \mu_t. \quad (4.5)$$

The relationship between the Corn, WMAZ and YMAZ futures returns was measured by the coefficient ϕ , where the error term e_t represents the unexplained daily Corn futures returns for period t under review. An EGARCH (p, q) process was utilised to determine the size of the volatility spill-over effect between the daily Corn and WMAZ and YMAZ futures returns. The assumption is made that the error term e_t in equation 4.3 is normally distributed, the mean is equal to zero and that the variance will follow an EGARCH (p, q) process:

$$\ln \sigma_{C,t}^2 = \varpi_1 + \beta_3 \ln \sigma_{C,t-1}^2 + \gamma_1 \frac{\varepsilon_{C,t-1}}{\sigma_{C,t-1}} + \alpha_1 \frac{|\varepsilon_{C,t-1}|}{\sigma_{C,t-1}}. \quad (4.6)$$

The natural log of the conditional variance for e_t in period t is a function of the natural log of the past conditional variance denoted by $\sigma_{C,t-1}^2$, the time invariable mean reversion value is denoted by ϖ , and the absolute value of the standardised residuals is denoted by \mathcal{K} and the level of the standardised residuals denoted by $\frac{\varepsilon_{C,t-1}}{\sigma_{C,t-1}}$. Note that the subscript C denotes

Corn futures returns.

The second assumption is that the error term of the daily WMAZ and YMAZ futures returns denoted by μ_t is normally distributed, with a mean equal to zero and a variance that tracks an EGARCH (p, q) process, and can be calculated as follows for WMAZ and YMAZ, respectively:

$$\ln \sigma_{j,t}^2 = \varpi_2 + \beta_4 \ln \sigma_{WM,t-1}^2 + \gamma_2 \frac{\varepsilon_{WM,t-1}}{\sigma_{WM,t-1}} + \alpha_2 \frac{|\varepsilon_{WM,t-1}|}{\sigma_{WM,t-1}} + \mathcal{K}_i \sigma_{C,t}^2, \quad (4.7)$$

$$\ln \sigma_{j,t}^2 = \varpi_2 + \beta_4 \ln \sigma_{YM,t-1}^2 + \gamma_2 \frac{\varepsilon_{YM,t-1}}{\sigma_{YM,t-1}} + \alpha_2 \frac{|\varepsilon_{YM,t-1}|}{\sigma_{YM,t-1}} + \mathcal{K}_i \sigma_{C,t}^2, \quad (4.8)$$

where $\kappa_i \sigma_{C,t}^2$ in equation 4.6 represents the conditional variance of the daily Corn futures returns, and consequently represents the relationship between the volatility of the daily WMAZ and YMAZ futures returns and the daily Corn futures returns. Introducing the terms $\frac{|\varepsilon_{WM,t-1}|}{\sigma_{WM,t-1}}$ and $\frac{\varepsilon_{C,t-1}}{\sigma_{C,t-1}}$ for WMAZ and $\frac{|\varepsilon_{YM,t-1}|}{\sigma_{YM,t-1}}$ and $\frac{\varepsilon_{C,t-1}}{\sigma_{C,t-1}}$ for YMAZ enabled the modelling of the asymmetric volatility of historic shocks given $\gamma_2 \neq 0$. Hence when $\gamma_2 < 0$, then bad news should result in a greater effect on volatility than good news. When $\beta_4 > 0$, the reverse holds true.

Before an EGARCH model could be constructed, the VAR is estimated with a lag length of one. Utilising Akaike information criterion (AIC) and Schwarz criterion (SC), various lag specification models were estimated for each dataset to determine the appropriate lag specification for the EGARCH (p, q) model. The best model was one in which the values of the AIC and SC were minimised. The difference between the AIC and its alternative, the SC, is that the AIC penalises the model when additional coefficients are added.

The AIC is calculated as follows (QMS, 2009):

$$AIC = -2 \frac{l}{T} + 2 \frac{k}{T}. \quad (4.9)$$

The SC is calculated as follows (QMS, 2009):

$$SC = -2 \frac{l}{T} + 2 \frac{(k \log T)}{T}, \quad (4.10)$$

where the term l represents the value of the log likelihood, the term T represents the number of observations and the term k represents the number of parameters. The AIC and SC are based on -2 times the average log likelihood function, which is adjusted by a penalty factor. The AS models¹² selected under the AIC and SC for the WMAZ and YMAZ were EGARCH 121 and EGARCH 211, respectively.

¹² The AS models were constructed using a VAR model with a lag length of 1. The data used to construct the VAR model was integrated to I(0) from I(1) and the residuals of the EGARCH model were normally distributed.

The AS model enabled the formal testing of the relationship of both volatility and returns on the Corn, WMAZ and YMAZ futures markets. The results of the EGARCH 121 and 211 for the WMAZ and YMAZ AS model are presented in tables 4.7 and 4.8, respectively.

Table 4.7 EGARCH 121 AS model for Corn and WMAZ.

Mean equation

Variable	Coefficient	AIC	SC
WITLAG1	0.059846 [†]	-4.979318	-4.961963
CORNFOUT	0.165645 [†]		

Variance equation

Commodity	ϖ_2	α_2	γ_2	β_4	κ
WMAZ	-1.048215 [†]	0.34338 [†]	-0.026113 [†]	0.642318 [†]	-0.056476 [†]

CORNFOUT or ϕ = represents the relationship between the daily Corn futures returns and the daily WMAZ and YMAZ futures returns and is derived from the equations 4.4 and 4.5; ϖ_2 = represents the invariable mean reversion value, from equation 4.6; α_2 = represents the past conditional variance; γ_2 = ascertains the asymmetric function of volatility; β_4 = represents the volatility persistence; κ = ascertains the level of volatility spill-over; [†] = indicates that a coefficient is statistically significant at the 5% level.

It can be deduced from the mean equation in the table above that the effect of the daily Corn futures returns on the daily WMAZ futures returns is negative for the period under review. This means that when returns decrease on the Corn futures contract, the decrease will also be experienced on the WMAZ futures returns and vice versa. A 1 unit increase in the daily Corn futures returns will result in a 0.1656 unit increase in the daily WMAZ futures returns; thus, the coefficient is statistically significant. Apart from the measurement of the daily returns, the EGARCH model also allows the measurement of volatility characteristics regarding the influence of the Corn futures contract on the WMAZ futures contract. The asymmetric effect for good and bad news is measured by the parameter γ_2 , where $\gamma_2 = 0$ equates to no asymmetric effects being experienced, $\gamma_2 > 0$ equates to good news having a greater effect than bad news, and $\gamma_2 < 0$ equates to bad news having a larger effect than good news. Furthermore, it can be deduced from table 4.7 that bad news effecting returns on Corn futures will have a marginally larger effect on the WMAZ futures returns. This indicates a negative asymmetric distribution of the volatility function between good and bad news on the Corn futures returns and the WMAZ futures returns.

The degree of volatility persistence is measured by the coefficient β_4 in table 4.7. This coefficient is statistically significant and smaller than 1. Xu and Fung (2005) found that if the coefficient is smaller than 1, the volatility persistence term is stable. A large value for this term indicates that volatility will persist for an extended period, thus increasing uncertainty among market participants. This appears to be the case for the model in question, where volatility persists in the market for an extended period.

The actual volatility spill-over effect is measured by the term \mathcal{K} in table 4.7. The results indicate that the volatility spill-over between the Corn futures returns and the WMAZ futures returns is marginally negative and statistically significant. For a 1 unit increase in the volatility of Corn futures returns, WMAZ futures returns will experience a 0.056 unit decrease in volatility. This indicates that market integration between the WMAZ futures returns and the Corn futures returns is not as high as was previously expected. Table 4.8 presents the findings regarding the Corn futures returns and the YMAZ futures returns.

Table 4.8 EGARCH 211 AS model for Corn and YMAZ.

Mean equation

Variable	Coefficient	AIC	SC
GEELLAG1	0.037659 [†]	-5.157917	-5.140561
CORNFOUT	0.169799 [†]		

Variance equation

Commodity	ϖ_2	α_2	γ_2	β_4	\mathcal{K}
YMAZ	-0.593563 [†]	0.368924 [†]	-0.14052 [†]	0.968755 [†]	-0.022233 [†]

CORNFOUT or ϕ = represents the relationship between the daily Corn futures returns and the daily WMAZ and YMAZ futures returns and

is derived from the equations 4.4 and 4.5; ϖ_2 = represents the invariable mean reversion value, from equation 4.6; α_2 = represents the past conditional variance; γ_2 = ascertains the asymmetric function of volatility; β_4 = represents the volatility persistence; \mathcal{K} = ascertains the level of volatility spill-over; [†] = indicates that a coefficient is statistically significant at the 5% level

It can be deduced from the mean equation in table 4.8 that the effect of the daily Corn futures returns on the daily YMAZ futures returns is negative for the period under review. This means that when returns decrease on the Corn futures contracts, the decrease will also be experienced on the YMAZ futures returns and vice versa. A 1 unit increase in the daily Corn futures returns will result in a 0.169799 unit increase in the daily YMAZ futures return; thus, the coefficient is statistically significant. Apart from the measurement of the daily returns, the EGARCH model also allows the measurement of volatility characteristics regarding the

influence of the Corn futures contract on the YMAZ futures contract. The asymmetric effect for good and bad news is measured by the parameter γ_2 , where $\gamma_2 = 0$ equates to no asymmetric effects being experienced, $\gamma_2 > 0$ equates to good news having a greater effect than bad news, and $\gamma_2 < 0$ equates to bad news having a larger effect than good news. Furthermore, it can be deduced from table 4.8 that bad news affecting returns on Corn futures will have a larger effect on the YMAZ futures returns. This indicates a negative asymmetric distribution of the volatility function between good and bad news on the Corn futures returns and the YMAZ futures return. The YMAZ futures returns are more skewed to bad news from Corn futures than WMAZ.

The degree of volatility persistence is measured by the coefficient β_4 in table 4.8. This coefficient is statistically significant, which indicates that volatility persists in this market for an extended period. The volatility persistence appears to be larger on YMAZ futures returns than on WMAZ futures returns.

The actual volatility spill-over effect is measured by the term K in table 4.8. The results indicate that the volatility spill-over between the Corn futures returns and the YMAZ futures returns is marginally negative and statistically significant. For a 1 unit increase in the volatility of Corn futures returns, YMAZ futures returns will experience a 0.022 unit decrease in volatility. This indicates that market integration between the YMAZ futures returns and Corn futures returns is not as high as was previously expected.

From the results of both models, as given in tables 4.7 and 4.8, it would appear that the volatility spill-over effect of Corn futures returns on WMAZ and YMAZ futures returns has not been that significant, even though the Granger causality tests indicated that the WMAZ and YMAZ futures markets, respectively, are integrated with the Corn futures market. Given these findings, it is necessary to summarise the results obtained from the empirical study. The next section will aim to provide this summary.

4.4.3 Results of the empirical study

The aim of the empirical study was to gain a better understanding of the effect of the Corn futures returns on the WMAZ and YMAZ futures returns and the amount of price and volatility spill-over to the last mentioned markets from the former. With this in mind, the

results obtained from the empirical study will be interpreted with the use of the volatility theories described under section 3.3.4. The relationship between Corn futures returns and WMAZ and YMAZ futures returns should be interpreted by its inherent contagious or interdependent nature. Bearing this in mind, when market correlations increase during periods of high volatility, markets becomes more integrated and this situation represents a contagion effect (Bonfiglioli & Favero, 2005:1300).

Markets in countries that share strong fundamental trade relations tend to transmit contagion and price correlations more rapidly than countries that do not share this link (Chan-Lau *et al.*, 2004:390). Given this background, there is no evidence of significant sustained import and export transactions of physical maize between the US and SA (SAGIS, 2011). Moreover, the correlation between the Corn, WMAZ and YMAZ futures returns for the period under review is 17.22% and 16.72%, respectively. According to the theory explained by Chan-Lau *et al.* (2004), this indicates low market integration between the SA and US markets in terms of futures returns. This is further supported by the results obtained from the volatility spill-over term K in tables 4.7 and 4.8, respectively, which indicated that negative volatility spill-over effects from Corn futures returns are experienced by WMAZ and YMAZ futures returns.

The statistically significant results given in tables 4.7 and 4.8, with regard to the asymmetric effect of news flows on futures returns demonstrate that bad news in the Corn futures market, has a greater effect on the WMAZ and YMAZ futures returns than good news. Further to this point, the results also indicated that price spill-overs occur between these markets; however, the effect of this is relatively small, with a 1 unit move in the Corn futures returns, resulting in 0.1656 and 0.169799 unit movement for the WMAZ and YMAZ futures returns, respectively. It should be noted that even though WMAZ futures returns are more volatile than YMAZ futures returns (see the standard deviation in table 4.1), YMAZ futures returns appear to receive marginally more price spill-overs from a 1 unit change in Corn futures returns than WMAZ. This situation also holds true for the level of volatility persistence between these two commodities, with YMAZ futures returns experiencing 0.9687 units of volatility persistence compared with the 0.64232 units of volatility persistence experienced by the WMAZ futures returns from a 1 unit change in the Corn futures returns.

Given the findings of the empirical study, the following conclusions can be drawn:

- WMAZ futures returns are negatively skewed and the most volatile of the three datasets tested.
- YMAZ futures returns are evenly distributed over time, less volatile than WMAZ futures returns and more volatile than Corn futures returns.
- Corn futures returns are positively skewed over time and less volatile than WMAZ and YMAZ futures returns.
- Corn futures returns Granger cause WMAZ and YMAZ futures returns. This indicates that WMAZ and YMAZ futures returns are susceptible to contagion from the Corn futures returns.
- Price spill-overs originating from the Corn futures returns to the WMAZ and YMAZ futures returns is present and statistically significant. The transference is relatively small, with a 1 unit increase in the Corn futures returns resulting in a 0.1656 and 0.169799 unit change in the WMAZ and YMAZ futures returns, respectively.
- WMAZ and YMAZ futures returns are asymmetrically skewed in that bad news in the Corn futures returns has a larger effect than good news on the WMAZ and YMAZ futures returns, respectively.
- Volatility persistence originating from the Corn futures returns on both the WMAZ and YMAZ futures returns is present and stable, with the level of volatility persistence affecting the YMAZ futures returns for a greater period than the WMAZ futures returns.
- The volatility spill-over effect on both the WMAZ and YMAZ futures returns is marginally negative and statistically significant. This indicates that the volatility of Corn futures returns does not consistently spill over to the WMAZ and YMAZ futures returns, respectively. Further evidence for this is the research conducted by Auret and Schmitt (2008), who investigated the determinants of the WMAZ futures price. In their study, the Corn variable proved not to be significant at the 5% level and was subsequently not included in their final model on the determinants of the white maize price in SA.

4.5 Conclusion

The aim of this study was to establish the level of volatility spill-over from the Corn futures returns on the WMAZ and YMAZ futures returns. The results of the study will have important implications for the expectations of market participants regarding futures returns

on WMAZ and YMAZ. The expectations formed by market participants are used to make hedging, arbitrage and speculative decisions. In executing these decisions, via the derivatives market, it is important for the market participant to have quantified the volatility spill-over component from a foreign market to the local market. This quantification will in many cases result in a higher or lower price being paid for a certain derivatives contract, given the level of volatility spill-over experienced on the local market.

In order to measure and better understand volatility spill-over effects on markets, an overview of previous research was given to form the basis for this study. It was found that the optimum testing procedure for volatility spill-over effects in markets is to first test the direction of the spill-over effect and market integration by running a Granger causality test, And then to apply an AS model to test the level of volatility and price. The former found that the WMAZ and YMAZ returns were integrated with the returns of Corn futures returns and that volatility spilled over from the Corn futures returns to the WMAZ and YMAZ futures returns, respectively. The second step of the procedure demonstrated that the level of volatility spill-over was marginally negative and that price spill-over did occur but not to a substantial degree. Considering all of the above, it can be concluded on a statistically significant bases that no volatility is spilled over from the Corn futures contracts to the WMAZ and YMAZ.

Chapter 5

Conclusion

We don't have to be smarter than the rest; we have to be more disciplined than the rest.

Warren Buffet

(Hagstrom, 2005)

5.1 Introduction

Volatility is an important factor in pricing derivatives contracts and affects the expectations formed by market participants about what the true value of a commodity should be at a future date. Volatility in agricultural commodities is an even more sensitive matter, especially considering that certain commodities act as a staple food of a country. It is of cardinal importance for all market participants who trade on these types of markets to understand fully how prices are formed and the extent to which outside markets contribute to local market volatility. Understanding volatility will enable these market participants to better manage the price of the final product. Failure to understand how volatility affects agricultural commodities can lead to catastrophic consequences in the form of spiralling inflation and possible social unrest.

Chapter 5 will present a brief overview of all the relevant information contained within this study. The chapter will commence with a review of the aim of the study in section 5.2. This section will be followed by a review of maize as a global commodity (chapter 2) in section 5.3, after which a review of the pricing mechanisms of derivative contracts and volatility measurement (chapter 3) will be provided in section 5.4. This section will be followed by a review of the volatility spill-over effect as measured between Corn and WMAZ and YMAZ (chapter 4), respectively, in section 5.5. Finally, suggestions for further study will be made in section 5.7.

5.2 Aim of the study

The aim of the study on which this dissertation reports was to determine the extent to which volatility in the Corn market spills over to the WMAZ and YMAZ markets and to provide the South African market participants with greater insight in to the amount of foreign volatility that should be priced into the local options price via the volatility input on SA option

contracts. This information is important for market participants, since the isolation of the international volatility component will enhance the decision-making models for market participants trading option contracts. If a large amount of volatility is spilled over from the Corn market to the WMAZ and YMAZ markets, SA market participants will find that they will pay more for options of similar value in SA than would have been the case had no volatility been spilled over from the Corn market.

This increased premium for option contracts will then be due to international volatility and not necessarily volatility generated by local supply and demand conditions. This study thus also aimed to determine the extent to which a market participant should follow volatility changes in the Corn contract, if he or she wishes to trade options on WMAZ and YMAZ. Knowing how international volatility will affect the value of local options will be a large factor in determining the success of a local market participant. The next section will review all the chapters of this study starting with the review of maize as a global commodity, followed by a review of the pricing mechanisms of derivative contracts and volatility measurement. This section will be followed by a review of the volatility spill-over effect as measured between Corn and WMAZ and YMAZ and finally, suggestions for further study will be made in the last section.

5.3 Review of maize as a global commodity

Chapter 2 explored the history of maize and the spread of this commodity spread throughout the world to eventually become an important commodity for animal feed, industrial usage and human consumption in the economy. The market size and composition of corn in the US and maize in SA were described with reference to when planting, harvesting and marketing occurred in the respective markets. Chapter 2 also explored the fundamental price determinants of the commodity and the influence of variations in these fundamentals on the price of the commodity. In this regard, the term structure of prices was described in various market supply and demand conditions

It was also noted that when a surplus of a commodity exists, a contango market condition will arise, and when a deficit occurs, a backwardation market condition will arise. Chapter 2 also discussed the two exchanges, the CME Group's CBOT designated contract market where Corn is traded and the JSE's SAFEX market where WMAZ and YMAZ are traded. The

factors explored in chapter 2 are vital for a market participant to form an expectation of the market direction and where that market participant can execute a transaction to support his or her view of the market in the form of a trade.

5.4 Review of pricing of derivatives and volatility measurement

Chapter 3 explored the pricing of derivatives and the models constructed to measure volatility and summarised various volatility transmission theories. To this end, the derivative pricing methodology of forward, futures and option contracts was discussed in detail. Since volatility is an important component in the calculation of the various derivatives contracts available to market participants, this topic was discussed in more detail, with specific reference to its importance as an input into the Black–Scholes option pricing model. The price volatility of a stock or commodity represents the process of risk pricing and risk transfer related to changes in the underlying market supply and demand conditions. Therefore, when volatility suddenly increases or decreases, the pricing of an option contract can be adversely affected. This sudden movement in prices can result in unexpected losses or profits for a market participant trading in options. It is essential for a market participant to be able to gauge the volatility of a commodity. As part of determining volatility, it is essential that a market participant be able to isolate the volatility spill-over generated from the Corn contract when deciding on trading options on WMAZ and YMAZ contracts.

In determining the level of volatility, the ARCH family of models can be used. There are a number of models, each with its own constraints that make it suitable for measuring certain types of volatility. The EGARCH model was used for this study because it has the ability to isolate the volatility spill-over effect and the asymmetric effect of both good and bad news on the price of a commodity.

In this chapter, theories that seek to explain volatility transmission between countries were discussed. These theories state that when countries are linked by the physical trade of goods and services and have integrated financial markets, the behaviour of market participants with regard to news flows will heighten the risk of contagion and volatility spill-over between markets.

5.5 Review of the volatility spill-over effect

Chapter 4 reviewed previous studies that had measured the volatility spill-over effect. These studies found that the data on the volatility of returns in an underlying stock or commodity offers additional information to returns data. The data on returns volatility provided valuable information on the flow of information and the extent to which markets, commodities and stocks are linked across borders and time zones. Market participants form expectations on markets, stocks and commodities given information caused by economic shocks and events in foreign countries. The behaviour of the market participants transmits the volatility of the news flows across markets, stocks and commodities that share common macro-economic factors. Moreover, trade and financial linkages are essential in transmitting economic factors across markets. The links between countries, as explained by the theories in chapter 4, have a direct impact on the co-movement of the returns generated in markets and can facilitate volatility spill-over from one market to the next. The results of this study proved that with statistical significant figure that no volatility was transmitted between the Corn contract onto the WMAZ and YMAZ contracts using a continuous data set.

5.6 Conclusion

The aim of the study was to determine the extent to which volatility generated in the Corn market spills over to the WMAZ and YMAZ market. In quantifying the volatility spill-over between these markets, the study utilised an AS model, which incorporated an EGARCH process. This approach isolates and measures the level of the volatility spill-over between the international and local markets. With statistically significant results it was proven that no volatility spill-over effect from the Corn market to the WMAZ and YMAZ markets was found. A possible explanation for no significant volatility spill-over from the Corn market being experienced in the WMAZ and YMAZ markets might be that no sustained physical trade of maize occurs between the US and SA. This is an important point with regard to the level of market integration, contagion and volatility spill-over as explained by the theories at the end of chapter 3. Regardless of the lack of physical trade of maize between the US and SA, these two markets started to integrate in 2010 with the listing of an foreign-referenced corn contract trading on SAFEX. This contract enables market participants to track the trade dynamics of the corn movements of Corn on SAFEX more closely. Finally, the behaviour of

market participants up until 2010 was limited to trading in the local maize market only, thus limiting the effect that volatility generated by the Corn contract could have on the WMAZ and YMAZ contracts.

5.7 Recommendations for further research

The aim of this study was to present additional information on the reaction of the WMAZ and YMAZ markets to volatility in the Corn market. It was found with statistically significant results that no volatility was spilled over from the Corn contract to the WMAZ and YMAZ contracts, given the continuous price series between these commodities. This indicates that a market participant interested in trading in options does not need to pay an additional premium for the volatility generated in the Corn contract, since very little of its volatility spills over to the SA market. Moreover, the volatility generated should by default be generated by local supply and demand conditions; thus, this research finding indicates that volatility is locally driven for the SA maize market. Therefore, a market participant should pay greater attention to local supply and demand conditions than international volatility when trading in the SA maize market.

Given the conclusion of this study, it is recommended that future research be conducted on determining the size of the volatility spill-over effect before and after the listing of the foreign-referenced Corn contract on SAFEX. That local market participants can now trade the Corn contract more freely should increase market integration between the SA and US grain markets through market participant behaviour.

REFERENCES

Abbassian, A. 2006. Maize: International market profile. Washington: World Bank Trade and Markets Division. 25 p.

ABM (Australian Bureau of Meteorology). 2006. Southern Oscillation Index. <http://www.bom.gov.au/lam/glossary/soid.htm> Date of access: 20 Dec. 2011.

Asteriou, D. & Hall, S.G. 2007. *Applied econometrics: A modern approach*. Revised ed. New York: Palgrave MacMillan. 397 p.

Athanassakos, G. & Robinson, M.J. 1994. The day-of-the-week anomaly: The Toronto Stock Exchange experience. *Journal of business finance and accounting*, 21(6):833–856.

Auret, C.J. & Schmitt, C.C. 2008. An explanatory model of South African white maize futures prices. *Studies in economics and econometrics*, 32(1):102–131.

Baele, L. 2005. Volatility spill-over effects in European equity markets. *Journal of financial and quantitative analysis*, 40(2):373–401.

Barclay, M., Litzenberger, R. & Warner, J. 1990. Private information, trading volume and stock return variances. *Review of financial studies*, 3(2):233–252.

Becker, K.G., Finnerty, J.E. & Tucker, A.L. 1992. The intraday interdependence structure between U.S. and Japanese equity markets. *Journal of financial research*, 15(1):27–37.

Benhamou, E., ed. 2007. *Global derivatives: Products, theory and practices*. Hackensack: World Scientific. 384 p.

Bernstein, J. 2000. *How the futures markets work*. 2nd ed. New York: Institute of Finance. 328 p.

Berument, H. & Kiyamaz, H. 2001. The day of the week effect on stock market volatility. *Journal of economics and finance*, 25(2):181–193.

Bodie, Z., Kane, A. & Marcus, A.J. 2002. *Investments*. 5th ed. Boston: Irwin/McGraw-Hill. 1015 p.

Bollerslev, T., 1986. Generalized autoregressive conditional heteroskedasticity. *Journal of econometrics*, 31(3):307–327.

Bonfiglioli, A. & Favero, A.C. 2005. Explaining co-movements between stock markets: The case of US and Germany. *Journal of international money and finance*, 24(8):1299–1316.

Boshoff, W.H. 2006. The transmission of foreign financial crises to South Africa: A firm-level study. http://mpa.ub.uni-muenchen.de/9029/1/MPRA_paper_9029.pdf Date of access: 10 Jan. 2012.

Briys, E., Bellalah, M., Mai, H.M. & De Varenne, F. 1998. Options, futures and exotic derivatives: Theory, application and practice. New York: Wiley. 425 p.

Chan-Lau, J.A., Mathieson, D.J. & Yao, J.Y. 2004. Extreme contagion in equity markets. *IMF staff papers*, 51(2):386–408.

CME (Chicago Mercantile Exchange). 2011. Corn futures specifications. http://www.cmegroup.com/trading/agricultural/grain-and-oilseed/corn_contract_specifications.html Date of access: 20 Dec. 2011.

Collins, D. & Biekpe, N. 2003. Contagion and interdependence in African stock markets. *South African journal of economics*, 71(1):181–194.

Cox, J.C., Ross, S.A. & Rubinstein, M. 1979. Option pricing: A simplified approach. *Journal of Economics*, 7(3):229–263.

DAFF (Department of Agriculture, Forestry and Fisheries) *see* South Africa. Department of Agriculture, Forestry and Fisheries.

Dalton, B. 2008. Financial products: An introduction using mathematics and Excel. Cambridge: Cambridge University Press. 395 p.

Daly, K. 2008. Financial volatility: Issues and measuring techniques. *Physica A: statistical mechanics and its applications*, 387(11):2377–2393.

Dravid, R.F., Richardson, M. & Craig, A. 1993. Explaining overnight variation in Japanese stock returns: The information content of derivative securities. Working paper no. 93:5. Philadelphia: Weiss Center for International Financial Research. 33 p.

Du Toit, D. 2002. The South African money market. Johannesburg: South African Institute of Financial Markets. 84 p.

Engle, R.F. 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica*, 50(4):987–1008.

Epps, T.W. 2007. Pricing derivative securities. 2nd ed. Hackensack: World Scientific. P660.

Falkena, H.B. & Kok, W.J. 2000. The futures market. Halfway House: Southern Book Publishers. 86 p.

Falkena, H.B., Kok, W.J., Luus, C.W. & Raine, G.E. 1991. The futures market. 2nd ed. Halfway House: Southern Book Publishers. 198 p.

Geman, H. 2005. Commodities and commodity derivatives: Modeling and pricing for agriculturals, metals and energy. West Sussex: Wiley. 396 p.

Geyser, M. & Cutts, M. 2007. SAFEX maize price volatility scrutinised. *Agrekon*, 46(3):291–305.

Gonzalo, J. & Olmo, J. 2005. Contagion versus flight to quality in financial markets. Working paper no. 05-18. 32 p.
<http://docubib.uc3m.es/WORKINGPAPERS/WE/we051810.pdf> Date of access: 10 Jan. 2012.

- Gujarati, D.N. 2009. *Basic econometrics*. 5th ed. Boston: McGraw-Hill. 1002 p.
- Hagstrom, R.G. 2005. *The Warren Buffett way*. 2nd ed. New Jersey: Wiley. 272 p.
- Hamao, Y., Masulis, R.W. & Ng, V. 1990. Correlations in price changes and volatility across international stock markets. *Review of financial studies*, 3(2):281–307.
- Hansen, J.W., Jones, J.W., Kiker, C.F. & Hodges, A.W. 1999. El Niño–Southern Oscillation impacts on winter vegetable production in Florida. *Journal of climate*, 12(1):92–102.
- Hinebaugh, M. 1985. Corn. (In Pring, M.J., ed. *The McGraw-Hill handbook of commodities and futures*. New York: McGraw-Hill. p. 7–41.)
- Hoerling, M.P., Kumar, A. & Zhong, M. 1997. El Niño, La Niña, and the nonlinearity of their teleconnections. *Journal of climate*, 10(8):1769–1786.
- Hull, J.C. 2002. *Fundamentals of futures and options markets*. 4th ed. Upper Saddle River: Prentice Hall. 491 p.
- JSE (Johannesburg Stock Exchange). 2010. *Commodities derivative market dealer examination material*. Johannesburg: South African Institute of Financial Markets. 177 p.
- JSE (Johannesburg Stock Exchange). 2011. *Commodity derivatives monthly update November 2011*. <http://www.jse.co.za/Markets/Commodity-Derivatives-Market/Commodity-Derivatives-Market-data-and-price-info.aspx#updates> Date of access: 20 Dec. 2011.
- Kaminsky, G.L., Reinhart, C.M. & Végh, C.A. 2003. The unholy trinity of financial contagion. *Journal of economic perspectives*, 17(4):51–74.

Kanas, A. 1998. Volatility spillovers across equity markets: European evidence. *Applied financial economics*, 8(3):245–256.

Keynes, J.M. 1936. The general theory of employment, interest and money. London: MacMillan. 403 p.

Khalid, A.M. & Rajaguru, G. 2005. Financial market contagion: Evidence from Asia using fraction co-integration and multivariate GARCH approach.

http://www.economics.smu.edu.sg/events/Paper/ahmed_khalid.pdf Date of access: 6 Feb. 2012.

King, M.A. & Wadhvani, S. 1990. Transmission of volatility between stock markets. *Review of financial studies*, 3(1):5–33.

Kleinman, G. 2001. Commodity futures and options: A step-by-step guide to successful trading. London: Prentice Hall. 268 p.

Kolb, R.W. 1997. Understanding futures markets. 5th ed. Malden: Blackwell Business. 530 p.

Kolb, R.W. 1998. Understanding futures markets. 6th ed. Malden: Blackwell Business. 364 p.

Kolb, R.W. & Overdahl, J.A., eds. 2010. Financial derivatives: Pricing and risk management. Hoboken: Wiley. 600 p.

Koutmos, G. & Booth, G.G. 1995. Asymmetric volatility transmission in international stock markets. *Journal of international money and finance*, 14(6):747–762.

Krugel, L.J. 2003. White maize futures contracts in South Africa. Potchefstroom: Potchefstroom University for Christian Higher Education. (Thesis – M.Com.) 93 p.

Lence, S.H. 2002. Do futures benefit farmers who adopt them? Paper presented at the Annual Meeting of the American Agricultural Economics Association, Long Beach, CA, 28–31 July. <http://ageconsearch.umn.edu/bitstream/19768/1/sp02le04.pdf> Date of access: 27 July 2012. 12 p.

Lin, W.-L., Engle, R.F. & Ito, T. 1994. Do bulls and bears move across borders? International transmission of stock returns and volatility. *Review of financial studies*, 7(3):507–538.

Madura, J. 2000. International financial management. 6th ed. Cincinnati: South-Western College Publishing. 696 p.

Martin, R.V., Washington, R. & Downing, T.E. 2000. Seasonal maize forecasting for South Africa and Zimbabwe derived from an agroclimatological model. *Journal of applied meteorology*, 39(9):1473–1479.

Marx, J., Mporu, R.T., Nortje, A. & Van de Venter, T.W.G. 2006. Investment management. 2nd ed. Pretoria: Van Schaik. 254 p.

Natenberg, S. 1994. Option volatility and pricing: Advanced trading strategies and techniques. 2nd ed. New York: McGraw-Hill. 463 p.

Nelson, D.B. 1991. Conditional heteroskedasticity in asset returns: A new approach. *Econometrica*, 59(2):347–370.

Neumark, D., Tinsley, P.A. & Tosini, S. 1991. After-hours stock prices and post-crash hangovers. *Journal of finance*, 46(1):159–178.

Ng, A. 2000. Volatility spillover effects from Japan and the US to the Pacific-Basin. *Journal of international money and finance*, 19(2):207–233.

Piesse, J. & Hearn, B. 2005. Integration and the asymmetric transmission of volatility: A study of equity markets in sub-Saharan Africa. *South African journal of economics*, 73(1):36–53.

Poon, S.-H. 2005. A practical guide to forecasting financial market volatility. Hoboken: Wiley. 219 p.

Pritsker, M. 2000. The channels for financial contagion.
<http://www.citeseer.ist.psu.edu/viewdoc/summary?doi=10.1.1.203.4120> Date of access: 10 Jan. 2012.

QMS (Quantitative Micro Software). 2009. EViews version 9. User's guide II. Irvine: Quantitative Micro Software. 822 p.

Ramchand, L. & Susmel, R. 1998. Volatility and cross correlation across major stock markets. *Journal of empirical finance*, 5(4):397–416.

Reilly, F.K. & Brown, K.C. 2003. Investment analysis and portfolio management. 7th ed. Mason: Thomson Learning. 1100 p.

Ross, S.A. 1989. Information and volatility: The no-arbitrage Martingale approach to timing and resolution irrelevancy. *Journal of finance*, 44(1):1–17.

SAGIS (South African Grain Information Service) *see* South Africa. South African Grain Information Service.

Salvador, R.J. 1997. History, society and culture. (*In* The encyclopaedia of Mexico, 2:1–1794.)

Samouilhan, N.L. 2006. The relationship between international equity market behaviour and the JSE. *South African journal of economics*, 74(2):248–260.

Sbracia, M. & Zaghini, A. 2003. The role of the banking system in the international transmission of shocks. *The World Economy*, 26(5):727-754.

Schwert, G.W. 1990. Stock volatility and the crash of '87. *Review of financial studies*, (3):77–102.

Sharpe, W.F. 1970. Portfolio theory and capital markets. New York: McGraw-Hill. 316 p.

Soros, G. 2003. The alchemy of finance. Hoboken: Wiley. 391 p.

South Africa. Department of Agriculture, Forestry and Fisheries. 2011. Crop Estimate Committee: Final area planted and crop production figures of commercial maize, sunflower seed, soyabeans, groundnuts and sorghum for 2011. Pretoria: Government Printer. 2 p.

South Africa. Department of Agriculture, Forestry and Fisheries. 2010. Maize market value chain profile 2011–2012. Pretoria: Government Printer. 44 p.

South Africa. South African Grain Information Service. 2011. Conversion table. <http://www.sagis.org.za/> Date of access: 4 Dec. 2011.

Strong, R.A. 2002. Derivatives: An introduction. Cincinnati: South-Western College Publishing . 397 p.

Susmel, R. & Engle, R.F. 1994. Hourly volatility spillovers between international equity markets. *Journal of international money and finance*, 13(1):3–25.

Tanizaki, H. & Hamori, S. 2009. Volatility transmission between Japan, UK and USA in daily stock returns. *Empirical economics*, 36(1):27–54.

Thomson Reuters. 2011. Thomson Reuters DataScope reference data. 20 Nov.

United States of America. United States Department of Agriculture. 2010. Field crops: Usual planting and harvesting dates. Agricultural handbook no. 628. Oct. 50 p.
<http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf> Date of access: 18 Dec 2011.

United States of America. United States Department of Agriculture. 2010. Supply and demand review. Jul. 3 p.
http://www.cmegroup.com/trading/agricultural/files/ht_charts/snd_cbt.pdf Date of access: 18 Dec. 2011.

USDA (United States Department of Agriculture) *see* United States of America. United States Department of Agriculture.

Valsamakis, A.C., Vivian, R.V. & Du Toit, G.S. 1996. Risk management. Johannesburg: Heinemann. 410 p.

Van Rijckeghem, C. & Weder, B. 2001. Sources of contagion: Is it Finance or trade? *Journal of international economics*, 54(2):293-308.

Venter, T. 2011. General Maize and Corn fundamentals. [personal interview]. 25 NOV., Klerksdorp.

Wang, H.-J., Zhang, R.-H., Cole, J. & Chavez, F. 1999. El Niño and the related phenomenon Southern Oscillation (ENSO): The largest signal in interannual climate variation. *Proceedings of the National Academy of Sciences of the United States of America*, 96(20):11071–11072.

Watsham, T.J. 1998. Futures and options in risk management. 2nd ed. London: Thomson. 606 p.

Worthington, A.C. & Higgs, H. 2004. Transmission of equity returns and volatility in Asian developed and emerging markets: A multivariate GARCH analysis. *International journal of finance and economics*, 9(1):71–80.

Xu, X.E. & Fung, H.-G. 2005. Cross-market linkages between U.S. and Japanese precious metals futures trading. *Journal of international financial markets, institutions and money*, 15(2):107–124.