Model closure and price formation under switching grain market regimes in South Africa

by

Ferdinand Meyer

Submitted
in partial fulfilment of the requirements
for the degree

PhD

Department of Agricultural Economics, Extension, and Rural Development
Faculty of Natural and Agricultural Sciences
University of Pretoria

June 2006

I declare that the dissertation that I hereby submit for the degree in Agricultural Economics at the University of Pretoria has not previously been submitted by me for degree purposes at any other university.

SIGNATURE:………..………………….. DATE: ………………………………

ACKNOWLEDGEMENTS

This research project would not have been possible without the support and encouragement of various individuals. Firstly, I wish to express my sincere appreciation to Prof. Johann Kirsten[1] and Prof. Patrick Westhoff[2] for their excellent supervision and guidance of the work and for providing all the necessary opportunities to complete this study. It is truly a rewarding experience to be led by researchers that can provide guidance, initiative, support and constructive criticism on literally all aspects of a dissertation of this nature.

My appreciation is also extended to colleagues and friends in the industry and government for providing me with the necessary industry background and real-world issues and examples that I could test and apply in my study. Thanks are also due to the University of Pretoria for their financial support through an academic bursary and to the Department of Agricultural Economics, Extension and Rural Development for their financial support in the form of a post-graduate bursary for the first part of the study. Much appreciation also goes to Julian Binfield[2] for his companionship and help, especifically with the design of the regime-switching mechanism. To my friends and colleagues, Marnus Gouse, PG Strauss, Ghian du Toit, and Thomas Funke, who stood in for me on a number of occasions with teaching responsibilities, presentations, meetings and administration, I am deeply indebted.

To my family I give thanks for their continued faith in me. To my wife, Marilee, goes my deepest appreciation for her unfailing love, support and faith in me. She was my motivation to finish my study. Finally, our Creator, who has provided us with the talents we can use; to him be all the praise.

Ferdinand Meyer
Pretoria, South Africa
June 2006

[1] Department of Agricultural Economics, Extension, and Rural Development at the University of Pretoria, South Africa
[2] Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri, Columbia, USA

ABSTRACT

MODEL CLOSURE AND PRICE FORMATION UNDER SWITCHING GRAIN MARKET REGIMES IN SOUTH AFRICA

by

Ferdinand Meyer

Degree:	PhD Agricultural Economics
Department:	Agricultural Economics, Extension, and Rural Development
Study Leaders:	Prof. J.F. Kirsten and Prof P. Westhoff

This study develops the structure and closure of an econometric regime-switching model within a partial equilibrium framework that has the ability to generate reliable estimates and projections of endogenous variables under market-switching regimes. Models used in policy evaluation usually either ignore the possibility of regime switching, using just a single method of price determination based on average effects, or incorporate highly stylised components that may not reflect the complexities of a particular market. This study proposes an approach that allows the incorporation of features of regime switching in a multisector commodity level model which capture salient features of the South African market and are therefore able to produce more reliable projections of the evolution of the sector under alternative shocks. The following hypothesis is tested in the study:

With the correct model structure and closure, a combination of modelling techniques can be applied to develop a simulation model that has the ability to generate reliable estimates and projections of endogenous variables under market-switching regimes.

The technique that is used to "close" a simultaneous or recursive simulation model determines the manner in which market equilibrium is achieved in the model. The choice of closure technique will depend on the equilibrium pricing condition in a specific

market, specifically which market regime prevails in the market. It is important to note that trade flow and equilibrium pricing conditions under various trade regimes in the SA grain markets do not occur strictly according to these definitions. In the SA white and yellow maize markets some level of trade does occur with neighbouring countries at price levels that suggest that the market is trading under a type of regional autarky isolated from world markets. Industry experts argue that trade in the Southern African region is largely driven by regional issues like staple food, adverse weather conditions, location and quality concerns of genetically modified imported maize from non-African destinations, and to a lesser extent by arbitrage opportunities. This study, therefore, refers to "near-autarky". Given the fact that markets can fluctuate between different trade regimes (therefore equilibrium pricing conditions), some type of regime-switching model needs to be utilised to determine model closure. A switching mechanism is introduced that allows the white maize model to switch between model closer under import parity, near-autarky, and export parity, the yellow maize model to switch between model closure under import parity and near-autarky, and the wheat model to close under import parity.

Various approaches are used to test whether the regime-switching model complies with the hypothesis of this study. The first approach involves the simulation of baseline projections under a combination of different trade regimes in the grain markets. The second approach illustrates the usefulness of the automated switch between the various model closure techniques by comparing *ex-post* simulation results of the regime-switching model to the results of a previous version of the sector model that does not have the ability to switch between various market regimes. The last approach presents a more hands-on application of the regime-switching model to real-life examples by analysing the impact of a combination of market- and policy-related shocks in the form of scenario analysis.

This study proves that the regime-switching model is able to capture a richer variety of market behaviour than standard models as a result of the regime-switching innovation outlined, therefore more accurately capturing the likely effects of shocks on the domestic market. It is therefore consistent with the hypothesis of this study. The regime-switching model is, by design, more rigorous than the previous model in that it emphasises price formation and correct model closure under alternative regimes. Although the model is particularly appropriate for the South African grain market as specified here, it provides a template for which models for other countries and commodities may be developed.

TABLE OF CONTENTS

CHAPTER 3: THEORETICAL FOUNDATION OF PARTIAL EQUILIBRIUM MODELLING

CHAPTER 4: THE REGIME-SWITCHING MODEL

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Over the past decade economic literature has studied the transmission of prices between spatial markets and analysed the extent to which markets are integrated. According to the basic principles laid down by the theory of the law of one price when trade occurs between two markets, the markets are integrated and the difference in the prices equals the transaction costs to move the goods between those markets in the long run (Goodwin, Grennes and Wohlgenant, 1990). The equilibrium price in the smaller market can be estimated as a function of the equilibrium price in the dominant market, the exchange rate and the transaction costs. As soon as the difference in the market prices becomes less than the transaction costs, trade is discontinued and the markets are no longer integrated (Sexton, Kling and Carmen, 1991). The market equilibrium (equilibrium price) is then a function of the domestic supply and demand factors in each market respectively. Thus, the formation of prices, also referred to as the equilibrium pricing condition (Barrett, 1999) in a specific market, changes as the market switches between different market regimes. According to Barret (1999), if a commodity moves from a non-tradable (importable) to an exportable (non-tradable) equilibrium, the correlation between the parity price and the local market prices should jump from (to) zero to (from) significantly positive, to (from) one if the law of one price holds strictly.

From a modelling perspective, the technique that is used to "close" a simultaneous or recursive simulation model determines the manner in which market equilibrium is achieved in the model. Many different model closure techniques exist. The choice of closure technique will depend on the equilibrium pricing condition in a specific market, specifically on which market regime prevails in the market. Models used in policy evaluation usually either ignore the possible existence of more than one market regime using just a single linear method of price determination based on average effects, or incorporate highly stylised components that may not reflect the complexities of a particular market. This implies that the estimated price transmission elasticity is likely to be moderate, understating the true elasticity when supplies are either large or small relative to domestic demand, but overstating the true response when domestic supply and demand are in balance. Although these models may appear statistically sound, they could present a simplification of the price-formation process. Colman (1995) noted that the concept of an elasticity of price transmission needs to be treated carefully. In particular, equating perfect price transmission with an elasticity of one only makes sense if all duties and transport costs are proportional to price. Barrett and Li (2002) referred to the "messy character of market relationships" arising from treating price transmissions mostly as a linear phenomenon. Balcombe (2003) more recently raised the concern that parameters in transmission equations do not correspond to the structural parameters which they are thought to represent. He also noted that theoretical models often contain either assumptions that are not met in practice, or identification conditions that cannot be established by examining the data alone. This comment is especially relevant in the Southern African markets where price relationships often indicate no opportunity for arbitrage and trade still occurs between the nations. This point will be discussed further in chapter 2.

In South Africa only a handful of studies have addressed price transmission and price formation in the agricultural market, and even fewer studies have addressed these issues within a partial equilibrium framework. Schimmelpfennig, Meyer, Beyers and Scheepers (2003) undertook one of the most recent studies on price transmission and presented an Error-Correction-Model (ECM) of the short- and long-run equilibrium between the world price of maize, the local producer and consumer price of maize, and the exchange rate. Although this study focused on long- and short-term shocks in the maize market, the switch of trade regimes[1], which determines the equilibrium pricing condition, was not taken into account and just a single method of price determination based on average effects was represented in the model. The study was also not undertaken within a partial equilibrium framework. Meyer and Kirsten (2005) presented the price-formation process

[1] For the period of the study (January 1998 – January 2002) the local maize market switched from an export parity regime, to near-autarky, to import parity.

in the wheat industry within a partial equilibrium framework, but did not address the possibility of a switch in market regimes.

Switching market regimes are a reality and the challenge is to apply econometric principles and applications to provide reliable simulation results of reality. This study proposes an approach that allows the incorporation of features of regime switching in a multisector commodity level model which capture salient features of the South African market and are therefore able to produce more reliable projections of the evolution of the sector under alternative shocks.

1.2 PROBLEM STATEMENT AND JUSTIFICATION OF RESEARCH

With the abolition of the agricultural marketing boards in 1997 a major shift took place in the price formation of South African agricultural commodities (Kirsten and Vink, 2000). The agricultural market division of the South African Futures Exchange (SAFEX), which was established in 1996, became the primary price-formation mechanism for wheat and maize. The shift from a regulated towards a free market essentially implied that price formation moved from a single-channel marketing system, where prices were set by the marketing boards, to an environment where prices are formed by fundamentals in the marketplace. Over the past eight years role players had to adapt to this new marketing environment where domestic markets are to a large extent integrated with world markets. For literally all of the grains and most of the livestock commodities, South Africa can be regarded as a "small nation" in terms of world production, consumption and trade. Therefore, role players participating in commodity markets essentially operate in an open economy of a small nation; "open" due to the ambitious deregulation of agricultural markets and "small" due to the fact that South African commodity markets do not significantly influence world price levels. South Africa is relatively small in the world market, but not so small as to have no impact.

Due to this new and dynamic agricultural environment, role players must almost continuously make decisions concerning their respective pricing, distribution and production policies.. Decision makers not only require the basic fundamental market information, for example crop estimates, stock levels, trade flow and domestic and foreign prices, they also need to understand what impact a shift in the basic market fundamentals could have on the market place. Commodity modelling can be regarded as one of the tools that process basic fundamental market information and, therefore, can play an important role in assisting role players in decision making, especially when it is applied to scenario planning and forecasting. The fact that price formation has changed so drastically in the South African commodity markets has major implications for all basic econometric modelling techniques that involve price formation, integration and market equilibrium in the South African commodity markets.

The determination of domestic prices is dictated by a country's specific trade and policy regimes. These regimes determine how domestic market prices are integrated with world market prices. Most econometric simulation models do not distinguish between the various trade regimes present in a specific commodity market and estimate the critical relationships between parity and domestic prices as an average over the trade and policy regimes. Figure 1.1 presents three regimes where the formation of prices differs fundamentally.

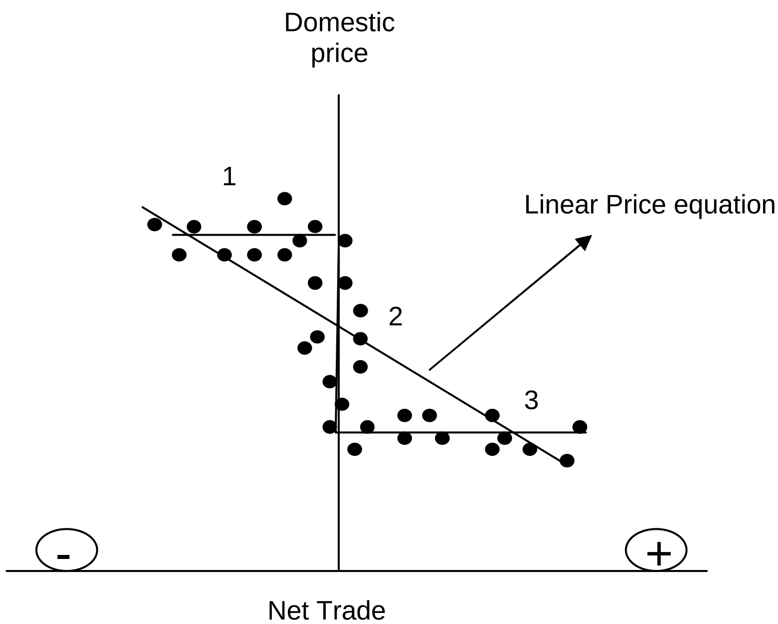

Figure 1.1 Three different market regimes

These regimes are summarised as follows:

Regime 1: Import parity

If domestic prices are high enough, the country is a net importer and the domestic price is a function of the world market price. As imports increase, so the domestic supply increases. Under this scenario one expects a high rate of transmission from the world price to the domestic price. One would especially expect the market price in South Africa to move with the price in exporting countries, plus the cost of shipping commodities to South Africa and any import taxes. Since South Africa is regarded as a small nation, the world price will not be significantly affected by South African imports.

Regime 2: Autarky

If domestic prices are in the middle range, in other words between import and export parity, domestic prices are determined by fundamental factors in the local market. Hence, in this region prices are largely disconnected from world market prices. The dictionary definition of autarky refers to an economic policy or situation in which a nation is independent of international trade and not reliant on imported goods.

Regime 3: Export parity

If domestic market prices are low enough, the country is a net exporter and the domestic price is again a function of the world market price. In this scenario, the domestic prices are again integrated with world market prices and the rate of transmission from world prices to the domestic market price is high. One would expect domestic market prices to be closely related to the price paid in importing countries, less relevant transportation costs and taxes.

Figure 1.1 shows that if the domestic price is estimated as a linear function of the world price, the critical relationship between the dependent and independent variables is estimated as an average over the three regimes. Hence, the equation does not capture the three distinct regimes where price formation differs fundamentally. Many of the econometric price transmission models face this problem. Although these models may appear statistically sound, they present a simplification of the price formation process.

This point was clearly illustrated when the stochastic projections by the South African grain, livestock, and dairy sector model, developed by Meyer and Westhoff (2003), overestimated the white and yellow maize price levels for the 2005 production season by more than 20 percent. In this season, the maize market moved from import parity levels to a situation closer to export parity levels within a matter of two months. Various scenarios were tested with the model and even when the latest crop estimates by the National Crop Estimates Committee (CEC) were introduced in the model, the model still overestimated prices by an unacceptably high margin. The levels of exports were overestimated, which occurred mainly because of the model structure. In the model, white and yellow maize exports and imports are estimated as a linear function of domestic consumption, production and the world price. In reality, export demand is expected to be small and inelastic when domestic supplies roughly match local demand, but much more price responsive when surpluses build up and prices fall to export parity levels.

Exactly the same principle can be illustrated by another practical example. Assume that a severe drought reduces the domestic production in a small nation. If the model structure is set up in such a way that the domestic price is directly linked to the world price, then the drought will have no impact on the local market price for a small nation. However, if the model is set up to solve the price within the domestic market, and therefore take the local production and consumption levels into account, then the drought will have an effect on the local market price, but with no guarantee that prices will be bound by important import parity levels.

In essence, it is clear that a distinction needs to be made between the term “endogenous” in a statistical sense and “endogenous” in a market-related sense. A price can be modelled as a function of world prices, which implies that the price is a behavioural equation in the system of equations and, therefore, endogenous in a statistical sense. However, this price is predetermined by the world price and is therefore not solved endogenously in the domestic market by means of supply and demand.

Market integration, equilibrium pricing conditions and formation, and price transmissions have been researched over many years. The formation of prices in a specific market changes as the market switches between different trade and policy regimes. To the author's knowledge, Barrett (1999) conducted the only study where the shift in equilibrium pricing conditions has been introduced in a partial equilibrium framework. However, no regime-switching methodology was applied in the study and model closure under the shifting equilibrium pricing conditions was not addressed. Chapter 2 reviews further studies that utilised threshold models and parity bound models, to accommodate the discontinuities of trade. Some of these studies have applied regime-switching techniques and others have considered transaction flow, but no study has addressed model closure techniques within large multi-market models under switching trade regimes. Without the correct structure and closure, even models that appear to exhibit good econometric properties will not be able to generate reliable estimates of endogenous variables. This study incorporates a range of techniques and principles to develop a partial equilibrium model that can be applied to real market and policy analysis under market switching regimes.

1.3 STATEMENT OF HYPOTHESIS

Typically, studies on price transmission, integration, and market equilibrium revolve around single equation parameter estimates for prices and transaction costs in different regions. For theses studies hypothesis testing normally does not pose any difficulties and can be implemented with a high level of efficiency. However, Barrett (2001) does mention that it is unclear how one aught to interpret rejections of the hypothesis that, for example, international agricultural markets are in competitive equilibrium, given uncertainties like variable trade policies.

Working with system of equations makes hypothesis testing a daunting task. Apart from identities, the multi-market model that is applied in this study consists of 126 behavioural equations. Naturally, one can design a hypothesis test for each coefficient, estimated within the system of equations, but the practicality and usefulness of this exercise is highly questionable. Furthermore, statistical hypothesis testing cannot be undertaken in those cases where synthetic modelling techniques are applied in big multi-market commodity models. As previously stated, this study presents the structure and closure of an econometric regime-switching model within a partial equilibrium framework that has the ability to generate reliable estimates and projections of endogenous variables under market-switching regimes. A number of statistical criteria, like Thiel's inequality coefficient (Thiel's U Statistics) for example, can be applied to test hypotheses on the statistical performance of the model. However, even if the model performs well by standard statistical measures, it still does not imply that the model is able to handle real-world issues and shocks. For the purposes of this study it is therefore appropriate to design a hypothesis around the real-world issues rather than the statistical performance of the model. This study sets out to test the following hypothesis:

With the correct model structure and closure, a combination of modelling techniques can be applied to develop a simulation model that has the ability to generate reliable estimates and projections of endogenous variables under market-switching regimes.

The methodology that will be applied to test this hypothesis is discussed in the following section. Hypothesis testing with regards to the statistical performance of the model falls beyond the scope of this study.

1.4 OBJECTIVES AND METHODOLOGY OF THE STUDY

The objectives of this study can be arranged into two main groups: Firstly, the development of a multisector commodity level model that is able to generate reliable estimates and projections under switching market regimes and secondly, the practical implementation and application of this model to examine real-world issues.

The primary objective of this study is to redesign the model specification and closure of the white maize, yellow maize, and wheat industries in the existing South African grain, livestock and dairy multisector commodity model, in order to accommodate the switching between various market regimes. The first version of the South African grain, livestock and dairy model was developed and operationalised by Meyer and Westhoff in 2003 (Meyer and Westhoff, 2003). It can be classified as a large-scale multisector commodity level simulation model and in total, six crops, five livestock and five dairy commodities are included in the current version of the model (table 1.1). The model is maintained within the Bureau for Food and Agricultural Policy (BFAP) at the University of Pretoria.

Table 1.1: Products included in the SA grain, livestock and dairy model

Cereals	**Oilseeds**	**Meat**	**Other**
White Maize	Sunflowers	Chicken	Eggs
Yellow Maize	Soybeans	Beef	Milk
Wheat		Mutton	Cheese
Sorghum		Pork	Butter
			Skimmed Milk Powder
			Whole Milk Powder

Source: BFAP baseline, 2005

The improved version of the model must be able to generate reliable estimates and projections under the three alternative market regimes introduced in figure 1.1. The re-estimation of the system of equations will combine econometric methods with simulation techniques to generate reliable projections for commodity markets. All the improvements and analysis will be undertaken within the already existing partial equilibrium framework. This model will, by design, be more rigorous than the previous model in that it emphasises price formation and correct model closure under alternative regimes.

Separate price formation blocks will be developed that include actual import and export parity price levels. The critical objective of the study is to design a "switch mechanism" that incorporates principles of threshold effects developed by Balcombe (2003), the difference between equilibrium and integration developed by Barrett and Li (2002) and the parity bounds model by Baulch (1997). The switch mechanism allows for a switch between different approaches to model closure, as markets move between import and export parity. This suggests that price transmission elasticity levels will change as markets move.

The lack of long-run time series data determines to a large extent the methodology that is followed in this dissertation. Interestingly, in their study of stochastic regime-switching models Bac, Chevet and Ghysel (2001) noted that they were hampered by relatively short data sets of *"only"* 40-50 years of data in order to conduct testing of cointegration, unit roots, or mean version. Although data on the total area planted to maize are available since the early sixties, the split between white and yellow maize area planted has only been reported since 1992. When an equation with two to three exogenous variables is estimated with only thirteen observations, many formal statistical validation procedures are difficult to apply. Brooks and Melyukhina (2005) referred to the difficulty of obtaining robust estimates without good data on both prices and traded volumes as the "fundamental dilemma", and even then the econometric techniques available may not be capable of providing accurate *ex ante* predictions of price transmission.

Since the principle objective of this study is to develop a well-behaved econometric model that is able to simulate regime switching in commodity markets, alternative estimation and validation procedures are followed in some cases to find estimates that provide an accurate prediction of reality. Where necessary, synthetic parameters are imposed to ensure reasonable model behaviour.

Although eighteen agricultural commodities are included in the model, this study only focuses on price formation and model closure in the white maize, yellow maize and wheat market. The main reason for choosing these three industries is that each industry represents a unique trade and policy environment. Furthermore, maize is the single most important agricultural commodity that influences literally all the South African field crops and livestock markets. Internationally, South Africa can be treated as a small nation with an open economy with respect to all three industries. This is, however, not the case in the Southern African region. South Africa is the largest maize producer in this region and can therefore be regarded as a large nation in the region. Variable import levies have been introduced for white and yellow maize and wheat can be imported with an *ad valorem* tariff of 2 percent, which implies that the tariff is so low that it hardly has any impact on the domestic market price. South Africa is primarily a net exporter of white maize and a net importer of wheat. In the case of yellow maize, South Africa is sometimes a net importer and sometimes a net exporter.

In summary, this study will develop alternative model closure techniques for white maize, yellow maize and wheat under the following market regimes:

- White maize: import and export parity, and autarky
- Yellow maize: import parity and autarky
- Wheat: import parity

After the model structure has been developed, model results will be validated and an illustration of the practical implementation of the model in the real market provided. Despite undertaking statistical validation procedures where possible, essentially most of the validation of the model results will be market orientated to ensure that the model simulates reality accurately. The construction of elasticity matrices and a summary table of price and trade impact multipliers will form part of the validation procedures. The usefulness of the model will be illustrated by means of scenario analyses, which will be conducted in the form of case studies that incorporate two main levels of scenarios. These levels are market-related scenarios and policy scenarios. Market-related scenarios will analyse the impact of key drivers (e.g. world prices, the exchange rate and weather patterns) on the market place. The scenario analyses of a shock in world prices will illustrate how the level of integration between domestic and world markets changes as markets shift between the various trade regimes. Policy scenarios will include shocks on the current tariff dispensations of the grains. The results of the scenario analysis will be applied to test the hypothesis of this study.

1.5 OUTLINE OF STUDY

This thesis is organised into six chapters. Following this introductory chapter, the second chapter contains a literature survey on price formation and modelling systems of equations, particularly pertaining to agricultural commodities. This chapter also includes a descriptive overview of the functioning of the white maize, yellow maize and wheat markets in South Africa. Chapter 3 introduces the theoretical foundation for the structure and closer of the model. The empirical results and performance of the single-equation estimations are reported and discussed in chapter 4. The impact multipliers and simulation results of the various scenarios generated within the closed system of equations are presented in chapter 5. A summary of the study and concluding remarks are given in chapter 6.

CHAPTER 2

MODEL CLOSURE AND PRICE FORMATION: CONCEPTS AND APPLICATIONS

2.1 INTRODUCTION

The first section of this chapter presents a review of the literature. The purpose of the literature review is twofold. The first is to provide a basic review of alternative approaches to price formation and the closure of selected equilibrium commodity models. The second purpose is to establish the uniqueness of the modelling approach that is presented in this study by explaining how alternative approaches were incorporated into the development of the new approach. The technical detail of this approach is presented in chapter 3 and 4.

A good understanding of the function of commodity markets with respect to price formation and trade is central to a solid understanding of model development. A descriptive overview of the functioning of the South African maize and wheat markets is presented in the second section of this chapter. This section includes a discussion of the database for the analysis of price formation and trade. In addition, various trade regimes are identified for each of the commodities based on the monthly trade flow and the fluctuation of the domestic market price between the export and import parity prices. A distinction is made between trade within the Southern African region and trade with the rest of the world.

2.2 PRICE FORMATION AND MODEL CLOSURE: A REVIEW

This study develops the structure and closure of an econometric regime-switching model within a partial equilibrium framework. The technique that is used to close a simultaneous or recursive simulation model determines the manner in which market equilibrium is achieved in the model. The choice of closure technique will depend on the formation of prices in a specific market, specifically on which market regime prevails in the market. It needs to be pointed out that although one can find many studies and textbooks explaining the basic structure of econometric models, only a handful of studies specifically address the closure of econometric partial equilibrium models. Once the technique for model closure, and thus the formation of prices in the domestic market has been established, the degree to which prices are transmitted between domestic and world markets needs to be determined. Price formation changes as the market switches between different market regimes. Therefore, regime switching modelling techniques also need to be included in the review of literature. The review of literature firstly focuses on the basic background and concepts of price formation, price transmission and regime switching and then on simulation modelling, where model closure is discussed.

2.2.1 BACKGROUND OF PRICE FORMATION

The review of literature on price transmission and price formation would be incomplete without the inclusion of literature related to the law of one price. After all, according to Goodwin, Grennes and Wohlgenant (1990) the law of one price (LOP) is an essential ingredient in theories of international trade and exchange rate determination. In short, the LOP maintains that foreign and domestic prices of a commodity are equal when both are expressed in the same currency and net of transportation costs. When this is not the case, there is an opportunity for arbitrage. In economics, arbitrage is the practice of taking advantage of a state of imbalance between two or more markets. The dictionary definition of arbitrage is “the purchase of securities on one market for immediate resale on another market in order to profit from a price discrepancy”. Arbitrage has the effect of causing prices in different markets to converge and, therefore, for the markets to integrate. As a result of arbitrage, the currency exchange rates and the prices of commodities in different markets tend to converge to the same price, in all markets, in each category.

A fairly common practice is to assume an elasticity value of unity to indicate complete price transmission. This, however, only makes sense if all duties and transport costs are proportional to price (Brooks and Melyukhina, 2005). In the case of an *import*, we expect the domestic price to be higher than the world price before transport costs are paid, so perfect price transmission would imply an elasticity of *less* *than one*. In the case of an *export*, perfect price transmission would correspond to an elasticity *greater than one* (Brooks and Melyukhina, 2005; Sharma, 2002).

Empirical literature on LOP is extensive. Traditional literature was based on the assumption that parity should hold contemporaneously. Goodwin *et al* (1990) argued in their paper on a revised test of the LOP that this assumption overlooks the fact that international commodity arbitrage and trade occur over time as well as across spatially separate markets and parity should not be expected for contemporaneous spot prices unless arbitragers have perfect foresight. Their revised LOP test included the estimation of rationally formed expected futures prices and a nonparametric analysis of price parity. The shortcoming of this approach was that parity was only based on expectation of parity prices and actual trade flow was not taken into consideration. The result is that empirical evidence could suggest that markets are integrated, even though no trade flow took place. It is interesting to note that the authors did mention that border prices are more appropriate for the LOP than internal prices because they better represent arbitrage opportunities.

Sexton, Kling and Carmen (1991) argued that integration should not be treated as an "all or nothing" proposition because regions may often be linked by arbitrage, but not others, depending upon the supply-demand conditions in each region at time t. This is a fundamentally important observation with respect to this study since it introduces the concept that price formation differs under various trade regimes. In other words, when regions are linked by arbitrage, the equilibrium price in one region is determined by the equilibrium price in the other region since prices converge, but if arbitrage does not hold, then price formation takes place by means of domestic supply-demand conditions. The authors distinguish between the following three regimes where price formation differs fundamentally: effective arbitrage, relative shortage, and relative glut. Maximum likelihood methods were applied to estimate a switching regime model that relied exclusively on price data. Although the switching regime approach was applied for the estimation of the pass through of prices under the various market regimes, the switch between the various regimes did not occur automatically as the model solved for prices between the various regimes. Instead the likelihood function was utilised to estimate the probability of arbitrage or that the law of one price holds under the various trade regimes.

In their analysis of meat consumption in the UK, Kostov and Lingard (2004) also recognised the shortcomings of linear models with fixed parameters over time and introduced a regime-switching approach in a vector error correction model to yield a non-linear model with time-varying coefficients. The authors explained that "the basic idea of regime switching models is that the process is time invariant, conditional on a regime variable indicating the regime prevailing at time t". It is worthwhile to note a fundamental point made by the authors that while the importance of regime shifts seems to be generally excepted, there is no established theory suggesting a unique approach for specifying econometric models that embody changes in regime, and now follows the most important part: "increasingly regime shifts are considered not as singular deterministic events (i.e. structural breaks), but the unobservable regime is assumed to be governed by a stochastic process". This clearly shows that the authors made provision in the model structure so that regime shifts of the past can be expected to continue to occur in the future in a similar fashion. In a South African context, for example, this implies that droughts will occur in future that can cause the domestic market to shift from an export parity regime to an import parity regime. Another very important feature of the regime-switching approach that is illustrated in this study, is that regime-switching models characterise a non-linear data-generating process as being piecewise linear by restricting the process to be linear in each regime. This feature is illustrated in chapter 4 where the linear parameters for each trade regime are presented separately.

Baulch (1997) identified two more shortcomings of conventional tests of market integration; firstly, that they fail to recognise the pivotal role played by transfer costs, and secondly, many researchers make erroneous assumptions concerning the continuity of trade. Baulch developed a parity-bound model (PBM) that uses transfer costs as well as commodity prices in order to take explicit account of the possibility of discontinuous trade between two markets. PBM made use of border prices. He applied the principle of spatial arbitrage conditions to determine the parity bounds within which the prices of a homogenous commodity in two distinct regions can vary, or stated differently, to establish probabilistic limits within which the spatial arbitrage conditions are likely to be binding. The author assessed the extent of market integration by distinguishing three possible trade regimes: regime 1, at the parity bounds (in which spatial price differentials equal transfer costs); regime 2, inside the parity bounds (in which price differentials are less than transfer costs); and regime 3, outside the parity bounds (in which differentials exceed transfer costs). The principle of the parity bounds was adopted for the development of the regime-switching model in this study by means of calculating "parity bounds" in the form of import and export parity prices. The application of this principle is illustrated in section 4.4 of chapter 4 where the switching mechanism of the model is discussed.

Apart from the regime-switching and parity-bound approach, one more approach is worth mentioning for the purpose of this study, namely the threshold approach. Cluff (2003) undertook a review of spatial price transmission in major world commodity models. He refers to Enders and Silkos (1999), who introduced threshold models, when he argues that threshold models are aimed at testing for the presence of non-linear transaction costs, and in general for the existence of price bands within which there is no transmission. Stated differently, price changes in one market only transmit to another market when the price difference between the two markets exceeds a threshold level. In his study Balcombe (2003) researched the threshold effects in price transmission and found that there might not only be one threshold in which no transmission takes place, but there may be more distinct equilibrium relationships between prices.

Meyer (2003) developed a threshold vector error correction model to incorporate effects of transaction costs into the study of market integration and price transmission. According to Meyer, transportation costs in spatial markets will limit the transmission of price shocks below a critical level because potential gains from trade cannot outweigh these costs and hence a perfect price adjustment will not occur. Meyer identified a "regime of non-adjustment" and a second regime where the deviation from the long-term equilibrium is greater than the threshold and price adjustment takes place. At the risk of stating the obvious, price transmission between regions only takes place with price adjustment. Literature shows that threshold effects can be postulated in models where each country has a supply and demand schedule, but where transport costs play a key role in determining whether trade takes place. However, literature on developments in the threshold model is relatively recent and due to the complex nature of transaction costs, the application of these models to a range of markets and commodities could prove difficult (Brooks and Melyukhina, 2005).

A review of market integration and price formation would be incomplete without the inclusion of the extensive research carried out by Christopher Barrett. Barrett (1999) examined the effects of real exchange rate depreciation on stochastic producer prices in low-income agriculture and proposed that one should find a structural shift in the correlation between border parity prices and local market prices where depreciation of the exchange rate induces a shift among equilibrium pricing conditions. A number of variables can cause a shift in equilibrium pricing conditions. For example, if the impact of a drought in the local market moves a commodity from a non-tradable to an importable equilibrium, the correlation between border parity prices and local market prices should jump from zero to significantly positive, to one if the law of one price holds strictly.

In a later study Barrett (2001) criticises the methods used to investigate integration and efficiency in international markets, indicating that data insufficiency poses a serious constraint because empirical tests that rely on just prices cannot separate tests of the market efficiency hypothesis from tests of the strong assumptions underpinning model specification.

Barrett and Li (2002) argued that the Parity Bound Model (PBM) and related switching models do not exploit trade flow data and therefore really only study equilibrium conditions and not market integration. The reason for this is that these models identify price differentials less than transfer costs as “integration”, even when no trade occurs and there is no transmission of price shocks between the two markets. The authors developed a spatial model in which they focused on two issues: firstly, the possibility that price transmission occurs in the absence of trade, and that trade takes place in the absence of price transmission; and secondly, that most econometric applications are aimed at testing the most restrictive condition, in which both market integration and a competitive equilibrium are verified. Even more relevant for this study, the authors referred to the “messy character of market relationships” arising from treating price transmissions mostly as a linear phenomenon. This relates to the shortcomings of linear models that were later identified by Kostov and Lingard

(2004). Although laying down a very robust methodology, the difficulties of applying the approach by Barrett and Li (2002) stem more widely from a) high frequency data requirements, and b) a relatively sophisticated econometric specification.

The concept that trade between two nations is based on expectations of future market conditions, as presented by Goodwin *et al* (1990), hints at an area of research that needs to be mentioned, namely to distinguish between short- and long-run market integration and equilibrium. This concept is based on the fact that trade takes time to arrange and to complete and there is a delivery lag from where an arbitrage opportunity arises until the actual trade flow has taken place (Sexton *et al*, 1991). One of the most popular approaches in recent years to estimate short- and long-run market integration is the estimation of error correction models. For example, Roche and Mcquinn (2003) used a vector error-correction approach to determine whether the law of one price holds over the long run and attempted to capture the salient features of the Irish grain prices in the short run. Another example is the vector error correction model by Kostov and Lingard (2004) discussed earlier.

Industry specialists are of the opinion that for the South African grain market a rule of thumb for the delivery lag of imports and exports is approximately six weeks. Taking into consideration that the model that was developed for this study is an annual model, a six-week lag is irrelevant as one can argue that over a year the market will reach long-run equilibrium. Even more important is the fact that all the crops that are included in the model are annual crops. This implies that if for example there is a short crop in a particular season, the local prices tend to move closer to import parity prices for the full season, and when there is a surplus, the local prices tend to move closer to export parity prices for the full season. Therefore, short- and long-run market integration and equilibrium could easily be estimated on an annual basis. However, data constraints complicate issues. These constraints are discussed further in later sections of this chapter and in chapter 4, but in essence, price formation in South African grain markets changed with deregulation in 1997. There are inadequate annual observations for the estimation of reliable estimates. As a result, the distinction between the various trade regimes is based on monthly observations.

In South Africa only a handful of studies have addressed price transmission and price formation in the agricultural market. All these studies treated price transmission as a linear phenomenon with the estimation of a single set of parameters. Schimmelpfennig, Meyer, Beyers and Scheepers (2003) undertook the most recent study on price transmission and presented an Error-Correction-Model (ECM) of the short- and long-run equilibrium between the world price of maize, the local producer and consumer prices of maize, and the exchange rate. This study focused on long- and short-term shocks in the maize market, but crucially the switch of trade regimes, which determines the equilibrium-pricing condition, was not taken into account. A single method of price determination based on average effects was represented in the model. This model has thus fallen prey to the flawed assumption of continuous trade taking place with no switch in the correlation between domestic and world prices.

To summarise, the following links can be made between the existing approaches and the methodology that is developed in this study: In common with most switching regression models, the PBM and threshold models solve for spatial price equilibrium between distinct markets, whereas the regime-switching model devised in this study solves for market equilibrium in a partial equilibrium framework (where demand equals supply) under three distinct trade regimes. While existing regime-switching models switch between various intercepts and/or parameter estimates of specific single equations, the switch in this study occurs between the various model closure techniques that each consist of a combination of single equations and identities with different intercepts and parameter estimates. This study focuses on equilibrium pricing conditions and the relevant model closure to enable the correct formation of prices under distinct trade regimes in a multi-commodity model, rather than just price transmission and market integration between distinct markets. For this study the concept of "price bands" within which domestic price formation takes place under free market conditions and the existence of price bands within which there is no transmission, was adopted from PBM and threshold models. In addition to the concept of "price bands", this study takes into consideration that a shift in equilibrium pricing conditions changes the correlation between domestic and world prices and therefore different correlation coefficients between domestic and world prices are used for the various trade regimes. The concept of shifting equilibrium conditions (Barret 1999, 2001; Barret & Li 2002) was adopted to address the "messy character of market relationships" arising from treating price transmission as a linear phenomenon.

The following section highlights the alternative approaches to price formation in selected partial-equilibrium models, with the emphasis on model closure. Model closure is crucial since it determines how prices are formed in the model.

2.2.2 CONCEPTUALISING MODEL CLOSURE

The development of equilibrium models and system of equations is well established and has become an integrated part of world economies and world economic reviews. Two main categories of equilibrium modelling exist. On the one hand, if one takes into account that agricultural markets may have meaningful impacts on non-agricultural sectors, models that account explicitly for interactions between agricultural and non-agricultural sectors of the economy have an obvious advantage. These models are referred to as general equilibrium models or economy-wide models. On the other hand, one can argue for a model that covers many countries and commodities and pays close attention to cross-commodity effects. These models are referred to as partial equilibrium models (Van Tongeren, Meijl and Surry, 2000).

According to Westhoff, Fabiosa, Beghin and Meyers (2004), cross-commodity interaction in the partial-equilibrium framework provides the modeller with the opportunity to include considerable and very current detail in representing markets and policies for selected countries and commodities. This study follows the partial equilibrium approach to model detailed equilibrium pricing conditions for various commodities under switching market regimes. Given the focus of this study – which is that of developing and implementing distinct closures for a multi-commodity partial equilibrium model under alternative market regimes – it is chosen to elaborate on the development of a multi-commodity model structure and closure that results in the correct price formation under various market regimes. Only a small number of studies have addressed model structure and closure *per se* and far more studies have rather focused on price transmission.

In its simplest form, the closure of equilibrium models can be illustrated by assuming that stock changes and international trade are minor, the quantity supplied is a function of price and production costs, the quantity demanded is a function of price and income, and the resulting price represents the market clearing level where the quantity demanded equals the quantity supplied (Ferris, 1998). This system of equations can be illustrated as follows:

Equation 2.1: $QD = a + a_1 P_t + a_2 Y_t + e_t$ (Ferris, 1998)

Equation 2.2: $QS = b + b_1 P_{t-1} + b_2 C_t + e_t$ (Ferris, 1998)

At equilibrium each year $QD = QS$

Therefore:

Equation 2.3: $-a_1 P_t = -QS_t + a_0 + a_2 Y_t + e_t$ (Ferris, 1998)

$$P_t = -\frac{a_0}{a_1} + \frac{1}{a_1} QS_t - \frac{a_2}{a_1} Y_t + e_t$$ (Ferris, 1998)

Thus, price is estimated as a function of production and income. In this simplified illustration of model closure, price transmission and market integration are obviously not addressed and price formation takes place in the domestic market place, isolated from international markets. This can also be regarded as price formation under a perfect autarkic market regime. Depending on the aim of equilibrium models, a more general approach would include stock levels and international trade as substantive components. Model closure immediately becomes more involved since relationships of prices across spatial markets are at the core of issues such as trade policy and hold implications for how markets are linked and how shocks are dispersed among them.

Cluff (2003) addressed price transmission in relation to model closure in his comprehensive review of spatial price transmission in main multi-country multi-market models used for medium-term outlook projections. Models examined in this study broadly follow similar standard approaches of price transmission and therefore model closure. Although different price transmission and model closure techniques are applied to suit distinct market regimes for various commodities, none of these models have the capacity to switch between the market regimes. The FAO World Food Model links domestic and world prices in a linear price linkage equation with constant elasticity specifications as follows:

Equation 2.4: $$P_t^D = P_{t-1}^D.(\frac{P_t^W}{P_{t-1}^W})^\eta$$ (Cluff, 2003)

where, P_t^D and P_t^W are domestic and world prices and η is the elasticity of price transmission. Although later versions of the model included a price wedge between domestic and world prices, mainly to reflect transportation costs, the biggest shortcoming of this approach is that exchange rates are not included in the model.

Price formation and model closure are treated similarly in FAPRI's world commodity model under import and export parity regimes, but with the advantage of including exchange rate and policy variables, for example an *ad valorem* tariff, as follows:

Equation 2.5: $$P_t^D = \alpha + \beta P_t^W .r_t.(1 - d_t) + e_t$$ (Cluff, 2003)

This equation provides the combination that the divergence of the domestic and border price that does not depend on the price level is captured by α and the error term captures the random divergence. FAPRI's model also allows for imperfect transmission between world and domestic prices, which is presented by β. The price transmission elasticity that is estimated in equation 2.5, can be presented as

Equation 2.6: $$\eta = \frac{\partial P_t^D}{\partial P_t^W}.\frac{P^W}{P^D} = \beta(1+d).\frac{P^W r}{P^D}$$ (Cluff, 2003)

It is interesting to note that the FAPRI approach acknowledges the fact that a long time series gives no guarantee of precise estimates because the longer data are also more susceptible to incorporating different policy regimes (Cluff, 2003). FAPRI's models account for shifts in policy regimes through the inclusion of dummy variables.

When domestic prices are defined by a single set of parameters (equation 2.4 and 2.5), trade is used to close the model under the import and export parity market regimes in the form of a residual of domestic supply and demand. Whether a country is a net exporter or net importer does not fundamentally change the model closure and price formation in a specific market. Domestic prices are still estimated as a function of world prices, transaction costs and policy variables. The only difference is that net exports (imports) will serve as closing identity when the market is trading at export (import) parity levels. This form of model closure can be presented as follows (net exports as closing identity):

Equation 2.7: $$QNED_t = QEST_{t-1} + QS_t - QDD_t - QEST_t$$ (Ferris, 1998)

where, $QNED_t$ is the net export demand, $QEST_{t-1}$ and $QEST_t$ are the beginning and ending stock, and QS_t and QDD_t represent the domestic demand and supply.

The OECD's Aglink model has a heterogeneous set of price transmission equations across countries and commodities, ranging from simple double-log price-price linkages, to linear equations to domestic market equilibrium, where local demand and supply factors determine price. Exchange rates, policy variables and a range of intervention prices are explicitly accounted for in the model, which complicates the calculation of price elasticities to such an extent that actual parameters in equations only give an indication of actual transmission elasticities in some rare cases.

Although frequent modelling work has been conducted in the South African context, most of the modelling work focused solely on single equation estimations of demand and supply and only a few studies applied modelling techniques within an equilibrium framework. One of the first equilibrium studies was presented by Cleasby, Darroch and Ortmann (1993), who specified a simultaneous-equation model containing yellow maize export demand and supply functions. Two Stage Least Squares (2SLS) was used to estimate the single equations, which were then used to run a system of equations. The market equilibrium condition of total demand equal to total supply was used to close the simultaneous-equation model. The results indicated that the world price of maize, as well as the exports of the previous year, had an influence on the export demand of yellow maize. The real Chicago Board of Trade corn price was used as the world price. The results supported the *a priori* expectations that local yellow maize producers are price takers on the world market and that export supply reacts sluggishly to changes in the lagged producer price of yellow maize. This equilibrium model applied a single method of price formation based on average effects and did not take a possible switch of market regimes into account. It is, however, worth mentioning that price formation in the yellow maize market at that period in time did not take place under free market conditions, but that the marketing boards set the prices.

Poonyth, Van Zyl and Meyer (2000) applied FAPRI's approach to the South African grain market by conducting a study on the market outlook for maize and sorghum. They used the two-stage least squares estimation method to ensure cross-equation and cross-commodity consistency. The domestic demand and supply equations for maize and sorghum were developed. A possible switch in market regimes was not accounted for and only one technique of model closure, namely net trade, was used to close the model. This involved the linking of the domestic price with the world price via a price linkage equation. The price transmission elasticities from the US corn and sorghum prices to the South African maize and sorghum prices were estimated at 1.19 and 0.73 respectively. Apart from the fact that no distinction was made between white and yellow maize, a transmission elasticity of 1.19 seems to be high, especially when considering that the local maize markets occasionally trade under autarkic market regimes where very little or no trade takes place. Another shortcoming of this study was that no distinction was made between white and yellow maize. Although white and yellow maize can be treated as much the same product on farm-level, on the consumption side white and yellow maize serve two fundamentally different markets.

Over recent years, the Bureau for Food and Agricultural Policy (BFAP) at the Department of Agricultural Economics, Extension and Rural Development (LEVLO) at the University of Pretoria has played a leading role in the development of partial equilibrium models for South African commodity markets. The South African grain, livestock and dairy model (also referred to as "BFAP sector model"), which is used in this study, was developed by Meyer and Westhoff (2003) and can be classified as a multi-commodity partial equilibrium model for the South African grain, oilseeds, livestock and dairy market. The model is maintained within BFAP and the modelling approach that is used builds on the FAPRI approach and includes the most important determinants of supply and demand with a selection of price relationships. For a typical crop, for example, these include the area under production, yield per hectare, total production, direct human consumption, industrial use, exports, imports, and ending stocks. Only one technique is used to close each of the commodity models in the system. The choice of closure currently depends on the nature of the dominant market regime and therefore equilibrium pricing condition for each commodity. In other words, if for instance the white maize price predominantly solves under autarky, then the white maize model is closed by equating demand and supply, similar to equation 2.3. The model does not take the possibility of switching market regimes into consideration.

No formal publication has appeared on the complete BFAP sector model, and only model structures of selected commodities have been published. The latest publication, by Meyer and Kirsten (2005), presents the market outlook and policy alternatives for the South African wheat industry within a partial equilibrium framework. In this study the price of wheat was modelled as a function of the import parity price and domestic wheat production and the model was closed on net imports in order to simulate market equilibrium (see equation 2.7 above). The model did not address the possibility of a switch in regimes and consequently modelled an average of the three trade regimes. This is clearly illustrated by the price transmission elasticity of 0.46, which can be regarded as very low when bearing mind that South Africa is a net importer of wheat and therefore the domestic wheat price should mainly be determined by the import parity price of wheat and not the domestic production.

To the author’s knowledge, Barrett (1999) conducted the only study where the shift in equilibrium pricing conditions has been introduced in a partial equilibrium framework. In his analysis of the effects of real exchange rate depreciation on domestic equilibrium price distributions, Barrett applied generalised autoregressive conditional heteroskedastic (GARCH) econometric techniques on monthly price data. A distinction was made between tradables and non-tradables, with the non-tradable band being established by the world price plus and less transfer costs, and not by the point where domestic demand equals domestic supply as illustrated in equation 2.3.

Furthermore, demand and supply were estimated independently of the exchange rate, which implies that demand and supply levels were basically not modelled as a part of the integrated system. This study illustrated how local price distributions and the correlation between local and world prices change when equilibrium pricing conditions shift. However, no regime-switching methodology was applied in the study and model closure under the shifting equilibrium pricing conditions was not addressed.

In conclusion, it is important to note that although a significant shift in a market regime will influence the rate of price transmission between spatial markets and thus change the correlation between parity and local market prices, the shift will not necessarily induce a switch in equilibrium pricing conditions (i.e. a switch in model closure),, for example from import parity to autarky for a specific commodity. This implies that if there is no switch in equilibrium pricing conditions, estimation techniques, for instance dummy variables, can be applied to improve parameter estimates under switching policy regimes because the choice of the model closure technique need not change. If, however, a switch in market regimes induces a switch in equilibrium pricing conditions, then an alternative method of model closure has to be implemented. In the following section, after an overview of the data, the various market regimes for the white maize, yellow maize and wheat market are identified.

2.3 AN OVERVIEW OF THE GRAIN MARKETS

2.3.1 THE DATABASE

The lack of long-run time series data determines to a large extent the methodology that is followed in this study. Although data on the total maize area planted are available since the early sixties, the split between areas planted to white and yellow maize has only been reported since 1992. For this study, even fewer annual observations can be utilised since price formation in the South African grain markets changed completely with the abolition of the marketing boards in 1997. Before 1997 the marketing boards were the sole buyers in South Africa. Trade flow was not determined by the relative level of the domestic price, but rather by marketing board policies and marketing strategies. The domestic price was subsidised and the boards frequently exported surpluses into the world market at a loss. Clearly, the equilibrium pricing conditions (price formation) changed when this system was abolished, which implies that only nine relevant annual observations (1997-2005) can be used for estimating equations determining price formation and trade. It is, however, still possible to use longer time series for supply and demand equations.

When a typical equation is estimated with two to three exogenous variables and only nine observations, many formal statistical validation procedures are not applicable. Interestingly, in their study of stochastic regime switching models, Bac, Chevet and Ghysels (2001) noted that they were hampered by relatively short data sets of *"only"* 40-50 years of data in order to conduct testing of cointegration, unit roots, or mean version. It is, therefore, clear that for this study inadequate annual observations are available to model price formation and trade under market-switching regimes. This study, therefore, relies on monthly time series data to estimate the relevant price and trade equations under the different trade regimes. These parameter estimates and the calculated elasticities are then introduced in the annual simulation model. For example, the parameter estimates from the monthly price linkage equation under the import parity regime are also applied to the annual price linkage equation in the sector model under the import parity regime. It is expected that when the market is trading under import parity conditions, this price linkage equation will capture the transmission of world prices to the local market the best and thus provide plausible estimates of the domestic price. Whereas it is fairly uncomplicated to impose monthly parameter estimates of price equations in annual simulation models, it becomes a more daunting task to impose monthly parameter estimates of quantities, for example trade flows in annual models. The techniques that were used to impose the monthly estimates in the annual simulation model are discussed further in chapter 4.

Although the South African Customs Excise reports maize trade statistics on a monthly basis since 1988, the split between white and yellow maize was only recorded and published on a monthly basis by South African Grain Information Service (SAGIS) since May 2000. Hence, the database for the determination of price formation and trade consists of 60 observations (May 2000-April 2005). This database also includes the various price ranges that are required for the estimations. The average monthly nearby spot price traded on the South African Futures Exchange

(SAFEX) represents the domestic market price. This price is only traded at one specific reference point, called Randfontein. Randfontein is located close to the main grain consumption hub in the country, namely Gauteng. The calculation of the import and export parity prices is illustrated in the section below. All data for the construction of the crop balance sheets are provided by the National Department of Agriculture (DoA) and the South Africa Grain Information Service (SAGIS). Macroeconomic data are provided by the South African Reserve Bank and population data are obtained from Statistics South Africa. The complete datasets are presented in Appendix 1.

2.3.2 IDENTIFYING THE ALTERNATIVE MARKET REGIMES

The objective of this section is to identify the various trade regimes; in other words, the equilibrium pricing conditions under which the maize and wheat markets traded during the period May 2000 – April 2005. The identification of the various trade regimes is based on the trade flow as well as the level of the domestic equilibrium price. In a perfect market, the equilibrium price in the domestic market can be determined anywhere between the import and export parity prices, depending on the specific trade regime (Barrett, 1999). As mentioned in the previous section, the average monthly nearby spot price traded on SAFEX represents the domestic market price. All transaction costs, for example freight rate, insurance and discharging costs, are taken into consideration in order to calculate the import and export parity prices.

It is important to note that various reference points are used to calculate the parity prices of the various grains. Table 2.1 and 2.2 illustrate the calculation of the import and export parity prices for an arbitrary month in the period of estimation. The reference points depend on the main locations where trade takes place and whether the country is a net importer or net exporter. For all three grains the main export destinations are located in neighbouring African countries, for example Harare in Zimbabwe, Maputo in Malawi and Windhoek in Namibia. Grain traders are of the opinion that on average the transportation costs of grain from Randfontein to the main African destinations compare favourably with the transportation costs of grain from Randfontein to Durban harbour. Therefore, these transportation costs are included in the calculation of the African export parity price. For example, in February 2005 the

African export parity price for yellow maize for a grain trader located in Randfontein was R411.82/ton (table 2.1). Table 2.1 also presents the calculation of the export parity price for what industry specialists refer to as deep sea exports. These are the exports of grains to non-African destinations, for example the Middle East. Clearly, the deep sea export parity price is lower than the African export parity price since loading costs are also included.

Table 2.1: Export parity price for yellow maize, February 2005

	Feb-05
US No 3 Y. Maize fob Gulf value ($/t)	91.57
SA yellow maize premium in market	4.58
SA FOB price ($/ton)	96.15
Exchange rate (1$=)	611.14
SA FOB price (R/ton)	587.60
Financing costs (R/t) (Prime rate)	7.78
Transport: Randf.- Africa	168.00
Africa Export Parity – Randfontein	**411.82**
Transport: Randf.-Durban harbour	168.00
Loading costs: Durban (R/t)	90.81
Sea Export Parity – Randfontein	**321.01**

Source: SAGIS

Two locations were used for the import parity calculations, namely Durban harbour in the case of yellow maize and Randfontein in the case of white maize and wheat. The reason for using Durban harbour for the calculation of the yellow maize import parity price is because large feed mills are located close to the harbour and it is often cheaper to import yellow maize than to transport it from inland production areas to the feed mills on the coast. This is also partly the reason why the domestic yellow maize price tends to trade closer to import parity than export parity (figure 2.2). There are also large feed mills in the Western Cape close to the Cape Town harbour, but statistics show that the Durban harbour free on rail (F.O.R) price is a good proxy for the F.O.R price in Cape Town harbour. Table 2.2 presents the calculation of the import parity price for yellow maize for February 2005.

Table 2.2: Import parity price for yellow maize, February 2005

	Feb-05
US No 3 Yellow Maize fob Gulf value ($/t)	91.57
Freight rate ($/t)	49.00
Insurance (0.3%)	0.27
Cost, Insurance and Freight (CIF)	**140.84**
Exchange rate (1$=)	611.14
Converted to R/t	860.76
Financing costs (R/t) (Prime rate)	7.78
Discharging costs: Durban (R/t)	90.81
Import Tariff (R/t)	84.24
F.O.R at Durban harbour (R/t)	**1043.59**
Transport: Durban harbour-Randf.	168.00
Import Parity Randfontein	1211.59

Source: SAGIS

Ranfontein is used as reference point for the calculation of the import parity price for white maize and wheat. As will be discussed below, white maize is predominantly exported and SA very rarely imports white maize. It can be argued that white maize is only imported when there is a really big shortfall in the human consumption regions, of which Randfontein falls right next to the largest human consumption hub in South Africa. In the case of wheat, South Africa is a net importer and imported wheat has to be transported to Randfontein, which is also the largest consumption hub for wheat. Over the past three years domestic wheat farmers have only supplied 64 percent of the local wheat consumed.

In figure 2.1, 2.2 and 2.3 the price space is plotted against trade flow for white maize, yellow maize and wheat respectively. It is important to note that whereas in the case of white maize the price space is plotted against the level of net exports, the yellow maize and wheat price space is plotted against the level of net imports. The various market equilibriums under which each of the grains has traded over the past five production seasons, are clearly marked in the figures. For example in figure 2.1, region 1 shows that the white maize market traded at export parity levels with a high level of net exports and the domestic equilibrium price at African export parity levels. The high level of exports was induced by a bumper crop in the 2000 production season. The white maize market also traded under similar equilibrium pricing conditions in region 4 and 6. Based on the theoretical principles laid down in the previous section, the correlation between the export parity price and the domestic market price should be significantly positive and if the law of one price holds strictly, it should be one. In the case of yellow maize (figure 2.2), only region 1 represents a short period of time where the local market traded under an export parity regime.

For a number of periods, equilibrium in the domestic maize markets was established between import and export parity levels (white maize – region 3, yellow maize – regions 2,4 and 6) and therefore market equilibrium was established under an autarkic market regime. Strictly speaking, under autarky domestic prices are mainly determined by domestic supply and demand and no trade takes place as domestic prices trade at levels where no arbitrage for trade is triggered. Therefore, the domestic price is not influenced by the world price and the exchange rate. However, in the South African white and yellow maize markets some level of trade did occur with neighbouring countries at price levels (figure 2.1 and 2.2), which suggests that the market was trading under a type of regional autarky isolated from world markets.

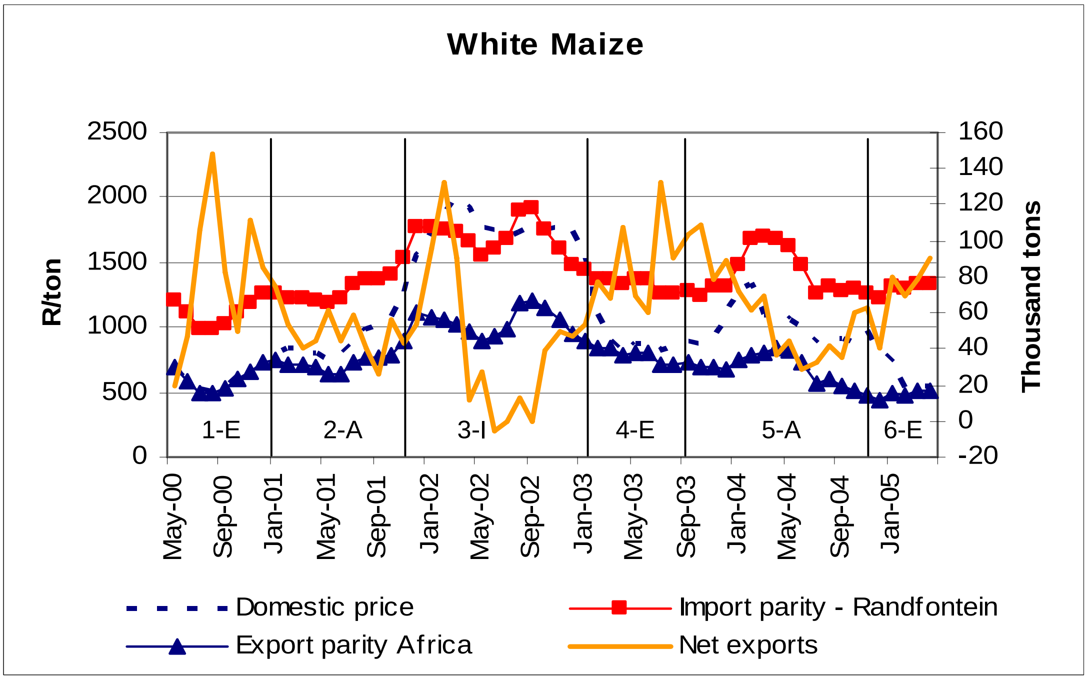

Figure 2.1: Price and trade space for white maize, May 2000 – May 2005

Industry experts argue that trade in the Southern African region is largely driven by regional issues like staple food, adverse weather conditions, location and quality concerns of genetically modified imported maize from non-African destinations, and to a lesser extent by arbitrage opportunities. Since trade flow and equilibrium pricing conditions do not occur strictly according to the definition of autarky, this study refers to the market regime where the domestic market price trades between import and export parity, with some trade flow occurring as *"near-autarky"*. At this point it is worth mentioning that in one of his findings Barrett (1999) noted that there is "mixed evidence regarding the hypothesis that structural change in equilibrium pricing conditions, from tradability to non-tradability or vice versa, engenders discontinuity in the correlation between domestic and world market prices". He argues that present data and estimation methods are indeterminate as to whether tradability really brings with it closer correspondence to international market price signals.

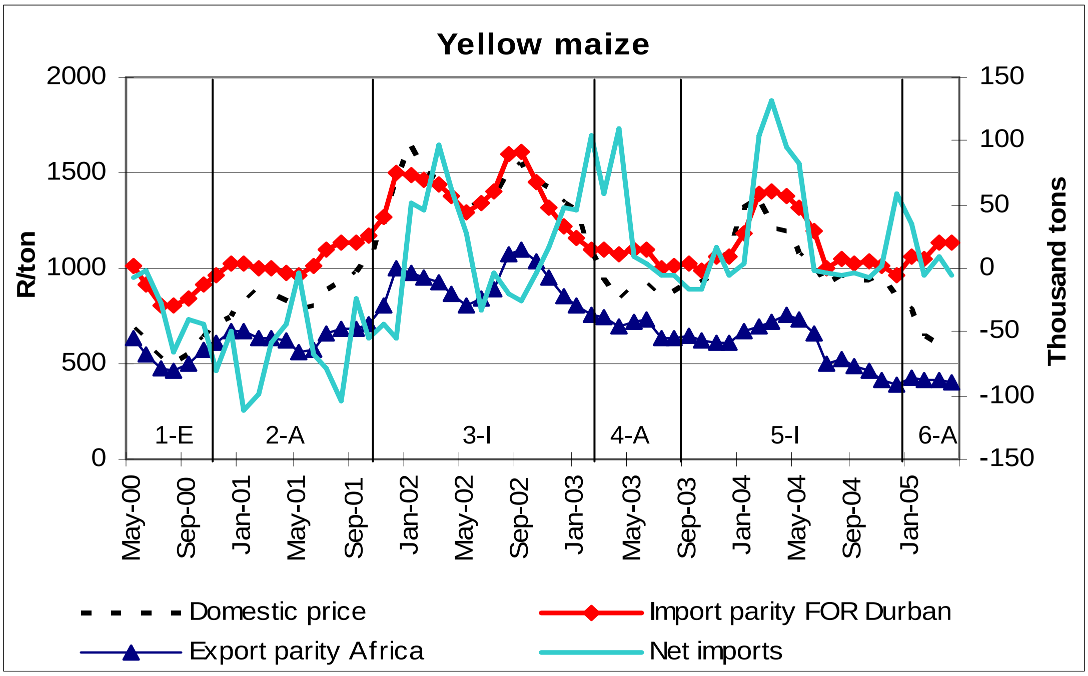

Figure 2.2: Price and trade space for yellow maize, May 2000 – May 2005

From the perspective of trade regimes, the wheat industry is far less complicated than the maize industry, with domestic wheat prices trading at import parity levels for the past five seasons. With the deregulation of the wheat market in 1997, a structural shift took place in the wheat area planted and the area decreased to a level where South Africa has never been able to produce a surplus of wheat again. As a matter of fact, South Africa has on average been importing approximately one-third of its domestic consumption since the structural shift occurred. Figure 2.3 clearly illustrates a structural shift that took place in the relationship between the domestic price and the import parity price after the sharp decrease of the rand in 2002. Whereas wheat traded slightly under the Randfontein import parity price before the sharp depreciation of the rand, the domestic wheat price is now trading right on top of the Randfontein import parity price. Large volumes of wheat are transported inland and one can argue that the reference point for the import parity price should be Randfontein.

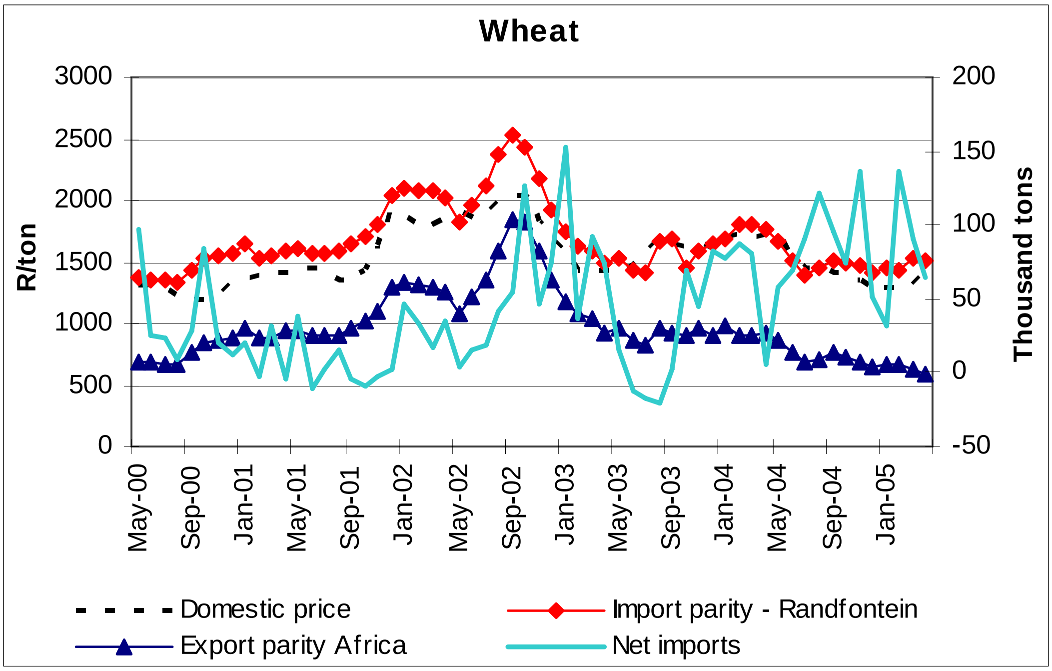

Figure 2.3: Price and trade space for wheat, May 2000 – May 2005

To summarise, whereas the white maize market has traded under all three market regimes, the yellow maize market has traded under import parity and autarky and the wheat market has only traded under import parity. Equilibrium pricing conditions change as markets switch between different regimes. A shift in equilibrium pricing conditions should induce a structural shift in the correlation between parity prices and local market prices. The choice of model closure will depend on the equilibrium pricing condition in a specific market. Chapter 4 will show how the regime-switching model has the ability to switch between three distinct techniques of model closure in order to represent the correct equilibrium pricing conditions in the case of white maize, two different closures in the case of yellow maize. No switch occurs in the case of wheat since the wheat market only trades under import parity.

2.4 SUMMARY

This chapter has provided an overview of literature relating to price formation, price transmission, regime switching and model closure techniques. This was followed by a discussion on the application of these techniques within a partial equilibrium framework. The uniqueness of the modelling approach that is developed in this study was established and the various market regimes for each of the commodities identified. It is important to note that for the remaining chapters of this study a distinction is made between the textbook definition of autarky and the definition of near-autarky formulated in this chapter. From a modelling perspective, the fact that pure autarky does not hold in the Southern African context poses immediate challenges. The fact that trade still occurs, even though prices are not trading at parity levels, implies that there might be some level of integration between domestic and world markets under near-autarky. This has a direct impact on the model closure technique because under the traditional approach, the equilibrium price was obtained by equating local demand and supply and the world price did not have any effect on the local price. It is important to note that the uniqueness of this study does not lie in the development of a new methodology for the treatment of market integration or the law of one price, but in the development of alternative model closure techniques and the application of a regime-switching methodology that captures the salient features of the market in the modelling of a simultaneous closed system of equations.

CHAPTER 3

THE THEORETICAL FOUNDATION OF PARTIAL EQUILIBRIUM MODELLING

3.1 INTRODUCTION

This chapter introduces the theoretical foundation for the structure and closure of an econometric regime-switching model within a partial equilibrium framework. The first section presents the domestic supply and demand components of a partial equilibrium model as they appear in the pre-existing BFAP sector model. The uniqueness of this study lies in the application of the regime-switching methodology in the modelling of a recursive closed system of equations. This regime-switching methodology was not applied in the previous version of the sector model. From a modeling perspective the technique that is used to "close" a simultaneous or recursive simulation model determines the manner in which market equilibrium is achieved in the model. Many different model closure techniques exist. The choice of closure technique will depend on the equilibrium pricing condition in a specific market, specifically on which market regime prevails in the market.

The concepts of model closure and price formation under various market regimes are introduced in the second section of this chapter in the form of a P-Q space and a flow diagram. This graphic depiction is complemented by a discussion of the underlying theory of the redesigned trade and price linkage components for the white and yellow maize and wheat industries. Together with the existing domestic demand and supply components, the trade and price linkage components complete the partial equilibrium framework. Finally, the modelling procedures, the estimation process and the validation of the models are discussed.

3.2 THE DOMESTIC DEMAND AND SUPPLY COMPONENTS OF THE EXISTING PARTIAL EQUILIBRIUM MODEL

3.2.1 DOMESTIC SUPPLY

Total domestic supply consists of production plus beginning stocks/inventory. Production is calculated as the total area harvested multiplied by the average yield.

3.2.1.1 PRODUCER SUPPLY

According to neo-classic theory, the producer is assumed to be a maximiser of profit or net returns, subject to some technical and institutional constraints. In this regard, economic theory suggests that the supply of products to the next highest level of the market channel depends on the expected profits accruing to the decision maker. Varian (1984) referred to the firm's production plan as the firm's technical constraints, which define the physical relationship between factor inputs and the maximum output level for the given technology, per unit of time. To illustrate this physical relationship between output and factor inputs, consider a farm that uses land -L, labour -W, and other inputs (fertiliser and capital) -K, in the production of the specific commodity.

Equation 3.1:

$$Q = F(L, W, K)$$

If the input- and output prices are taken into account, let p denote the expected output price, l the rental cost for land L, w the cost of labour W, and k the cost of other inputs K. Assume that output and the output prices are independently distributed random variables and that the farmer is risk neutral. The objective of the farmer is to maximise profit, which is the difference between total revenue from the sale of outputs and the expenditure on all factor inputs. The farmer's profit function is algebraically defined as follows:

Equation 3.2:

$$Max \prod = p\,Q - C(L, W, K)$$

thus

$$\prod (p, l, w, k, TFC) = Max \prod_{L,W,K} \left[pF(L, W, K) - lL - wW - kK - TFC \right]$$

The expected revenue is represented by pF(L,W,K), *l*L denotes the costs of land rental, *w*W represents the costs of labour, *k*K refers to the costs of capital and other inputs, and *TFC* is the total fixed costs. The profit maximisation or cost minimisation approach can now be used to derive the output supply response from the profit function by means of the first order conditions.

Dynamic relationships are particularly important in the modelling of supply and demand in the agricultural sector. Biological delays and cycles are inherent in the agricultural production process. In some cases producers base their decisions on expectations. Time may be introduced explicitly in supply functions in several ways. The two most common approaches are the partial adjustment approach and the adaptive expectations approach. These are two distinct approaches for the specification of dynamic output supply response.

The partial adjustment methodology is based on the assumption that movements from the current level of supply and demand to new equilibrium levels consequent to changes in economic or technical conditions may not be instantaneous. The partial adjustment model is commonly used to model the gradual adjustment of agricultural producers to changes within the total production environment (Sadoulet and de Janvry, 1995). The partial adjustment model is based on the principle that the change in a variable, for example supply (S) from one period to the next, can be expressed as some portion of the difference between the current level of supply and the desired level of supply. In other words, in each period actual output is adjusted in proportion to the difference between the output desired in the long-run equilibrium and the actual output. This can be illustrated as follows:

Equation 3.3:

$$S_t - S_{t-1} = \delta\,(S_t^* - S_{t-1}) + u_t$$

or

$$S_t = (1-\delta)\,S_{t-1} + \delta\,S_t^* + u_t$$

S_t^* denotes the desired long-run equilibrium level of output, S_t represents the current level of output, and S_{t-1} signifies the level of output from the previous year. δ is an adjustment factor with a numerical value of between 0 and 1. If δ =1, then a complete adjustment in the level of output has taken place from the previous period to the current period. However, if δ =0, then no adjustment has taken place and $S_t^* = S_{t-1}$.

However, the problem with equation 3.3 is that it cannot be estimated since the long-run equilibrium output level, S_t^*, is unobservable. This level of output needs to be estimated as a function of some observed variable. For simplicity, assume the following relationship:

Equation 3.4: $$S_t^* = \alpha + \beta P_t^e$$

Equation 3.4 can now be substituted back into equation 3.3 and the result can be presented as follows:

Equation 3.5: $$S_t = \alpha\delta + (1-\delta)\, S_{t-1} + \delta\beta\, P_{t-1} + u_t$$

The adjustment coefficient (δ) can now be used to calculate a short- and long-term price effect. The short-term price effect is the estimated coefficient of the price variable ($\delta\beta$) and the long-term price effect (β) is obtained by dividing the short-term price effect by the adjustment coefficient. From these price effects, short- and long-term price elasticities can be calculated.

Adaptive expectation models are based on the assumption that agricultural producers base their decisions on certain expectations regarding the future values of relevant prices. Hence, cropping decisions are based on the expected prices at the time of harvest.

Equation 3.6: $$S_t = \alpha + \beta P_t^e + u_t$$

S_t denotes the current level of output and P_t^e represents the expected price prevailing at time t. In the adaptive expectation model prices of the previous period prevail and expectations are revised each period, with the revision proportional to the error in the previous expectations. This revision can be presented as follows:

Equation 3.7: $$P_t^e - P_{t-1}^e = \gamma\,(P_{t-1} - P_{t-1}^e)$$

or

$$P_t^e = \gamma\, P_{t-1} + (1-\lambda)\, P_{t-1}^e$$

Equation 3.7 illustrates the revision for period t. γ is called the coefficient of expectation. If γ=0, then the actual prices will have no effect on the expected prices, and if γ=1, then expected prices will be equal to the last period's actual prices. This implies that the actual prices of the previous period have prevailed perfectly. The expected price at time t can now be expressed as a function of previous actual prices over a longer period of time.

Equation 3.8: $$P_t^e = \gamma\, P_{t-1} + (1-\lambda)\, P_{t-2} + \gamma(1-\lambda)^2\, P_{t-3} + \gamma(1-\lambda)^3\, P_{t-4} ....$$

Equation 3.8 shows that producers base their price expectations solely on an extrapolation of past prices.

In the Nerlovian supply model the partial adjustment model and the adaptive expectation model are combined. The Koyck transformation is used to obtain the final form of the equation. In its simplest form, the model assumes that there is a desired level of supply (S_t^*), which depends on an expected price level (P_t^e). Algebraically, it can be presented as follows:

Equation 3.9: $$S_t^* = \alpha + \beta P_t^e$$

Furthermore, it is also assumed that actual supply, S, adjusts towards the desired level according to the partial adjustment model (equation 3.5) and the adaptive expectations model (equation 3.8) is used to determine the expectations regarding the prices.

Equation 3.10: $$S_t = (1-\partial)\, S_{t-1} + \partial\, S_t^* + u_t$$

Equation 3.11: $$P_t^e = \gamma\, P_{t-1} + (1-\lambda)\, P_{t-1}^e$$

The first step is to substitute S_t^* into S_t. This will yield the following equation:

Equation 3.12: $$S_t = \alpha\delta + (1-\delta)\, S_{t-1} + \delta\beta\, P_{t-1}^e + u_t$$

The second step is to substitute equation 3.11 into equation 3.12. This substitution is presented in equation 3.13:

Equation 3.13: $$S_t = \alpha\delta + (1-\delta)S_{t-1} + \delta\beta\left[P_{t-1} + (1-\gamma)P_{t-2} + ...\right] + u_t$$

One can argue that both the partial adjustment model and the adaptive expectation model can be applied in the South African grain market. However, careful analysis and discussions with industry experts suggest that the adaptive expectation approach might be more relevant under the current free market conditions and that the partial adjustment approach was the correct approach to use under the regulated market environment. The reason for this is simply because farmers make increasing use of the future market and base their production decisions on expected prices. Equation 3.8 shows that producers base their price expectations solely on an extrapolation of past prices.

In the existing sector model total producer supply is derived from area harvested multiplied by yield. The producer has to make the initial decision on the size of the area to be planted. Due to the unavailability of data on area planted, it has been common practice to begin crop modelling with area harvested, since area harvested is normally a good proxy for the area planted. Using the area harvested in the determination of potential supply does, however, also have some problems, as the total area planted is not always harvested. In South Africa, there has traditionally been little difference between the area planted and the area harvested and the differences that do occur appear randomly.

A feature of the existing model is that all the supply equations are driven by expected gross return-type variables. For each commodity the real expected gross return is calculated as the trend yield per hectare multiplied by the expected price and deflated by the consumer price index for food products. The total grain area harvested ($TGAH_t$) is estimated as a function of the weighted sum of the all the crops' expected real gross returns ($EGRT_{All}$), rainfall (R_t) and the price of inputs ($P_{I,t}$). Gross returns are weighted according to each crop's share of the total area harvested. The total acreage response function can be presented as follows:

Equation 3.14: $$TGAH_t = f(EGRT_{All}, R_t, P_{I\,t})$$

The area harvested for each crop is expressed as a share ($AHSH_t$) of the total area harvested and estimated as a function of the expected real gross returns of the own crop divided by the sum of expected real gross returns for the rest of the crops. A typical grain acreage share response function, specified according to the Nerlovian approach, can be postulated as:

Equation 3.15: $$AHSH_t = f\left(\frac{EGRT_t}{SUM(EGRT_t)}\right)$$

Equation 3.16 shows how the acreage share for each commodity is multiplied by the total area harvested to calculate the area harvested for each crop.

Equation 3.16: $$GAH_t = AHSH_t * TGAH_t$$

This methodology is applied to six crops in the existing model, namely white maize, yellow maize, wheat, sorghum, sunflower and soybeans. This approach has major advantages for estimating the substitution effect between various crops and the usefulness of this approach is illustrated in chapter 5 with the calculation of a supply elasticity matrix for all the crops.

After the producer has decided to plant, the yield, which is also influenced by weather conditions, will determine the total production of the crop. Equation 3.17 relates yield to rainfall and a trend variable. It is argued that in many cases farmers increase inputs, for instance fertiliser, as the output prices increase. However, empirical evidence suggests that in the case of South Africa yields are not a function of the expected output prices. Different regions produce maize and wheat, and maize is a summer crop and wheat is a winter crop. Therefore, the rainfall variables used in the model reflect the regions and specific months that influence the area planted and production of each crop. Typically, rainfall from October to December influences the decision on the maize area and rainfall from December to March influences maize production. For wheat these two periods are April – July and July – October, respectively. The inclusion of a trend variable can be motivated by the rapid improvement in technology that has occurred over the past decade.

Equation 3.17: $YIELD = f(RAIN, TREND)$

Finally, producer supply (domestic production) can be expressed as follows:

Equation 3.18: $PROD = GAH_t * YIELD_t$

3.2.1.2 BEGINNING STOCKS

In this study, ending stocks are modelled as a behavioural equation and, therefore, beginning stocks equal lagged ending stocks. Ending stocks are discussed in section 3.2.2.3.

3.2.2 DOMESTIC DEMAND

The "law of demand" states that the higher the price, the less of a given good will be purchased (Ferris, 1998). This implies that the demand curve is downward sloping. For the ultimate buyer of food, demand could relate retail prices to amounts that will actually be consumed within a given time frame. However, the final consumer is not the only actor on the demand side. We can distinguish between two main categories of domestic demand, namely demand for direct use and inventory demand. The demand for direct use consists of primary as well as derived demand. Primary demand is the demand at a retail level where the individual consumer can make decisions based on price and preference. Derived demand can also be referred to as intermediate demand, for example the demand of wheat for baking bread or the demand for grain as a livestock feed. Inventory demand strongly reflects expectations and consists of the demand for storage and the demand for speculation. Expectations are determined by expected utilisation, product availability, market prices and factors such as agricultural policies.

In the demand block, human consumption, feed and seed consumption, exports, and ending stocks determine the total demand for South African maize and wheat. White maize and wheat are mainly utilised in the human consumption market, while yellow maize is mainly consumed in the feed market. The data that report on seed use are unreliable. As a result, two categories, viz. human and feed consumption, are estimated by means of behavioural equations. Seed use is included as an exogenous variable in the calculation of total demand.

3.2.2.1 CONSUMER DEMAND

To enable the derivation of the consumer demand function we have to assume that the consumer has a rational, continuous, and locally non-satiated preference relation, and we take $U(x)$ to be a continuous utility function representing these preferences (Mas-Colell, Whinston, and Green, 1995). Suppose the consumer is faced with the problem of choosing a bundle of goods in order to maximise his or her utility subject to given prices and the level of income. Hence, the consumer will purchase a combination of goods, which will provide him with the highest level of satisfaction. This is also referred to as "the rational behaviour hypothesis". The utility maximisation problem can be presented mathematically as follows:

Equation 3.19:

$$MAX\ U(x_1, x_2, ...x_n)$$
$$subject\ to$$
$$m = \sum_{i=1}^{n} p_i x_i$$

$U(x_1, x_2, ...x_n)$ is the consumer's utility function. $m = \sum_{i=1}^{n} p_i x_i$ represents the budget constraint and consists of m, the consumer's total available budget and p_i, the unit price of commodity x_i. The utility function is a strictly quasi-concave and twice differentiable (Mas-Colell *et al*, 1995). This problem is solved through the use of the Lagrange Multiplier. This method starts by defining an auxiliary function known as the Lagrangian.

Equation 3.20:

$$L = U(x_1, x_2, ..., x_n) - \lambda(\Sigma\, p_i x_i - m)$$

The new variable, λ, is called the Lagrange Multiplier since it is multiplied by the budget constraint. According to the Lagrange theorem an optimal choice or utility maximisation must satisfy the First Order Condition (FOC), which involves the partial derivation of equation 3.20 with respect to x_i and λ.

Equation 3.21:

$$\frac{\partial L}{\partial x_i} = \frac{\partial U(x_i)}{\partial x_i} - \lambda p_i = 0 \quad \text{with } i = 1,2,.....n.$$

Equation 3.22: $$\frac{\partial L}{\partial \lambda} = (\Sigma\, p_i x_i - m) = 0$$

The FOC simply sets the derivatives of the Lagrangian with respect to x_i and λ each equal to zero. Hence, equation 3.21 is merely the budget constraint that is set equal to zero. Solving the (n+1) FOC equations we can show that λ is equal to marginal utility divided by price for all commodities, which indicates the increased rate of satisfaction derived from spending an additional rand on a particular commodity. The Lagrange Multiplier can thus be interpreted as the marginal utility of income.

The simultaneous solution of equation 3.21 and equation 3.22 yields the demand function of x_i, which is an implicit function of own prices, the prices of complementary or substitute goods, and consumer income. The demand function of x_i can be presented as follows:

Equation 3.23: $$x_i = x_i\,(p_1, p_2, ..., p_i, m), \quad i = 1,2..., n$$

This demand function represents the demand for x_i of every individual consumer and is homogeneous of degree zero in prices and income. The aggregated retail demand for x_i is calculated by multiplying the individual demand for x_i by the number of consumers in the market. In this study total human consumption is divided by the total population to obtain the *per capita* consumption of maize and wheat. *Per capita* consumption is estimated as follows:

Equation 3.24: $$PCC_t = f\,(P_{G,t}, P_{s,t}, INC_t, G)$$

PCC_t denotes the *per capita* consumption in period *t*, $P_{D\ t}$ denotes the domestic price of the grain, $P_{s\ t}$ denotes the price of a range of commodities that can be used as substitute or as complementary products in the human market, *INC* denotes the level of disposable income *per capita*, and *G* denotes government policies. The existing model structure consists of human consumption equations for white maize, yellow maize, wheat and sorghum. It is important to note that for food demand, symmetry does not hold for Marshallian equations (like the ones estimated in the model), but rather for Hicksian responses representing pure substitution effects holding utility constant.

3.2.2.2 FEED DEMAND

The demand for grain in the feed sector is derived from the profit maximisation condition of the livestock sector. Yellow maize is the dominant feed grain in South Africa by far. White maize and wheat can be regarded as a substitute product for yellow maize. For the sake of simplicity, assume that the quantity of livestock production is a function of the quantity of white maize, yellow maize and wheat. The livestock production function can thus be represented as follows:

Equation 3.25: $$Q_L = f(Q_{WM}, Q_{YM}, Q_{WH})$$

where Q_L denotes the production of livestock products and Q_{WM}, Q_{YM} and Q_{WH} represent the quantities of white maize, yellow maize and wheat utilised as feed in the feed market.

For example, the derived demand of yellow maize in the feed market can now be determined in a similar fashion as the derived demand for x_i in equation 3.21. By setting the FOC equal to zero and solving the system of equations simultaneously, the following derived demand function for yellow maize can be determined.

Equation 3.26: $$Q_{Feed} = g_1(P_L, P_G, P_S)$$

Therefore, the derived demand for white maize, yellow maize and wheat in the feed sector is a function of the price of the livestock product (P_L), the own price (P_G), and the price of the substitute commodities (P_S).

In the existing model structure the feed demand equations are taken one step further by linking the feed grain demand to the level of livestock production by means of a weighted total feed demand. The weighted total feed demand is derived from the level of livestock production and the inclusion rate of grains in the various feed rations and is expressed in tons. Feed grain consumption is, therefore, estimated as a function of the weighted total feed demand (*TFD*), the own price of grain (P_G), and the price of the substitute feed grains (P_S).

Equation 3.27: $$Q_{Feed} = f(TFD, P_G, P_S)$$

3.2.2.3 ENDING STOCKS/ INVENTORY

Due to the biological nature of agricultural production, many agricultural products are supplied to the market only at one specific period during a year, whereas consumption occurs throughout the whole year. Since inventories provide a constant supply of products throughout the year, they are an important component in the commodity models and play a decisive role in determining the prices of mainly agricultural goods where production and consumption are relatively inelastic. Bressler and King (1970) identified three motives for holding stock: transaction demand, precautionary demand and speculative demand.

Transaction and precautionary demand are related to domestic demand and supply. Transaction demand specifies that the level of stock is a fraction of the current production. A higher (lower) level of production implies that inventories should rise (decrease). The precautionary demand can also be referred to as the “buffer stock”. In the case of maize and wheat when the marketing boards were still functioning, they retained a buffer stock to deal with uncertainties in the local food balance sheet, which could potentially occur due to unknown and unexpected demand and supply shocks. This buffer stock, also referred to as the “Joseph Rule”, was sufficient to satisfy the demand for each commodity over a period of three months. Even in the absence of government policies in the deregulated market, the market will usually hold at least some grain for transaction and precautionary reasons. Whereas transaction demand is specified as a fraction of varying production, precautionary demand is usually treated as a constant. Simplistically, the first two reasons for holding stock can be presented as follows:

Equation 3.28: $$S_t = \omega_1 + \omega_2 Q_t$$

Q_t is the total production in period t, ω_2 represents the marginal fraction of production stored and ω_1 denotes a constant level of precautionary stocks.

The final reason for holding stock is speculative. It is assumed that stock operators are rational decision-makers. Due to market uncertainty, storage operators hold stock and position[1] themselves in the market so that they are able to benefit from future market conditions. Speculative demand for stocks is thus based on expected prices in the next period t+1. Hence, expected prices also need to be included in the specification of stock behaviour. In summary, speculative commodity stock holdings can be specified as follows:

Equation 3.29: $$S_t = f(S_{t-1}, Q_t, P_{t+1})$$

In equation 3.29 stock holdings are expressed as a function of beginning stock[2], the expected price in the next period and current production. In the current sector model ending stocks are estimated as follows:

Equation 3.30: $$ENDS_t = f(ENDS_{t-1}, PROD_t, P_{D,t})$$

Ending stocks in period t depend on the beginning stocks in period t, local production and the market price. Ending stocks in period t are equal to the beginning stocks for period t+1. In the flow diagram (figure 3.1 and 3.2), a dotted line is used to denote the lagged effect between ending stocks in period t and beginning stocks in period t+1.

Since the deregulation of the markets, speculative stock holding has become a major factor in the South African grain market. The level of uncertainty surrounding speculative stocks has increased with the increasing popularity of on-farm storage facilities. In many cases farmers base their expectancy of higher prices on the seasonal nature of agricultural production. Many agricultural products trace out fairly definable and consistent seasonal patterns. This is primarily due to the seasonal nature of agricultural production, but may also relate to seasonal demand factors. In the case of grains, it is generally expected that prices are at their lowest level at harvest time and increase as time passes. Hence, farmers and storage operators tend to carry stocks at harvest time and sell the grain at a later stage. Opportunity costs also play a major part in stock holding behaviour. Once opportunity costs are perceived as being too high, stock holders will consider selling their grain, even if prices have not increased.

---

[1] Storage operators hedge their positions in the market by making use of future markets

[2] Beginning stock is equal to the ending stock of the previous year

3.3 MODEL CLOSURE AND PRICE FORMATION UNDER SWITCHING MARKET REGIMES

The previous section presented the theoretical foundation of domestic supply and demand components of the previous sector model. However, a partial equilibrium model also consists of trade and price components. These are the components that have to be redesigned for the new regime-switching model. Price and trade are instrumental for a model to reach equilibrium. In an equilibrium framework, total demand has to equal total supply. The technique that is used to "close" a recursive simulation model determines the manner in which market equilibrium is achieved in the model. Many different model closure techniques exist. The choice of technique will depend on the equilibrium pricing condition in a specific market, specifically on which market regime prevails in the market. This section makes use of flow and price-quantity (P-Q) diagrams to provide easy guidance towards the understanding of important economic and biological relationships. These diagrams also distinguish between the model closures under different market regimes. This discussion leads to the theoretical foundation of the trade and price components of an equilibrium model.

3.3.1 THE FLOW DIAGRAM AND THE PRICE QUANTITY (P-Q) DIAGRAM

Flow diagrams portray the elements of the supply, demand, trade, and price linkage blocks and the relationship between them. The supply block consists of the function determining total area harvested, yield, production and beginning stocks/inventory. The demand block consists of human, feed and seed consumption, and ending stock.

Figure 3.1 and 3.2 show the flow of a typical grain, like maize or wheat, through the market channel from the producer to the ultimate consumer of the product. While the model cannot replicate all the decisions occurring within the industry, the major behavioural relationships are captured. The dashed lines represent lagged relationships between variables. As explained in the first section of this chapter, the farmers' decision to plant is influenced by the lagged price of the product, the weather, and the lagged price of substitute products and inputs. Yield is also influenced by the weather. Beginning stocks equal the ending stocks of the previous season. The current price influences domestic consumption and ending stocks.

Figure 3.1 illustrates model closure and, therefore, the equilibrium pricing condition under near-autarky. Strictly speaking, under the definition of autarky no trade takes place as domestic prices trade at levels where no arbitrage for trade is triggered. However, as previously explained, in the South African white and yellow maize market some level of trade does occur with neighbouring countries at price levels which suggest that the market is trading under a type of regional autarky (in this study referred to as "near-autarky") isolated from world markets. Since significant trade occurs under near-autarky, experts argue that although domestic prices are mainly determined by domestic demand and supply, trade does have an impact on the domestic equilibrium price. Because net trade is modelled as a function of the world price and the exchange rate, these variables subsequently have an impact on the domestic price. The two-directional arrow between net trade and the domestic price illustrates this point. The block arrows versus the two-directional line arrow make a clear distinction between the impacts of domestic supply and demand, and trade respectively.

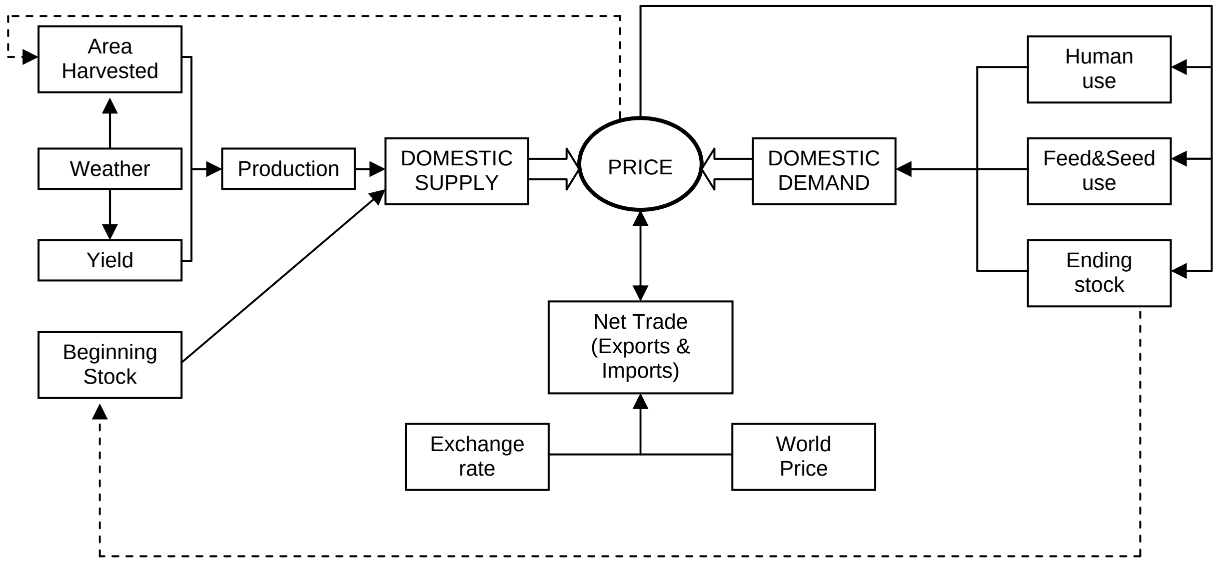

Figure 3.1: Flow diagram of SA grain market in near-autarky

In this type of model the equilibrium price is simulated by setting demand equal to supply in a price equilibrator framework. Price is thus solved endogenously in the domestic market and not as an endogenous variable in a behavioural equation.

Figure 3.2 represents model closure under an import parity or export parity regime. Under the import and export parity regimes, the domestic price is modelled as a function of the import and export parity price respectively and can, therefore, be regarded as predetermined in the system of equations. The exchange rate is factored into these prices. This is also referred to as the price linkage equation. Thus, under this trade regime it can be expected that the correlation between world prices, exchange rate and domestic prices is high and the market should thus be integrated into the world market. If the estimated coefficients of the price linkage equations are equal to one, then the law of one price holds. Net trade (either net exports or net imports) is used to close the model in the form of an identity. Block arrows show how domestic demand and supply determine the level of trade.

The domestic price is also influenced by the level of trade. This is contrary to what particular applications of economic theory suggests for a small, open economy trading in the world market, but industry experts are of the opinion that in the South African market exports to neighbouring countries also have an impact on the domestic price. It is important to note that whereas South Africa can be regarded as a large nation in the Southern African region, it is a small nation with respect to the world. Three possible motivations for trade affecting prices are, firstly, the regional issues as discussed, secondly, the possibility of transaction costs rising as quantities increase, and thirdly, goods may not be perfect substitutes, so a wider price gap is required to encourage the movement of products across borders.

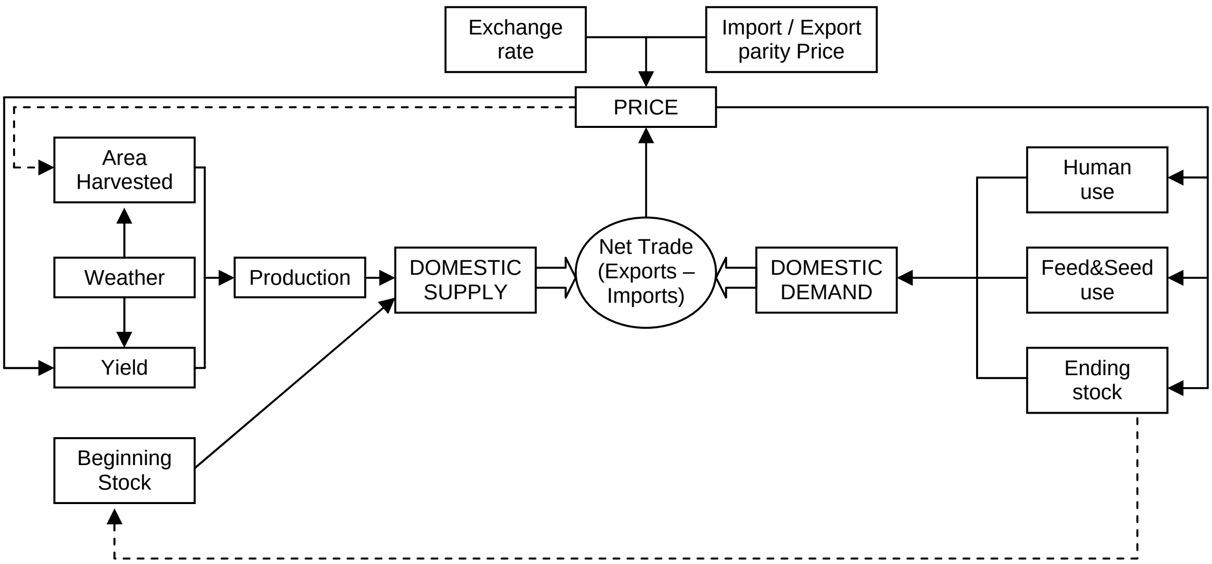

Figure 3.2: Flow diagram of a typical grain market in net export or net import parity

The P-Q diagram (figure 3.3) and the flow diagram are closely related. The P-Q diagram reflects the different layers of the market. The P-Q diagram also consists of the supply and demand blocks. The supply block consists of the functions that determine total area harvested, average yield, production, and beginning stocks. The sum of these components equals domestic supply. The demand block consists of human and feed consumption, ending stocks, and net trade. It is important to note that the P-Q diagram depicts the economic relationships among the dependent and explanatory variables at different layers in the commodity markets, for example the production layer, the consumption layer, and the trade layer. In addition to the relationship between own-price and quantities, the impacts of other variables are depicted by means of arrows (shifters). A rightward shifter is used to explain a positive relationship between the dependent and independent variable, i.e. the expected sign of the parameter associated with the variable in the estimated equation is positive. A negative sign is expected for a leftward shifter.

The P-Q diagram is constructed according to scale and illustrates the price elasticities at the different layers in the market. This implies that the various sections all add up to the equilibrium market condition. The area harvested is perfectly inelastic (vertical line) towards the current price because it is a function of the lagged price. It is expected that there is no relationship between yield and price and therefore yield is vertical (perfectly inelastic) with respect to the current price. It is expected that production of agricultural products is inelastic due to the seasonality and the biological nature of production. Once you have planted, the level of production is mainly determined by the weather. Production and the beginning stocks equal the total domestic supply (oa + ob = oc). Beginning stocks are equal to ending stocks and are thus estimated on the demand side of the model.

Human and feed consumption are both downward sloping. A positive relationship between income, population and human consumption is expected. Feed consumption is positively related to the feed index, which is derived from the size of livestock operations. Ending stocks are downward sloping, which indicates the negative relationship between ending stocks and prices, as discussed in the first section of this chapter.

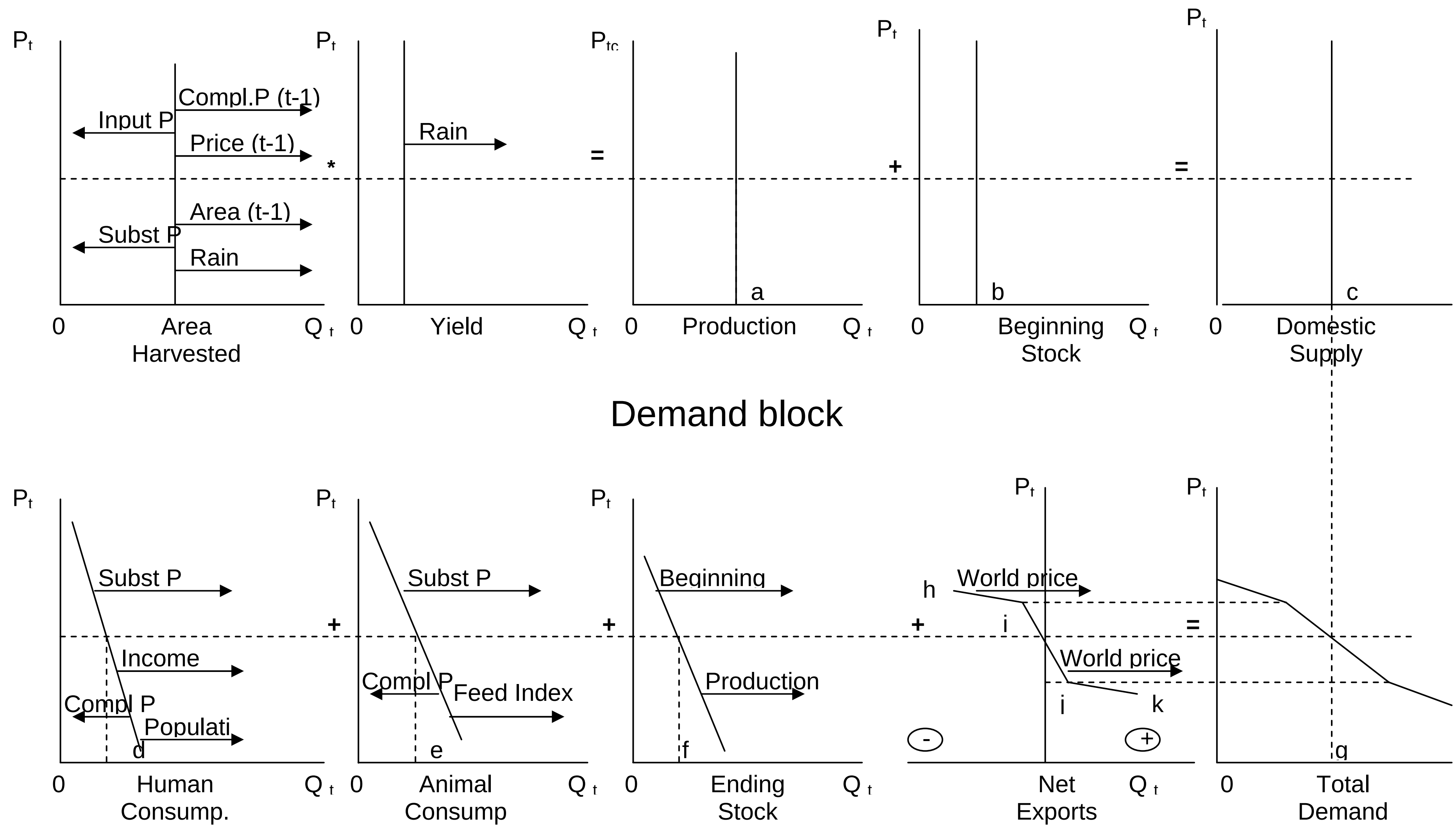

Figure 3.3: P-Q diagram for three different trade regimes.

Taking the objectives of this study into account, the most important graph in the P-Q diagram is the one for net exports. All three regimes are captured in this graph, with hi representing the demand for imports (negative net export demand) under an import parity regime, ij representing some level of negative and positive net trade under near-autarky, and jk representing the demand for exports under an export parity regime.

The essence of this graph lies in the portrayal of the price elasticities under the various market regimes. Under true autarky, ij should be vertical and thus perfectly price inelastic. However, in the South African markets some trade still occurs under near-autarky conditions and consequently the domestic price has an impact on the net trade position. As one moves from near-autarky to import parity or export parity, the elasticity increases sharply to become almost infinitely elastic. From the above discussion it becomes clear that the relationship between world market prices, trade and domestic prices varies in the case of discontinuous trade, consequently changing the model closure technique. To distinguish clearly between the various market regimes, trade and price equations have to be estimated independently for each regime..

In the case of a small nation, it is expected that the demand for imports and supply of exports are infinitely elastic towards the domestic price because the domestic market is integrated with the international market and any change in the net trade position of the small country has no effect on the world price. The elasticity of the net export demand equation depends on the domestic demand and supply elasticities. Lower elasticities will induce larger internal price changes.

A rightward shift is used to illustrate the relationship between net trade and the world price. In the case of net imports (negative net exports), a rightward shift implies a decrease in imports, illustrating the negative relationship between imports and the world price. In the case of exports, the rightward shift implies a positive relationship between the world price and the level of exports. A shift in the world price can almost be seen as a vertical shift since higher world prices increase the export and import parity prices.

Total demand equals the sum of domestic consumption, ending stocks and net trade (od + oe + of = og). In this P-Q diagram, market equilibrium is reached in the range between the import parity and export parity price where no trade occurs. Any increase (decrease) in the domestic price would trigger the demand for imports (exports), which would then have to be deducted from (added to) the total demand.

3.3.2 THE TRADE AND PRICE LINKAGE COMPONENTS UNDER SWITCHING MARKET REGIMES

From the above discussion it becomes clear that the relationship between world market prices, trade and domestic prices varies in the case of discontinuous trade, consequently changing the model closure technique. To distinguish clearly between the various market regimes, trade and price equations have to be estimated independently for each regime. The underlying methodology of these behavioural equations and identities is based on the principles that were explained by the flow diagram and the P-Q space.

3.3.2.1 NEAR-AUTARKY

When the market is in autarky, prices are used to close the model. They are solved endogenously by means of a price equilibrator. The equilibrator is based on the principle that net export demand must equal export supply. Net export demand is estimated as a function of domestic and world prices, and domestic production and consumption. The inclusion of production and consumption into the net export equation could create problems with simultaneity since all that is lacking for this equation to be an identity is the change in ending stocks. However, in some of the South African grain markets (for instance, white maize) this specification can be justified as the key decision is whether to store or export surplus production. It is important to note that one can expect the world price not to matter very much because the main factors causing some limited trade under near-autarky are more regionally demand driven by the factors mentioned above than by price movements in the world and domestic markets.

In equation 3.31 the level of net export demand is defined as a function relating the quantity of net export demand ($NEXD_t$) to the ratio of the domestic price ($P_{D,t}$) over the average of the import ($P_{IP,t}$) and export parity price ($P_{EP,t}$), and the local grain production ($PROD_t$) – consumption ratio ($CONS_t$). The exchange rate, transaction costs and government trade policies are already factored into the import and export parity price calculations[1]. According to the definition of autarky, domestic prices are expected to fluctuate between import and export parity prices and, therefore, the average of these two price levels is applied in this equation.

Equation 3.31: $$NEXD_t = f\left(\frac{P_t}{Avg(P_{IP,t} \,\&\, P_{EP,t})}, \frac{PROD_t}{CONS_t}, e_t\right)$$

Export supply EXS_t is calculated in the form of an identity

Equation 3.32: $$EXS_t = PROD_t - CONS_t - (BEGS_t - ENDS_t)$$

In order to set up the price equilibrator, the difference between $NEXD_t$ and EXS_t, due to market disequilibria, is calculated. The new market clearing price is simulated by linking the old market price to the difference between $NEXD_t$ and EXS_t, and solving the model with the help of a Gauss Seidel algorithm. The new market equilibrium price is reached once the difference between $NEXD_t$ and EXS_t is zero.

Often industry specialists and policy makers prefer distinguishing between exports and net exports. To meet this requirement, imports (IMP_t) are simply modelled as a function of $NEXD_t$, as illustrated in equation 3.33, and imports are then added to $NEXD_t$ to calculate exports (equation 3.34).

Equation 3.33: $$IMP_t = f(NEXD_t, e_t)$$

Equation 3.34: $$EXS_t = NEXD_t + IMP$$

[1] Chapter 2

3.3.2.2 IMPORT AND EXPORT PARITY

Under an import/export parity market regime domestic prices are determined by behavioural price linkage equations. These equations determine the relationship between import and export parity prices (world prices, transaction costs, and the exchange rate taken into consideration) and the domestic prices. Price linkage equations are most appropriate when domestic markets are integrated with world markets with continuous trade flow. Under these conditions, the law of one price suggests that the correlation between the world price and the domestic price equals one but the elasticities are not equal to one.

Equations 3.35 and 3.36 define the price linkage equations for the import and export parity regime respectively, where the domestic price ($P_{D,t}$) is estimated as a function of the import ($P_{IP,t}$) and export parity ($P_{EP,t}$) price and net export demand ($NEXD_t$). Trade is only perfectly elastic at import or export parity if a number of assumptions hold that may not be true in the case of South Africa, like the assumptions that products are homogenous, that South Africa has a true small-country status and the supply of transportation services is infinitely elastic. Therefore, net export demand is included in these equations. Barrett and Li (2002) also argued that trade flow has to be taken into consideration when market integration is analysed. Industry specialists are of the opinion that although parity prices mainly determine the local price when the market is trading at import or export parity levels, trade flow matters, but it is expected that its influence is much smaller than that of the parity price. As previously mentioned in chapter 2, parity prices can also be referred to as "border prices". Border prices are more appropriate for the estimation of market integration than internal prices because they better represent arbitrage opportunities (Goodwin *et al*, 1990).

Equation 3.35: $$P_{D,t} = f(P_{IP,t} NEXD_t)$$

Equation 3.36: $$P_{D,t} = f(P_{EP,t} NEXD_t)$$

The price linkage equation formalises the interaction between the domestic market and the world markets. Under the parity regimes, the model is closed on net trade. In the case of the import parity regime, the model is closed on net imports, and in the case of the export parity regime the model is closed on net exports. The net trade identity can be expressed as

Equation 3.37: $$NT_t = BEGS_t + PROD_t - CONS_t - ENDS_t$$

, where net trade (NT_t) equals beginning stock ($BEGS_t$) plus local grain production ($PROD_t$) less local consumption ($CONS_t$) less ending stocks ($ENDS_t$).

3.4 ESTIMATION PROCEDURES, MODEL SOLVING AND VALIDATION

With a total of 126 equations, the BFAP sector model can be classified as a relatively large-scale, multisector commodity level econometric simulation model and in total, eight crops, five livestock and five dairy commodities are included in the current version of the model. The term "econometric" refers to statistically measured relationships between endogenous and exogenous variables that are included in the simulation framework. According to Ferris (1998), most large econometric multi-market models include statistically estimated relationships as well as equations that are transformation of technical relationships and synthetic equations that are not derived – and so the term "simulation" is added.

At this point it is worth reminding the reader that only the white maize, yellow maize and wheat models of the previous version of the sector model will be redesigned. In short, the redesigned sector model will be made up of the demand and supply components from the previous version of the sector model, redesigned price and trade equations for alternative market regimes, and most importantly, a switching mechanism that allows the model to switch between various model closure techniques that are dictated by the equilibrium pricing conditions. The re-estimation of the system of equations combines econometric methods with simulation techniques. The domestic supply and demand components will not be re-estimated, but for the purpose of completeness of this study, chapter 4 reports the actual equations that are included in the previous version of the sector model. A unique set of price and trade equations will be estimated for each of the market regimes that were identified for the three grain markets for the newly designed regime-switching model. To achieve this, a separate database has to be constructed for each of the possible regimes by distributing all the observations among the three possible trade regimes. Alternative estimation procedures are followed in some cases to find estimates that provide an accurate estimate of reality. Where necessary, synthetic parameters are imposed to ensure reasonable model behaviour. In some equations, indicator variables have been used to "dummy" out the effects of one or more observations that reflect anomalous events or that significantly change the equation elasticities from *a priori* equations. All the improvements and analysis will be undertaken within the already existing partial equilibrium framework.

After the parameters have been estimated or imposed, the next step is to simulate or solve the model. The model is solved in the form of a recursive system of equations. The prevalence of the biological lag in agriculture makes the applications of recursive econometric models most appropriate. The process of simulation can simply be referred to as the mathematical solution of a set of different equations. Whereas traditional approaches to solving a set of linear equations involved inverting large matrices, by the early 1970s large-scale model builders turned to the Gauss-Seidel technique. The Gauss-Seidel algorithm is also used in this study to solve the model's simultaneous system of equations. The procedure is a fairly simple one and involves a step-wise-and-error method to achieve an approximate solution.

Since the evaluation criteria become more complicated with multi-equation simulation models, this study embraces a broad definition of model validation as stated by Pindyck and Rubinfeld (1998): "In practice, it may be necessary to use specifications for some of the equations that are less desirable from a statistical point of view but that improve the ability of the model to simulate well". For the monthly estimations the standard statistical measures like the goodness of fit can be applied, but for the simulation model, alternative techniques have to be applied. These include techniques to determine if the model behaviour is plausible and if it can handle realistic shocks and provide reasonable results. One of the most popular techniques utilised for model validation is to plot the actual and simulated values on a graph and to conduct a visual inspection of how well the model simulates the turning points in the data. The ability of a model to pick up the turning points or rapid changes in the actual data is an important criterion for model evaluation.

Selective *ex-post* simulation tests will be conducted to determine whether the inclusion of the regime switch in the sector model improves the model's ability to track reality and produce the smallest error term for a specific year under switching market regimes. It is expected that the model closure that correlates with the market regime of a specific year, also produces the smallest error term. For the purpose of this study more emphasis will be placed on the economical significance than on the statistical significance of the simulation results. Economic significance refers to the model's ability to simulate real-world issues and salient features of the South African agricultural industry. Even more important for testing the hypothesis of this study, economic significance refers to the model's ability to generate reliable estimates and projections of endogenous variables under market-switching regimes. A number of shocks can occur that can cause a market to switch between various market regimes. It is important that the model is able to handle these shocks in the forecasting period. Before shocks can be introduced, a benchmark is needed for the forecasting period. This benchmark is also referred to as a baseline and is simulated for the next ten years. The baseline is a simulation of the South African grain, livestock and dairy sector model under agreed policy and certain macroeconomic assumptions. Shocks will be introduced in the form of scenario analyses. The forecasts under a specific scenario will then be compared to the baseline results. The model's performance in the forecasting period will be undertaken in chapter 5.

3.5 SUMMARY

This chapter has laid down the theoretical foundations for this study by presenting the theory of domestic supply and demand, trade, switching regimes, model closure, and price formation. Flow and price-quantity (P-Q) diagrams were used to provide easy guidance towards the understanding of important economic and biological relationships. Essentially, these diagrams provide a clear graphic illustration of the hypothesis of this study, namely that the model structure and closure need to be determined for each product under a specific market regime to ensure a true reflection of reality. The empirical results of the models are presented and the performance of the model validated in chapter 4.

CHAPTER 4

THE REGIME-SWITCHING MODEL

4.1 INTRODUCTION

This chapter presents the structure and the empirical results of the BFAP sector model with a redesigned model specification for the white maize, yellow maize and wheat industries. A switching mechanism has been introduced in this version of the sector model that can switch between alternative model closure techniques. The structure of the model is based on a thorough understanding of the functioning of markets as well as the theoretical foundation, as presented in chapters 2 and 3. In the first section of this chapter the estimated equations are reported and discussed. This includes the parameter estimates, the calculated elasticities and a clear distinction between the alternative model closure techniques that are used for each of the commodities. A detailed discussion of the technical implementation of the switching mechanism in the model follows. The switching mechanism enables the switch between various model closure techniques, which are dictated by the equilibrium pricing conditions, as was discussed in chapter 2 and 3.

4.2 EMPIRICAL RESULTS

The equations reported in this section form the new maize and wheat models. The domestic supply and demand components of the existing models remain unchanged and only the explanatory variables, the parameter estimates and the elasticities are reported for these components. Only the economic significance of the existing equations is taken into consideration and not the statistical significance. The estimated results of the redesigned price and trade equations include the parameter estimates, p-values, R^2, Durban Watson statistics (DW), and the elasticities. The elasticities were calculated at the mean values of the corresponding variables. In order to better understand and interpret the economic significance of the variables used in the equations, a definition of all the variables is included with every equation. The focus of the discussion of the results falls on the economic significance of the equations and how the results relate to the existing literature and the explanation of the functioning of the markets in chapter 2. The results are organised by categories of demand, supply and model closure, and not by commodity.

4.2.1 DOMESTIC SUPPLY

The total grain area harvested represents the sum of the area harvested for all six crops in the model. It is modelled (equation 4.1) as a function of the weighted sum of expected real gross market returns for all six crops, rainfall in the summer production area that influences the decision to plant, and the real price of fuel. Real gross market returns are weighted according to the commodities' share of the total area harvested.

Equation 4.1: *Total grain area harvested (Thousand hectares)*

Explanatory variable	Parameter	Elasticity
Intercept	4264.9	
LAG(G6REGMW)	0.710	0.22
RASAD	1.575	0.12
RFUEL	-466.40	-0.11
SHIFT98	-733.13	

Variable name	Definition	Units
G6REGMW	Weighted sum of expected real gross market return – 6 crops	R/ton
RASAD	Rainfall: summer grain area decision	mm
RFUEL	Real fuel price index	Index
SHIFT98	Indicator variable equal to 1 from 1998 onwards	

The price elasticity of 0.22 implies that if the weighted sum of expected real gross returns for all six crops increases by 10 percent, the total area harvested increases by 2.2 percent. Similarly, a 10 percent increase in rainfall in the specific months that influence the decision to plant will increase the area harvested by 1.2 percent and a 10 percent increase in the real price of fuel will decrease the area harvested by 1.1 percent. SHIFT98 was introduced in the equation to capture the large shift of marginal land out of crop production in the first production season after the deregulation of the markets in 1997. The shift implies that 733 000 ha were lost to grain production for reasons not explained by changes in gross market returns.

All the crops in the model are expressed as a share of the total grain area harvested and estimated as behavioural equations, except for white maize. Since the deregulation of the markets, white maize has made up approximately 40 percent of the total grain area harvested. The white maize area harvested is equal to one less the sum of the area shares for the remaining crops. Therefore, the area shares for yellow maize and wheat will be presented first before the white maize area share is presented.

The yellow maize area harvested share of the total grain area harvested is modelled as a function of the ratio of the real expected gross market return for yellow maize divided by the sum of the expected gross market return for the remaining five crops. The estimated signs of the parameters comply with *a priori* expectations and the elasticities show that the yellow maize area harvested share is inelastic. This complies with recent stable trends in the yellow maize area harvested.

Equation 4.2: *Yellow maize share of total grain area (percentage)*

Explanatory variable	Parameter	Elasticity
Intercept	0.15	
LAG(YMRGMSA)	0.06754	0.37

Variable name	Definition	Units
YMRGMSA	Yellow maize expected real gross market return / Sum of 5 grains expected market return	Percentage

The yellow maize area harvested is calculated in the form of an identity that relates the share of yellow maize area harvested to the total grain area harvested.

Equation 4.3: *Yellow maize area harvested (thousand hectares)*

YMAHSA = G6AHSA*YMAHSH

Variable name	Definition	Units
YMAHSA	Yellow maize area harvested	Thousand hectares
G6AHSA	Total grain area harvested	Thousand hectares
YMAHSH	Yellow maize area harvested share	Percentage

The wheat area harvested in South Africa can be split up into two main production regions, namely the summer and the winter rainfall regions. Although the summer rainfall region also includes the wheat area harvested under irrigation, the nature of the commodities that can be used for substitutes is very similar to those of the dryland summer area harvested. Wheat summer area harvested share (WSAHSH) is estimated as a function of the expected real gross market returns for wheat divided by the sum of the expected real gross market returns of the remaining five crops in the model.

Equation 4.4: *Wheat summer area share of total grain area (percentage)*

Explanatory variable	Parameter	Elasticity
Intercept	0.05201	
LAG(WRGMSA)	0.0416	0.57

Variable name	Definition	Units
WRGMSA	Wheat expected real gross market return / Sum of 5 grains expected market return	Percentage

Wheat winter area harvested share (WWAHSH) is estimated as a function of the expected real gross market returns for wheat divided by the sum of the expected real gross market returns of the remaining five crops in the model and the real carcass price for mutton. SHIFT01 is included to account for the shift of area out of wheat production since 2001.

Equation 4.5: *Wheat winter area share of total grain area (percentage)*

Explanatory variable	Parameter	Elasticity
Intercept	0.058	
LAG(WRGMSA)	0.01513	0.35
RMUAPSA	-5.96E-06	-0.17
SHIFT01	0.00966	

Variable name	Definition	Units
WRGMSA	Wheat expected real gross market return / Sum of 5 grains expected market return	Percentage
RMUAPSA	Real mutton auction price	c/kg
SHIFT01	Indicator variable equal to 1 from 2001 onwards	

The own price elasticities in the summer and winter share area?? equations clearly illustrate the different characteristics of wheat production in the two regions. Although both estimated elasticities are fairly inelastic in reflecting steady cropping mix between grains and oilseeds, the elasticity in the summer rainfall area is almost twice as large as the elasticity in the winter rainfall area. The reason for this is that the farmers in the summer rainfall region have more commodities to choose from, which can be planted instead of wheat. The farmers in the winter rainfall region only have a few options and are often caught up in a fixed rotational cropping programme, which makes it more difficult to respond to price changes. The real price of mutton is also included in the winter rainfall area harvested, since sheep production forms an integral part of the rotational cropping system.

The area harvested for wheat in the summer and winter region is calculated as the area harvested share times the total grain area harvested.

Equation 4.6: *Wheat summer area harvested (Thousand hectares)*

WSAHSA = G6AHSA*WSAHSH

Variable name	Definition	Units
WSAHSA	Wheat area harvested	Thousand hectares
G6AHSA	Total grain area harvested	Thousand hectares
WSAHSH	Wheat summer area harvested share	Percentage

Equation 4.7: *Wheat winter area harvested (Thousand hectares)*

WWAHSA = G6AHSA*WWAHSH

Variable name	Definition	Units
WWAHSA	Wheat winter area harvested	Thousand hectares
G6AHSA	Total grain area harvested	Thousand hectares
WWAHSH	Wheat winter area harvested share	Percentage

Since the deregulation of the markets, white maize has made up approximately 40 percent of the total grain area harvested. The white maize area harvested share is equal to one minus the sum of the area shares for the remaining crops. Given parameters in the other share equations, the white maize share of total area harvested will increase when white maize prices increase, and decrease when other crop prices increase.

Equation 4.8: *White maize share of total grain area (percentage)*

WMAHSH = 1-(YMAHSH+WSAHSH+WWAHSH+SSAHSH+SGAHSH+SBAHSH)

Variable name	Definition	Units
YMAHSH	Yellow maize area harvested share	Percentage
WSAHSH	Wheat summer area harvested share	Percentage
WWAHSH	Wheat winter area harvested share	Percentage
SSAHSH	Sunflowers area harvested share	Percentage
SGAHSH	Sorghum area harvested share	Percentage
SBAHSH	Soybeans area harvested share	Percentage

Given parameters in the other share equations, the white maize share of total area harvested will increase when white maize prices increase, and decrease when other crop prices increase. The white maize area harvested equation is derived by multiplying the area harvested share by the total grain area harvested. This identity can be presented as follows:

Equation 4.9: *White maize area harvested (thousand hectares)*

WMAHSA = G6AHSA*WMAHSH

Variable name	Definition	Units
WMAHSA	White maize area harvested	Thousand hectares
G6AHSA	Total grain area harvested	Thousand hectares
WMAHSH	White maize area harvested share	Percentage

In order to estimate total production, the area harvested for each crop is multiplied by yield. White maize yield is estimated as a function of rainfall and a trend variable. The rainfall variable used in the model reflects the regions and specific months that influence the area planted and the production of white maize. Initially, the expected price of white maize was included in the equation, but the coefficient turned out to be statistically insignificant. In South Africa, mainly white maize grown under irrigation has sufficient upward potential that one would expect farmers to respond to higher price expectations by increasing the level of inputs. Limited observations and the preponderance of weather impacts on yields make it difficult to identify price effects on yields. A dummy variable (indicator variable) was introduced in 1992 to capture the effect of the worst drought in the history of maize production in South Africa.

Equation 4.10: *White maize yield (t/ha)*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	0.0111		
RASPRD	0.0030	*	0.62
TREND	0.0567	*	0.38
DUM92	-1.253	*	

Variable name	Definition	Units
RASPRD	Rainfall summer grain production	Mm
TREND	Trend variable; 1979 = 1 and 2014 = 36	
DUM92	Indicator variable equal to 1 in 1992, 0 otherwise	

White maize production is an identity equal to the area harvested multiplied by the yield.

Equation 4.11: *White maize production (thousand tons)*

WMPROSA = WMAHSA*WMYSA

Variable name	Definition	Units
WMPROSA	White maize production	Thousand tons
WMAHSA	White maize area harvested	Thousand hectares
WMYSA	White maize yield	t/ha

Equation 4.12 illustrates the estimation of yellow maize as a function of rainfall and a trend variable. As is the case with white maize, no statistically significant relationship could be established between expected prices and yield. Although the average yield for yellow maize and white maize over the past decade has been approximately the same (2.94 t/ha), the yellow maize yield is more sensitive to rainfall with an elasticity of 0.82 compared to 0.63 in the case of white maize. An all-time record yield of 4.37 t/ha is estimated for the current season (2004/05) by the Crop Estimates Committee (CEC). This follows a yield of 3.73 t/ha in the previous season.

Equation 4.12: *Yellow maize yield (t/ha)*

Explanatory variable	Parameter	Elasticity
Intercept	-3.21	
RASPRD	0.0036	0.82
LNTREND	1.33	1.55

Variable name	Definition	Units
RASPRD	Rainfall summer grain production	mm
LNTREND	Logarithmic trend variable	

Yellow maize production is estimated as the yellow maize area harvested multiplied by the yellow maize yield. Equation 4.13 presents this identity.

Equation 4.13: *Yellow maize production (thousand tons)*

YMPROSA = YMAHSA*YMYSA

Variable name	Definition	Unit
YMPROSA	Yellow maize production	Thousand tons
YMAHSA	Yellow maize area harvested	Thousand hectares
YMYSA	Yellow maize yield	t/ha

In the case of wheat, the existing model distinguishes between wheat yields in the summer rainfall region and winter rainfall region. Equation 4.14 and 4.15 suggest that yields in the winter rainfall area are more sensitive (elasticity = 0.56) to rainfall than yields in the summer rainfall area (elasticity = 0.23). These elasticities comply with *a priori* expectations since wheat in the winter rainfall region is only grown under dryland conditions, whereas in the summer rainfall region wheat is also produced under irrigation.

Equation 4.14: *Wheat summer yield (t/ha)*

Explanatory variable	Parameter	Elasticity
Intercept	0.12849	
RAWSPRD	0.00402	0.23
LNTREND	0.54991	0.71

Variable name	Definition	Units
RAWSPRD	Rainfall wheat summer production	Mm
LNTREND	Logarithmic trend variable	

DUM97 is included in the winter yield equation to capture the effect of a drought in this region in 1997.

Equation 4.15: *Wheat winter yield (t/ha)*

Explanatory variable	Parameter	Elasticity
Intercept	0.239302	
RAWPRD	0.004595	0.56
LNTREND	0.071472	0.09
DUM 97	-0.485678	

Variable name	Definition	Units
RAWPRD	Rainfall wheat winter production	Mm
LNTREND	Logarithmic trend variable	
DUM 97	Indicator variable equal to 1 in 1997, 0 otherwise	

Wheat production is an identity equal to the area harvested multiplied by the yield. Over the past three seasons farmers in the summer rainfall area have produced 66 percent of all wheat produced locally. This percentage has been as high as 75 percent and as low as 58 percent.

Equation 4.16: *Wheat summer production (thousand tons)*

WSPROSA = WSAHSA*WSYSA

Variable name	Definition	Unit
WSPROSA	Wheat summer production	Thousand tons
WSAHSA	Wheat summer area harvested	Thousand hectares
WSYSA	Wheat summer yield	t/ha

Equation 4.17: *Wheat winter production (thousand tons)*

WWPROSA = WWAHSA*WWYSA

Variable name	Definition	Unit
WWPROSA	Wheat winter production	Thousand tons
WWAHSA	Wheat harvested in winter rainfall area	Thousand hectares
WWYSA	Wheat winter yield	t/ha

4.2.2 DOMESTIC DEMAND

Domestically, white maize is used for food, seed and animal feed. . Total domestic demand equals domestic use plus ending stocks. Equations 4.18 and 4.19 present the human and feed consumption estimations for white maize. Seed consumption makes up approximately five percent of the market and the reported data are unreliable. For this reason, the model does not estimate a category for seed use.

The existing sector model estimates two categories for the domestic consumption of yellow maize, namely human consumption and feed consumption. Total domestic demand is calculated as domestic consumption plus ending stocks. Equations 4.22 and 4.23 present the human and feed consumption estimations, and equation 4.25 presents the function for ending stocks. Whereas white maize is mainly consumed in the human market, on average only 6 percent of all yellow maize has been consumed in the human market over the past five years. Yellow maize is the dominant feed grain in the South African feed market.

Wheat is consumed domestically for food, seed and feed. The total domestic demand for wheat is calculated as the sum of domestic consumption plus ending stocks. Seed consumption makes up less than five percent of the market and the reported data are unreliable. For this reason, the model did not estimate a category for seed use.

Human consumption was estimated as *per capita* consumption. White maize *per capita* consumption is defined as the white maize gross human consumption divided by the population and was estimated in equation 4.18 as a function of the real white maize SAFEX price, the real wheat SAFEX price, and the real *per capita* gross domestic product and a dummy variable for 1992.

Equation 4.18: *White maize human consumption (kg/capita)*

Explanatory variable	Parameter	Elasticity
Intercept	99	
RWMPPSA	-0.02	-0.16
RWPPSA	0.008	0.09
RPCGDP	-0.00072	-0.14
DUM92	-56.77	

Variable name	Definition	Units
RWMPPSA	Real white maize SAFEX price	R/ton
RWPPSA	Real wheat SAFEX price	R/ton
RPCGDP	Real *per capita* gross domestic product	R'000 / capita
DUM92	Indicator variable equal to 1 in 1992, 0 otherwise	

The fact that white maize is the staple food of South Africa creates numerous *a priori* expectations about the elasticities. If all the variables were in nominal terms, the homogeneity condition would not have been satisfied because the sum of the price and income elasticities does not equal zero. However, the variables are in real terms and therefore the homogeneity condition is not violated. This is because the implicit elasticity with respect to the price deflator is equal to the negative of the sum of the price (own and cross) and income elasticities. The sum of elasticities equals -0.21 (-(-0.16+0.9-0.14), therefore the price deflator (proxy for inflation) elasticity is 0.21. The deflator has exactly the opposite impact because it is below the line. If we increase all the prices and income by 10%, it implies that inflation also increases by 10% and the total effect is zero (-0.21 + 0.21). If the equation was in nominal terms and the total elasticity was -0.21, the homogeneity condition would be violated and a 10% increase in prices and income would decrease human consumption by 2.1%.

The own-price, cross-price, and income elasticity can all be classified as inelastic. The negative real income elasticity of -0.14 indicates that white maize is an inferior product. The negative income effect implies that price inflation has a positive effect on white maize consumption, if nominal income and nominal maize and wheat prices are held constant. This implies that as general inflation increases, so the human consumption of white maize increases. The estimation shows that white maize competes with wheat in the human consumption market, with a cross-price elasticity of 0.09. With the severe drought in 1992, only yellow maize was imported and the human consumption of white maize dropped from an average level of approximately 80 kg/capita to only 26 kg/capita. A dummy variable is included in the estimation to capture this effect.

Per capita consumption of yellow maize is defined as the gross human consumption of yellow maize divided by the population. It was estimated in equation 4.19 as a function of the real yellow maize SAFEX price, a shift variable in 1999, and a dummy variable in 1992 to capture the effect when only yellow maize was imported to supplement domestic drought-stricken supplies of white maize. Previous estimations did not find any statistical significant relationship between level of income and consumption of yellow maize in the human market. This complies with *a priori* expectations. The limited use of yellow maize in the human market can only be explained by the own price of yellow maize with an elasticity of -0.153.

Equation 4.19: *Yellow maize human consumption (kg/capita)*

Explanatory variable	Parameter	Elasticity
Intercept	4.445	
YMPPSA	-0.00109	-0.153
SHIFT99	1.7026	
DUM92	52.029	

Variable name	Definition	Units
YMPPSA	Yellow maize SAFEX price	R/ton
SHIFT99	Indictor variable equal to 1 from 1999 onwards	
DUM92	Indicator variable equal to 1 in 1992, 0 otherwise	

Per capita consumption of wheat is defined as the gross human consumption of wheat divided by the population and was estimated in equation 4.20 as a function of the real wheat SAFEX price, the real white maize SAFEX price, and the real *per capita* gross domestic product. The function is estimated in real terms and therefore also complies with the homogeneity condition. The signs of the estimated parameters follow *a priori* expectations. A negative own price elasticity and a positive income elasticity suggest that wheat is a normal product. Shift90 is used to illustrate the structural shift in the wheat consumers' market that took place in 1990 when the bread subsidy was terminated and the Wheat Board no longer regulated the price of bread.

Equation 4.20: *Wheat human consumption (kg/capita)*

Explanatory variable	Parameter	Elasticity
Intercept	63.1	
RWPPSA	-0.01	-0.194
RWMPPSA	0.008	0.062
RPCGDP	0.0005	0.130
SHIFT90	-11.3	

Variable name	Definition	Units
RWPPSA	Real wheat SAFEX price	R/ton
RWMPPSA	Real white maize SAFEX price	R/ton
RPCGDP	Real *per capita* gross domestic product	R'000 / capita
SHIFT90	Indicator variable equal to 1 from 1990, onwards	

It is important to note that equation 4.18 shows that white maize is an inferior product. Thus, the human consumption market for white maize and wheat differs and wheat can almost be classified as the "luxury" product compared to white maize; not "luxury" in the strictly theoretical sense where the income elasticity has to be larger than one, but luxury compared to white maize. *Per capita* consumption of wheat has increased over the past five years, while the *per capita* consumption of white maize has decreased. It can be argued that white maize is the staple food of South Africa, but as *per capita* income rises and the rate of urbanisation increases, wheat (in the form of bread) is the preferred product because of less preparation time. A detailed analysis and comparison of the human consumption patterns of white maize and wheat falls beyond the focal area of this study and is recommend for further research.

On average, less than ten percent of local consumption of white maize is used for animal feed, which implies that the major portion of South African white maize is used for human consumption. White maize will only be used for animal feed if it is sufficiently cheaper than yellow maize to compensate for the additional supplements that have to be included in the ration if white maize is fed. Industry experts currently estimate this margin to be between R40/ton and R50/ton. In the years when large surpluses of maize are being produced, white maize tends to be cheaper than yellow maize. However, if there is a shortage of white maize in the food market, white maize can trade at significantly higher prices than yellow maize.

Synthetic parameter estimates are imposed for all feed consumption equations in the existing sector model. It is worth pointing out that symmetry was imposed. In other words, while the parameter estimates are "made up", they are made up in a manner that is not arbitrary and is actually consistent with some aspects of theory. White maize feed consumption is modelled as a function of total demand for maize feed, the real price for white maize, and the real price of a number of substitute feed grains. The total maize feed demand is derived from the level of livestock production and the inclusion rate of white maize in the rations of the various feeds. The own price elasticity of -1.36 indicates that the demand for white maize feed is elastic. The price of yellow maize also has a large impact on the demand for white maize feed..

Equation 4.21: *White maize feed consumption (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	120.0	
MFDISA	0.15	0.92
RYMPPSA	1.00	1.08
RWMPPSA	-1.20	-1.36
RWPPSA	0.05	0.08
RSGPPSA	0.05	0.05

Variable name	Definition	Units
MFDISA	Total maize feed demand	Thousand tons
RYMPPSA	Real yellow maize SAFEX price	R/ton
RWMPPSA	Real white maize SAFEX price	R/ton
RWPPSA	Real wheat SAFEX price	R/ton
RSGPPSA	Real sorghum market price	R/ton

Approximately 85 percent of all feed grain consumed in the South African feed market is yellow maize. The substitute feed grains are white maize, wheat and sorghum. As was explained in the previous section, ,white maize only competes with yellow maize if the price differential is large enough and the wheat and sorghum feed markets are very small.

As in the case of white maize, synthetic parameter estimates are imposed on the yellow maize feed consumption estimation that is presented in equation 4.22. Yellow maize feed consumption is modelled as a function of the total maize feed demand, the real price for yellow maize, and the real price for the substitute feed grains. The total demand for maize feed is derived from the level of livestock production and the inclusion rate of yellow maize in the rations of the various feeds. The own price elasticity of -0.65 implies that feed demand is inelastic and downward sloping. Since the yellow maize feed market is approximately five times larger than the white maize feed market, it is plausible that the demand for white maize is far more price sensitive than the yellow maize market. As expected, an almost unitary elasticity (elasticity = 1) has been imposed for the yellow maize feed consumption with respect to the total maize feed demand.

Equation 4.22: *Yellow maize feed consumption (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	500	
MFDISA	0.9	1.15
RYMPPSA	-2.9	-0.65
RWMPPSA	1	0.23
RWPPSA	0.15	0.05
RSGPPSA	0.09	0.02

Variable name	Definition	Units
MFDISA	Total maize feed demand	R/ton
RYMPPSA	Real yellow maize SAFEX price	R/ton
RWMPPSA	Real white maize SAFEX price	R/ton
RWPPSA	Real wheat SAFEX price	R/ton
RSGPPSA	Real sorghum market price	R/ton

On average, less than two percent of the local consumption of wheat is used for animal feed, which implies that the major portion of South African wheat is used for human consumption. Wheat will only be used for animal feed if the price of lower-quality wheat competes with the price of yellow maize in the feed market. This occurs mainly in the Western Cape feed market, since no yellow maize is produced in this province and all the maize has to be transported from inland regions or be imported. Despite the fact that the animal feed market is very small, the existing model estimates a feed demand category, mainly to capture cross-substitution effects between yellow maize and wheat. Synthetic parameter estimates are imposed on the wheat feed consumption equations. Wheat feed consumption is modelled as a function of the total wheat feed demand, the real price for wheat, and the real price for a number of substitute feed grains. The total feed demand is derived from the level of livestock production and the inclusion rate of wheat in thevarious feed rations.

With an own price elasticity of -2.12, equation 4.23 shows that wheat feed demand is the most sensitive of the three commodities with respect to a shift in the own price. Taking into consideration that the wheat feed market is the smallest of the cereal feed markets, the elastic downward sloping demand curve is plausible.

Equation 4.23: *Wheat feed consumption (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	20	
WFDISA	1	1.07
RYMPPSA	0.15	1.26
RWMPPSA	0.05	0.43
RWPPSA	-0.155	-2.12
RSGPPSA	0.005	0.04

Variable name	Definition	Units
WFDISA	Wheat feed demand index	R/ton
RYMPPSA	Real yellow maize SAFEX price	R/ton
RWMPPSA	Real white maize SAFEX price	R/ton
RWPPSA	Real wheat SAFEX price	R/ton
RSGPPSA	Real sorghum market price	R/ton

If one assumes that all feed grains are homogeneous, that there are no restrictions on availability of any of the feed grains and the price that the feed miller is paying is actually the price that we are estimating, then we expect that the sum of the price parameter estimates has to equal zero. This is based on the principles of cost minimisation by the feed miller. If all prices increase by the same amount, and all the assumptions hold, then there should not be any impact on the consumption of feed. However, when these assumptions do not hold, we tend to focus more on the sum of elasticities. The sum of the price elasticies for white maize (-0.15), yellow maize

(-0.35) and wheat feed demand (-0.38) show that the demand for feed decreases if all the prices for grain are increasing. Thus, all three equations are downward sloping. Compared to yellow maize, feed demand for white maize and wheat is almost twice as elastic as yellow maize feed demand. As previously explained, this can be expected since the white maize and wheat feed markets are very small and volatile.

Total domestic use for maize and wheat is an identity defined as the *per capita* consumption times total population, plus feed and seed consumption. Seed consumption is very small relative to human and feed consumption. Hence, it is not estimated as a behavioural equation and is treated as an exogenous variable. Equations 4.24 through 4.26 present the domestic use of maize and wheat respectively.

Equation 4.24: *Domestic use of white maize (thousand tons)*

WMDUSA = WMPCCSA*POP + WMFCSA + WMSCSA

Variable name	**Definition**	**Units**
WMDUSA	White maize domestic use	Thousand tons
WMPCCSA	White maize *per capita* consumption	Kg/capita
POP	Population	Millions
WMFCSA	White maize feed consumption	Thousand tons
WMSCSA	White maize seed consumption	Thousand tons

Equation 4.25: *Domestic use of yellow maize (thousand tons)*

YMDUSA = YMPCCSA*POP + YMFCSA + YMSCSA

Variable name	**Definition**	**Unit**
YMPCCSA	Yellow maize *per capita* consumption	Kg/capita
POP	Population	Millions
YMFCSA	Yellow maize feed consumption	Thousand tons
YMSCSA	Yellow maize seed consumption	Thousand tons

Equation 4.26: *Domestic use of wheat (thousand tons)*

WDUSA = WPCCSA*POP + WFCSA + WSCSA

Variable name	Definition	Unit
WPCCSA	Wheat *per capita* consumption	Kg/capita
POP	Population	Millions
WFCSA	Wheat feed consumption	Thousand tons
WSCSA	Wheat seed consumption	Thousand tons

In equation 4.27 white maize ending stocks are modelled as a function of the lagged ending stocks, production less net exports, and the inverted real white maize price. Domestic production and net exports remain crucial factors that determine the level of ending stocks, but the impact of speculative stocks increases rapidly as market players become more acquainted with the elements of a free market environment. The estimated price elasticity indicates that, all else being equal, ending stocks decrease as prices increase. In 2002 the white maize price surged to record levels, but stock levels still increased sharply. Not only was the 2002 crop larger than the previous year, but due to a sharp depreciation in the exchange rate and looming crop failures in neighbouring states, prices increased above import parity levels. Many grain traders and producers increased speculative stocks as they expected prices to move even higher with a weaker exchange rate. Some traders even imported white maize to sell at higher prices in the domestic market. A dummy variable was introduced in the model to represent this shock.

Equation 4.27: *White maize ending stocks (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	-1363.9	
LAG(WMENDSA)	0.4	0.59
(WMPROSA – WMNESA)	0.21	1.32
1/RWMPPSA	334637	0.84
DUM02	1181	

Variable name	Definition	Units
WMENDSA	White maize ending stocks	Thousand tons
WMPROSA	White maize production	Thousand tons
WMNESA	White maize net exports	Thousand tons
RWMPPSA	Real white maize SAFEX price	R/ton

Yellow maize ending stocks are estimated as a function of the beginning stock (lagged ending stocks), yellow maize production, and the real yellow maize SAFEX price. Industry experts are of the opinion that the level of speculation on yellow maize stocks is far lower than on white maize stocks. Yellow maize stocks have over the past five years comprised only 33 percent of total maize stocks. Yellow maize production is the key driver of stock levels, with an elasticity of 2.15. If the yellow maize price increases by 10 percent, yellow maize stocks decrease by 10.05 percent, which implies that yellow maize stocks are basically unitarily elastic and downward sloping.

Equation 4.28: *Yellow maize ending stocks (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	-280.43	
LAG(YMENDSA)	0.15	0.24
YMPROSA	0.287	2.15
RYMPPSA	-0.65	-1.05
SHIFT97	290.0	

Variable name	Definition	Units
YMENDSA	Yellow maize ending stocks	Thousand tons
YMPROSA	Yellow maize production	Thousand tons
RYMPPSA	Real yellow maize SAFEX price	R/ton
SHIFT97	Indicator variable equal to 1 from 1997 onwards	

In equation 4.29 wheat ending stocks are estimated as a function of the lagged ending stock, production plus imports, and the real wheat SAFEX price. With an own price elasticity of -0.69, the results suggest that the demand for wheat ending stocks is downward sloping and inelastic towards the price. If the sum of wheat production and imports increases by 10 percent, wheat ending stocks increase by 6.2%. Over the past three seasons ending stocks have remained fairly constant and not nearly the same amount of speculation is present in the wheat ending stock market as is the case in the white and yellow maize ending stock markets. This is because South Africa is a net importer of wheat and the level of stocks is mainly determined by pipeline requirements.

Equation 4.29: *Wheat ending stocks (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	180	
LAG(WENDSA)	0.50	0.624
WRPDSA+ WISA	0.10	0.624
RWPPSA	-0.24	-0.696

Variable name	Definition	Units
WENDSA	Wheat ending stocks	Thousand tons
WRPDSA	Wheat production	Thousand tons
WISA	Wheat imports	Thousand tons
RWPPSA	Real wheat SAFEX price	R/ton

4.2.3 MODEL CLOSURE

In chapter 2 it was determined that the South African white maize market trades under all three market regimes, yellow maize trades under near-autarky and import parity, and wheat only trades under import parity.

Equations 4.30 and 4.31 represent the required equations to close the white maize model under near-autarky, and equations 4.32 through to 4.35 represent the model closure under the import and export parity market regimes. When the market is in near-autarky, net exports are estimated as a behavioural equation and prices are used to close the model. In equation 4.30 net exports of white maize are modelled as a function of the production divided by consumption and the ratio of the white maize SAFEX price over the average of the white maize import parity and export parity price. The annual production-consumption ratio is used in the monthly model by keeping the ratio constant for all the months of a specific year.

Under strict autarky, no trade occurs as domestic markets fluctuate between import and export parity. However, chapter 2 explains that under near-autarky, regional demand driven by weather, location and quality concerns of genetically modified imported maize from non-African destinations causes limited trade with neighbouring countries. With only limited trade taking place, it can be expected that statistically the equation will not perform well. The estimation results indeed prove this with an R^2 value of only 0.21, an F-value of 2.15, and a DW of 0.638. The p-values suggest that the production-consumption ratio is statistically more significant than the ratio of prices. The estimated parameter signs comply with *a priori* expectations, capturing the positive relationship between the level of net exports and domestic production, and the negative relationship between net exports and the domestic price. The elasticities show that net exports are price inelastic (-0.607), but elastic (2.207) towards the production-consumption ratio. At this point it is important to mention that equation 4.30 presents the equation where the monthly parameter estimates have already been converted for the annual simulation model. The annual parameter estimates are calculated from the monthly estimated elasticities and the annual averages for the respective variables for the period 2000-2005. As already mentioned in chapter 2, this was the period that was used for the monthly estimations as well. The principle of Least Squares (Gujarati, 1995) is now applied and an intercept term is chosen for the annual model that makes the sum of all error terms for the period 2000-2005 equal to zero.

Equation 4.30: *White maize net exports (thousand tons): Near-Autarky*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	-622.02		
WMPROSA / WMDUSA	1745.01	0.082	2.207
(WMPPSA / (WMIMR+WMEXA / 2))	-586.40	0.343	-0.607

R^2 = 0. 212 DW = 0.63 F-value = 2.15

Variable name	Definition	Units
WMPROSA	White maize production	Thousand tons
WMDUSA	White maize domestic use	Thousand tons
WMPPSA	White maize SAFEX price	R/ton
WMIMR	White maize import parity – Randfontein	R/ton
WMEXA	White maize export parity – Africa	R/ton

The P-Q diagram in chapter 3 can be used as a graphic depiction of this equation. Section "*ij*" of net export demand graphically depicts this net export demand equation. The section "*ij*" clearly illustrates that under autarky conditions net export demand is expected to be inelastic; in the case of white maize -0.607.

Equation 4.31 illustrates the market clearing identity where the new equilibrium price equals the old equilibrium price plus excess demand. The model solves for market equilibrium with the help of the Gauss-Seidel algorithm and the new market equilibrium is reached when the export demand equals zero. Equation 4.31 illustrates the equilibrator in a purely technical sense. The equilibrator is based on the closing identity as presented in equation 3.32[1] and the market equilibrium price is reached once excess demand is zero

Equation 4.31: *Real white maize SAFEX price (R/ton) – Autarky equilibrator*

Variable name	Formula
Beginning real white maize price	1. = LAG (RWMPPSA)
White maize net export demand	2. = WMNESA
White maize export supply	3. = WMPROSA + LAG(WMENDSA) - WMDUSA – WMENDSA
White maize excess demand	4. = 2-3
New real white maize producer price	5. = LAG (RWMPPSA) + Excess demand

Under the import parity regime domestic prices are determined by behavioural price linkage equations. Price linkage equations are most appropriate when domestic markets are integrated with world markets with continuous trade flow. Under these conditions, the law of one price suggests that the correlation between the world price and the domestic price equals one. In equation 4.32, the real domestic white maize price is estimated as a function of the real import parity price in Randfontein. The model performs well with a R^2 of 0.81 and a price transmission elasticity close to 1 at 0.916. As mentioned in chapter 2, in the case of imports a transmission elasticity smaller than one is plausible because we expect the domestic price to be higher than the world price before transport costs are paid (Brooks and Melyukhina, 2005; Sharma, 2002). This equation clearly suggests that if the domestic market is trading under an import parity regime, the domestic market is well integrated with the world market. Because trade is only perfectly elastic at import or export parity if a number of assumptions hold that may not be true in the South African case, like the assumptions that products are homogenous, net export demand was included in the estimations but proved to be statistically insignificant. Therefore, when the market is trading under import parity, the domestic market price is only modelled as a function of the import parity price.

[1] $EXS_t = PROD_t - CONS_t - (BEGS_t - ENDS_t)$

It is important to note that equation 4.32 is actually the inverted import supply equation that is portrayed by section "*hi*" in the P-Q diagram (chapter 3) as negative export demand. In chapter 3 this section is illustrated as being very elastic, but because net exports are not included in equation 4.32, it implies that section "*hi*" is in fact infinitely elastic for white maize.

Equation 4.32: *Real white maize SAFEX price (R/ton): Import parity regime*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	-6.219		
RWMIMR	0.9240	0.001	0.916

R^2 = 0. 813 DW = 2.28 F-value = 6.93

Variable name	Definition	Units
RWMIMR	Real white maize import parity – Randfontein	R/ton

Where the market trades under the export parity regime, it is expected that the domestic market is well integrated with the world market and the domestic price is a function of the export parity price. Equation 4.33 presents the results of the price linkage equation under the export parity scenario. This equation performs even better than the price linkage equation under the import parity regime and, interestingly, net exports proved to be significant and are therefore included in the model with an elasticity of -0.101. This negative relationship between net exports and the domestic prices often causes great confusion as one tends to forget that this equation is actually an inverted export demand equation. In an export demand equation the negative relationship between the domestic price and net exports can easily be explained since net exports are expected to increase as domestic prices decrease. This same negative relationship holds in the inverted export demand equation. However, it is important to keep in mind that the impact of net trade (elasticity = -0.101) on price is much lower compared to the impact of the export parity price on the domestic price (elasticity = 1.18).

Equation 4.33: *Real white maize SAFEX price (R/ton) – Export parity regime*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	12.43		
WMNESA	-0.06	0.132	-0.09
RWMEXA	1.39	0.001	1.18

R^2 = 0. 934 DW = 1.36 F-value = 84.75

Variable name	Definition	Units
WMNESA	White maize net exports	Thousand tons
RWMEXA	Real white maize export parity – Africa	R/ton

For the same reason that one expects that perfect price transmission in the case of imports implies an elasticity of less than one, in the case of exports we expect that perfect price transmission would correspond to an elasticity greater than one (1.18 in the case of white maize exports).

Again the P-Q diagram can be used for the graphic depiction of this inverted export demand equation, with the almost infinite-elastic section "*jk*" that depicts the positive level of net exports. One can obtain a good indication of the elasticity for section "*jk*" by calculating the inverted elasticity from equation 4.33 as follows:

$$\text{Export demand elasticity} = \frac{1}{-0.09} = 11.1$$

This calculation shows clearly that the net export demand is very elastic under the export parity regime.

For the import and the export parity regime, net exports are used as the closing identity for the model. Net exports are calculated as follows:

Equation 4.34: *White maize net exports (thousand tons)*

WMNESA = LAG (WMENDSA) + WMPROSA – WMDUSA - WMENDSA

Variable name	Definition	Units
WMNESA	White maize net exports	Thousand tons
WMENDSA	White maize ending stocks	Thousand tons
WMPROSA	White maize production	Thousand tons
WMDUSA	White maize domestic use	Thousand tons

In order to derive exports, imports are modelled as a function of net exports (equation 4.35) and added to net exports (equation 4.36).

Equation 4.35: *White maize imports (thousand tons)*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	268.873		
WMNESA	-0.2238	0.02	-10.695

R^2 = 0. 386 DW = 1.97 F-value = 6.93

Variable name	Definition	Units
WMNESA	White maize net exports	Thousand tons

Equation 4.36: *White maize exports (thousand tons)*

WMESA = WMNESA + WMISA

Variable name	Definition	Units
WMESA	White maize exports	Thousand tons
WMISA	White maize imports	Thousand tons

Equations 4.37 and 4.38 represent the equations required to close the yellow maize model under near-autarky, and equations 4.39 through 4.40 represent the model closure under the import parity market regime.

When the market is in near-autarky, net exports are estimated as a behavioural equation and prices are used to close the model. In equation 4.37 yellow maize net exports are modelled as a function of the ratio of the yellow maize SAFEX price over the average of the yellow maize import parity and export parity price. In contrast to white maize, no relationship was statistically determined between production, consumption and net exports. From the results below, the equation evidently also does not perform well with a R^2-value of only 0.13. A price elasticity of -0.93 also seems to be too high if one takes into consideration that under true autarky no trade occurs and prices are not influenced by the level of trade. However, industry specialists are of the opinion that the relationship between domestic and parity prices does play a major role in the trade flow of yellow maize, and not regional demand issues as was the case with white maize. Human consumption only makes up approximately six percent of total domestic consumption. Therefore, the regional demand issues in the yellow maize market are fundamentally different from those in the white maize market. Yellow maize net exports are frequently zero, whereas average white maize net exports over the past five years have been approximately 900 000 tons.

Equation 4.37: *Yellow maize net exports (thousand tons): Near-autarky*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	207.09		
(YMPPSA/(YMIMD+YMEXA/2))	-144.84	0.16	-0.93

R^2 = 0. 13 DW = 1.074 F-value = 2.19

Variable name	Definition	Units
YMPPSA	Yellow maize SAFEX price	R/ton
YMIMD	Yellow maize import parity – Durban	R/ton
YMEXA	Yellow maize export parity – Africa	R/ton

If one relates these results to the P-Q diagram, it implies that section "*ij*" of export demand is actually more elastic towards the domestic price than is illustrated by the diagram. Theory suggests that export demand under autarky should be perfectly inelastic. However, with an elasticity of -0.93, net export demand for yellow maize under the near-autarky regime is almost unitarily elastic. Since the statistical performance of this model is so weak, the performance evaluation of simulation results in chapter 5 will determine if this equation is behaving correctly under various scenario analyses.

The yellow maize price equilibrator is based on the same principles as the white maize equilibrator. Equation 4.38 illustrates the equilibrator in a purely technical sense. This is the market clearing identity for yellow maize where the new equilibrium price equals the old equilibrium price plus export demand. The new market equilibrium price is reached when the export demand equals zero.

Equation 4.38: *Real yellow maize SAFEX price (R/ton): Near-Autarky equilibrator*

Variable name	Formula
Beginning real yellow maize price	1. = LAG (RYMPPSA)
Yellow maize net export demand	2. = YMNESA
Yellow maize export supply	3. = YMPROSA + LAG(YMENDSA) - YMDUSA – YMENDSA
Yellow maize excess demand	4. = 2-3
New real yellow maize producer price	5. = LAG (RYMPPSA) + excess demand

Under the import parity scenario, prices are linked to the world market by means of a price linkage equation, allowing net exports to be determined as the difference between supply and demand at those prices. Equation 4.39 shows that under import parity conditions the law of one price holds with the elasticity (1.064) basically equal to one. This function can also be interpreted as the inverted import supply function that is represented by section "*hi*" (negative net export demand, therefore, imports) of net export demand in the P-Q diagram (figure 3.3). As was the case with white maize, net trade in yellow maize was included in earlier versions of the model, but proved to be statistically insignificant and was dropped from the equation. This implies that yellow maize imports (section "*hi*") are perfectly elastic when the market trades under the import parity regime. Equation 4.39 performs very well with a high R^2 value and F-value.

Equation 4.39: *Real yellow maize SAFEX price (R/ton): Import parity regime*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	-24.47		
RYMIMD	1.066	0.001	1.06

R^2 = 0. 979 DW = 1.21 F-value = 344.93

Variable name	Definition	Units
RYMIMD	Real yellow maize import parity – Durban	R/ton

Net exports are used as the closing identity for the model under the import parity regime. As mentioned previously, yellow maize exports have shrunk drastically in recent years and over the past three years South Africa has in fact been a net importer of yellow maize. Early projections suggest that a reasonable surplus will be produced in the current season and net exports will be positive. Net exports are calculated as follows:

Equation 4.40: *Yellow maize net exports (thousand tons)*

YMNESA = LAG(YMENDSA) + YMPROSA – YMDUSA - YMENDSA

Variable name	Definition	Units
YMNESA	Yellow maize net exports	Thousand tons
YMENDSA	Yellow maize ending stocks	Thousand tons
YMPROSA	Yellow maize production	Thousand tons
YMDUSA	Yellow maize domestic use	Thousand tons

Yellow maize imports are directly related to net exports in equation 4.41. The equation performs very well and shows a strong relationship between imports and net exports. Eighty-three percent of any change in net trade is reflected in imports.

Equation 4.41: *Yellow maize imports (thousand tons)*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	534.287		
YMNESA	-0.83383	0.001	-2.71
SHIFT02	-295.895	0.073	
DUM94	1750.31	0.001	

R^2 = 0. 967 DW = 1.35 F-value = 89.5

Variable name	Definition	Units
YMNESA	Yellow maize net exports	Thousand tons
SHIFT02	Indicator variable equal to 1 from 2002 onwards	
DUM94	Indicator variable equal to 1 in 1994, 0 otherwise	

Exports can now be derived as an identity (equation 4.42) by adding imports to net exports.

Equation 4.42: *Yellow maize exports (thousand tons)*

YMESA = YMNESA + YMISA

Variable name	Definition	Units
YMESA	Yellow maize exports	Thousand tons
YMISA	Yellow maize imports	Thousand tons

Of the three crops included in this study, the wheat model has the most basic structure with model closure only set up to solve for prices under an import parity market regime, allowing net imports to be calculated as the difference between domestic supply and domestic demand. This makes South Africa a net importer of wheat with the domestic markets integrated with world markets and, according to the law of one price, a coefficient of one is expected in the linear price transmission equation if all the elements in the import parity calculations are in the same units.

Equation 4.43: *Real wheat SAFEX price (R/ton): Import parity regime*

Explanatory variable	Parameter	p-value	Elasticity
Intercept	38.54		
RWIMR	0.87	0.001	0.93
SHIFT 02	37.11	0.001	

R^2 = 0. 92 DW = 1.2 F-value = 237.92

Variable name	Definition	Units
RWIMR	Real wheat import parity – Randfontein	R/ton
SHIFT 02	Indicator variable equal to 1 from 2002, onwards	

Equation 4.43 relates the wheat SAFEX price to the import parity price of hard red winter wheat at Randfontein, and results suggest a price transmission elasticity of 0.93. As mentioned previously, in the case of imports a transmission elasticity smaller than one is plausible because we expect the domestic price to be higher than the world price before transport costs are paid (Brooks and Melyukhina, 2005; Sharma, 2002).

Chapter 2 (figure 2.3) shows that the wheat SAFEX price traces the import parity price of hard red winter wheat very closely. A shift is included in the equation to capture the structural shift that occurred in the wheat market in 2002. Whereas the domestic price traded below the import parity price before 2002, it has been trading correctly at import parity levels for the past three years. This structural shift can be explained by the sharp depreciation in the rand together with a short maize crop in the Southern African region, which led to a sharp increase in the maize prices. Farmers in the summer rainfall region substituted wheat for maize; hence, domestic production of wheat decreased and large volumes of wheat had to be transported inland to the main consumption hub, Gauteng, lying next to Randfontein. Whereas South African wheat farmers have on average produced 78 percent of domestic use over the past five years, the sharp decrease over the past three years in the area planted to wheat in the summer rainfall region has resulted in farmers only supplying 64 percent of domestic use.

The origin of imports also plays a major role since the quality of the wheat is largely determined by the origin. Argentinean wheat is, for instance, regarded in the domestic market as lower-quality wheat and is mixed into the “grist” of wheat that is used in the milling and baking process. Depending on the season, Argentinean wheat can be imported more cheaply into South Africa than American hard red winter wheat. The distinction between origins of imports goes beyond the scope of this study.

Since South Africa is a net importer of wheat, net imports are used as the closing identity for the model. Net imports are calculated as the difference between total domestic consumption plus ending stocks, and total production plus beginning stocks.

Equation 4.44: *Wheat net imports (thousand tons)*

WNISA = WDUSA + WENDSA - LAG(WENDSA) - WPROSA

Variable name	Definition	Units
WNISA	Wheat net imports	Thousand tons
WDUSA	Wheat domestic use	Thousand tons
WENDSA	Wheat ending stocks	Thousand tons
WPROSA	Wheat production	Thousand tons

Exports are estimated as a function of net imports. Equation 4.45 shows that exports decrease by 13.7 percent if net imports increase by 10 percent.

Equation 4.45: *Wheat exports (thousand tons)*

Explanatory variable	Parameter	Elasticity
Intercept	220.63	
WNISA	-0.11	-1.37

Variable name	Definition	Units
WNISA	Wheat net imports	Thousand tons

Wheat imports are calculated as wheat net imports plus wheat exports.

Equation 4.46: *Wheat imports (thousand tons)*

WISA = WNISA + WESA

Variable name	Definition	Units
WISA	Wheat imports	Thousand tons
WNISA	Wheat net imports	Thousand tons
WESA	Wheat exports	Thousand tons

4.3 THE REGIME-SWITCHING MECHANISM

This section explains the technical introduction of the mechanism or selector in the model that determines the switch between various model closure techniques, which are dictated by the market regime. The white maize model consists of a selector that can switch between three different model closure techniques' namely model closure under import parity, export parity and near-autarky. The selector in the yellow maize model can switch between model closure under import parity and near-autarky. No selector is introduced in the wheat model since this model only closes under the import parity market regime.

Figure 4.1 presents the regime selector graphically and shows clearly how the domestic price can fluctuate between the export parity price (lower band) and the import parity price (upper band). The simple construction shows that the mean parity price anchors a symmetric band with a width equal to transaction costs included in the calculation of the import and export parity prices as presented in chapter 2.

Theoretically speaking, an arbitrage opportunity for importing (exporting) should only surface if the domestic market-clearing price is greater (less) than or equal to the import (export) parity prices. If the domestic market price is trading between the import and export parity prices, no opportunity for arbitrage should exist and therefore no trade should occur. However, since some level of trade does occur under what this study refers to as near-autarky, the switch between the different model closure techniques cannot be based on the level of trade flow but on the level of the domestic market-clearing price. In other words, the selection of an alternative model closure technique for a specific commodity is triggered by the level of the domestic market-clearing price. For example, if South Africa has a short crop due to a drought, the equilibrium pricing conditions will solve for a market-clearing price closely equal to the import parity price as grain is imported into the country. Now an alternative model closure technique is triggered and the selector will switch to the appropriate model closure.

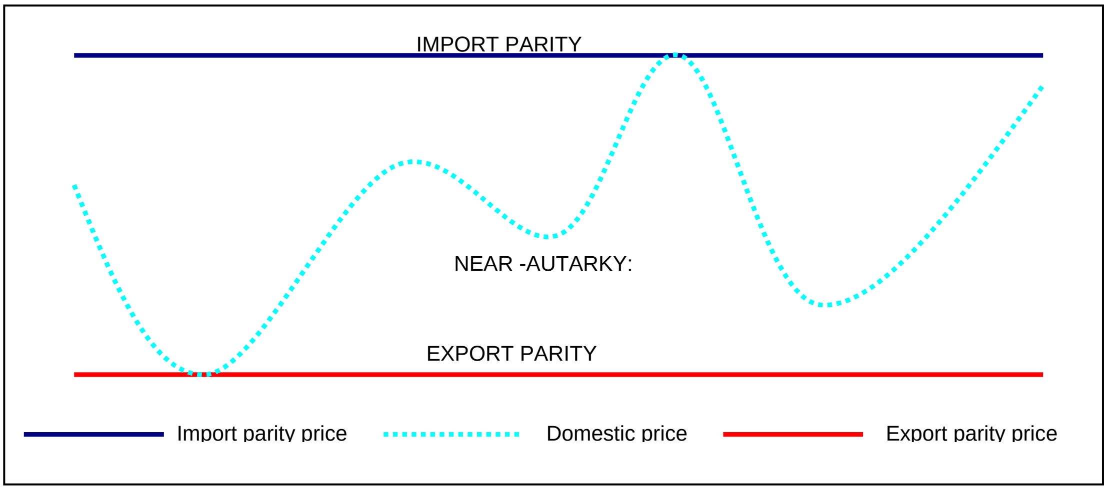

Figure 4.1: The regime selector

When the model is solved and the iteration process starts, it begins with the domestic price set to the average of the import and export parity price solving using the near-autarky closure. The model explores the price space bound by import parity and export parity. In other words, the model solves under near-autarky until the prices that are solved in the iteration process move to the import or export parity boundary, at which stage a new model closure technique is triggered and the model switches to close the industry either by means of net imports or net exports. This mechanism is established through a range of *if*-statements in Excel. The inclusion of the regime-switching technique sharply increased the number of iterations necessary for the model to reach equilibrium in all markets.. After resetting itself, the new sector model reaches equilibrium in all the commodity markets after approximately 3000 iterations.

Alternative market equilibriums can now be simulated for a range of alternative equilibrium pricing conditions. This will be illustrated in chapter 5. The model solves for only one market-clearing price under the appropriate model closure technique. The model also assumes a constantly changing long-run equilibrium that is defined by the relative regime probabilities. It should be clear that since the exact timing of future regime changes cannot be predicted (for example the occurrence of a drought), the long-run equilibrium can be subject to a kind of path dependency. This seems to contradict the conventional view of market equilibrium, but presents a more realistic view of economic processes and the impact of external influences on the sector.

It is important to note that the various model closures are triggered by the same set of parity prices that are used in the estimations of the various parameter estimates that are imposed in the simulation model. For example, in the white maize model the trigger mechanism for model closure under an import parity regime is based on the import parity price at Randfontein. Once the model has switched to an import parity regime, the domestic price is modelled as a function of the import parity prices in Randfontein. Although the domestic market is influenced by the import parity price at the harbours, it is actually the inland (Randfontein) import parity price that determines the upper level of the domestic prices in the case of white maize and wheat since large volumes are transported to the main inland consumption hubs. In the yellow maize market, the import parity price at Durban harbour is used for the trigger mechanism and the actual estimation.

In the white maize model, the selector is set up so that the model will close under the import parity regime if the domestic price moves higher than the import parity price at Randfontein, and the model will close under the export parity regime if the model moves lower than the export parity price into Southern African markets. For prices between these levels, the model will use the near-autarky equations. In the same fashion, in the yellow maize model the selector is set up so that the model will close under the import parity regime if the domestic price moves higher than the import parity price at Durban harbour, and for any other price the model closes under autarky. The wheat model constantly solves under the import parity regime.

4.4 SUMMARY

This chapter has postulated the structure of the redesigned commodity model that is able to generate estimates under switching market regimes. The white maize model consists of nine behavioural equations, seven identities and model closure is set up for all three market regimes. The yellow maize model consists of eight behavioural equations and six identities. Whereas the white maize model is set up to close under all three market regimes, the yellow maize model can close under autarky and the import parity regime, as South Africa has not been a significant net exporter of yellow maize since the deregulation of the markets in 1997. The wheat model consists of nine behavioural equations, seven identities and the model closes only under the import parity market regime.

The estimated price and trade equations for the various industries performed according to *a priori* expectations and a number of useful elasticities were calculated that explain the relationship between world and domestic prices, and net trade under the various trade regimes. Contrary to the theoretical principle that no trade occurs if the market is in autarky and the net export demand should be perfectly inelastic, trade occurs under what this study defines as near-autarky, and net export demand for white and yellow maize proved not to be perfectly inelastic, with estimated elasticities of -0.607 and -0.930. Under the import parity regime, net imports proved to be perfectly elastic and price transmission elasticities of 0.916 and 1.064 were estimated for white and yellow maize respectively. Under the export parity regime, net export demand for white maize proved to be very elastic (elasticity = 9.9) and a price transmission elasticity of 1.11 was estimated.

This chapter presented the performance of the single equation estimations. The true simulation capability and performance of the model will be analysed in the following chapter when the baseline projections are presented and shocks are introduced in the forecasting period. Whereas chapter 4 reported on the elasticities that were estimated by single equations, chapter 5 presents the elasticities that were generated in the dynamic, closed system of equations.

CHAPTER 5
BASELINE PROJECTIONS, IMPACT MULTIPLIERS, AND SCENARIO ANALYSES

5.1 INTRODUCTION

This chapter illustrates the regime-switching model's ability to generate reliable estimates and projections of endogenous variables under real-world conditions. The main purpose of this chapter is to test the hypothesis formulated in chapter 1. Various approaches are used to test the various aspects of the hypothesis. A useful technique to test a regime-switching model is to introduce a number of shocks in the form of scenario analyses that can cause a market to switch between various market regimes. It is important that the model is able to handle these shocks in the forecasting period.

A shift in world prices, which is imposed on the model under the various regimes, illustrates how the correlation between the world and domestic prices changes as the equilibrium pricing conditions change. The impacts are presented in the form of absolute and percentage effects (impact multipliers). In order to calculate the impact multipliers, the first step is to generate benchmarks under a combination of different trade regimes in the grain markets. These benchmarks are also referred to as baselines and are simulated for the forecasting period. The baseline projections under a combination of different trade regimes in the grain markets are presented in the first section of this chapter. This is followed by the presentation of the impact multipliers of a 10 percent increase in parity prices. According to Baulch (1997), border parity prices are more appropriate to use than world prices since parity prices already include the components like the exchange rates, the transportation costs, and the import tariff. Parity prices were also used in the estimation of the various price and trade components in chapter 4.

Apart from testing the correlation between domestic and parity prices under various trade regimes, an important aspect of the hypothesis that needs to be proven is whether the switching mechanism does actually improve the simulation model's performance. In order to show the usefulness of the automated switch between the various model closure techniques, the *ex-post* simulation results of the regime-switching model and the pre-existing sector model are compared. The previous sector model ignores the possibility of regime switching and just a single method of price determination is used. Section 5.4 compares the modelling results of the previous sector model with the new regime-switching sector model.

The elasticity matrices that are presented in section 5.5 provide a concise summary of a number of price and cross-price effects, production and consumption. The last section of the chapter presents a more hands-on application of the regime-switching model to real-life examples. When this simulation model was first presented to industry experts, it was quickly realised that a theoretical approach does not meet the requirements of the industry to understand the evolution of the sector under alternative shocks. This led to the development of scenario analysis and planning techniques, where the forecasts under a combination of scenarios can be compared to the baseline results. Various scenarios can be developed, including short-term and long-term effects.

5.2 THE BASELINE

A baseline is a simulation of the sector model under agreed policy and certain assumptions with respect to macroeconomics, the weather, and technological change. The baseline does not constitute a forecast, but rather presents a benchmark of what could happen under a particular set of assumptions. Inherent uncertainties, including policy changes weather, and other market disruptions, ensure that the future is highly unlikely to match baseline projections. A baseline can thus be looked upon as a "reference scenario" and can form part of the validation procedures. Many different reference scenarios can be developed under various assumptions, but the application and interpretation of a specific baseline (or reference scenario) will determine the significance of the baseline. This point is emphasized by Westhoff *et al* (2004) who mention that "sometimes analysts will argue that baselines are not important, because what matters is the change from the baseline that results when an alternative scenario is implemented, but the particular provisions of many trade agreements mean that baselines matter, and they often matter a lot".

In order to construct basic price and trade impact multipliers that portray the most important relationships between domestic and world prices and trade flow, three baseline projections are generated under a combination of different trade regimes in the grain market. These combinations are based on the number of regimes under which each market can trade.. The first combination presents the baseline projections where all three grain markets are trading under import parity. The second combination presents the baseline projections where white and yellow maize trade under autarky and wheat trades under import parity. In the third combination of regimes, baseline projections are generated where white maize trades under export parity, yellow maize trades under autarky, and wheat trades under import parity. The various combinations of trade regimes are established by basic assumptions on local weather conditions that influence crop conditions in 2007. These assumptions are introduced in the models in the form of once-off shocks in 2007. The baselines are simulated for the period 2006-2012.

Macroeconomic assumptions and world prices are required for the projection period to simulate the baseline results. In this study only one set of the macroeconomic assumptions and world prices is utilised for the various baseline projections. The macroeconomic assumptions (table 5.1) are based on forecasts prepared by a number of institutions like Global Insight, the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri, and the Actuarial Society of South Africa (for projections on population).

Table 5.1: Macroeconomic assumptions and world price forecasts, 2006 – 2012

Variables	Units	2006	2007	2008	2009	2010	2011	2012
Exchange Rate	c/US$	609.21	648.81	687.73	726.94	766.92	805.26	837.47
Population	Millions	47.64	47.68	47.65	47.54	47.39	47.22	47.04
Real per capita GDP	R/capita	16627.3	17192.6	17759.9	18346.0	18896.4	19444.4	19988.8
CPIF	Index ('00)	143.87	149.91	155.16	161.83	168.47	174.53	181.86
FUEL	Index ('00)	157.61	165.80	173.26	182.45	191.75	200.57	211.00
Freight rates	US$/t	33.72	41.97	48.19	54.44	55.73	57.06	58.44
Harbour costs	R/ton	115.62	120.47	124.69	130.05	135.38	140.26	146.15
Yellow maize, US No.2, fob, Gulf	US$/t	104.19	105.16	106.12	107.09	108.05	109.02	109.98
Wheat US No2 HRW fob (ord) Gulf	US$/t	150.39	153.44	155.50	158.21	160.52	162.43	164.61

Source: BFAP baseline, 2005

Only the most relevant macroeconomic assumptions and world price forecasts are included in the previous table. Harbour costs and freight rates are included to forecast the import and export parity prices for the various grains. It is important to mention that the baseline contains all currently agreed policies on an international as well as domestic level. This implies that trade policies, for example the import tariff dispensations for maize and wheat, will remain unchanged for the projected period.

Baseline projections are presented in the form of tables and figures. The tables present the various endogenous variables generated in the model in the form of crop balance sheets, which include production, consumption and trade. The figures illustrate how domestic market prices are projected to fluctuate in the band, established by the import and export parity price boundaries. Projected imports and exports are also portrayed in the figures. One would expect that if markets are trading under import parity, imports will be high and the domestic price will trade at the upper border parity price boundary, referred to as the import parity price. If, however, the market is trading under export parity, one would expect the domestic price to trade at the lower border parity price boundary, referred to as the export parity price. These figures are similar to the figures presented in chapter 2, but present the price band over the long run. Similar to chapter 2, the domestic market price that is simulated in the model is actually the SAFEX price and is also labelled as such in the figures presented in this chapter.

In order to generate the baselines under the alternative combinations of trade regime, assumptions on the level of domestic production are made. For the first baseline projection all three grains trade under import parity. Hence, a short crop has to be simulated in order for the white and yellow maize models to automatically switch to the import parity closure. As was discussed in chapter 4, the wheat model always closes under import parity. Tables 5.2 through to 5.4 present the first baseline projections where the assumption is made that a severe drought in 2007 reduces the white maize yield to 1.57 ton/ha, the yellow maize yield to 1.02 ton/ha, and the wheat yields in the summer and winter rainfall region to 1.39 ton/ha and 0.87 ton/ha respectively. These extremely low yields are not “far-fetched”/unrealistic since they are in line with the yields that were obtained with the severe drought of 1992.

Table 5.2: Baseline 1 - White maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
White maize area harvested	973.0	1590.8	1878.0	1596.9	1525.6	1546.3	1536.1
				t/ha			
White maize average yield	3.64	1.57	3.70	3.73	3.76	3.79	3.82
				Thousand tons			
White maize production	3538.1	2500.0	6953.3	5962.5	5743.1	5866.4	5871.7
White maize feed consumption	644.0	493.2	634.9	670.3	680.3	693.9	709.0
White maize human consumption	3696.1	3545.2	3699.6	3731.6	3712.8	3699.2	3682.1
White maize domestic use	4585.1	4363.5	4659.5	4727.0	4718.1	4718.1	4716.2
White maize ending stocks	1035.4	280.0	1181.3	1346.2	1361.7	1431.1	1488.1
White maize exports	431.2	0.0	1392.6	1099.9	1052.4	1106.4	1121.5
White maize imports	157.7	1108.0	0.0	29.3	42.9	27.4	23.0
				R/ton			
White maize domestic price	1025.6	1394.1	1067.0	995.7	1025.0	1031.5	1043.1

Table 5.3: Baseline 1 - Yellow maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Yellow maize area harvested	575.0	984.4	1052.4	995.1	968.7	971.6	970.1
				t/ha			
Yellow maize average yield	4.10	1.02	4.00	4.04	4.08	4.13	4.17
				Thousand tons			
Yellow maize production	2355.7	1000.0	4208.5	4022.7	3956.8	4008.5	4041.1
Yellow maize domestic use	3295.5	3345.4	3447.6	3559.0	3606.5	3657.9	3698.5
Yellow maize feed consumption	3921.7	3763.7	3872.3	3985.4	4030.6	4080.4	4118.8
Yellow maize human consumption	242.3	236.3	242.8	244.4	242.1	240.5	238.3
Yellow maize ending stocks	566.9	230.0	711.9	870.8	913.0	949.8	977.2
Yellow maize exports	98.6	0.0	214.2	218.2	219.1	220.3	220.9
Yellow maize imports	940.0	2426.8	359.9	339.7	335.1	329.0	326.0
				R/ton			
Yellow maize domestic price	976.9	1095.6	968.5	926.7	956.6	970.4	995.9

Table 5.4: Baseline 1 - Wheat

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Wheat summer area harvested	530.5	490.0	481.7	511.3	551.5	572.1	591.0
Wheat winter area harvested	323.5	344.3	328.7	329.5	338.2	345.5	351.2
				t/ha			
Wheat average yield: Summer area	2.71	1.39	2.75	2.77	2.78	2.80	2.82
Wheat average yield: Winter area	1.70	0.87	1.71	1.71	1.71	1.71	1.71
				Thousand tons			
Wheat production	1988.1	980.0	1884.7	1977.4	2113.9	2193.9	2267.2
Wheat feed consumption	90.7	98.8	75.2	63.7	60.9	56.9	54.6
Wheat human consumption	2751.8257	2811.191	2741.9	2716.4	2710.361	2700.38	2694.15
Wheat domestic use	2862.2	2929.7	2836.8	2799.8	2790.9	2777.0	2768.5
Wheat ending stocks	611.2	599.0	587.3	572.0	561.0	550.9	544.1
Wheat exports	123.9	7.5	117.2	131.9	147.4	157.6	166.3
Wheat imports	1003.1	1945.0	1057.6	938.8	813.4	730.6	660.6
				R/ton			
Wheat domestic price	1433.2	1564.2	1685.1	1822.8	1940.9	2054.3	2163.7

The figures below help explain the baseline projections simulated under the first combination of trade regimes. In response to the severe drought conditions, white and yellow maize are imported in 2007. The sharp increase in imports and the corresponding rise in the domestic market prices of white and yellow maize (to the upper border parity price boundary) are consistent with economic theory. Figure 5.2 might be confusing in the sense that the yellow maize market is trading at import parity levels for two years (2006 and 2007) in succession. The yellow maize model is already trading at import parity levels in 2006 due to very low plantings in the 2005/06 production season and not because of any shock that was already introduced in 2006. Chapter 2 explains why the yellow maize market tends to trade under import parity more frequently than the white maize market.

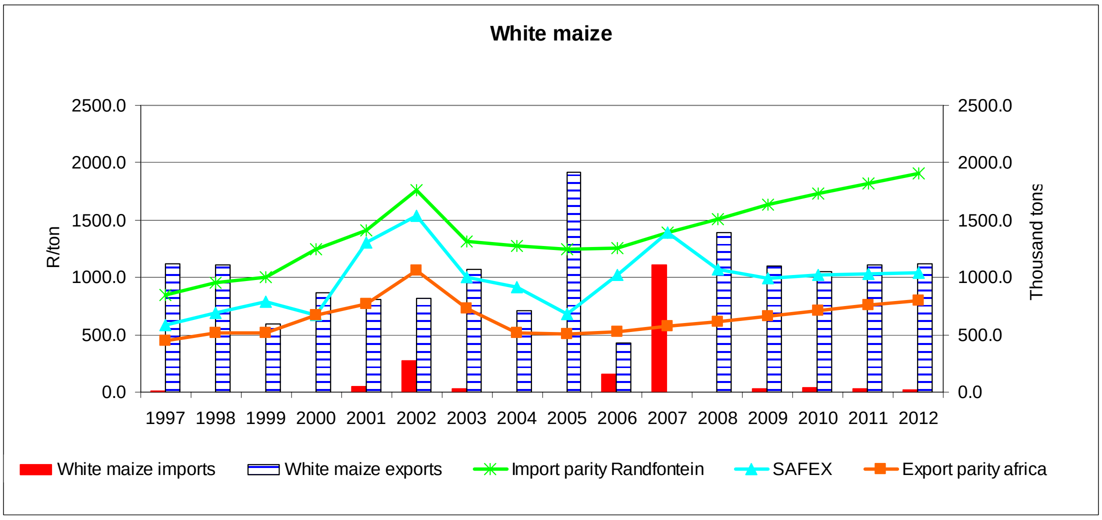

Figure 5.1: Baseline 1 - Price space for white maize, 1997 – 2012

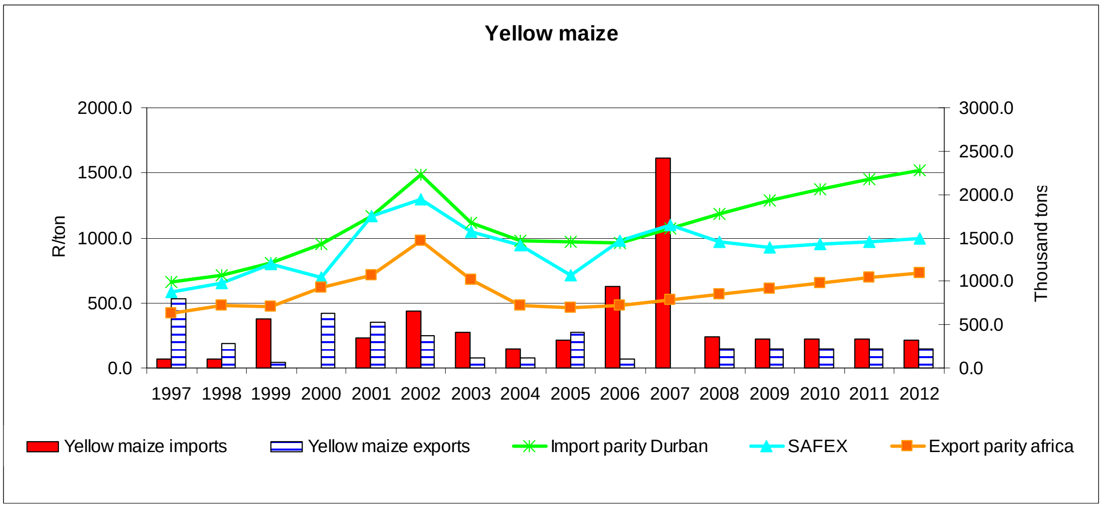

Figure 5.2: Baseline 1 - Price space for yellow maize, 1997 – 2012

Although imports increase sharply in response to a shock in the yields, the wheat domestic price is not affected by the drought conditions because the wheat market has been trading at import parity levels all along. It is interesting to note that figure 5.3 clearly illustrates the structural shift (also mentioned in chapter 2) that took place in the relationship between the domestic price and the import parity price after the sharp decrease in the value of the Rand in 2002. Whereas wheat traded slightly under the Randfontein import parity price before the sharp depreciation of the Rand, the domestic wheat price is now trading right on top of the Randfontein import parity price. Large volumes of wheat are transported to the inland and one can argue that the reference point for the import parity price should be Randfontein.

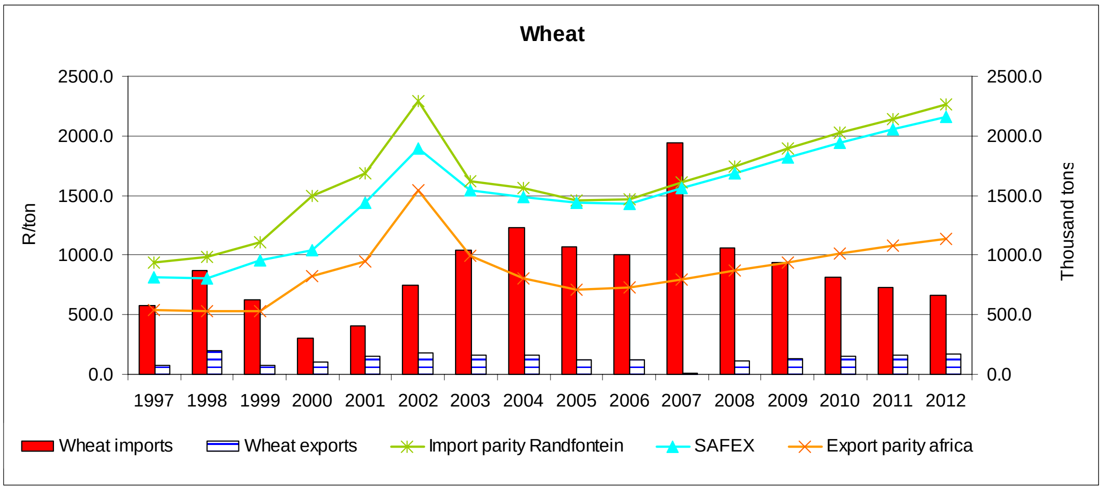

Figure 5.3: Baseline 1 - Price space for wheat, 1997 – 2012

Tables 5.5 through to 5.7 present the second set of baseline projections where white and yellow maize trade under autarky and wheat trades under import parity. Now special assumptions are made and no shocks are imposed to simulate this version of the baseline. Apart from the standard macroeconomic assumptions and world price forecasts, it is assumed that normal weather conditions will prevail into the future. The white and yellow maize markets are trading in near-autarky from 2007 onwards because domestic production meets consumption. The wheat market is trading under import parity. This set of baseline projections is used for the scenario evaluation exercise that is presented in the final section of this chapter.

Table 5.5: Baseline 2 - White maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
White maize area harvested	973.0	1613.7	1548.3	1502.5	1549.1	1556.1	1535.8
				t/ha			
White maize average yield	3.64	3.67	3.70	3.73	3.76	3.79	3.82
				Thousand tons			
White maize production	3538.1	5922.1	5732.3	5610.1	5831.6	5903.7	5870.6
White maize feed consumption	644.0	659.0	658.1	656.9	672.4	695.0	709.6
White maize human consumption	3696.1	3745.2	3742.3	3717.4	3708.0	3699.6	3682.7
White maize domestic use	4585.1	4729.2	4725.5	4699.3	4705.4	4719.6	4717.2
White maize ending stocks	1035.4	1237.1	1284.9	1260.2	1344.0	1435.6	1490.8
White maize exports	431.2	1038.3	1013.3	995.0	1077.9	1116.9	1121.3
White maize imports	157.7	47.0	54.2	59.5	35.6	24.4	23.1
				R/ton			
White maize domestic price	1025.6	954.4	969.7	1029.5	1036.9	1030.4	1041.7

Table 5.6: Baseline 2 - Yellow maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Yellow maize area harvested	575.0	984.4	977.2	964.6	970.9	968.8	970.3
				t/ha			
Yellow maize average yield	4.10	3.95	4.00	4.04	4.08	4.13	4.17
				Thousand tons			
Yellow maize production	2355.7	3891.9	3907.5	3899.4	3966.0	3997.1	4041.8
Yellow maize domestic use	3295.5	3419.7	3517.0	3566.5	3619.5	3656.5	3698.6
Yellow maize feed consumption	3921.7	3847.8	3945.5	3992.5	4043.8	4078.9	4119.0
Yellow maize human consumption	242.3	246.1	246.5	243.9	242.3	240.4	238.3
Yellow maize ending stocks	566.9	762.2	855.3	885.3	922.7	949.7	977.5
Yellow maize exports	940.0	364.5	347.6	341.1	334.4	329.1	326.0
Yellow maize imports	98.6	213.3	216.6	217.9	219.3	220.3	220.9
				R/ton			
Yellow maize domestic price	976.9	907.7	896.0	935.4	951.6	971.6	995.4

Table 5.7: Baseline 2 - Wheat

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Wheat summer area harvested	530.5	490.0	508.8	532.6	553.9	570.9	590.6
Wheat winter area harvested	323.5	321.4	324.9	332.5	339.7	345.3	351.1
				t/ha			
Wheat average yield: Summer area	2.71	2.73	2.75	2.77	2.78	2.80	2.82
Wheat average yield: Winter area	1.70	1.70	1.71	1.71	1.71	1.71	1.71
				Thousand tons			
Wheat production	1988.1	1885.0	1952.7	2041.5	2123.2	2190.4	2266.1
Wheat feed consumption	90.7	75.4	68.3	65.1	60.8	57.0	54.6
Wheat human consumption	2751.8	2731.2	2724.8	2722.1	2712.3	2700.2	2693.9
Wheat domestic use	2862.2	2826.3	2812.8	2806.8	2792.8	2776.9	2768.2
Wheat ending stocks	611.2	599.8	586.2	572.9	561.7	551.2	544.2
Wheat exports	123.9	118.3	127.5	137.9	148.2	157.3	166.2
Wheat imports	1003.1	1048.3	974.0	890.0	806.6	733.3	661.2
				R/ton			
Wheat domestic price	1433.2	1564.2	1685.1	1822.8	1940.9	2054.3	2163.7

Despite a significant level of trade occurring, baseline projections (figure 5.4 and 5.5) suggest that the domestic prices of white and yellow maize fall consistently within what Barrett (1999) refers to as the "non-tradables band" established by the import and export parity price band. This is typical of the condition of local the market which this study refers to as "near-autarky". Although prices fall in the non-tradables band, trade occurs to neighbouring countries. White and yellow maize prices are projected to decrease in 2007 in response to increased production and then level off as production and consumption stabilise.

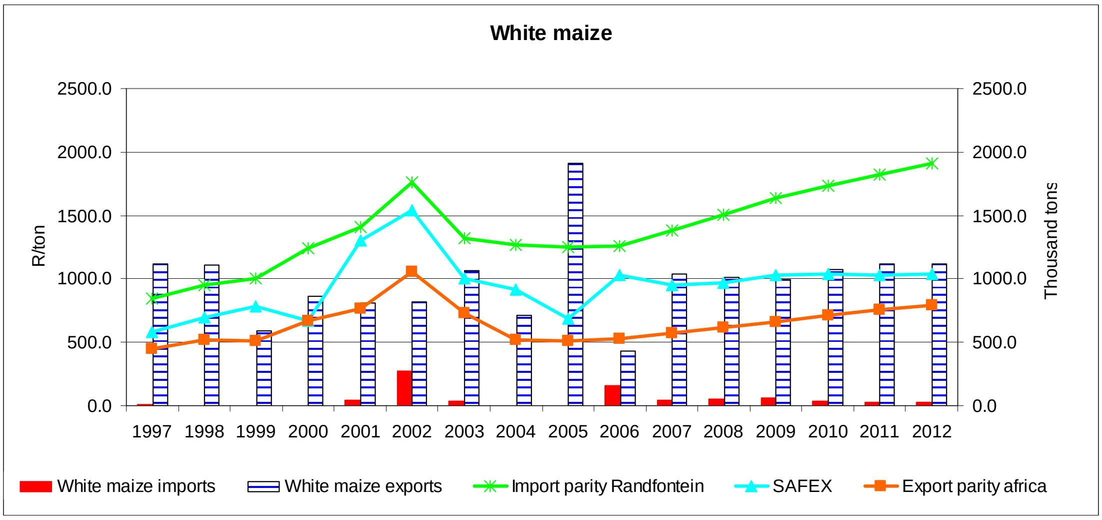

Figure 5.4: Baseline 2 - Price space for white maize, 1997 – 2012

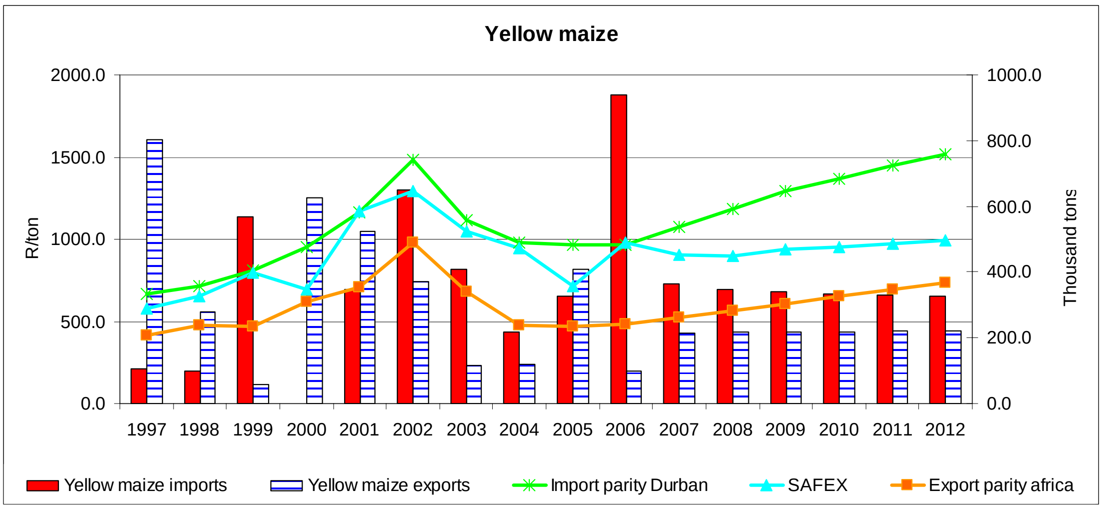

Figure 5.5: Baseline 2 - Price space for yellow maize, 1997 – 2012

The domestic wheat price is projected to increase as import parity prices increase. Although a decline in wheat imports is projected, the wheat market will remain at import parity levels throughout 2012.

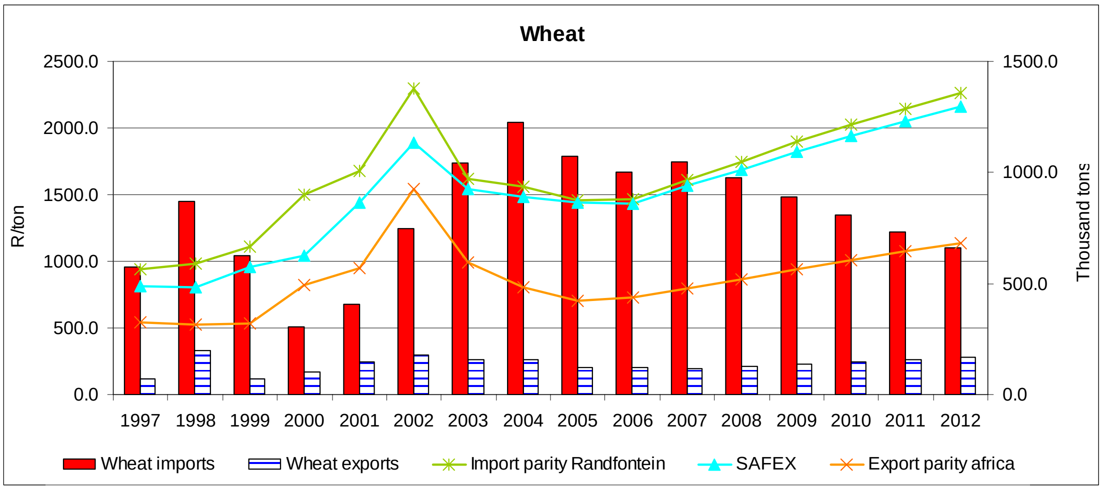

Figure 5.6: Baseline 2 - Price space for wheat, 1997 – 2012

The third set of baseline projections is generated where white maize trades under export parity, yellow maize trades under autarky, and wheat trades under import parity. This combination of trade regimes is established by assuming that favourable weather conditions induce record yields and therefore surpluses that are exported. The white maize model automatically switches to close under the export parity model closure technique, the yellow maize model closes under near-autarky, and the wheat model closes under import parity.

Table 5.8: Baseline 3 – White maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
White maize area harvested	973.0	1631.8	1188.2	1450.0	1553.9	1567.0	1535.2
				t/ha			
White maize average yield	3.64	4.83	3.70	3.73	3.76	3.79	3.82
				Thousand tons			
White maize production	3538.1	7800.0	4399.2	5414.1	5849.5	5945.2	5868.3
White maize feed consumption	644.0	749.6	727.0	638.5	669.8	694.4	710.4
White maize human consumption	3696.1	3913.2	3766.5	3711.0	3702.9	3699.9	3683.0
White maize domestic use	4585.1	4987.8	4818.4	4674.5	4697.7	4719.3	4718.3
White maize ending stocks	1035.4	2227.6	1342.6	1216.7	1322.1	1439.5	1492.3
White maize imports	157.7	0.0	164.6	75.2	34.7	20.8	23.3
White maize exports	431.2	1620.1	630.4	940.7	1081.1	1129.2	1120.5
				R/ton			
White maize domestic price	1025.6	585.1	914.7	1044.9	1049.6	1029.6	1040.9

Table 5.9: Baseline 3 – Yellow maize

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Yellow maize area harvested	575.0	984.4	854.8	999.3	962.1	971.5	969.0
				t/ha			
Yellow maize average yield	4.10	4.57	4.00	4.04	4.08	4.13	4.17
				Thousand tons			
Yellow maize production	2355.7	4500.0	3418.1	4039.5	3930.0	4008.3	4036.7
Yellow maize domestic use	3295.5	3665.0	3398.5	3612.5	3615.3	3660.2	3697.3
Yellow maize feed consumption	3921.7	4107.1	3822.9	4039.7	4039.2	4082.8	4117.6
Yellow maize human consumption	242.3	260.1	242.4	245.3	241.9	240.6	238.3
Yellow maize ending stocks	566.9	1050.9	793.1	911.2	918.7	952.4	976.8
Yellow maize exports	940.0	314.4	361.0	337.1	335.7	328.7	326.1
Yellow maize imports	98.6	223.2	214.0	218.7	219.0	220.4	220.9
				R/ton			
Yellow maize domestic price	976.9	638.2	974.8	909.8	960.2	968.7	996.4

Table 5.10: Baseline 3 – Wheat

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Wheat summer area harvested	530.5	490.0	571.2	554.3	557.4	569.8	590.3
Wheat winter area harvested	323.5	303.3	331.9	338.5	340.8	345.4	351.0
				t/ha			
Wheat average yield: Summer area	2.71	3.67	2.75	2.77	2.78	2.80	2.82
Wheat average yield: Winter area	1.70	2.64	1.71	1.71	1.71	1.71	1.71
				Thousand tons			
Wheat production	1988.1	2600.0	2136.3	2111.6	2134.8	2187.5	2265.0
Wheat feed consumption	90.7	48.4	72.7	63.9	61.7	56.8	54.6
Wheat human consumption	2751.8	2664.0	2715.2	2724.7	2714.3	2700.1	2693.8
Wheat domestic use	2862.2	2732.0	2807.5	2808.2	2795.6	2776.5	2768.1
Wheat ending stocks	611.2	599.3	587.6	574.6	562.9	551.7	544.3
Wheat exports	123.9	207.4	148.1	145.4	149.2	157.1	166.1
Wheat imports	1003.1	327.5	807.7	829.0	798.4	734.9	661.9
				R/ton			
Wheat domestic price	1433.2	1564.2	1685.1	1822.8	1940.9	2054.3	2163.7

Baseline results under the third combination of trade regimes project that the domestic white maize price will fall to the lower border parity price boundary (export parity price) in 2007 as exports increase rapidly. Although the yellow maize model closes under near-autarky and the domestic yellow maize price is projected to move closer to export parity levels, the model projects that the domestic yellow maize price will trade at approximately R50/ton above the domestic white maize price. An analysis of price trends over the past decade shows clearly that in the years when large surpluses of maize are being produced, white maize tends to be cheaper than yellow maize. Industry experts currently estimate this margin to be between R40/ton and R50/ton.

Table 5.9 shows an increase in the use of white maize for feed compared to the first and second baseline projections. White maize will only be used for animal feed if it is sufficiently cheaper than yellow maize to compensate for the additional supplements that have to be included in the ration if white maize is fed. This again proves that the model has the ability to produce reliable projections of the evolution of the sector under alternative shocks.

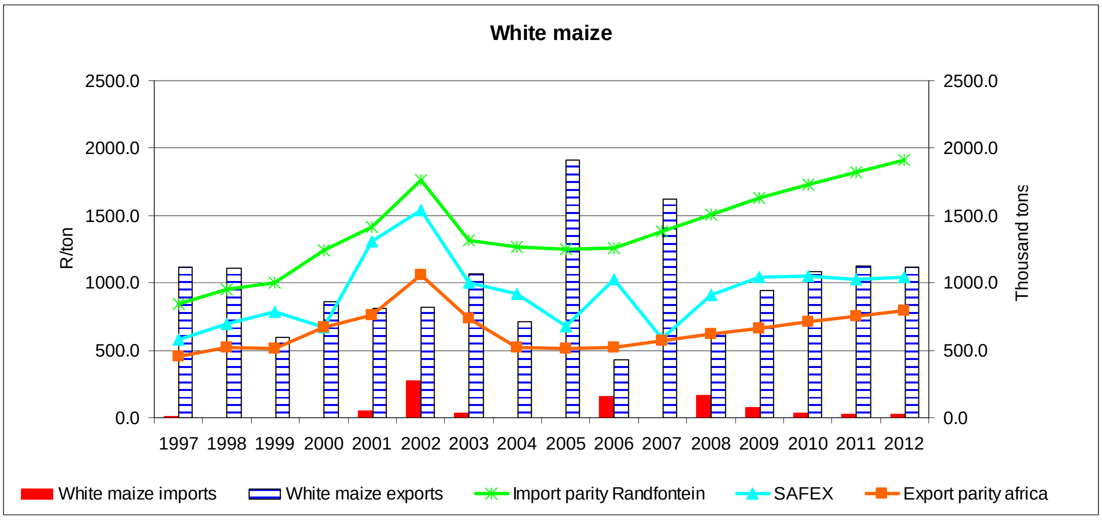

Figure 5.7: Baseline 3 - Price space for white maize, 1997 – 2012

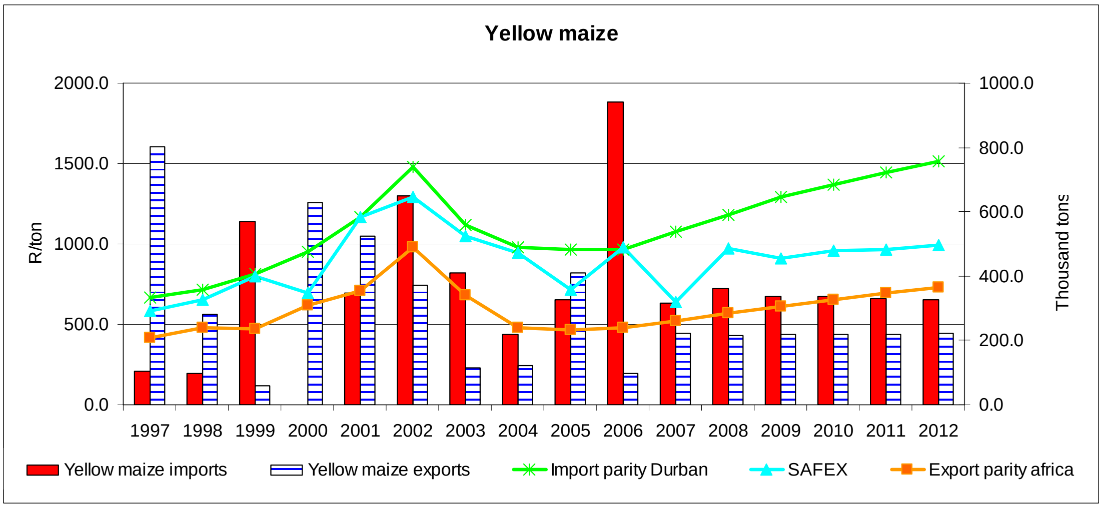

Figure 5.8: Baseline 3 - Price space for yellow maize, 1997 – 2012

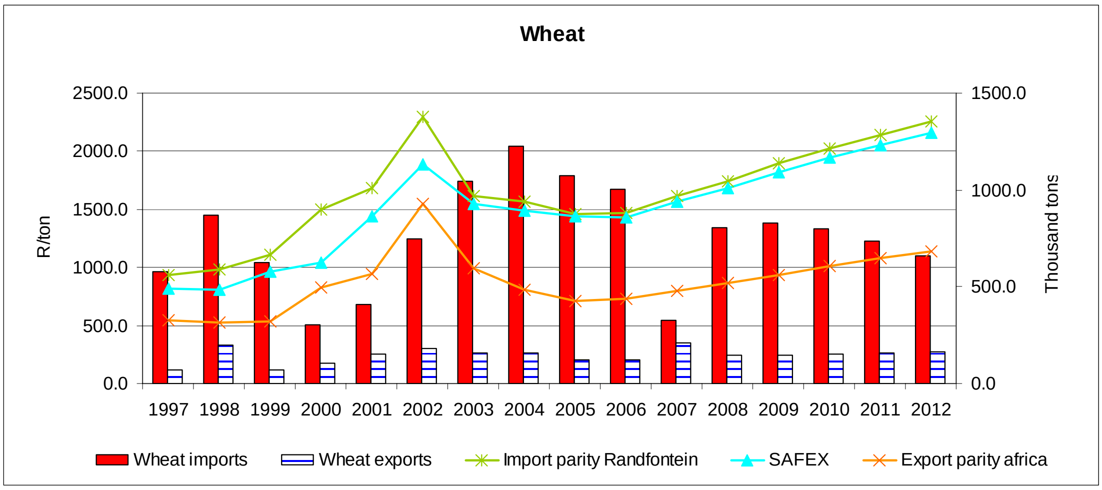

Figure 5.9: Baseline 3 - Price space for wheat, 1997 – 2012

Finally, the recursive effects that take place in the model have to be stressed. Recursive effects are clearly illustrated in the model where the forecast values of the various baseline projections differ over the period 2008 - 2010. This is due to the methodology of price expectations that is applied in the model. For example, the 2008 maize area harvested in baseline 1 is higher than the 2008 maize area harvested in baselines 2 and 3. This is caused by farmers responding to the higher producer prices (at import parity levels) in 2007 and increasing plantings in 2008. What is also worth mentioning is that although the wheat model closes only under import parity and the drought has no direct impact on the level of domestic prices, cross-commodity linkages in the model induce shifts in the area harvested to wheat, and the level of human and feed consumption.

The baseline projections show that by switching between different closure techniques, the new regime-switching model captures the salient features of the grain markets trading under a combination of different trade regimes. This section only illustrates the model's ability to simulate realistic projections of endogenous variables under different regimes. The next step is to determine if the model is able to distinguish between the level of integration between domestic and world markets when a switch in market regimes occurs.

5.3 IMPACT MULTIPLIERS

A shift in parity prices, which is imposed on the model under the various regimes, will be used to illustrate how the integration between world and domestic prices changes as the equilibrium pricing conditions change. The impact of a 10 percent increase in parity prices on domestic prices and trade flow is calculated by comparing the scenario results to the baseline projections under a combination of different trade regimes in the grain market. If the parity price shock for each grain is applied to the three different regime combinations one by one, it implies that six scenarios will be analysed. The shock in the parity prices is introduced in 2007. The actual tables are developed by presenting the absolute and percentage changes from the 2007 baseline values as presented in the baseline section above. Tables 5.11 through to 5.16 present the results of the impact multipliers for each of the scenarios.

Only the impact multipliers for year one and two (2007 and 2008) after the 10 percent shock are included in the tables below to illustrate the current and lagged effects of the shock. The full tables that show how the model settles down after oscillating, are included in Appendix B.

Table 5.11: 10 percent increase in the white maize parity prices – import parity regime

	2007			2008		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1590.8	0.0	0.0%	1878.0	90.6	4.8%
Production	2500.0	0.0	0.0%	6953.3	335.4	4.8%
Ending Stock	280.0	0.0	0.0%	1181.3	152.4	12.9%
Human Consumption	3545.2	-32.7	-0.9%	3699.6	33.0	0.9%
Feed Consumption	493.2	-17.5	-3.6%	634.9	4.8	0.8%
Exports	0.0	0.0		1392.6	145.1	
Imports	1108.0	-50.2		0.0	0.0	
Domestic Price	1394.1	128.1	9.2%	1067.0	-75.1	-7.0%

Table 5.12: 10 percent increase in the white maize parity prices – autarky regime

	2007			2008		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1613.7	0.0	0.0%	1548.3	36.5	2.4%
Production	5922.1	0.0	0.0%	5732.3	135.1	2.4%
Ending Stock	1237.1	-25.3	-2.0%	1284.9	43.3	3.4%
Human Consumption	3745.2	5.9	0.2%	3742.3	7.7	0.2%
Feed Consumption	659.0	-11.6	-1.8%	658.1	5.0	0.8%
Exports	1038.3	24.1		1013.3	41.7	
Imports	47.0	-7.0		54.2	-12.0	
Domestic Price	954.4	43.3	4.5%	969.7	-17.5	-1.8%

Table 5.13: 10 percent increase in the white maize parity prices – export parity regime

	2007			2008		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1631.8	0.0	0.0%	1188.2	62.4	5.3%
Production	7800.0	0.0	0.0%	4399.2	231.2	5.3%
Ending Stock	2227.6	-90.6	-4.1%	1342.6	43.0	3.2%
Human Consumption	3913.2	-2.8	-0.1%	3766.5	6.1	0.2%
Feed Consumption	749.6	-24.6	-3.3%	727.0	3.3	0.5%
Exports	1620.1	117.9		630.4	68.4	
Imports	0.0	0.0		164.6	-19.7	
Domestic Price	585.1	62.3	10.6%	914.7	-13.9	-1.5%

Table 5.14: 10 percent increase in the yellow maize parity prices – import parity regime

	2007			2008		
Yellow Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	984.4	0.0	0.0%	1052.4	47.5	4.5%
Production	1000.0	0.0	0.0%	4208.5	189.9	4.5%
Ending Stock	230.0	0.0	0.0%	711.9	87.6	12.3%
Human Consumption	236.3	-6.0	-2.5%	242.8	4.2	1.7%
Feed Consumption	3345.4	-101.7	-3.0%	3447.6	81.4	2.4%
Exports	0.0	0.0		214.2	2.8	
Imports	2426.8	-107.7		359.9	-13.9	
Domestic Price	1095.6	114.7	10.5%	968.5	-81.8	-8.4%

Table 5.15: 10 percent increase in the yellow maize parity prices – autarky regime

	2007			2008		
Yellow Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	984.4	0.0	0.0%	977.2	6.9	0.7%
Production	3891.9	0.0	0.0%	3907.5	27.4	0.7%
Ending Stock	762.2	-10.6	-1.4%	855.3	8.2	1.0%
Human Consumption	246.1	-1.1	-0.5%	246.5	0.5	0.2%
Feed Consumption	3419.7	-2.3	-0.1%	3517.0	6.0	0.2%
Exports	213.3	2.3		216.6	0.3	
Imports	364.5	-11.7		347.6	-1.7	
Domestic Price	907.7	21.5	2.4%	896.0	-10.2	-1.1%

Table 5.16: 10 percent increase in the wheat parity prices – import parity regime

		2007			2008		
Wheat		Baseline	Absolute	%	Baseline	Absolute	%
	Area Harvested:Summer	490.0	0.0	0.0%	481.7	18.9	3.9%
	Area Harvested:Winter	344.3	0.0	0.0%	328.7	10.4	3.2%
	Production	980.0	0.0	0.0%	1884.7	69.7	3.7%
	Ending Stock	599.0	-18.5	-3.1%	587.3	-9.5	-1.6%
	Human Consumption	2811.2	-8.7	-0.3%	2741.9	-13.2	-0.5%
	Feed Consumption	98.8	0.6	0.6%	75.2	-7.2	-9.6%
	Exports	7.5	2.9		117.2	8.9	
	Imports	1945.0	-23.6		1057.6	-72.3	
	Domestic Price	1564.2	140.6	9.0%	1685.1	0.0	0.0%

Tables 5.11 through to 5.16 do not present the ordinary single-equation multipliers, but rather impact multipliers that reflect a full model response to a shock. Only absolute deviations from the baseline are reported for imports and exports in each of the six scenarios. The reason for this is that trade is by definition smaller in the near-autarky case and, therefore, the percentage deviations will exaggerate the impact of a shock in parity prices on net trade.

Results suggest that a shift in equilibrium pricing conditions changes the correlation between domestic and world prices and, therefore, different impact multipliers in response to a 10 percent shift in parity prices are generated under the various trade regimes. There is a higher level of integration between domestic and world grain markets under the import/export parity regimes than under near-autarky. The absolute changes in imports and exports in response to a 10 percent increase in the parity prices of each commodity demonstrate that the absolute changes in trade are larger under import and export parity than in near-autarky. Chapter 4 shows that because some trade still occurs under near-autarky, net trade is modelled as a function of parity prices and the exchange rate when the grain markets are trading under near-autarky. Subsequently, these variables will have an impact on the domestic price.

In the case of the domestic price of white maize, an impact multiplier of 4.5 percent was simulated under near-autarky compared to an impact multiplier of 9.2 percent and 10.6 percent simulated for import and export parity respectively. In the case of the domestic price for yellow maize, an impact multiplier of 2.4 percent was simulated under near-autarky compared to an impact multiplier of 10.5 percent simulated for import parity. The integration between domestic and world markets is also highlighted by the level of trade that is higher under import and export parity than in near-autarky. A shift in domestic prices not only shifts net trade, but also induces a shift in domestic production and consumption levels. An increase in domestic prices generally reduces domestic human and feed consumption and increases the area harvested in 2008.

The wheat model has the most basic structure and is only set up to solve for prices under an import parity market regime. Therefore, only the impact multipliers for the import parity scenario can be presented. In response to a 10 percent increase in the parity price, the domestic wheat price increases by 9 percent. Farmers respond to the higher domestic prices and the area harvested in 2008 increases by 3.9 percent and 3.2 percent in the summer and winter region, respectively.

The price and trade impact multipliers for the alternative regimes are summarised in table 5.17.

Table 5.17: Price and trade impact multipliers under alternative market regimes, 2007

	Import parity			Near - Autarky			Export parity		
	Baseline	Absolute	%	Baseline	Absolute	%	Baseline	Absolute	%
White Maize									
Exports	0.0	0.0		1038.3	24.1		1620.1	117.9	
Imports	1108.0	-50.2		47.0	-7.0		0.0	0.0	
Domestic Price	1394.1	128.1	9.2%	954.4	43.3	4.5%	585.1	62.3	10.6%
Yellow Maize									
Exports	0.0	0.0		213.3	2.3				
Imports	2426.8	-107.7		364.5	-11.7				
Domestic Price	1095.6	114.7	10.5%	907.7	21.5	2.4%			
Wheat									
Exports	7.5	2.9							
Imports	1945.0	-23.6							
Domestic Price	1564.2	140.6	9.0%						

5.4 THE OLD VERSUS THE NEW MODEL

Another aspect of the hypothesis that needs to be tested is whether a model that takes account of a switch in market regimes has an advantage, with respect to the modelling of real-world issues, over a model that just makes use of a single linear method of price determination. In order to prove that the switching mechanism improves the model's ability to track real-world issues, the previous version of the BFAP sector model, referred to as the "old model", is used to simulate one of the scenarios that were presented in the section above. Similar to models that are usually applied in policy evaluation, the old sector model applies just a single linear method of price determination. Therefore, the old model does not consist of any switching mechanisms between different model closure techniques. The white and yellow maize models are closed under autarky, which implies that the estimated price transmission elasticities are likely to be moderate, understating the true elasticity when supplies were either large or small relative to domestic demand, but overstating the true response when domestic supply and demand are in balance. Hence, in order to clearly show the advantage of the regime-switching model, a scenario has to be selected where the white and yellow maize markets are not trading under autarky, but rather under import parity or export parity.

The first baseline results of the regime-switching model (tables 5.2 and 5.3) were generated under the combination of trade regimes where all three grain markets are trading under import parity. This combination was introduced by making the assumption that a severe drought will decrease maize yields sharply and will cause a shortage in the market. When the same scenario is simulated in the old model, the output of the two models can be compared. The results of the old model are presented in tables 5.18 and 5.19. Figures 5.10 and 5.11 graphically illustrate the price space and the impact multipliers are presented in tables 5.20 and 5.21.

Table 5.18: White maize baseline projections – old model

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
White maize area harvested	973.0	1590.8	2128.7	1375.5	1539.3	1552.2	1541.9
				t/ha			
White maize average yield	3.64	1.57	3.70	3.73	3.76	3.79	3.82
				Thousand tons			
White maize production	3538.1	2500.0	7881.4	5136.1	5794.5	5889.0	5894.1
White maize feed consumption	644.0	432.7	589.0	708.1	659.0	696.0	708.4
White maize human consumption	3696.1	3198.2	3790.5	3722.7	3707.4	3697.0	3682.9
White maize domestic use	4585.1	3955.9	4704.4	4755.8	4691.4	4718.0	4716.2
White maize ending stocks	1035.4	280.0	1630.8	1267.8	1336.6	1422.8	1493.0
White maize imports	157.7	744.1	0.0	102.5	37.4	26.1	21.0
White maize exports	431.2	0.0	1826.2	845.8	1071.7	1110.9	1128.6
				R/ton			
White maize domestic price	1025.6	2156.9	860.2	1016.9	1038.2	1037.1	1041.1

Table 5.19: Yellow maize baseline projections – old model

	2006	2007	2008	2009	2010	2011	2012
				Thousand hectares			
Yellow maize area harvested	575.0	984.4	1277.5	837.3	1009.3	958.4	974.0
				t/ha			
Yellow maize average yield	4.10	1.02	4.00	4.04	4.08	4.13	4.17
				Thousand tons			
Yellow maize production	2355.7	1000.0	5108.3	3384.7	4122.8	3954.2	4057.2
Yellow maize domestic use	3295.5	2485.4	3855.8	3422.6	3658.2	3645.8	3702.9
Yellow maize feed consumption	3921.7	2861.2	4299.1	3843.2	4084.1	4067.6	4123.4
Yellow maize human consumption	242.3	193.8	261.3	238.6	243.9	239.9	238.5
Yellow maize ending stocks	566.9	230.0	1112.6	796.2	945.0	942.0	980.4
Yellow maize exports	940.0	1675.6	299.5	357.1	330.0	330.6	325.5
Yellow maize imports	98.6	0.0	226.2	214.7	220.1	220.0	221.0
				R/ton			
Yellow maize domestic price	976.9	1914.4	611.6	1038.3	921.3	982.2	991.6

After the yields in 2007 are reduced due to severe drought, the old model projects that prices will increase sharply to R2156/ton and R1914/ton for white and yellow maize respectively. It is clear that prices increase way beyond import parity prices, as illustrated in figures 5.10 and 5.11. Due to the unrealistically high domestic prices, consumption decreases sharply and imports do not rise to the same extent as was the case with the baseline 1 projections of the regime-switching model. The lagged effects in the baseline projections also suggest that the areas planted in 2008 are overestimated due to the high domestic prices in 2007. Whereas tables 5.2 and 5.3 show that the areas harvested under white and yellow maize will in 2008 increase to 1.8 million and 1 million hectares respectively, tables 5.18 and 5.19 show that the old model projects that the areas harvested under white and yellow maize will increase to 2.1 million and 1.2 million hectares respectively.

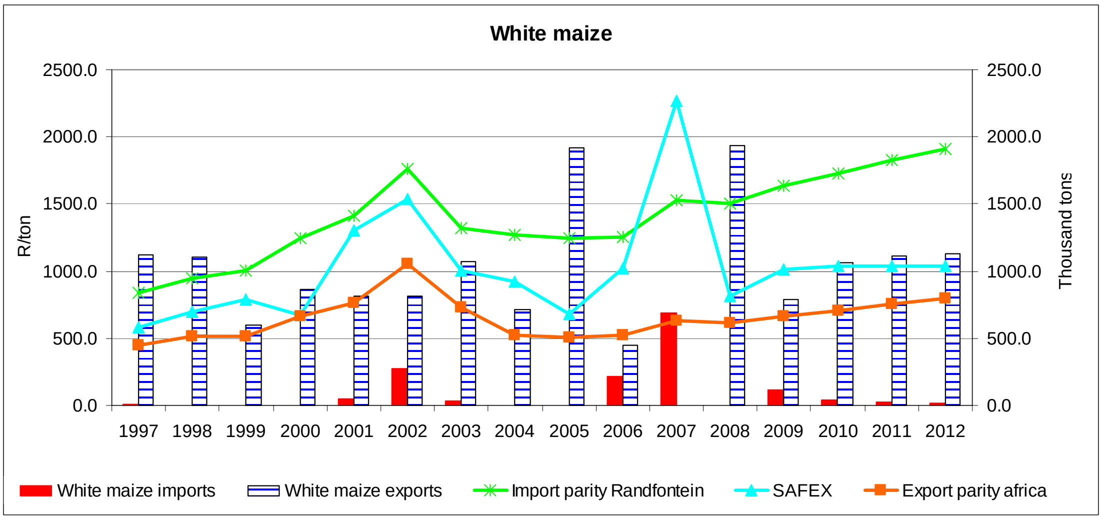

Figure 5.10: Price space for white maize – old model, 1997 – 2012

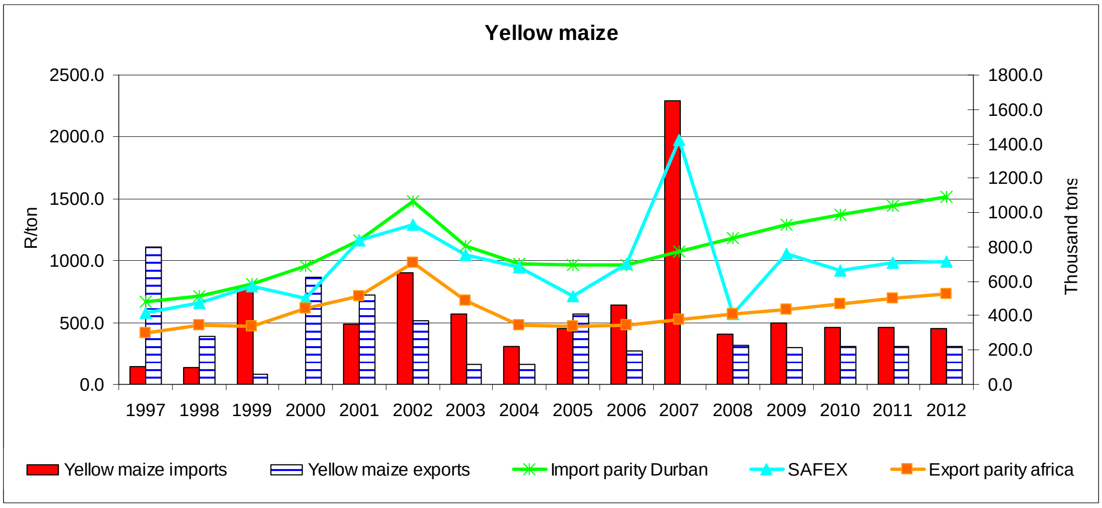

Figure 5.11: Price space for yellow maize – old model, 2007 – 2012

This scenario relates well to the example used in the opening chapter of this study where the possible impact of a drought was used to illustrate the impact of alternative model closure techniques on the formation of prices. Although the old model was set up to solve for prices within the domestic market and therefore takes the local production and consumption levels into account, the model was not bound by the import parity levels. Figures 5.10 and 5.11 show clearly how the white and yellow maize models solve for unrealistically high prices.

Apart from the unrealistically high prices, the impact multipliers (tables 5.20 and 5.21) show that the correlation between domestic and parity prices is low, despite high volumes of imports. A 10 percent increase in the parity prices in 2007 results in a 5.1 percent increase in the white maize price and a 3.1 percent increase in the yellow maize price. As mentioned by Barrett (1999), if a commodity moves from a non-tradable to an importable equilibrium, the correlation between the parity price and the local market prices should jump from zero to significantly positive, to one if the law of one price holds strictly. Table 5.17 shows how the regime-switching model that was developed in this study complies with *a priori* expectations and simulates an increase in the domestic white maize price of 9.2 percent and yellow maize price of 10.5 percent due to a 10 percent increase in the parity price. The results highlight what Barrett and Li (2002) referred to as the "messy character of market relationships" arising from treating price transmissions mostly as a linear phenomenon. This proves that the regime-switching methodology that was developed to allow the new sector model to switch between various techniques of model closure, provides the model with the ability to simulate the most realistic formation of equilibrium prices under switch market regimes and is therefore consistent with the hypothesis of this study.

Table 5.20: White maize impact multipliers – old model, 2007

	2007			2008		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1618.8	0.0	0.0%	2128.7	72.6	3.4%
Production	2500.0	0.0	0.0%	7881.3	268.8	3.4%
Ending Stock	280.0	0.0	0.0%	1630.8	130.2	8.0%
Human Consumption	3198.2	-24.6	-0.8%	3790.4	21.7	0.6%
Feed Consumption	432.7	-32.7	-7.6%	589.0	10.0	1.7%
Exports	0.0			1826.2	106.7	
Imports	744.1			0.0	0.0	
Domestic Price	2156.8	110.3	5.1%	860.2	-49.3	-5.7%

Table 5.21: Yellow maize impact multipliers – old model, 2007

	2007			2008		
Yellow Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1115.3	0.0	0.0%	1277.5	21.1	1.7%
Production	1000.0	0.0	0.0%	5108.3	84.4	1.7%
Ending Stock	230.0	0.0	0.0%	1112.6	40.2	3.6%
Human Consumption	193.8	-3.0	-1.6%	261.3	2.0	0.8%
Feed Consumption	2485.4	-23.8	-1.0%	3855.8	34.1	0.9%
Exports	0.0	0.0		226.2	1.3	
Imports	1675.6	-26.9		299.5	-6.6	
Domestic Price	1914.4	58.6	3.1%	611.6	-38.9	-6.4%

For this section an import parity scenario was specifically selected to highlight the difference between the old and new versions of the model. Although the difference between the two models will be smaller if white and yellow maize are trading under near-autarky, there are other improvements to the new model that need to be considered that will also distinguish the new from the old model. Apart from the advantage of the switching mechanism, the new version of the sector model also incorporates parity prices into the trade and price equations, which implies that shocks to the transaction costs can also be simulated in the model. The old model only included world prices and exchange rates in the price and trade components. The advantage of incorporating parity prices is illustrated clearly in section 5.6, where the scenario analysis of real-world issues is undertaken.

5.5 ELASTICITY MATRICES

Elasticity matrices provide a very helpful summary of all the own price and cross-price effects in the model. These effects help to better understand the dynamic interaction between various commodities in the model, especially when market-related scenarios are analysed that cover a number of the commodities in the model.

The following matrices present system elasticities (response) that are generated in the sector model. A 10 percent shock is introduced in the domestic prices in 2006, and the resulting elasticity point estimates are generated by the model. Although this study only focuses on the maize and wheat sectors, the area elasticities for all the grains are presented in table 5.22. Table 5.23 presents the elasticities for the human consumption response of white maize, yellow maize and wheat to a 10 percent increase in domestic prices and table 5.24 presents the elasticities for the feed grain consumption response to a 10 percent increase in the domestic price.

Table 5.22: Area harvested own and cross price elasticity matrix, 2006

	Price						
Area harvested	**W maize**	**Y maize**	**Wheat**	**Sunflower**	**Sorghum**	**Soybean**	**All 6 prices**
White maize	**0.535**	0.040	-0.110	-0.300	-0.003	-0.272	0.234
Yellow maize	-0.049	**0.340**	-0.046	-0.016	-0.003	-0.020	0.234
Summer wheat	-0.258	-0.141	**0.755**	-0.080	-0.013	-0.104	0.234
Winter wheat	-0.089	-0.049	**0.371**	-0.028	-0.005	-0.036	0.234
Sunflower	-0.198	-0.108	-0.185	**0.752**	-0.010	-0.021	0.234
Sorghum	-0.072	-0.039	-0.067	-0.022	**0.429**	-0.029	0.234
Soybean	-0.011	-0.007	-0.011	-0.004	-0.001	**0.245**	0.234
Total area	0.073	0.039	0.068	0.022	0.004	0.029	**0.234**

The calculated area elasticity matrix complies with *a priori* expectations, capturing the own price effect and the substitution between the alternative crops in the form of the cross-price elasticities. It is important to note that the sum of the individual responses to a shock in price is equal to the total response if all prices are shocked simultaneously.

Table 5.23: Human grain consumption own and cross-price elasticity matrix, 2006

	Prices			
Human Consumption	W maize	Y maize	Wheat	All 3 prices
White maize	**-0.137**	0.000	0.083	-0.054
Yellow maize	0.000	**-0.173**	0.000	-0.173
Wheat	0.073	0.000	**-0.137**	-0.064
Total human consumption	-0.045	-0.007	-0.011	**-0.063**

The system elasticities of human consumption stress the findings (chapter 4) that white maize and wheat products can be regarded as staple food and, therefore, price inelastic.

Table 5.24: Feed grain consumption cross-price elasticity matrix, 2006

	Prices			
Feed Consumption	W maize	Y maize	Wheat	All 3 prices
White maize	**-0.95**	0.74	0.05	-0.17
Yellow maize	0.15	**-0.45**	0.03	-0.28
Wheat	0.28	0.79	**-1.22**	-0.17
Total feed consumption	-0.02	-0.23	0.01	**-0.24**

System elasticities of domestic feed consumption comply with *a priori* expectations. The white maize and wheat feed markets are very small compared to the yellow maize feed market, and therefore the own price elasticities for white maize and wheat are high compared to the own price elasticity of yellow maize. Whereas white maize and wheat have a very small cross-effect on yellow maize, a shift in the yellow maize price results in a relatively large shift in the white maize and wheat feed markets.

5.6 SCENARIO ANALYSIS

This section presents the combination of shocks that are introduced in the model in the form of a scenario. Scenarios represent a sequence of events that take place in a logical way in order to present the possible outcome of reality. Various scenarios can be developed by the inclusion of short-term and long-term assumptions and can be presented in the form of short- and long-run impact multipliers. A distinction needs to be made between once-off or sustained shocks to one or a combination of the exogenous variables.

In this section once-off and sustained shocks are performed on important exogenous variables within the system to examine short-run as well as long-run impacts on all endogenous variables. These impacts are presented in the form of absolute and percentage changes (impact multipliers). Although percentages provide a very clear idea of what the total effect of a shock on the system is, they might be misleading (especially in the case of trade) because percentage changes can turn out to be very large simply because the baseline absolute values are very small and the relative changes large.

To ensure that the model is truly applied to real-world issues, the scenario that is presented in this section is not specifically designed for the academic purpose of this study, but was selected from a range of scenarios developed to analyse the possible impact of ethanol production from maize on the South African agricultural industry. Some of the assumptions in the scenario focus more on the shift of economic drivers in the market place (for example exchange rates and world prices) and other assumptions focus on the impact of alternative policies (for example import tariffs) on market equilibrium. The ethanol scenario reads as follows:

Scenario: The impact of ethanol production on the South African agricultural industry. Time period for which scenario is developed: 2006 - 2010

The first ethanol plant is constructed in 2007 with a capacity to process 370 000 tons of maize into 110 000 tons of dried distillers grain (DDG) and 150 million litres of ethanol. Due to the political sensitivity of using white maize, which is regarded as staple food in the African region, it is decided that only yellow maize will be used in the production of ethanol. Despite this, government decides to abolish the import tariffs on white and yellow maize from 2008 onwards so that imported maize can be cheaper. The rand depreciates against the US dollar in response to an improving US economy and the European economies are struggling due to political and economical instability. China’s economic growth declines due to high inflation, leading to a recession in the demand for oil and precious metals like gold. The rand depreciates further in response to the declining demand for gold to a level of R9.50 per US dollar in 2010. The decrease in demand for international shipping leads to the stabilisation of freight rates. Farmers' input costs decrease as a result of lower oil prices. Due to the depreciation of the rand, the local industry is more competitive in the export market.

The first step in analysing this scenario is to introduce the various economic and political assumptions in the regime-switching model. The macroeconomic and policy assumptions of the scenario are summarised in table 5.25.

Table 5.25: Assumptions of exogenous variables – ethanol scenario

Variables	Units	2006	2007	2008	2009	2010
Exchange rate	c/US$	650.0	750.0	850.0	900.0	950.0
Freight rates	US$/t	33.7	33.7	33.7	33.7	33.7
Oil price	US $/barrel	45.0	40.0	35.0	30.0	25.0
Maize tariff	R/ton	37.7	36.3	0.0	0.0	0.0
Input cost index	Index ('00)	144.7	139.7	134.7	129.7	124.7

The second set of baseline projections presented in the first section of this chapter will be used as the baseline from where the absolute and percentage deviations for this scenario are calculated. Impact multipliers are calculated for 2007 and 2010 in order to capture the short-term and long-term effects. Tables 5.26 and 5.27 present the impact multipliers in response to the economic and political shocks alone. The impact multipliers in response to all the assumptions of the scenario are presented in tables 5.28 and 5.29. For the purpose of this study, only the impact on the white and yellow maize industries will be presented and not the corresponding impacts on the various livestock industries in the model.

Table 5.26: White maize impact multipliers – economic and political shocks

	2007			2010		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1613.7	66.2	4.1%	1549.1	35.3	2.3%
Production	5922.1	242.9	4.1%	5831.6	132.8	2.3%
Ending Stock	1237.1	74.1	6.0%	1344.0	111.7	8.3%
Human Consumption	3745.2	23.4	0.6%	3708.0	36.5	1.0%
Feed Consumption	659.0	-11.6	-1.8%	672.4	6.1	0.9%
Total Consumption	4729.2	11.8	0.2%	4705.4	42.6	0.9%
Exports	1038.3	107.2	10.3%	1077.9	72.1	6.7%
Imports	47.0	-30.9	-65.7%	35.6	-20.8	-58.4%
Producer Price	954.4	-2.2	-0.2%	1036.9	-24.7	-2.4%

Table 5.27: Yellow maize impact multipliers – economic and political shocks

	2007			2010		
Yellow Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	984.4	52.7	5.4%	970.9	24.7	2.5%
Production	3891.9	208.4	5.4%	3966.0	100.7	2.5%
Ending Stock	762.2	62.9	8.3%	922.7	70.2	7.6%
Human Consumption	246.1	2.1	0.9%	242.3	2.0	0.8%
Feed Consumption	3419.7	80.5	2.4%	3619.5	78.8	2.2%
Total Consumption	3847.8	82.6	2.1%	4043.8	80.9	2.0%
Exports	213.3	5.3	2.5%	219.3	4.5	2.0%
Imports	364.5	-26.6	-7.3%	334.4	-22.5	-6.7%
Producer Price	907.7	-41.1	-4.5%	951.6	-39.4	-4.1%

Despite lower freight rates, parity prices increase in response to the fast weakening of the rand. The higher parity prices in 2006 induce an increase in domestic prices in 2006 and farmers respond by increasing the areas planted in 2007. Therefore, white and yellow maize production increase in 2007, which causes domestic prices to decrease slightly by 0.2 percent and 4.5 percent in the case of white and yellow maize respectively. White and yellow maize exports increase and imports decrease due to the higher level of production.

The assumption of ethanol production from maize is now also introduced in the model. Apart from yellow maize feed and human consumption, an additional consumption category of 370 000 tons is incorporated in the model in 2007. The livestock industries are influenced by the shift in domestic yellow maize consumption and the entrance of DDG into the feed market as an alternative feed stock.

Table 5.26: White maize impact multipliers – ethanol scenario, 2007 - 2010

	2007			2010		
White Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	1613.7	66.2	4.1%	1549.1	44.8	2.9%
Production	5922.1	242.9	4.1%	5831.6	168.6	2.9%
Ending Stock	1237.1	52.0	4.2%	1344.0	109.0	8.1%
Human Consumption	3745.2	15.0	0.4%	3708.0	33.8	0.9%
Feed Consumption	659.0	57.6	8.7%	672.4	42.9	6.4%
Total Consumption	4729.2	72.6	1.5%	4705.4	76.7	1.6%
Exports	1038.3	77.1	7.4%	1077.9	67.8	6.3%
Imports	47.0	-22.2	-47.2%	35.6	-19.6	-54.9%
Domestic Price	954.4	16.2	1.7%	1036.9	-18.0	-1.7%

Table 5.27: Yellow maize impact multipliers – ethanol scenario, 2007 - 2010

	2007			2010		
Yellow Maize	Baseline	Absolute	%	Baseline	Absolute	%
Area Harvested	984.4	52.7	5.4%	970.9	77.6	8.0%
Production	3891.9	208.4	5.4%	3966.0	316.9	8.0%
Ending Stock	762.2	-21.5	-2.8%	922.7	82.3	8.9%
Human Consumption	246.1	-6.8	-2.8%	242.3	-3.2	-1.3%
Feed Consumption	3419.7	-162.5	-4.8%	3619.5	-62.9	-1.7%
Total Consumption	3847.8	200.8	5.2%	4043.8	303.9	7.5%
Exports	213.3	-0.3	-0.1%	219.3	1.9	0.9%
Imports	364.5	1.5	0.4%	334.4	-9.5	-2.8%
Domestic Price	907.7	130.6	14.4%	951.6	62.6	6.6%

At first glance, the impact multipliers show a larger effect on the yellow maize market than on the white maize market. What may come as a surprise, is that the total consumption of yellow maize does not increase by the full 370 000 tons that are required for the production of ethanol. Instead, feed consumption decreases by 162 000 tons in 2007 and 62 000 tons in 2010. This is due to the substitution effect of yellow maize between the feed and ethanol markets. Some of the loss in total maize feed consumption will be made up by an increase in white maize feed consumption in 2007 and 2010.

Clearly, the increase in domestic consumption has a positive impact on white and yellow maize prices in 2007. However, as farmers respond over time to the increase in domestic prices, the impact of prices reduces and in the case of white maize the domestic price even decreases by 1.7 percent compared to the baseline projections. This is, however, not the case with yellow maize where domestic prices are supported by the increase in domestic consumption of 200 800 tons in 2007 and 303 900 ton in 2010.

5.7 SUMMARY

The main purpose of this chapter was to test the hypothesis formulated in chapter 1. A number of approaches were used to test various aspects of the hypothesis. Firstly, benchmarks, also referred to as baseline projections, were simulated under a combination of different trade regimes. A shift in parity prices was imposed on the regime-switching model under the various baselines to illustrate how the correlation between parity and domestic prices changes as the equilibrium pricing conditions change. Results show that the correlation between the parity and local prices is high when local grain markets are trading under import/export parity and the correlation is relatively low when markets are trading under near-autarky. The observed impact multipliers also suggest that the absolute effect on trade due to a shock in parity prices is much higher under import/export parity, than under near-autarky.

The second approach involved a comparison between the regime-switching model developed in this study, and the pre-existing version of the model where a regime switch is not included. Results showed that the pre-existing model simulates unrealistically high domestic prices and the correlation between parity and domestic prices is too low when there is a shortage in local grain markets. Finally, the analysis of a scenario involving real-world issues was conducted to illustrate the model's ability to simulate the impact of market-related and policy impacts on local grain markets.

This chapter has proven that the regime-switching methodology that was developed to allow the new sector model to switch between various techniques of model closure, enables the model to simulate the most realistic estimates and projections of endogenous variables under market-switching regimes. It is therefore consistent with the hypothesis of this study. The proposed regime-switching model is, by design, more rigorous than the pre-existing model in that it emphasises price formation and correct model closure under alternative regimes.

CHAPTER 6

SUMMARY AND RECOMMENDATIONS

This study presents an alternative regime-switching methodology to allow multisector simulation models to switch between various techniques of model closure in order to simulate the most realistic formation of equilibrium prices. The first part of this study provided the theoretical foundation of price formation and model closure. This included an overview of literature to illustrate the uniqueness of the methodology that was developed in this study. While the existing regime-switching models switch between various intercepts and/or parameter estimates of specific single equations, the switch in this study occurs between the various model closure techniques that each consist of a combination of single equations and identities with different intercepts and parameter estimates. Hence, this study focused on equilibrium pricing conditions and the relevant model closure to enable the correct formation of prices under distinct trade regimes in a multi-commodity model, rather than just price transmission and market integration between distinct markets.

The next step was to identify the alternative market regimes in the various grain markets. The fact that trade occurs, even though prices are not trading at parity levels, implies that there might be some level of integration between domestic and world markets under autarky. Analyses show that, contrary to economic theory, there is indeed some level of integration between domestic and world markets when domestic markets are trading under what this study refers to as near-autarky. A detailed discussion followed on the concepts of model closure and price formation under various market regimes. Flow and price-quantity (P-Q) diagrams were used to provide easy guidance towards the understanding of important economic and biological relationships.

The next section of the study presented the empirical results. A clear distinction was made between the previous version of the BFAP sector model and the redesigned regime-switching sector model. The domestic supply and demand components of the existing model remained unchanged. The estimated results of the redesigned price and trade equations include the parameter estimates, p-values, R^2, Durban Watson statistics (DW), and the elasticities. The elasticities were calculated at the mean values of the corresponding variables. The empirical results were followed by a detailed discussion of the technical implementation of the switching mechanism in the model. In short, the redesigned sector model is made up of the demand and supply components from the previous version of the sector model, redesigned price and trade equations for alternative market regimes, and most importantly, a switching mechanism that allows the model to switch between various model closure techniques that are dictated by the equilibrium pricing conditions.

In the last section various approaches were used to test whether the redesigned sector model complies with the hypothesis of this study. The first approach involved the simulation of baseline projections under a combination of different trade regimes in the grain markets. Ten percent shocks in parity prices were imposed on the alternative baseline projections to calculate absolute and percentage deviations (impact multipliers) from the baseline. The second approach illustrated the usefulness of the automated switch between the various model closure techniques by comparing *ex-post* simulation results of the regime-switching model to the results of the pre-existing sector model. Results proved that the previous sector model, which does not consist of a switching mechanism, simulated unrealistic results under switching market regimes. The last approach presented a more hands-on application of the regime-switching model to real-life examples by analysing the impact of a combination of market- and policy-related shocks in the form of scenario analysis.

This study has proven that the redesigned regime-switching model is able to capture a richer variety of market behaviour than standard models as a result of the regime-switching innovation outlined, therefore capturing more accurately the likely effects of shocks on the domestic market. It is therefore consistent with the hypothesis that with the correct model structure and closure, a combination of modelling techniques can be applied to develop a simulation model that is able to generate reliable estimates and projections of endogenous variables under market-switching regimes. The regime-switching model is, by design, more rigorous than the previous sector model in that it emphasises price formation and correct model closure under alternative regimes. Over the past production seasons a number of local agribusinesses have tested and applied this model successfully in the field of scenario planning and analyses. Although the model is particularly appropriate for the South African grain market as specified here, it provides a template for which models for other countries and commodities may be developed.

This study identified a number of important issues that need to be addressed in future studies. The first point that needs to be made is that the focus of this study fell predominantly on the economic significance and the practical application of the redesigned sector model to real-world issues. The idea of undertaking a study of this nature was initiated through close interaction with a number of agribusinesses and industry experts. The fact that the old sector model could not handle some of the most important features of the industry implied that a new approach had to be developed. The automated switching mechanism added to the flexibility of the model and its ability to model a number of short- and long-run policy and market-related shocks simultaneously. Future studies should focus more on finding statistical tests, specifically a consistent statistical test to test the significance of a regime-switching model with three possible regimes. Although Meyer (2003) did not apply any automated regime-switching methodology when he developed a threshold vector error correction model, he also mentioned the shortcoming of formal statistical tests to test for the significance of having multiple regimes in a model.

The lack of adequate data hampered the applications of more advanced statistical techniques like Error Correction Models (ECM) that, for example, test for the stationarity of the data and provide refined tests of price transmission. The challenge is to develop equilibrium models that are able to reproduce a degree of price transmission consistent with the one estimated under the distinct market regimes, but which are able to switch between the various regimes over the projection period. ECM are frequently used to test for short- and long-run equilibrium, without taking into consideration that regime switching has a major impact on the outcome of the results.

Specific improvements to the regime-switching model include the implementation of the regime-switching methodology for other commodities in the model due to cross-commodity correlations. A regime switch in the major commodity markets, for example maize or poultry, can easily force a change in regime in the smaller commodity markets. The issue of price expectations also needs to be readdressed. One can argue that since the deregulation of the markets and the effective operation of the futures markets, farmers do not respond to price expectations anymore because they have far more accurate price information and the opportunity to fix prices for the full season in advance. Therefore, farmers are not purely backward-looking in developing their price expectations. Hence, if farmers had something more closely approaching rational or even quasi-rational expectations, the model oscillations of the cobweb effect would not happen or at least be mitigated.

To conclude, it is important to categorise the different shifts that can take place in an industry. For example, a shift in trade policy regime could influence the rate of price transmission between spatial markets and thus change the correlation between parity and local market prices, but it will not necessarily induce a switch in equilibrium pricing conditions (i.e. a switch in model closure) for example from import parity to near-autarky for a specific commodity. This implies that if there is no switch in equilibrium pricing conditions, estimation techniques, for instance dummy variables, can be applied to improve parameter estimates under switching policy regimes because the choice of the model closure technique need not change. If, however, a switch in market regimes induces a switch in equilibrium pricing conditions, then an alternative method of model closure has to be implemented.

It becomes far more complex if one takes into consideration that there are a number of exogenous factors/market drivers that could potentially bring on a permanent complete structural shift in the agricultural industry. One needs to make a clear distinction between shifts that have occurred in the past and will appear again in the future, and shifts that have not occurred in the past but where there is a chance that they will occur in future and the outcome of these shifts is uncertain. Adverse weather conditions serve as a good example for the first category of shifts. South Africa has experienced a number of droughts and floods in the past, and the chances are very high that it will occur again. Although adverse weather conditions have caused shifts in equilibrium pricing conditions, the shifts were not of a permanent nature. The regime-switching model has demonstrated that it has the ability to model these non-permanent shifts.

The second category of shifts is trickier to handle. For example, in the eighties and early nineties South Africa occasionally produced a wheat surplus, but since deregulation South Africa has become a net importer of wheat. The shift in marketing policies has, thus, resulted in a permanent structural shift in the industry. This implies that a typical econometric model, where parameter estimates were purely based on historic data before the shift in marketing regimes, would not have been able to project the possible impact of this shift. At a danger of stating the obvious, it is far more difficult to predict the impact of a shift that has not occurred before, compared to a shift that has taken place in the past. The most refined statistical techniques and tests will not provide good estimates of these shifts. Projecting the possible impact of land reform policies also poses a major challenge to any existing simulation model. Land reform policies could lead to a structural shift in the South African agricultural sector that has not occurred before. The advantage of the modelling approach that is developed in this study is that when time series analyses are not realistically applicable due to inadequate or poor-quality data, or just because a complete structural shift that has not occurred in the past could take place in the future, this methodology combines modelling techniques, scenario analyses and industry expertise into a simulation modelling framework that is able to capture the real-world issues of commodity markets.

REFERENCES:

Bac, C., J. Chevet and E. Ghysels (2001). "Time-series Model with periodic Stochastic Regime Switching", Macroeconomic Dynamics, Vol. 5, 2001.

Balcombe, K. (2003). "Threshold Effects in Price transmission: The case of Brazilian Wheat, Maize, and Soya Prices", Consultancy paper provided to the OECD Secretariat, 2003.

Barret, C.B. (1999). "The Effects of real Exchange Rate depreciation on stochastic Producer Prices in low-income Agriculture", Agricultural Economics, Vol. 20, 1999.

Barret, C.B. (2001). "Measuring Integration and Efficiency in International Agricultural Markets", Review of Agricultural Economics, Vol. 23, No. 1, 2001.

Barret,C.B. and J.R. Li (2002). "Distinguishing between Equilibrium and Integration in Spatial Price Analysis", American Journal of Agricultural Economics Vol 84 (2): 292-307, 2002.

BFAP (2005). "South African Agricultural Outlook for the Grain, Livestock and Dairy Industry", University of Pretoria, June 2005.

Baulch, B. (1997)."Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration", American Journal of Agricultural Economics, Vol 79, May 1997.

Brooks, J. and O. Melyukhina (2005). "Estimating the Pass-Through of Agricultural Policy Reforms: An Application to Brazilian Commodity Markets", OECD Food Agriculture and Fisheries Working Papers, No. 2, OECD Publishing.

Bressler, G. and R.A. King (1970). "Markets Prices and Interregional Trade", McGraw-Hill, Inc., New York.

Chiang, Alpha C. (1984). "Fundamental Methods of Mathematical Economics", Third Edition, McGraw-Hill, Inc., New York,1984

Cleasby, R.C.G, M.A.G Darroch and G.F Ortmann (1993). "Factors Affecting the Demand for and Supply of South African Yellow Maize Exports, Agrekon, Vol 32, No 1, March 1993.

Cluff, M. (2003). "A Review of Spatial Price transmission in major World Commodity Models", Paper provided to the Aglink Users Group, OECD, 2003.

Enders, W. and P. Silkos (1999). "Cointegration and threshold adjustment", The University of Alabama Economics, Finance and Legal Studies, Working Paper Series, n. 01-03-02.

FAPRI (2005). "FAPRI 2005 World Agricultural Outlook", Iowa State University, University of Missouri-Columbia, 2005.

Ferris, J.N. (1998). "Agricultural Prices and Commodity Market Analysis", McGraw-Hill, Inc., New York.

Goodwin, B.K., T.J. Grennes, and M.K. Wohlgenant (1990). "A revised Test of the Law of One Price using Rational Price expectations", American Journal of Agricultural Economics, Vol 72, August 1990.

Gujarati, D.N. (1995). "Basic Econometrics", Third Edition, McGraw-Hill, Inc., New York.

Kirsten, J.F., and N. Vink (2000). "Deregulation of Agricultural Marketing in South Africa", The Free Market Foundation, No. 25.

Kostov, P. and J. Lingard (2004). "Regime-switching Vector Error Correction Model (VECM) analysis of UK meat consumption, Econometrics 0409007, September 2004.

Mas-Colell, A., M.D. Whinston, and J.R. Green (1995). "Microeconomic Theory", Oxford University Press, Inc., New York

Meyer, F.H. (2002). "Modelling the Market Outlook and Policy Alternatives for the Wheat Sector in South Africa", Unpublished MSc. (Agric) dissertation, University of Pretoria.

Meyer, F.H., and P Westhoff (2003). "The South African Grain, Livestock and Dairy Model", Presentation at Maize Trust Meeting, unpublished, Pretoria 2003.

Meyer, F.H and J.F. Kirsten (2005). "Modelling the wheat sector in South Africa", Agrekon, Vol 44, No 2, June 2005.

Meyer, J. (2003). "Measuring Market Integration in the Presence of Transaction Costs", Paper read at the Conference of the International Association of Agricultural Economists, August, Durban 2003.

NDA (2005). "Abstract of Agricultural Statistics, 2005", National Department of Agriculture, Pretoria.

Pindyck, R.S., and D.L. Rubinfeld (1998). "Econometric Models and Economic Forecasts", Forth Edition, McGraw-Hill, Inc., New York.

Poonyth, D. and F.H. Meyer (2000). "Forecasting the Market Outlook for the South African Maize and Sorghum Sector using Econometric Modelling", Agrekon, Vol 39, No 4, December 2000.

Quarterly Bulletin (2005). South African Reserve Bank, March 2005.

Roche M.J. and K. Mcquinn (2003). "Grain Price Volatility in a Small Open Economy", Paper read at the Conference of the International Association of Agricultural Economists. August, Durban 2003.

Sadoulet, E. and A. DeJanvry (1995). "Quantitative Development Policy Analysis", Baltimore: Johns Hopkins University Press.

Schimmelpfennig, D, F.H Meyer, L. Beyers, D. Scheepers (2003). "The Price of Staple Maize in South Africa: Stable Equilibrium or Short-run Disequilibrium?" Poster Paper read at the Conference of the International Association of Agricultural Economists. August, Durban 2003.

Sexton, R., C. Kling, and H. Carmen (1991). " Market Integration, Efficiency of Arbitrage, and imperfect Competition: Methodology and Application to U.S. Celery Markets", American Journal of Agricultural Economics, Vol 73, August 1991.

Sharma, R. (2002). "The Transmission of World Price Signals: Concepts, Issues, and some Evidence from Asian Cereal Markets", OECD Global Forum on Agriculture Discussion Paper, OECD Publishing.

Van Tongeren, F, H. van Meijl and Y. Surry (2000). "Global Models applied to agricultural and trade policies: a review and assessment", Agricultural Economics, Vol 26, 149 -172, August 2000.

Varian, H.R. (1984). "Microeconomic Analysis", WW Norton and Company, New York.

Westhoff, P.C., J.F. Fabiosa, J.C. Beghin, and W.H. Meyers (2004). "Challenges in Modelling the Effects of Trade Agreements on the Agricultural Sector", Paper read at the Southern Agricultural Economics Association Meetings, February, Tulsa, Oklahoma.

APPENDIX 1

Table A1.1: Commodity balance sheets

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
TOTAL MAIZE																
Area harvested: Total	1000 ha	3207.0	3487.0	3662.0	3904.0	2952.0	3307.0	3361.0	2956.0	2904.7	3230.4	2707.9	3016.8	3100.0	2843.0	2810.0
Yield: Total	t/ha	2.7	0.9	2.7	3.4	1.6	3.1	2.9	2.5	2.5	3.2	2.9	3.1	3.0	3.3	4.1
Production: Total	1000 tons	8614.0	2965.0	9997.0	13275.0	4866.0	10180.2	9732.0	7256.0	7311.0	10409.0	7936.0	9310.0	9392.0	9482.0	11450.0
Begin Stock	1000 tons	1189.0	957.0	457.0	1683.0	2730.0	595.0	1283.0	2608.0	1074.0	983.0	2115.0	1202.0	2710.0	2624.0	3148.0
Imports	1000 tons	342.0	3949.0	63.0	0.0	1119.0	139.0	109.0	98.0	569.0	0.0	395.0	925.0	441.0	219.0	325.0
Total supply	**1000 tons**	**10145.0**	**7871.0**	**10517.0**	**14958.0**	**8715.0**	**10914.2**	**11124.0**	**9962.0**	**8954.0**	**11392.0**	**10446.0**	**11437.0**	**12543.0**	**12325.0**	**14923.0**
Human consumption	1000 tons	3302.0	3051.0	3612.0	3449.0	3705.0	3416.0	3410.0	3381.0	3648.0	3685.0	4105.0	3892.0	3932.0	4028.0	4013.5
Per capita consump	1000 tons	91.2	82.5	95.6	89.3	93.9	84.2	82.7	80.2	84.7	79.2	88.2	83.1	83.4	85.3	84.3
Feed	1000 tons	4204.0	3760.0	3533.5	3601.0	3440.0	3315.0	2973.0	2960.0	3137.0	3239.0	3457.0	3478.0	3719.0	3745.0	3999.0
Seed & On-farm use	1000 tons	841.0	517.0	308.5	549.0	88.0	556.2	212.0	1159.0	534.0	865.0	347.0	169.0	1083.0	572.0	940.0
Exports	1000 tons	841.0	86.0	1380.0	4629.0	887.0	2344.0	1921.0	1388.0	652.0	1488.0	1335.0	1188.0	1185.0	832.0	2323.0
Ending stock	1000 tons	957.0	457.0	1683.0	2730.0	595.0	1283.0	2608.0	1074.0	983.0	2115.0	1202.0	2710.0	2624.0	3148.0	3647.5
Total demand	**1000 tons**	**10145.0**	**7871.0**	**10517.0**	**14958.0**	**8715.0**	**10914.2**	**11124.0**	**9962.0**	**8954.0**	**11392.0**	**10446.0**	**11437.0**	**12543.0**	**12325.0**	**14923.0**

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
WHITE MAIZE																
Area harvested	1000 ha	1717.0	1881.0	1984.0	2026.0	1401.0	1904.0	1794.0	1797.2	1829.7	2003.0	1596.0	1842.5	2083.0	1842.0	1700.0
Yield	t/ha	2.5	0.7	2.5	3.2	1.8	3.2	2.9	2.7	2.6	3.2	2.9	3.0	3.1	3.2	3.8
Production	1000 tons	4305.5	1252.0	4985.5	6520.5	2558.5	6125.5	5183.0	4806.0	4669.0	6440.0	4636.0	5576.0	6366.0	5805.0	6541.0
Begin Stock	1000 tons	947.0	725.0	397.0	727.0	1156.0	294.0	838.0	1247.0	682.0	609.0	1273.0	559.0	1718.0	2123.0	2402.0
Imports	1000 tons	0.0	0.0	0.0	0.0	747.0	88.0	5.0	0.0	0.0	0.0	47.0	274.0	33.0	0.0	0.0
Total supply	**1000 tons**	**5252.5**	**1977.0**	**5382.5**	**7247.5**	**4461.5**	**6507.5**	**6026.0**	**6053.0**	**5351.0**	**7049.0**	**5956.0**	**6409.0**	**8117.0**	**7928.0**	**8943.0**
Human consumption	1000 tons	3208.0	980.0	3421.0	3237.0	3495.0	3318.0	3316.0	3255.0	3457.0	3473.0	3858.0	3643.0	3687.0	3766.0	3746.5
Per capita consump.	kg/capita	88.6	26.5	90.5	83.8	88.5	81.8	80.4	77.3	80.3	74.7	82.9	77.7	78.2	79.7	78.9
Feed	1000 tons	529.0	50.0	453.5	453.1	290.0	465.0	268.0	331.0	452.0	783.0	446.0	105.0	641.0	733.0	606.0
Seed & On-farm use	1000 tons	413.5	499.0	231.0	512.4	50.5	492.5	76.0	677.0	239.0	659.0	281.0	126.0	597.0	315.0	320.0
Exports	1000 tons	377.0	51.0	550.0	1889.0	332.0	1394.0	1119.0	1108.0	594.0	861.0	812.0	817.0	1069.0	712.0	1914.5
Ending stock	1000 tons	725.0	397.0	727.0	1156.0	294.0	838.0	1247.0	682.0	609.0	1273.0	559.0	1718.0	2123.0	2402.0	2356.0
Total demand	**1000 tons**	**5252.5**	**1977.0**	**5382.5**	**7247.5**	**4461.5**	**6507.5**	**6026.0**	**6053.0**	**5351.0**	**7049.0**	**5956.0**	**6409.0**	**8117.0**	**7928.0**	**8943.0**

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
YELLOW MAIZE																
Area harvested	1000 ha	1490.0	1606.0	1678.0	1878.0	1551.0	1403.0	1567.0	1158.8	1075.0	1227.4	1111.9	1174.3	1017.0	1001.0	1110.0
Yield	t/ha	2.9	1.1	3.0	3.6	1.5	2.9	2.9	2.1	2.5	3.2	3.0	3.1	3.1	3.7	4.4
Production	1000 tons	4308.5	1713.0	5011.5	6754.5	2307.5	4054.7	4549.0	2450.0	2642.0	3969.0	3300.0	3734.0	3026.0	3677.0	4909.0
Begin Stock	1000 tons	242.0	232.0	60.0	956.0	1574.0	301.0	445.0	1361.0	392.0	374.0	842.0	643.0	992.0	501.0	746.0
Imports	1000 tons	342.0	3949.0	63.0	0.0	372.0	51.0	104.0	98.0	569.0	0.0	348.0	651.0	408.0	219.0	325.0
Total supply	**1000 tons**	**4892.5**	**5894.0**	**5134.5**	**7710.5**	**4253.5**	**4406.7**	**5098.0**	**3909.0**	**3603.0**	**4343.0**	**4490.0**	**5028.0**	**4426.0**	**4397.0**	**5980.0**
Human consumption	1000 tons	94.0	2071.0	191.0	212.0	210.0	98.0	94.0	126.0	191.0	212.0	247.0	249.0	245.0	262.0	267.0
Per capita consump.	Kg/capita	2.6	56.0	5.1	5.5	5.3	2.4	2.3	3.0	4.4	4.6	5.3	5.3	5.2	5.5	5.4
Feed	1000 tons	3675.0	3710.0	3080.0	3147.9	3150.0	2850.0	2705.0	2629.0	2685.0	2456.0	3011.0	3373.0	3078.0	3012.0	3393.0
Seed & On-farm use	1000 tons	427.5	18.0	77.5	36.6	37.5	63.7	136.0	482.0	295.0	206.0	66.0	43.0	486.0	257.0	620.0
Exports	1000 tons	464.0	35.0	830.0	2740.0	555.0	950.0	802.0	280.0	58.0	627.0	523.0	371.0	116.0	120.0	408.5
Ending stock	1000 tons	232.0	60.0	956.0	1574.0	301.0	445.0	1361.0	392.0	374.0	842.0	643.0	992.0	501.0	746.0	1291.5
Total demand	**1000 tons**	**4892.5**	**5894.0**	**5134.5**	**7710.5**	**4253.5**	**4406.7**	**5098.0**	**3909.0**	**3603.0**	**4343.0**	**4490.0**	**5028.0**	**4426.0**	**4397.0**	**5980.0**

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
WHEAT																
Area summer	1000 ha	1106.4	408.6	646.8	641.7	962.4	890.8	982.3	448.0	408.0	588.5	628.5	577.1	423.0	476.0	503.0
Area winter	1000 ha	327.6	334.9	418.0	397.8	400.8	403.0	400.0	300.0	310.0	345.5	345.0	364.0	325.0	354.0	302.0
Yield:Summer	t/ha	1.5	1.7	1.9	1.7	1.2	2.1	1.8	2.2	2.8	2.8	2.7	2.7	2.4	2.4	2.5
Yield: Winter	t/ha	1.5	1.9	1.8	1.9	2.0	2.0	1.4	1.8	1.9	2.0	2.1	2.5	1.6	1.5	2.1
Prod Summer	1000 tons	1636.5	688.8	1232.5	1094.1	1149.3	1894.0	1733.5	996.0	1133.5	1657.6	1720.0	1535.4	1010.0	1160.0	1260.0
Prod Winter	1000 tons	496.5	627.3	742.8	738.1	819.2	806.0	550.0	535.0	591.5	691.0	730.0	891.8	530.0	520.0	645.0
Begin Stock	1000 tons	341.0	348.0	330.0	268.0	403.0	286.0	578.0	1074.0	647.0	483.0	551.0	580.0	897.0	598.0	574.0
Imports	1000 tons	136.9	856.0	252.2	705.0	1007.0	508.0	575.0	871.0	624.0	304.0	407.0	747.0	1042.0	1227.0	1074.0
Total supply	**1000 tons**	**2610.8**	**2520.1**	**2557.5**	**2805.2**	**3378.6**	**3494.0**	**3436.5**	**3476.0**	**2996.0**	**3135.6**	**3408.0**	**3754.2**	**3479.0**	**3505.0**	**3553.0**
Human consumption	1000 tons	2130.0	2124.0	2249.0	2350.0	2407.0	2493.0	2250.0	2440.0	2345.0	2412.0	2519.0	2575.0	2652.0	2734.0	2762.0
Per capita consump.	kg/capita	58.8	57.4	59.5	60.8	61.0	61.4	54.6	57.9	54.5	51.9	54.1	54.9	56.2	57.9	58.2
Feed	1000 tons	4.8	3.8	7.2	4.4	24.0	21.0	30.0	85.0	24.0	39.0	98.4	30.0	50.0	23.0	41.0
Seed & On-farm use	1000 tons	55.3	49.5	33.3	32.8	81.6	42.0	10.5	106.0	72.0	30.6	61.6	24.0	21.0	16.0	22.0
Wheat Exports	1000 tons	72.7	12.8	0.0	15.0	580.0	360.0	72.0	198.0	72.0	103.0	149.0	179.0	158.0	158.0	122.0
Wheat Ending stock	1000 tons	348.0	330.0	268.0	403.0	286.0	578.0	1074.0	647.0	483.0	551.0	580.0	946.2	598.0	574.0	606.0
Wheat Total demand	**1000 tons**	**2610.8**	**2520.1**	**2557.5**	**2805.2**	**3378.6**	**3494.0**	**3436.5**	**3476.0**	**2996.0**	**3135.6**	**3408.0**	**3754.2**	**3479.0**	**3505.0**	**3553.0**

Table A1.2: Monthly price and trade data

	White maize						Yellow maize					
	Domestic price R/ton	Import parity Randfontein R/ton	Export parity Africa R/ton	Nr.2 Fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons	Domestic price R/ton	Import parity Durban R/ton	Export parity Africa R/ton	Nr.2 fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons
May-00	669.4	1210.0	684.3	100.7	0.0	20.0	678.6	1008.5	637.9	100.7	0.0	7.0
Jun-00	602.7	1108.8	577.1	89.8	0.0	47.0	610.5	915.7	544.0	89.8	0.0	1.0
Jul-00	535.0	986.0	492.7	79.5	0.0	106.0	528.5	803.8	470.5	79.5	0.0	28.0
Aug-00	506.8	980.3	486.9	78.0	0.0	148.0	502.4	799.0	465.5	78.0	0.0	65.0
Sep-00	539.4	1028.8	530.2	80.9	0.0	82.0	543.6	841.8	503.2	80.9	0.0	41.0
Oct-00	615.1	1114.0	610.2	86.6	0.0	50.0	629.5	916.7	572.8	86.6	0.0	44.0
Nov-00	672.0	1177.1	653.6	90.3	0.0	112.0	707.4	965.1	609.6	90.3	0.0	80.0
Dec-00	684.8	1250.9	726.1	99.0	0.0	85.0	737.9	1029.3	672.6	99.0	0.0	49.0
Jan-01	804.1	1260.7	745.9	96.0	0.0	74.0	821.8	1028.6	669.9	96.0	0.0	111.0
Feb-01	844.9	1221.8	708.8	94.3	0.0	53.0	885.0	994.6	636.0	94.3	0.0	98.0
Mar-01	819.0	1223.6	709.0	92.2	0.0	40.0	861.4	996.4	636.2	92.2	0.0	59.0
Apr-01	809.3	1204.3	687.0	89.0	0.0	44.0	823.7	980.0	616.1	89.0	0.0	44.0
May-01	755.1	1181.5	632.6	86.3	0.0	61.0	774.7	964.4	566.5	86.3	0.0	4.0
Jun-01	784.6	1229.9	641.2	84.6	0.0	45.0	800.8	1011.7	574.4	84.6	0.0	68.0
Jul-01	901.3	1328.2	727.7	90.8	0.0	59.0	876.0	1098.6	653.3	90.8	0.0	79.0
Aug-01	977.4	1362.8	759.3	93.6	0.0	40.0	927.7	1129.1	682.1	93.6	0.0	105.0
Sep-01	1002.8	1372.0	762.1	89.8	0.0	26.0	978.1	1137.9	684.6	89.8	0.0	24.0
Oct-01	1057.7	1412.8	792.9	87.5	0.0	56.0	1048.0	1174.7	712.8	87.5	0.0	54.0
Nov-01	1275.0	1524.0	891.0	92.8	0.0	43.0	1230.2	1272.9	802.3	92.8	0.0	43.0
Dec-01	1546.6	1776.5	1104.7	95.5	0.0	54.0	1463.9	1497.3	997.2	95.5	0.0	54.0
Jan-02	1728.5	1774.9	1079.7	93.8	0.0	95.0	1645.6	1485.3	973.3	93.8	82.0	31.0
Feb-02	1854.9	1747.8	1053.2	92.3	0.0	133.0	1516.3	1461.6	949.1	92.3	73.0	27.0
Mar-02	2006.9	1724.7	1029.2	90.6	0.0	90.0	1467.7	1441.7	927.1	90.6	106.0	9.0
Apr-02	1925.2	1655.1	968.0	87.8	47.0	58.0	1395.0	1380.0	871.3	87.8	87.0	25.0
May-02	1775.8	1558.3	891.7	92.2	48.0	75.0	1312.1	1293.3	801.7	92.2	47.0	19.0
Jun-02	1754.1	1608.0	937.4	94.7	76.0	70.0	1345.8	1336.9	843.3	94.7	14.0	47.0
Jul-02	1697.1	1677.7	991.5	99.9	44.0	44.0	1389.1	1399.4	892.6	99.9	27.0	30.0
Aug-02	1737.7	1897.3	1187.6	110.2	30.0	43.0	1491.9	1593.1	1071.5	110.2	0.0	21.0
Sep-02	1763.6	1922.4	1210.6	113.6	53.0	53.0	1543.9	1615.0	1092.4	113.6	0.0	26.0
Oct-02	1756.5	1751.9	1150.7	111.4	23.0	62.0	1467.8	1452.4	1037.7	111.4	31.0	34.0
Nov-02	1790.0	1608.8	1057.9	110.9	0.0	50.0	1410.0	1321.6	953.1	110.9	56.0	39.0
Dec-02	1744.4	1486.8	952.9	108.6	0.0	47.0	1346.0	1213.5	857.3	108.6	69.0	21.0
Jan-03	1531.9	1436.4	893.5	107.5	0.0	54.0	1301.2	1160.7	802.4	107.5	80.0	34.0
Feb-03	1097.7	1371.4	839.3	107.3	0.0	77.0	1088.8	1102.9	753.0	107.3	136.0	31.0
Mar-03	894.9	1370.1	833.7	106.6	0.0	68.0	942.3	1102.4	747.9	106.6	74.0	16.0

	White maize						Yellow maize					
	Domestic price R/ton	Import parity Randfontein R/ton	Export parity Africa R/ton	Nr.2 Fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons	Domestic price R/ton	Import parity Durban R/ton	Export parity Africa R/ton	Nr.2 fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons
Apr-03	793.5	1327.7	777.0	106.3	0.0	107.0	828.2	1067.4	696.2	106.3	117.0	8.0
May-03	878.4	1361.9	809.0	108.6	0.0	69.0	904.5	1097.4	725.3	108.6	22.0	12.0
Jun-03	887.0	1364.8	810.8	107.8	0.0	60.0	918.6	1100.1	727.1	107.8	9.0	5.0
Jul-03	830.0	1256.2	712.7	100.0	0.0	132.0	859.0	1004.6	637.6	100.0	2.0	7.0
Aug-03	859.0	1259.9	705.4	101.4	0.0	91.0	879.0	1009.3	631.0	101.4	0.0	5.0
Sep-03	901.0	1278.0	725.9	104.4	0.0	103.0	928.0	1024.8	649.7	104.4	0.0	17.0
Oct-03	884.0	1242.5	695.7	107.2	0.0	109.0	931.0	993.4	622.3	107.2	0.0	16.0
Nov-03	910.9	1305.4	685.2	113.0	0.0	79.0	973.9	1057.7	612.7	113.0	20.0	4.0
Dec-03	1094.0	1312.7	681.9	113.8	0.0	89.0	1115.3	1065.4	609.7	113.8	0.0	6.0
Jan-04	1302.5	1469.0	754.5	117.2	0.0	72.0	1312.2	1179.4	673.5	117.2	13.0	9.0
Feb-04	1327.7	1684.3	783.5	124.0	0.0	61.0	1378.7	1390.6	699.7	124.0	109.0	5.0
Mar-04	1090.7	1696.0	800.2	128.1	10.0	80.0	1202.3	1400.2	714.9	128.1	135.0	3.0
Apr-04	1111.6	1683.6	839.1	134.4	23.0	59.0	1196.4	1382.6	750.5	134.4	98.0	3.0
May-04	1050.2	1617.0	813.1	128.6	0.0	45.0	1077.3	1319.5	726.8	128.6	83.0	0.0
Jun-04	989.8	1478.5	731.8	123.0	0.0	28.0	998.6	1191.8	652.7	123.0	2.0	3.0
Jul-04	881.6	1264.0	558.6	104.6	0.0	32.0	904.8	1000.2	494.7	104.6	1.0	4.0
Aug-04	939.1	1315.1	595.0	104.1	0.0	42.0	964.4	1046.5	527.9	104.1	0.0	6.0
Sep-04	917.2	1282.1	553.4	98.7	0.0	35.0	953.5	1019.0	489.9	98.7	1.0	5.0
Oct-04	891.9	1290.1	517.8	94.4	0.0	60.0	940.8	1031.5	457.5	94.4	1.0	8.0
Nov-04	973.5	1259.8	475.6	94.8	0.0	63.0	963.7	1006.8	418.9	94.8	8.0	7.0
Dec-04	799.5	1216.7	442.2	95.9	0.0	41.0	857.5	968.1	388.4	95.9	66.0	7.0
Jan-05	734.7	1320.1	488.5	96.5	0.0	80.0	778.5	1065.4	430.7	96.5	43.0	8.0
Feb-05	537.1	1295.5	467.8	95.5	0.0	70.0	645.8	1043.6	411.8	95.5	0.0	5.0
Mar-05	539.0	1328.0	513.0	100.6	0.0	79.0	607.0	1133.0	417.0	100.6	14.0	5.0
Apr-05	551.0	1326.7	506.0	96.4	0.0	90.0	610.0	1130.0	408.0	96.4	0.0	6.0

	Wheat					
	Domestic price R/ton	Import parity Randfontein R/ton	Export parity Africa R/ton	HRW fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons
May-00	1305.0	1374.0	695.3	117.0	105.0	8.0
Jun-00	1322.0	1362.1	685.8	118.0	28.0	3.0
Jul-00	1292.0	1345.6	669.6	116.0	28.0	5.0
Aug-00	1211.0	1339.7	662.7	114.0	15.0	6.0
Sep-00	1197.0	1440.5	759.5	124.0	33.0	5.0
Oct-00	1199.0	1538.3	851.6	131.0	90.0	6.0
Nov-00	1244.0	1558.8	868.8	130.0	26.0	5.0
Dec-00	1338.0	1562.0	872.6	131.0	20.0	8.0
Jan-01	1379.7	1651.7	956.7	136.0	28.0	8.0
Feb-01	1396.5	1530.5	876.0	131.3	8.0	11.0
Mar-01	1409.8	1545.5	888.9	131.0	40.0	8.0
Apr-01	1405.1	1596.8	940.3	131.8	7.0	11.0
May-01	1425.3	1604.0	942.8	136.0	49.0	10.0
Jun-01	1448.4	1566.0	902.6	130.0	0.0	11.0
Jul-01	1424.0	1570.3	899.0	127.5	10.0	7.0
Aug-01	1355.8	1583.8	910.1	127.0	26.0	10.0
Sep-01	1351.4	1637.6	955.7	126.3	4.0	8.0
Oct-01	1430.0	1713.0	1019.9	127.3	0.0	9.0
Nov-01	1625.7	1806.4	1100.5	129.4	7.0	9.0
Dec-01	1931.9	2043.9	1298.6	125.3	15.0	12.0
Jan-02	1886.2	2102.2	1330.9	130.0	65.0	18.0
Feb-02	1811.5	2081.7	1310.5	127.0	45.0	11.0
Mar-02	1807.9	2069.4	1296.9	125.8	36.0	19.0
Apr-02	1870.0	2018.8	1253.6	125.3	49.0	14.0
May-02	1908.2	1817.1	1077.3	123.6	17.0	13.0
Jun-02	1859.8	1969.2	1220.4	135.8	25.0	9.0
Jul-02	1909.7	2124.1	1355.3	151.2	31.0	13.0
Aug-02	1974.0	2373.7	1578.9	165.2	52.0	11.0
Sep-02	2040.2	2536.6	1851.8	191.8	65.0	11.0
Oct-02	2034.0	2432.0	1822.6	194.4	138.0	12.0
Nov-02	1824.1	2173.4	1588.9	182.8	51.0	5.0
Dec-02	1685.4	1915.7	1355.2	164.7	78.0	4.0
Jan-03	1576.2	1735.4	1172.3	154.7	157.0	5.0
Feb-03	1438.3	1631.2	1081.0	153.8	55.0	18.0
Mar-03	1425.3	1589.7	1037.1	144.8	115.0	23.0
Apr-03	1430.0	1491.0	927.2	143.2	100.0	26.0
May-03	1416.7	1535.8	969.1	146.2	32.0	16.0

	Wheat					
	Domestic price R/ton	Import parity Randfontein R/ton	Export parity Africa R/ton	HRW fob Gulf US $/ton	Imports 1000 tons	Exports 1000 tons
Jun-03	1477.0	1428.1	865.7	132.7	0.0	13.0
Jul-03	1569.0	1412.2	825.5	133.8	0.0	17.0
Aug-03	1702.0	1668.4	963.4	155.1	0.0	20.0
Sep-03	1652.0	1685.8	919.0	149.8	21.0	18.0
Oct-03	1629.0	1457.8	893.7	151.0	75.0	5.0
Nov-03	1666.0	1587.4	953.0	169.3	52.0	7.0
Dec-03	1600.0	1646.9	908.0	169.9	101.0	18.0
Jan-04	1703.0	1692.5	978.1	170.1	91.0	14.0
Feb-04	1735.0	1802.7	900.8	164.1	108.0	20.0
Mar-04	1714.0	1812.2	911.0	169.0	108.0	27.0
Apr-04	1723.0	1760.8	911.8	171.9	17.0	12.0
May-04	1715.0	1666.1	858.3	164.3	70.0	12.0
Jun-04	1548.0	1513.2	763.5	157.5	86.0	17.0
Jul-04	1446.0	1397.0	687.6	152.4	96.0	5.0
Aug-04	1447.1	1448.0	710.3	145.3	131.0	10.0
Sep-04	1416.2	1510.4	757.6	155.5	107.0	11.0
Oct-04	1398.9	1491.1	719.8	154.8	85.0	11.0
Nov-04	1346.4	1463.7	686.1	163.3	156.0	20.0
Dec-04	1269.0	1406.0	638.5	160.4	64.0	13.0
Jan-05	1295.1	1460.5	675.5	157.5	45.0	13.0
Feb-05	1297.0	1429.6	661.5	151.5	156.0	20.0
Mar-05	1317.0	1538.0	631.0	150.4	100.0	10.0
Apr-05	1384.0	1503.0	589.0	150.0	78.0	14.0

APPENDIX 2

Table A2.1: 10 percent shock in parity prices in 2007 – scenario change from baseline 1

	White maize: Import parity				
	2006	**2007**	**2008**	**2009**	**2010**
White Maize Area Harvested			Thousand hectares		
Baseline	973.0	1590.8	1878.0	1596.9	1525.6
Scenario	973.0	1590.8	1968.6	1534.7	1522.8
Absolute Change	0.0	0.0	90.6	-62.1	-2.8
% Change	0.0%	0.0%	4.8%	-3.9%	-0.2%
White Maize Production			Thousand tons		
Baseline	3538.1	2500.0	6953.3	5962.5	5743.1
Scenario	3538.1	2500.0	7288.8	5730.5	5732.6
Absolute Change	0.0	0.0	335.4	-232.0	-10.5
% Change	0.0%	0.0%	4.8%	-3.9%	-0.2%
White Maize Ending Stock			Thousand tons		
Baseline	1035.4	280.0	1181.3	1346.2	1361.7
Scenario	1035.4	280.0	1333.7	1342.5	1355.7
Absolute Change	0.0	0.0	152.4	-3.7	-6.0
% Change	0.0%	0.0%	12.9%	-0.3%	-0.4%
White Maize Human Consumption			Thousand tons		
Baseline	3696.1	3545.2	3699.6	3731.6	3712.8
Scenario	3696.1	3512.5	3732.6	3733.2	3711.8
Absolute Change	0.0	-32.7	33.0	1.6	-1.0
% Change	0.0%	-0.9%	0.9%	0.0%	0.0%
White Maize Feed Consumption			Thousand tons		
Baseline	644.0	493.2	634.9	670.3	680.3
Scenario	644.0	475.7	639.7	682.8	675.6
Absolute Change	0.0	-17.5	4.8	12.5	-4.7
% Change	0.0%	-3.6%	0.8%	1.9%	-0.7%
White Maize Exports			Thousand tons		
Baseline	431.2	0.0	1392.6	1099.9	1052.4
Scenario	431.2	0.0	1537.7	1030.1	1050.5
Absolute Change	0.0	0.0	145.1	-69.8	-2.0
% Change	0.0%	0.0%	10.4%	-6.3%	-0.2%
White Maize Imports			Thousand tons		
Baseline	157.7	1108.0	0.0	29.3	42.9
Scenario	157.7	1057.8	0.0	49.4	43.5
Absolute Change	0.0	-50.2	0.0	20.1	0.6
% Change	0.0%	-4.5%	#DIV/0!	68.8%	1.3%
White Maize Producer Price			R/ton		
Baseline	1025.6	1394.1	1067.0	995.7	1025.0
Scenario	1025.6	1522.2	991.9	991.8	1027.5
Absolute Change	0.0	128.1	-75.1	-3.9	2.4
% Change	0.0%	9.2%	-7.0%	-0.4%	0.2%

	Yellow maize: Import parity				
	2006	2007	2008	2009	2010
Yellow Maize Area Harvested			Thousand hectares		
Baseline	575.0	984.4	1052.4	995.1	968.7
Scenario	575.0	984.4	1099.9	959.6	978.0
Absolute Change	0.0	0.0	47.5	-35.5	9.4
% Change	0.0%	0.0%	4.5%	-3.6%	1.0%
Yellow Maize Production			Thousand tons		
Baseline	2355.7	1000.0	4208.5	4022.7	3956.8
Scenario	2355.7	1000.0	4398.4	3879.3	3995.1
Absolute Change	0.0	0.0	189.9	-143.4	38.3
% Change	0.0%	0.0%	4.5%	-3.6%	1.0%
Yellow Maize Ending Stock			Thousand tons		
Baseline	566.9	230.0	711.9	870.8	913.0
Scenario	566.9	230.0	799.5	853.8	920.6
Absolute Change	0.0	0.0	87.6	-17.0	7.5
% Change	0.0%	0.0%	12.3%	-2.0%	0.8%
Yellow Maize Human Consumption			Thousand tons		
Baseline	242.3	236.3	242.8	244.4	242.1
Scenario	242.3	230.4	247.0	243.2	242.5
Absolute Change	0.0	-6.0	4.2	-1.2	0.4
% Change	0.0%	-2.5%	1.7%	-0.5%	0.2%
Yellow Maize Feed Consumption			Thousand tons		
Baseline	3295.5	3345.4	3447.6	3559.0	3606.5
Scenario	3295.5	3243.6	3529.0	3525.9	3618.4
Absolute Change	0.0	-101.7	81.4	-33.1	11.9
% Change	0.0%	-3.0%	2.4%	-0.9%	0.3%
Yellow Maize Exports			Thousand tons		
Baseline	98.6	0.0	214.2	218.2	219.1
Scenario	98.6	0.0	216.9	217.5	219.4
Absolute Change	0.0	0.0	2.8	-0.7	0.2
% Change	0.0%	0.0%	1.3%	-0.3%	0.1%
Yellow Maize Imports			Thousand tons		
Baseline	940.0	2426.8	359.9	339.7	335.1
Scenario	940.0	2319.2	346.1	343.4	333.9
Absolute Change	0.0	-107.7	-13.9	3.7	-1.2
% Change	0.0%	-4.4%	-3.8%	1.1%	-0.4%
Yellow Maize Producer Price			R/ton		
Baseline	976.9	1095.6	968.5	926.7	956.6
Scenario	976.9	1210.3	886.7	950.5	948.3
Absolute Change	0.0	114.7	-81.8	23.8	-8.3
% Change	0.0%	10.5%	-8.4%	2.6%	-0.9%

	Wheat: Import parity				
	2006	2007	2008	2009	2010
Wheat Summer Area Harvested			Thousand hectares		
Baseline	530.5	490.0	481.7	511.3	551.5
Scenario	530.5	490.0	500.7	519.8	554.0
Absolute Change	0.0	0.0	18.9	8.5	2.5
% Change	0.0%	0.0%	3.9%	1.7%	0.5%
Wheat Winter Area Harvested			Thousand hectares		
Baseline	323.5	344.3	328.7	329.5	338.2
Scenario	323.5	344.3	339.0	329.4	339.1
Absolute Change	0.0	0.0	10.4	-0.2	0.9
% Change	0.0%	0.0%	3.2%	0.0%	0.3%
Wheat Production			Thousand tons		
Baseline	1988.1	980.0	1884.7	1977.4	2113.9
Scenario	1988.1	980.0	1954.4	2000.7	2122.4
Absolute Change	0.0	0.0	69.7	23.2	8.5
% Change	0.0%	0.0%	3.7%	1.2%	0.4%
Wheat Ending Stock			Thousand tons		
Baseline	611.2	599.0	587.3	572.0	561.0
Scenario	611.2	580.6	577.9	568.1	559.3
Absolute Change	0.0	-18.5	-9.5	-3.9	-1.7
% Change	0.0%	-3.1%	-1.6%	-0.7%	-0.3%
Wheat Human Consumption			Thousand tons		
Baseline	2751.8	2811.2	2741.9	2716.4	2710.4
Scenario	2751.8	2802.5	2728.7	2715.8	2710.8
Absolute Change	0.0	-8.7	-13.2	-0.6	0.4
% Change	0.0%	-0.3%	-0.5%	0.0%	0.0%
Wheat Feed Consumption			Thousand tons		
Baseline	90.7	98.8	75.2	63.7	60.9
Scenario	90.7	99.4	68.0	65.2	60.4
Absolute Change	0.0	0.6	-7.2	1.5	-0.5
% Change	0.0%	0.6%	-9.6%	2.3%	-0.8%
Wheat Exports			Thousand tons		
Baseline	123.9	7.5	117.2	131.9	147.4
Scenario	123.9	10.4	126.1	133.7	148.1
Absolute Change	0.0	2.9	8.9	1.9	0.7
% Change	0.0%	38.9%	7.6%	1.4%	0.5%
Wheat Imports			Thousand tons		
Baseline	1003.1	1945.0	1057.6	938.8	813.4
Scenario	1003.1	1921.4	985.3	923.9	807.7
Absolute Change	0.0	-23.6	-72.3	-15.0	-5.6
% Change	0.0%	-1.2%	-6.8%	-1.6%	-0.7%
Wheat Producer Price			R/ton		
Baseline	1433.2	1564.2	1685.1	1822.8	1940.9
Scenario	1433.2	1704.7	1685.1	1822.8	1940.9
Absolute Change	0.0	140.6	0.0	0.0	0.0
% Change	0.0%	9.0%	0.0%	0.0%	0.0%

Table A2.2: 10 percent shock in parity prices in 2007 – scenario change from baseline 2

	White maize: Near-autarky				
	2006	2007	2008	2009	2010
White Maize Area Harvested			Thousand hectares		
Baseline	973.0	1613.7	1548.3	1502.5	1549.1
Scenario	973.0	1613.7	1584.7	1491.6	1544.6
Absolute Change	0.0	0.0	36.5	-10.9	-4.6
% Change	0.0%	0.0%	2.4%	-0.7%	-0.3%
White Maize Production			Thousand tons		
Baseline	3538.1	5922.1	5732.3	5610.1	5831.6
Scenario	3538.1	5922.1	5867.4	5569.4	5814.4
Absolute Change	0.0	0.0	135.1	-40.7	-17.1
% Change	0.0%	0.0%	2.4%	-0.7%	-0.3%
White Maize Ending Stock			Thousand tons		
Baseline	1035.4	1237.1	1284.9	1260.2	1344.0
Scenario	1035.4	1211.8	1328.2	1270.3	1343.4
Absolute Change	0.0	-25.3	43.3	10.1	-0.7
% Change	0.0%	-2.0%	3.4%	0.8%	0.0%
White Maize Human Consumption			Thousand tons		
Baseline	3696.1	3745.2	3742.3	3717.4	3708.0
Scenario	3696.1	3751.1	3750.0	3720.1	3708.1
Absolute Change	0.0	5.9	7.7	2.7	0.1
% Change	0.0%	0.2%	0.2%	0.1%	0.0%
White Maize Feed Consumption			Thousand tons		
Baseline	644.0	659.0	658.1	656.9	672.4
Scenario	644.0	647.3	663.2	662.0	672.1
Absolute Change	0.0	-11.6	5.0	5.1	-0.4
% Change	0.0%	-1.8%	0.8%	0.8%	-0.1%
White Maize Exports			Thousand tons		
Baseline	431.2	1038.3	1013.3	995.0	1077.9
Scenario	431.2	1062.4	1055.0	983.1	1073.2
Absolute Change	0.0	24.1	41.7	-11.9	-4.8
% Change	0.0%	2.3%	4.1%	-1.2%	-0.4%
White Maize Imports			Thousand tons		
Baseline	157.7	47.0	54.2	59.5	35.6
Scenario	157.7	40.1	42.2	62.9	37.0
Absolute Change	0.0	-7.0	-12.0	3.4	1.4
% Change	0.0%	-14.8%	-22.2%	5.8%	3.9%
White Maize Producer Price			R/ton		
Baseline	1025.6	954.4	969.7	1029.5	1036.9
Scenario	1025.6	997.7	952.2	1023.2	1036.6
Absolute Change	0.0	43.3	-17.5	-6.3	-0.2
% Change	0.0%	4.5%	-1.8%	-0.6%	0.0%

	Yellow maize: Near-autarky				
	2006	**2007**	**2008**	**2009**	**2010**
Yellow Maize Area Harvested			Thousand hectares		
Baseline	575.0	984.4	977.2	964.6	970.9
Scenario	575.0	984.4	984.0	959.0	972.6
Absolute Change	0.0	0.0	6.9	-5.6	1.7
% Change	0.0%	0.0%	0.7%	-0.6%	0.2%
Yellow Maize Production			Thousand tons		
Baseline	2355.7	3891.9	3907.5	3899.4	3966.0
Scenario	2355.7	3891.9	3934.9	3876.8	3973.0
Absolute Change	0.0	0.0	27.4	-22.6	6.9
% Change	0.0%	0.0%	0.7%	-0.6%	0.2%
Yellow Maize Ending Stock			Thousand tons		
Baseline	566.9	762.2	855.3	885.3	922.7
Scenario	566.9	751.6	863.5	880.5	923.3
Absolute Change	0.0	-10.6	8.2	-4.8	0.6
% Change	0.0%	-1.4%	1.0%	-0.5%	0.1%
Yellow Maize Human Consumption			Thousand tons		
Baseline	242.3	246.1	246.5	243.9	242.3
Scenario	242.3	245.0	247.1	243.7	242.4
Absolute Change	0.0	-1.1	0.5	-0.2	0.1
% Change	0.0%	-0.5%	0.2%	-0.1%	0.0%
Yellow Maize Feed Consumption			Thousand tons		
Baseline	3295.5	3419.7	3517.0	3566.5	3619.5
Scenario	3295.5	3417.3	3523.0	3558.0	3620.8
Absolute Change	0.0	-2.3	6.0	-8.5	1.3
% Change	0.0%	-0.1%	0.2%	-0.2%	0.0%
Yellow Maize Exports			Thousand tons		
Baseline	98.6	213.3	216.6	217.9	219.3
Scenario	98.6	215.6	217.0	217.8	219.3
Absolute Change	0.0	2.3	0.3	-0.1	0.0
% Change	0.0%	1.1%	0.2%	-0.1%	0.0%
Yellow Maize Imports			Thousand tons		
Baseline	940.0	364.5	347.6	341.1	334.4
Scenario	940.0	352.8	345.9	341.7	334.2
Absolute Change	0.0	-11.7	-1.7	0.7	-0.2
% Change	0.0%	-3.2%	-0.5%	0.2%	0.0%
Yellow Maize Producer Price			R/ton		
Baseline	976.9	907.7	896.0	935.4	951.6
Scenario	976.9	929.2	885.7	939.6	950.4
Absolute Change	0.0	21.5	-10.2	4.2	-1.1
% Change	0.0%	2.4%	-1.1%	0.4%	-0.1%

	Wheat: Import parity				
	2006	**2007**	**2008**	**2009**	**2010**
Wheat Summer Area Harvested	Thousand hectares				
Baseline	530.5	490.0	508.8	532.6	553.9
Scenario	530.5	490.0	534.4	536.7	555.2
Absolute Change	0.0	0.0	25.6	4.0	1.3
% Change	0.0%	0.0%	5.0%	0.8%	0.2%
Wheat Winter Area Harvested	Thousand hectares				
Baseline	323.5	321.4	324.9	332.5	339.7
Scenario	323.5	321.4	334.4	333.3	340.0
Absolute Change	0.0	0.0	9.5	0.9	0.3
% Change	0.0%	0.0%	2.9%	0.3%	0.1%
Wheat Production	Thousand tons				
Baseline	1988.1	1885.0	1952.7	2041.5	2123.2
Scenario	1988.1	1885.0	2039.3	2054.1	2127.2
Absolute Change	0.0	0.0	86.6	12.6	4.0
% Change	0.0%	0.0%	4.4%	0.6%	0.2%
Wheat Ending Stock	Thousand tons				
Baseline	611.2	599.8	586.2	572.9	561.7
Scenario	611.2	579.0	577.5	569.1	560.0
Absolute Change	0.0	-20.8	-8.7	-3.9	-1.7
% Change	0.0%	-3.5%	-1.5%	-0.7%	-0.3%
Wheat Human Consumption	Thousand tons				
Baseline	2751.8	2731.2	2724.8	2722.1	2712.3
Scenario	2751.8	2707.1	2721.7	2721.0	2712.2
Absolute Change	0.0	-24.1	-3.1	-1.1	0.0
% Change	0.0%	-0.9%	-0.1%	0.0%	0.0%
Wheat Feed Consumption	Thousand tons				
Baseline	90.7	75.4	68.3	65.1	60.8
Scenario	90.7	67.5	67.2	65.2	60.8
Absolute Change	0.0	-7.9	-1.1	0.1	-0.1
% Change	0.0%	-10.5%	-1.6%	0.2%	-0.1%
Wheat Exports	Thousand tons				
Baseline	123.9	118.3	127.5	137.9	148.2
Scenario	123.9	124.1	136.2	138.9	148.4
Absolute Change	0.0	5.8	8.7	1.0	0.2
% Change	0.0%	4.9%	6.8%	0.7%	0.1%
Wheat Imports	Thousand tons				
Baseline	1003.1	1048.3	974.0	890.0	806.6
Scenario	1003.1	1001.3	903.9	882.3	804.8
Absolute Change	0.0	-47.0	-70.1	-7.7	-1.7
% Change	0.0%	-4.5%	-7.2%	-0.9%	-0.2%
Wheat Producer Price	R/ton				
Baseline	1433.2	1564.2	1685.1	1822.8	1940.9
Scenario	1433.2	1704.7	1685.1	1822.8	1940.9
Absolute Change	0.0	140.6	0.0	0.0	0.0
% Change	0.0%	9.0%	0.0%	0.0%	0.0%

Table A2.3: 10 percent shock in parity prices in 2007 – scenario change from baseline 3

	White maize: Export parity				
	2006	**2007**	**2008**	**2009**	**2010**
White Maize Area Harvested			Thousand hectares		
Baseline	973.0	1631.8	1188.2	1450.0	1553.9
Scenario	973.0	1631.8	1250.6	1445.7	1546.7
Absolute Change	0.0	0.0	62.4	-4.3	-7.2
% Change	0.0%	0.0%	5.3%	-0.3%	-0.5%
White Maize Production			Thousand tons		
Baseline	3538.1	7800.0	4399.2	5414.1	5849.5
Scenario	3538.1	7800.0	4630.4	5398.2	5822.3
Absolute Change	0.0	0.0	231.2	-15.9	-27.3
% Change	0.0%	0.0%	5.3%	-0.3%	-0.5%
White Maize Ending Stock			Thousand tons		
Baseline	1035.4	2227.6	1342.6	1216.7	1322.1
Scenario	1035.4	2137.0	1385.6	1237.1	1323.8
Absolute Change	0.0	-90.6	43.0	20.5	1.8
% Change	0.0%	-4.1%	3.2%	1.7%	0.1%
White Maize Human Consumption			Thousand tons		
Baseline	3696.1	3913.2	3766.5	3711.0	3702.9
Scenario	3696.1	3910.5	3772.6	3715.6	3703.7
Absolute Change	0.0	-2.8	6.1	4.7	0.8
% Change	0.0%	-0.1%	0.2%	0.1%	0.0%
White Maize Feed Consumption			Thousand tons		
Baseline	644.0	749.6	727.0	638.5	669.8
Scenario	644.0	725.0	730.3	646.0	670.3
Absolute Change	0.0	-24.6	3.3	7.5	0.5
% Change	0.0%	-3.3%	0.5%	1.2%	0.1%
White Maize Exports			Thousand tons		
Baseline	431.2	1620.1	630.4	940.7	1081.1
Scenario	431.2	1738.0	698.8	936.4	1073.5
Absolute Change	0.0	117.9	68.4	-4.3	-7.6
% Change	0.0%	7.3%	10.8%	-0.5%	-0.7%
White Maize Imports			Thousand tons		
Baseline	157.7	0.0	164.6	75.2	34.7
Scenario	157.7	0.0	144.9	76.4	36.9
Absolute Change	0.0	0.0	-19.7	1.2	2.2
% Change	0.0%	0.0%	-12.0%	1.6%	6.3%
White Maize Producer Price			R/ton		
Baseline	1025.6	585.1	914.7	1044.9	1049.6
Scenario	1025.6	647.3	900.8	1033.8	1047.7
Absolute Change	0.0	62.3	-13.9	-11.1	-1.9
% Change	0.0%	10.6%	-1.5%	-1.1%	-0.2%

	Yellow maize: Near-autarky				
	2006	2007	2008	2009	2010
Yellow Maize Area Harvested			Thousand hectares		
Baseline	575.0	984.4	854.8	999.3	962.1
Scenario	575.0	984.4	860.6	993.3	963.6
Absolute Change	0.0	0.0	5.8	-5.9	1.5
% Change	0.0%	0.0%	0.7%	-0.6%	0.2%
Yellow Maize Production			Thousand tons		
Baseline	2355.7	4500.0	3418.1	4039.5	3930.0
Scenario	2355.7	4500.0	3441.4	4015.4	3936.1
Absolute Change	0.0	0.0	23.3	-24.0	6.1
% Change	0.0%	0.0%	0.7%	-0.6%	0.2%
Yellow Maize Ending Stock			Thousand tons		
Baseline	566.9	1050.9	793.1	911.2	918.7
Scenario	566.9	1041.2	800.0	905.6	918.8
Absolute Change	0.0	-9.7	6.9	-5.5	0.1
% Change	0.0%	-0.9%	0.9%	-0.6%	0.0%
Yellow Maize Human Consumption			Thousand tons		
Baseline	242.3	260.1	242.4	245.3	241.9
Scenario	242.3	259.1	242.9	245.1	241.9
Absolute Change	0.0	-1.0	0.5	-0.2	0.1
% Change	0.0%	-0.4%	0.2%	-0.1%	0.0%
Yellow Maize Feed Consumption			Thousand tons		
Baseline	3295.5	3665.0	3398.5	3612.5	3615.3
Scenario	3295.5	3666.8	3402.9	3601.8	3615.6
Absolute Change	0.0	1.8	4.4	-10.7	0.3
% Change	0.0%	0.0%	0.1%	-0.3%	0.0%
Yellow Maize Exports			Thousand tons		
Baseline	98.6	223.2	214.0	218.7	219.0
Scenario	98.6	224.7	214.3	218.6	219.0
Absolute Change	0.0	1.5	0.3	-0.1	0.0
% Change	0.0%	0.7%	0.1%	-0.1%	0.0%
Yellow Maize Imports			Thousand tons		
Baseline	940.0	314.4	361.0	337.1	335.7
Scenario	940.0	314.4	361.0	337.1	335.7
Absolute Change	0.0	0.0	0.0	0.0	0.0
% Change	0.0%	0.0%	0.0%	0.0%	0.0%
Yellow Maize Producer Price			R/ton		
Baseline	976.9	638.2	974.8	909.8	960.2
Scenario	976.9	658.0	965.8	913.7	959.2
Absolute Change	0.0	19.8	-9.0	3.9	-1.0
% Change	0.0%	3.1%	-0.9%	0.4%	-0.1%

	Wheat: Import parity				
	2006	**2007**	**2008**	**2009**	**2010**
Wheat Summer Area Harvested			Thousand hectares		
Baseline	530.5	490.0	571.2	554.3	557.4
Scenario	530.5	490.0	595.6	557.1	558.8
Absolute Change	0.0	0.0	24.4	2.8	1.4
% Change	0.0%	0.0%	4.3%	0.5%	0.2%
Wheat Winter Area Harvested			Thousand hectares		
Baseline	323.5	303.3	331.9	338.5	340.8
Scenario	323.5	303.3	341.4	339.2	341.0
Absolute Change	0.0	0.0	9.5	0.7	0.2
% Change	0.0%	0.0%	2.9%	0.2%	0.1%
Wheat Production			Thousand tons		
Baseline	1988.1	2600.0	2136.3	2111.6	2134.8
Scenario	1988.1	2600.0	2219.5	2120.7	2139.0
Absolute Change	0.0	0.0	83.2	9.1	4.2
% Change	0.0%	0.0%	3.9%	0.4%	0.2%
Wheat Ending Stock			Thousand tons		
Baseline	611.2	599.3	587.6	574.6	562.9
Scenario	611.2	578.8	579.1	570.6	561.1
Absolute Change	0.0	-20.4	-8.5	-3.9	-1.8
% Change	0.0%	-3.4%	-1.5%	-0.7%	-0.3%
Wheat Human Consumption			Thousand tons		
Baseline	2751.8	2664.0	2715.2	2724.7	2714.3
Scenario	2751.8	2643.3	2712.7	2722.8	2714.0
Absolute Change	0.0	-20.6	-2.4	-1.9	-0.3
% Change	0.0%	-0.8%	-0.1%	-0.1%	0.0%
Wheat Feed Consumption			Thousand tons		
Baseline	90.7	48.4	72.7	63.9	61.7
Scenario	90.7	40.6	71.8	63.9	61.6
Absolute Change	0.0	-7.7	-1.0	0.0	-0.1
% Change	0.0%	-16.0%	-1.3%	0.0%	-0.2%
Wheat Exports			Thousand tons		
Baseline	123.9	207.4	148.1	145.4	149.2
Scenario	123.9	212.8	156.3	146.1	149.5
Absolute Change	0.0	5.4	8.2	0.7	0.3
% Change	0.0%	2.6%	5.6%	0.5%	0.2%
Wheat Imports			Thousand tons		
Baseline	1003.1	327.5	807.7	829.0	798.4
Scenario	1003.1	284.1	741.2	823.3	796.2
Absolute Change	0.0	-43.4	-66.5	-5.6	-2.1
% Change	0.0%	-13.3%	-8.2%	-0.7%	-0.3%
Wheat Producer Price			R/ton		
Baseline	1433.2	1564.2	1685.1	1822.8	1940.9
Scenario	1433.2	1704.7	1685.1	1822.8	1940.9
Absolute Change	0.0	140.6	0.0	0.0	0.0
% Change	0.0%	9.0%	0.0%	0.0%	0.0%