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.

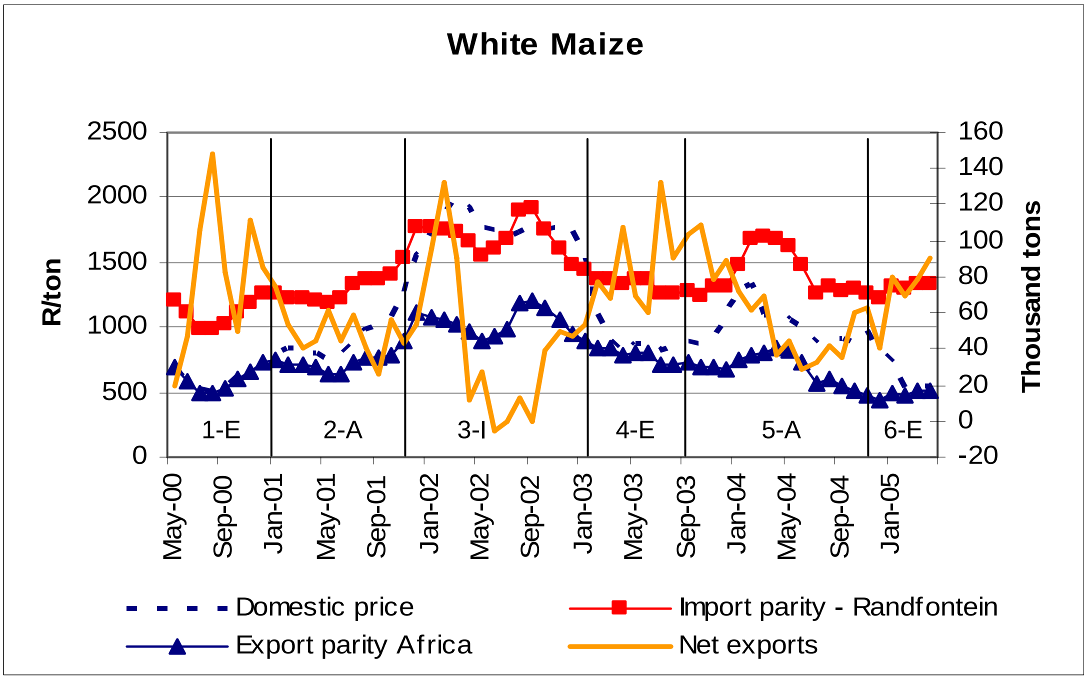

Figure 2.1: Price and trade space for white maize, May 2000 – May 2005

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.

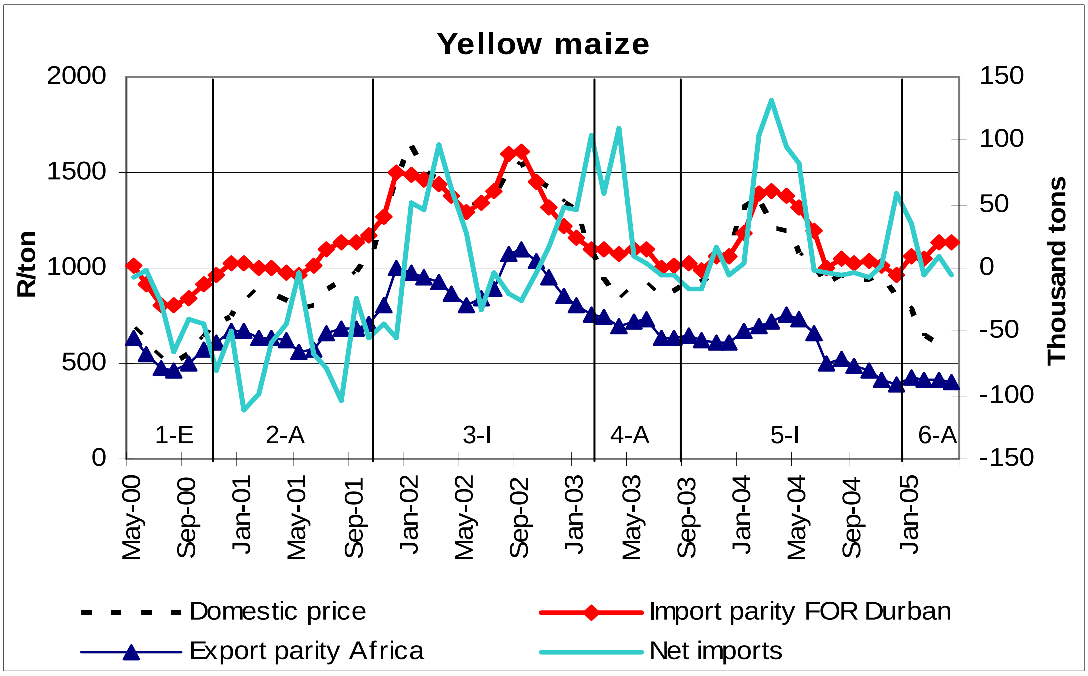

Figure 2.2: Price and trade space for yellow maize, May 2000 – May 2005

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.

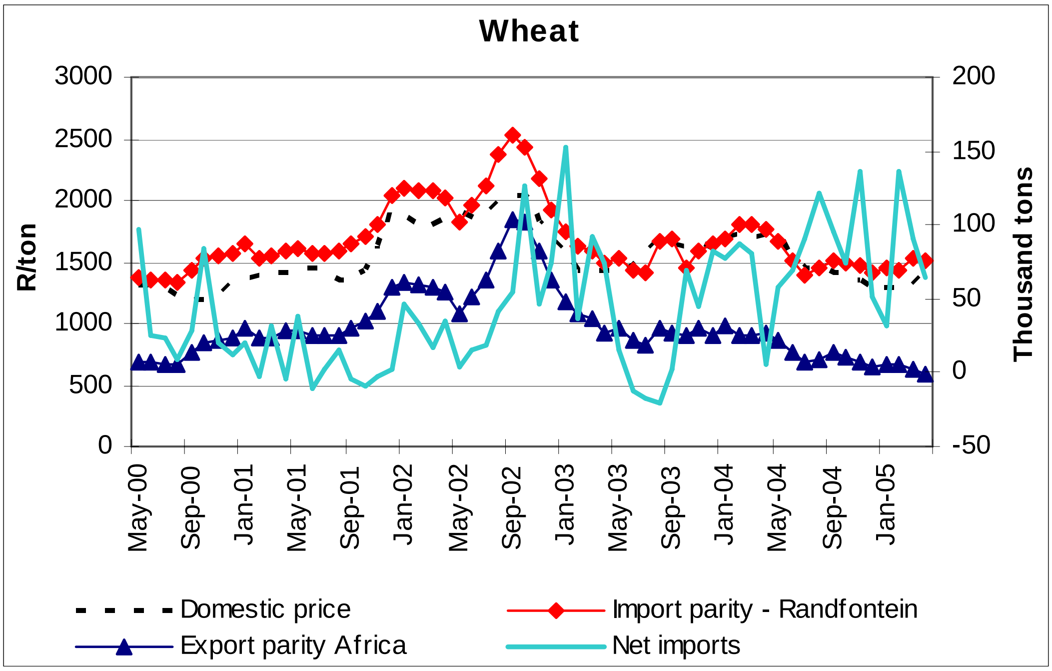

Figure 2.3: Price and trade space for wheat, May 2000 – May 2005

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.