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

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### Abstract

*This paper 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 paper proposes an approach that the authors believe allows the incorporation of features of regime switching in a multisector commodity level model that capture salient features of the South African market and therefore are able to produce more reliable projections of the evolution of the sector under alternative shocks.*

### 1. Introduction

When trade occurs between two markets, according to the law of one price, the markets are integrated and the difference in the prices equals the transactions costs to move the goods between those markets in the long run (Goodwin *et al*, 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 not integrated any longer (Sexton *et al*, 1991). Now the market equilibrium (equilibrium price) is 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 trade and policy regimes. According to Barret (1999), if a commodity moves from a nontradable (importable) to an exportable (nontradable) equilibrium, the

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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 which market regime prevails in the market. Most econometric simulation models do not make a distinction 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. 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) has 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. Schimmelpfennig *et al* (2003) presented an Error-Correction-Model (ECM) of the long-run equilibrium between the world price of maize, the local producer and consumer price of maize, and the exchange rate. In this study the switch of trade regimes<sup>3</sup> was ignored and just a single method of price determination based on average effects was represented in the model.

This paper 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. Although eighteen agricultural commodities are included in the model, this paper only focuses on price formation and model closure in the white maize, yellow maize and wheat market (Meyer and Westhoff, 2003).

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<sup>3</sup> 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.

## 2. The analytical model

The determination of domestic prices is dictated by a country's specific trade and policy regimes, which determine how domestic prices are integrated with world market prices. These regimes can be defined as follows:

### *Regime 1: Import parity*

The difference between the import parity price and the domestic price exceeds transfer costs and the possibility of arbitrage integrates the local and world markets at prevailing international prices. This would trigger imports of the commodity into the South African market. One would expect the market price in South Africa to move with the price on international markets, plus the cost of shipping commodities to South Africa and any import taxes.

### *Regime 2: Autarky*

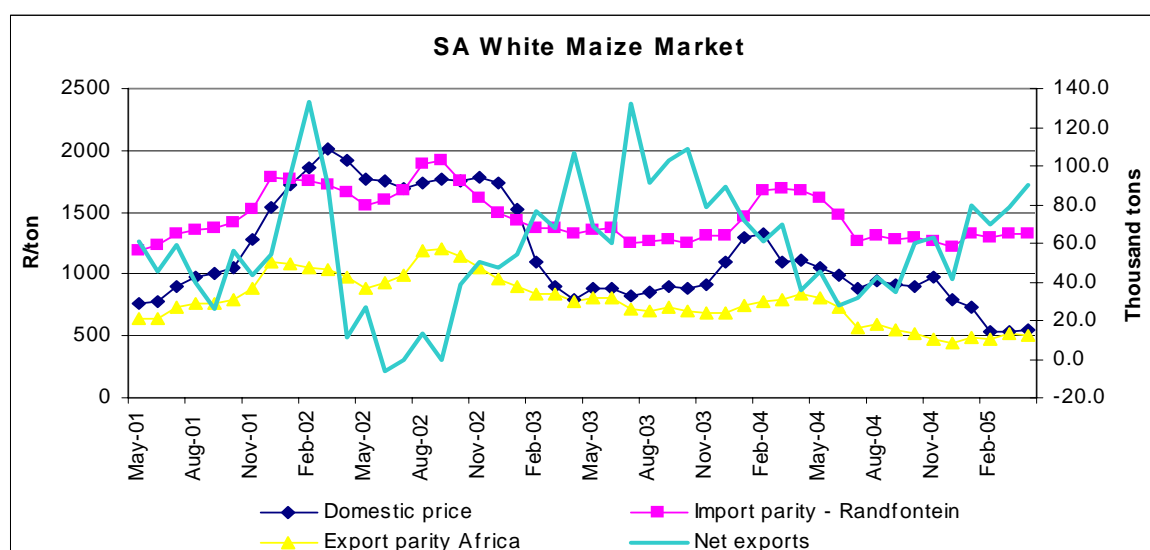
If domestic prices are below that which triggers imports, but not low enough to be competitive on international markets, domestic prices will be determined by supply and demand conditions in that market.

### *Regime 3: Export parity*

The difference between the export parity price and the domestic price exceeds transfer costs and the possibility of arbitrage integrates the local and world markets at prevailing international prices. The country can export grain to the world market.

However, important to note is 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 (Figure 1) which suggest that the market is trading under a type of regional autarky isolated from world markets. For example, between August 2001 and February 2002 the level of net exports increased as the domestic price traded between import and export parity and in fact moved closer to import parity. In theory, net exports are expected to be zero as domestic prices move closer to import parity. Net exports in the period between February 2003 and August 2003 correspond with domestic prices trading at export parity levels and, therefore, the trade flow and equilibrium prices conditions comply with theoretical principles. 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. In this study we, therefore, refer 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. The uniqueness of this study lies in 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.

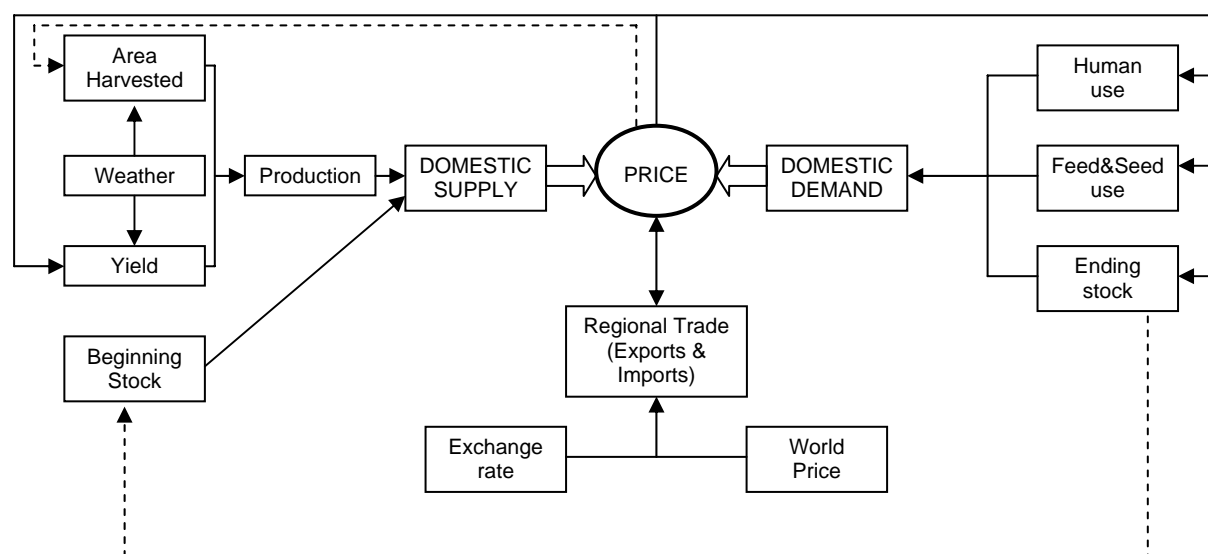


**Figure 1: White maize prices and net exports, May 2001 – April 2005**

### 3. Conceptualising model closure

Typical partial equilibrium models consist of domestic supply and demand components and trade and price components. Figure 2 and 3 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. The dashed lines represent lagged relationships between variables.

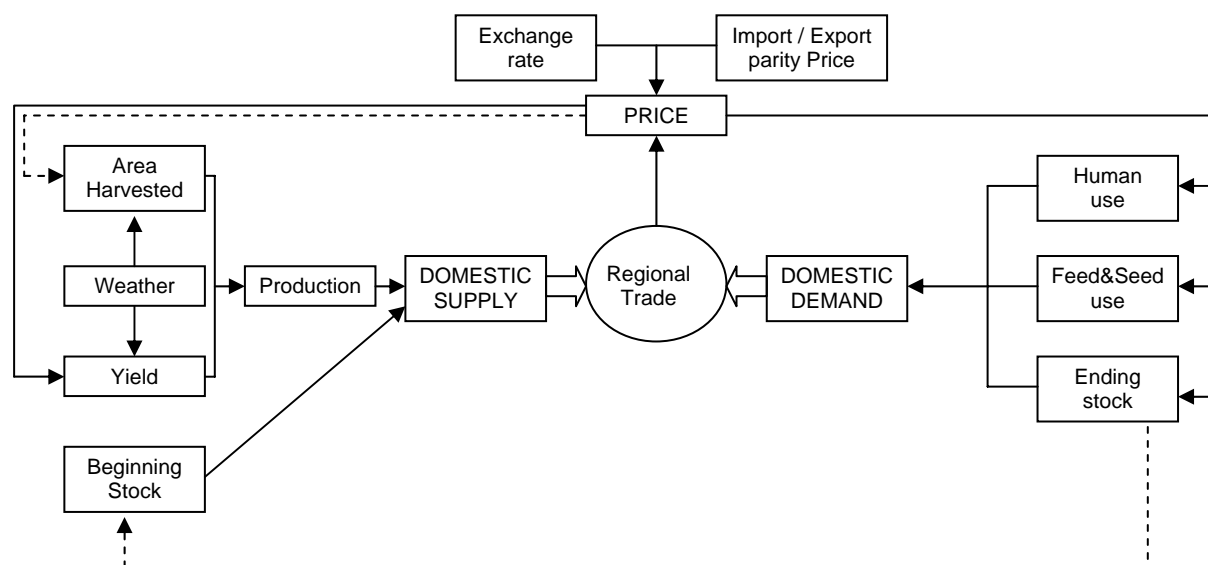
Figure 2 illustrates model closure and, therefore, the equilibrium pricing condition under near-autarky. Since significant trade occurs under near-autarky experts argue that trade does have an impact on the domestic equilibrium price. Because net trade is modelled as a function of the world price and the exchange rate, these variables will subsequently have an impact on the domestic price. The two-directional arrow between net trade and the domestic price illustrates this point. Price is thus solved endogenous in the domestic market and not as an endogenous variable in a behavioural equation.



**Figure 2: Flow diagram of SA grain market in near-autarky**

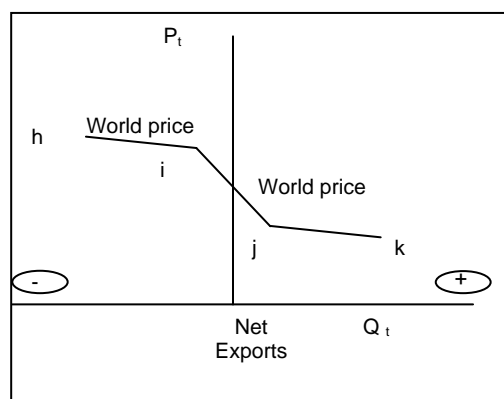
Figure 3 represents model closure under an import parity or export parity regime. Under the import and export parity regimes, the domestic price is modelled as a function of the import and export parity price respectively and, therefore, can be regarded as predetermined in the system of equations. The 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 thus should the market 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 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. Important to note is 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: Flow diagram of typical grain market in net export or net import parity**

Net exports can also be presented in the form of a P-Q diagram (Figure 4) to illustrate the impact of various trade regimes on price elasticities. All three regimes are captured in Figure 4 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.



**Figure 4: P-Q diagram for net exports under three different regions**

The essence of this diagram lays in the portrayal of the price elasticities under the different market regimes. Under true autarky,  $ij$  should be vertical and thus perfectly price inelastic. However, in the South African markets some regional trade still occurs under near-autarky 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. In order to make a clear distinction between the various market regimes, trade and price equations have to be estimated for each regime independently.

### 3.1 Near-autarky

In Equation 1 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 ( $CONS_t$ ) ratio. The exchange rate, transaction costs, and government trade policies are already factored into the import and export parity price calculations (Barrett, 2001). According to the definition of autarky, it is expected that domestic prices fluctuate between import and export parity prices and, therefore, the average of these two price levels is applied in this equation.

$$NEXD_t = f\left(\frac{P_{D,t}}{\text{Avg}(P_{IP,t} \& P_{EP,t})}, \frac{PROD_t}{CONS_t}, e_t\right) \quad (1)$$

Export supply  $EXS_t$  is calculated in the form of an identity

$$EXS_t = PROD_t - CONS_t - (BEGS_t - ENDS_t) \quad (2)$$

The domestic equilibrium price is solved endogenously by means of a price equilibrator. The equilibrator is based on the principle that net export demand must equal export supply. 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.



### 3.2 Import and export parity

Under an import/export parity market regime, domestic prices are predetermined 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 only prove useful 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. South African import and export markets differ, which provides another advantage of setting up the model to switch between import and export regimes.

Equations 3 and 4 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 ( $NEXD_t$ ). 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).

$$P_{D,t} = f(P_{IP,t} NEXD_t) \quad (3)$$

$$P_{D,t} = f(P_{EP,t} NEXD_t) \quad (4)$$

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. The net trade identity can be expressed as

$$NT_t = BEGS_t + PROD_t - CONS_t - ENDS_t \quad (5)$$

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

#### **4. Empirical results**

Apart from identities, the simulation model utilized for this study consists of 126 behavioural equations. For the purpose of this paper only the absolute and percentage effects (impact multipliers) of a 10 percent increase in the world price, simulated under alternative market regimes, will be illustrated and discussed. Before the empirical results are discussed the regime switching mechanism, which allows the model to switch automatically between various model closure techniques (depending on the market regime) is explained.

The trigger mechanism for the alternative model closures of each commodity is based on import and export parity price levels. 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 then solves under near-autarky until the prices that are solved in the iteration process move into the import or export parity band at which stage the model switches to the new closure technique. The inclusion of the regime switching technique increased the number of iterations necessary for the model to reach equilibrium in all markets sharply.

In order to calculate impact multipliers (Table 1), the first step is to generate baseline projections under a combination of different trade regimes in the grain markets. The purpose of this study, three combinations were identified that are required to construct basic price and trade impact multipliers that portray the most important relationships between domestic and world prices, and trade flow. These combinations are based on the number of regimes that each market can trade under. The three combinations are:

- White and yellow maize trade under import parity, wheat trades under import parity.
- White and yellow maize trade under autarky, wheat trades under import parity.
- White trades under export parity, yellow maize trades under autarky, and wheat trades under import parity.

The actual table was developed by conducting a range of scenario analyses. The impact of a 10 percent increase in world prices on the domestic prices and trade flow is calculated by comparing the scenario results to the baseline. If the world price shock for each grain is applied to the three different regime combinations one by one, it implies that six scenarios will be analysed. Table 1

presents the results of the impact multipliers for each of the scenarios. The “baseline” columns represent the basic projections for the 2005/06 production season for trade flow and prices under the three alternative market regimes. The absolute and percentage deviations from the baseline projections due to the 10 percent increase in world prices are illustrated by the “Absolute” and “%” columns.

**Table 1: Price and trade impact multipliers under alternative market regimes, 2006**

|                     | Near-autarky |          |      | Import parity |          |       | Export parity |          |      |
|---------------------|--------------|----------|------|---------------|----------|-------|---------------|----------|------|
|                     | Baseline     | Absolute | %    | Baseline      | Absolute | %     | Baseline      | Absolute | %    |
| <b>White Maize</b>  |              |          |      |               |          |       |               |          |      |
| Exports             | 719.2        | 38.6     | 5.4  | 0.0           | 0.0      | 0.0   | 1806.5        | 118.1    | 6.5  |
| Imports             | 139.0        | -11.1    | -8.0 | 722.3         | -76.1    | -10.5 | 0.0           | 0.0      | 0.0  |
| Producer Price      | 1044.7       | 67.4     | 6.5  | 1324.1        | 133.7    | 10.1  | 639.5         | 85.4     | 13.4 |
| <b>Yellow Maize</b> |              |          |      |               |          |       |               |          |      |
| Exports             | 245.7        | 1.6      | 0.7  | 0.0           | 0.0      | 0.0   |               |          |      |
| Imports             | 201.5        | -8.2     | -4.0 | 1650.2        | -137.7   | -8.3  |               |          |      |
| Producer Price      | 885.6        | 30.0     | 3.4  | 1102.7        | 123.2    | 11.2  |               |          |      |
| <b>Wheat</b>        |              |          |      |               |          |       |               |          |      |
| Exports             | 167.8        | 5.4      | 3.2  |               |          |       |               |          |      |
| Imports             | 648.4        | -43.3    | -6.7 |               |          |       |               |          |      |
| Producer Price      | 1576.2       | 125.8    | 8.0  |               |          |       |               |          |      |

Important to note is that Table 1 does not present the ordinary single-equation multipliers, but rather impact multipliers that reflect a full model response to a shock. Results clearly show that there exists a higher level of integration between domestic and world grain markets under the import/export parity regimes than under near-autarky. This clearly illustrates how a shift in equilibrium pricing conditions changes the correlation between domestic and world prices and, therefore, produces different impact multipliers in response to a 10 percent shift in parity prices are generated under the various trade regimes. In the case of the white maize producer price an impact multiplier of 6.5 percent was simulated under near-autarky compared to an impact multiplier of 10.1 percent and 13.4 percent simulated for import and export parity respectively. Thus, 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. 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 8 percent.

## 5. Conclusion

This study presented the alternative techniques of model closure under different market regimes. A regime-switching methodology that was developed to allow simulation models to switch between various techniques of model closure in order to simulate the most realistic formation of equilibrium prices. Empirical results prove that, contrary to economic theory, there exists some level of integration between domestic and world markets when domestic markets are trading under, what can be described as, near-autarky. Despite the fact that only one scenario, namely that of a 10 percent increase in the world price was evaluated the true usefulness of regime-switching models is found in the scenario evaluation process. The 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. Over the past production seasons a number of local agribusinesses have successfully tested and applied this model 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.

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