MODELLING THE MARKET OUTLOOK AND POLICY ALTERNATIVES FOR THE WHEAT SECTOR IN SOUTH AFRICA

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Ferdinand Meyer, Johann Kirsten, and Daneswar Poonyth

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Ferdinand Meyer, Johann Kirsten, and Daneswar Poonyth

Contact person:
Ferdinand Meyer
Dept Agricultural Economics, Extension and Rural Development
University of Pretoria
PRETORIA 0002
RSA

Email: fmeyer@postino.up.ac.za

Tel.no. 012 420 4583

Abstract:

In this study, the structure of the South African wheat market is analysed using economic theory and econometric modelling techniques. The developed model is used to make baseline projections regarding the supply and use of wheat in South Africa and to analyse the impacts of various policy alternatives on the wheat sector for the period 2002 – 2008. Results indicate that after an initial decline in the area harvested in 2003, the area harvested will increase over time. Domestic consumption will gradually decrease over time, which will result in lower levels of imports and higher level of exports. Three policy scenarios are analysed, the elimination of the import tariff for wheat, a twelve percent depreciation in the exchange rate, and the convergence of the elimination of the import tariff and the 12% depreciation in the exchange rate.

1. Introduction

Wheat is the most important grain crop in South Africa after maize and interestingly, the past decade has brought about a shift in the style of wheat marketing characterized by the transformation of a highly regulated dispensation to an essentially free one. As a result, the phasing out of the Wheat Board in 1997 has ensured that wheat producers are increasingly being exposed to international wheat markets. In addition, the economic policy in South Africa has changed dramatically, accompanying the almost global movement towards deregulation and liberalisation of the economy; resulting in a more market-based approach to both agricultural and macro-economic policy. The dynamic environment in which producers of agricultural products operate urges the need to understand the production and consumption patterns of the products that they produce. It is against this background that commodity modelling can play an important role to assist role players in decision-making.

Commodity modelling is a methodological and complete technique that provides a powerful analytical tool for examining the complexities of commodity markets. Generally, commodity models can be used for three levels of analysis, namely, market analysis, policy analysis, and as a forecasting tool (Belhassen, 1997). The specific approaches developed for commodity modelling in this study have not, as yet, been applied in South Africa, and may provide a systematic and comprehensive approach to analysing and forecasting the behaviour of commodity markets in the country. The application of this econometric modelling technique can be undertaken on a range of commodities and the econometric analysis of the wheat sector will thus only serve as an example of the usefulness of these kinds of modelling techniques.

The convenient and efficient methodology developed by the Food and Agricultural Policy Research Institute (FAPRI) for conducting policy analysis research, is particularly pertinent to this study and hence underpins the approach used for modelling the market and policy alternatives for the South African wheat sector. Ordinary Least Squares (OLS) is used to estimate single equations, which are collapsed into one system and estimated simultaneously using the Two-Stage-Least-Squares (2SLS) estimation method. After the validation of the model's performance it is used to make baseline projections for the South African wheat sector during the period 2002 to 2008.

The paper is organised as follows: The following section describes the theoretical structure of the model, using a Flow Diagram and a P-Q space. Section three presents the empirical results of the model, and discusses the performance of the model. Section four illustrates the baseline for the period 2002 – 2008 for the wheat sector in South Africa. The policy simulation results and their implications are reported in section five. A summary of the study and concluding remarks are given in section six.

2. Theoretical Structure of the Model

The Flow Diagram and a Price-Quantity (P-Q) diagram provide guidance towards the empirical estimation of the South African wheat model by means of illustrating the important economic and biological relationships, which are to be captured in the econometric model of the South African wheat sector. Figure 1 shows the flow of wheat through the market channel from the wheat producer to the ultimate consumer of the wheat product. The wheat model is basically composed of three blocks namely, the supply block, the demand block, and the price linkage block. In the supply block, 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 a good proxy for the area planted and it is also a reliable indicator of planned production.

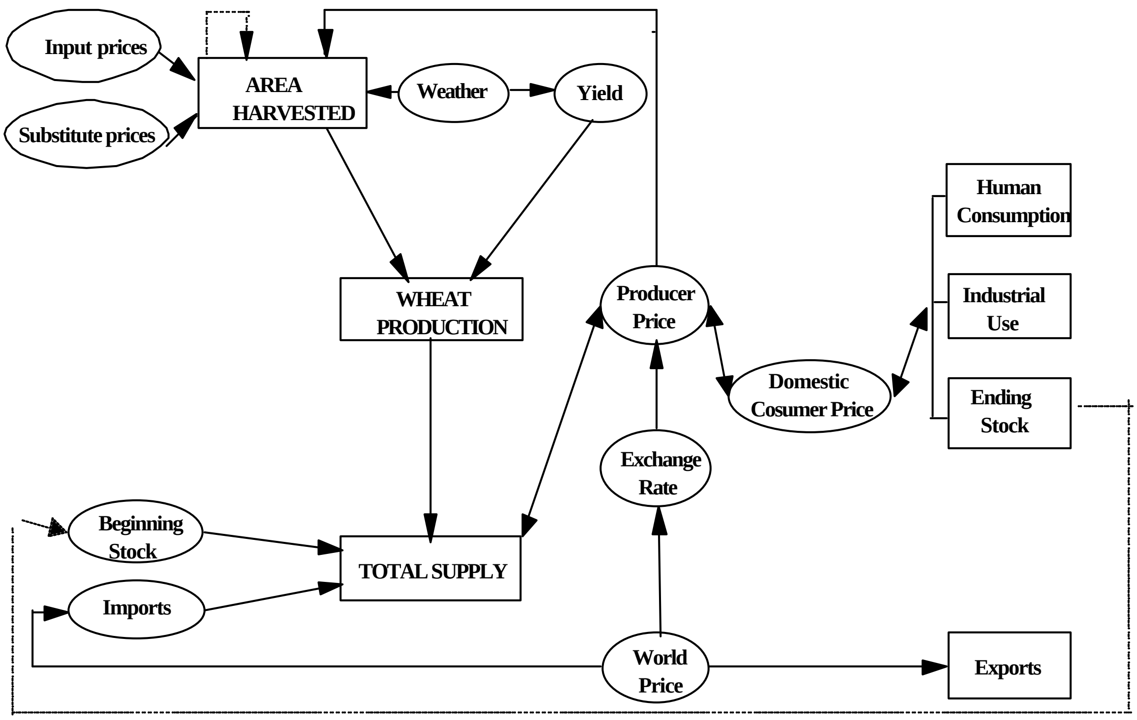

Figure 1: Flow Diagram of the South African Wheat Sector

The producer price of wheat, input prices, producer prices of substitutes and complements, the weather conditions, and the previous year's area planted will influence the wheat producer's decision. After the wheat producer has taken the decision to plant, the yield, which is also influenced by the weather conditions, will determine the total production of the crop. The total supply of wheat in South Africa is then calculated by adding the beginning stock and total imports to the total production of the country. Imports are determined by both the world price of wheat and local production figures.

In the demand block human consumption, feed and seed consumption, exports, and ending stocks determine the total demand for wheat in South Africa. Human consumption is influenced by the current consumer price and *via-versa*. A two-directional arrow illustrates this relationship. Feed consumption makes up less than five percent of the market and the data that reports on seed use is unreliable. As a result, these two categories are not estimated by means of behavioural equations but are included as exogenous variables in the calculation of total demand. Ending stocks in period t depend on the local production of wheat, the consumer price of wheat, and the beginning stocks in period t. Ending stocks in period t are equal to the beginning stocks for period t+1. A dotted line is used to denote the lagged effect between ending stocks in period t and beginning stocks in period t+1. Exports are not estimated by means of a behavioural equation and are used as the market-clearing commodity.

The price linkage block formalises the interaction between the supply block and the demand block and also links the world price to the local producer price, which in turn is linked to the local consumer price. The one-direction arrow from the world price to the local producer price indicates that the local price is influenced by the world price, but the local price does not influence the world price. The reason for this is that South Africa is a price taker in the world wheat market. The two-direction arrow from the local producer price to the consumer price illustrates that the relationship between the producer price and the consumer price is simultaneous. The producer price influences the consumer price and visa-versa. This relationship is vital to enable the closure of the model.

The P-Q diagram (Figure 2) and the flow diagram are closely related. The P-Q diagram reflects the different layers of the market. The P-Q diagram consists of two blocks. The first block is the supply block and consists of the total area harvested (summer and winter), the beginning stock, and imports. The second block is the demand block and consists of the total domestic consumption, the exports, and ending stock.

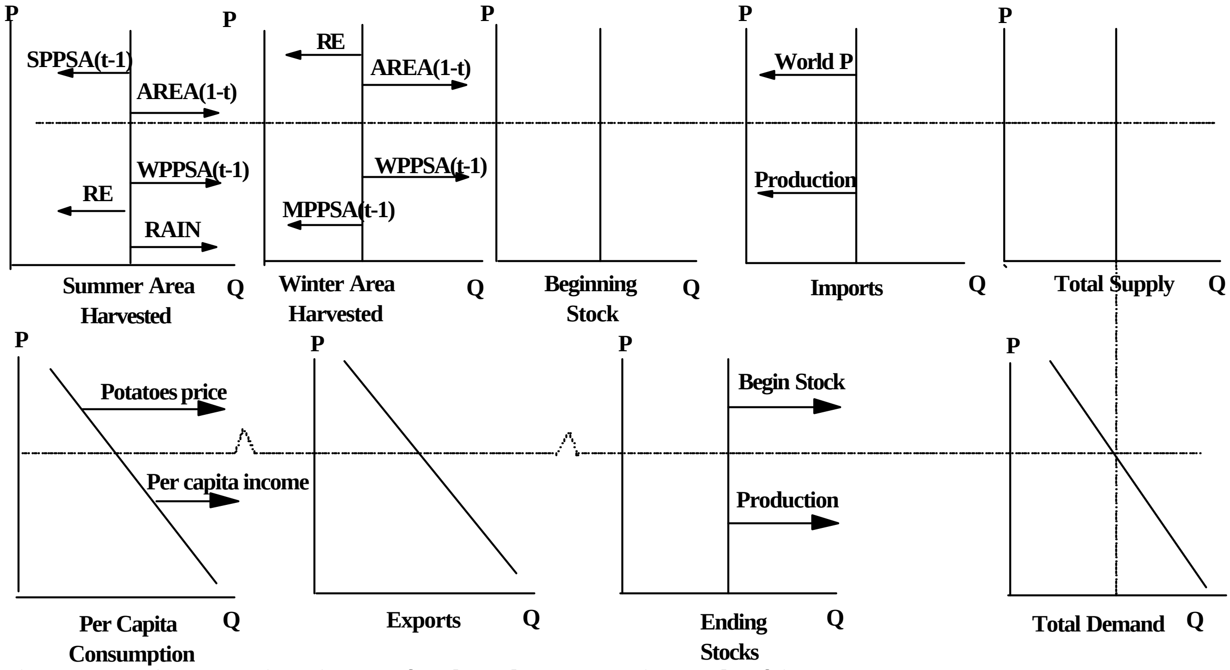

Figure 5.2: Price-Quantity Diagram for the Wheat Sector in South Africa

It is important to note that the P-Q diagram depicts the economic relationships amongst the dependent and explanatory variables at different layers in the wheat market. This implies that each layer is influenced by its own price and the intersection of total demand and total supply yields the equilibrium price, i.e. the area harvested is influenced by the producer price, the total domestic consumption is influenced by the retail price, and exports are influenced by the world price. The nature of the relationships among the dependent and explanatory variables is depicted by means of the shifters (arrows). 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.

3. Estimation Procedures, Results and Performance of Model

A single –equation approach is used in the first stage of the estimation procedures. Ordinary Least Squares (OLS) produces the best linear unbiased estimators for a single equation (Pindyck and Rubinfeld, 1998). Once the behavioural equations have been estimated, they will form part of a system of simultaneous equations that will express the interdependence of variables, which influence the supply and utilisation of wheat in South Africa. The equations in the model are estimated using the 2SLS estimation technique for the period 1976 – 2000.

The equations reported in this section form the South African wheat model and are taken from the 2SLS estimations. The estimated results include the parameter estimates, t-statistics in parenthesis, short-term elasticities in brackets, and long-term elasticities in square brackets. The R^2, DW, and DH statistics are reported for every equation. 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 detailed description of all the variables is included in the Appendix.

The South African wheat model consists of the following ten equations, six behavioural equations and four identities. The supply block is composed of equations 1 to 5, the demand block is composed of equations 6 to 8, and the wheat model is closed with the market clearing identity in equation 9. The price linkage block is given by equation 10.

1. ***Wheat Summer Area Harvested:***

$WSAHSA_t$ = 0.062 + 0.812 $WSAHSA_{t-1}$
(7.91)
+ 0.036 ((SHIFT97*(WPPSA)+(1-SHIFT97)*LAG(WPPSA))/ RESA
(3.13)
<0.31>
[0.76]
-0.028 $(SPPSA/PPIA)_{t-1}$ + 0.0015RAIN
(-1.60) (4.51)
<-0.21>
[-0.56]
-0.50 DUM92 + 0.22 DUM96
(-4.57) (2.39)

R^2 = 0.938 Adj. R^2 = 0.912 F Value = 34.96 D.H = 0.422

2. ***Wheat Winter Area Harvested:***

WWAHSA = 0.56 + 0.32 LAG(WWAHSA)
(1.59)
+ 0.017 ((SHIFT97*(WPPSA)+(1-SHIFT97)*LAG(WPPSA))/ RESA
(1.83)
<0.18>
[0.45]
-0.016 LAG (MPPSA/PPIA) -0.23 SHIFT90
(-1.54) (3.29)
<-0.15>
[-0.35]

R^2 = 0.925 Adj. R^2 = 0.905 F Value = 44.97 D.W = 1.795 D.H = 0.823

The results also show that South African wheat competes with sunflowers in the summer rainfall region and with mutton in the winter rainfall region with short run cross price elasticities of -0.21 and -0.15 and long run cross price elasticities of –0.56 and -0.35 respectively. The rainfall variable used in the model represents the sum of the rainfall for the months March, April, and May. The rainfall of these three months will influence the farmers planting decision.

3. ***Wheat Production***

WPROSA = (WSAHSA + WWAHSA)*WYSA

Wheat production is an identity equal to the sum of summer and the winter area harvested multiplied by the average yield. The variables used for the summer and winter areas harvested in equation 3 were estimated in equation 1 and 2. For this study yield was treated as an exogenous variable and was thus not estimated.

4. Wheat Imports

WISA = 22.16 – 737.82 (WPPKC*EXCH/100)/CPIF
(-1.22)
<-0.60>
– 0.103 (WPROSA) + 18.58 DUM96
(-1.48) (2.00)
<-0.79>

R^2 = 0.746 Adj.R^2 = 0.693 F Value = 13.98 D.W. = 1.981

South African wheat imports were modelled as a function of the Kansas City price of hard red winter wheat no.2 multiplied by the exchange rate. The negative relationship between production and the quantity of wheat imports can also be explained by economic theory.

5. Wheat Total Sypply

WTSSA = WPROSA + WBSSA + WISA

Wheat total supply as presented in equation 6.5, is an identity and was defined as the beginning stock of the production season plus the total production plus the imports.

6. Wheat Per Capita Consumption

WPCCSA = 9.63 - 2.597 ((7.06*WPPSA/1000*100)/PPIA) + 12.76 (PRPSA/PPIA)
(-2.09) (2.43)
<-0.32> <0.20>
+ 0.003 (PCGDP/PPIA) – 11.70 SHIFT90
(2.47) (-3.34)
<0.45>

R^2 = 0.854 Adj.R^2 = 0.824 F Value = 27.95 D.W = 1.550

The results of equation 6 show that wheat competes with potatoes on a retail level, with a cross price elasticity of 0.20. Contrary to what was expected, maize meal was not found to be a substitute for wheat. Per capita income was also found to have a positive effect on domestic wheat utilization with an income elasticity of 0.45.

7. Wheat Ending Stock

WENDSA = -0.55 + 0.80 LAG(WENDSA) + 0.32 WPROSA – 0.87 DUM88
(3.93) (2.99) (-2.58)

R^2 = 0.729 Adj.R^2 = 0.655 F Value = 9.73 D.W. = 1.934

In Equation 6.7 the ending stocks were estimated as a function of the lagged wheat ending stocks and total production. Initially wheat domestic prices and Free on Board (FOB) export prices were used as explanatory variables, but then dropped from the equation. Both produced wrong signs and were found to be statistically insignificant. These findings suggested that South African wheat stocks are perfectly inelastic with respect to their own price.

8. Wheat Total Domestic Use

WDUSA = WPCCSA*POP

South African domestic wheat use is an identity defined as wheat per capita consumption times total population.

9. Wheat Market Clearing Identity

WESA = WTSSA - WDUSA – WENDSA

Wheat exports were used as the market clearing identity. In other words, they were used to close the wheat model. They were defined as total wheat supply minus wheat domestic use minus wheat ending stocks. The market clearing identity is reached at an equilibrium price in the market. The equilibrium price is now linked to the world price (equation 10).

10. Wheat Price Linkage Equation

WPPSA = 160.70 + 0.33 (WPPKC*EXCH/100) – 78.21 WPROSA + 29.36 TREND
(1.88) (-2.54) (6.11)
<0.24> <-0.33>
R^2 = 0.965 Adj.R^2 = 0.961 F Value = 289.56 D.W. = 1.25

In order to complete the process of model development, the model is simulated over the historic period. In this study, the Gauss-Seidel algorithm is used to solve the model's simultaneous system of equations. Now the estimated system of equations is validated based on four criteria (Ferris, 1998 and Pindyck and Rubinfeld, 1998). These are: the Root Mean Square (*RMSE %)* error's; the Mean Error percentages; Theil's Inequality Statistics; and finally the response of the system to exogenous shocks, which is referred to as impact multipliers. The estimated equations were subjected tot the full range of statistical tests. Based on the results of theses tests, it can be concluded that the estimated econometric model provides reliable estimates of South African wheat supply and utilization. For the purpose of this paper, only the Goodness of Fit measures are illustrated in table 1. Results indicate that only two of the equations had percentages for the Root Mean Squared Error (RMSE%), which were significantly higher than ten percent. This implies that the simulated endogenous variables track their corresponding data series very closely.

Table 1: Measurements for the Goodness of Fit

Variable	Mean Error	Mean Error%	Mean A.Error	RMSE	RMSE%
WSAHSA	-0.0032	-0.2999	0.0675	0.0837	15.276

WWAHSA	-0.0001	1.3537	0.0498	0.0581	10.993
WPRODSA	-0.0110	0.2239	0.1243	0.1530	8.9219
WENDSA	-0.0218	0.5878	0.1111	0.1581	24.645
WPCCSA	-0.0292	0.3347	4.8119	5.3514	8.0988
WISA	0.0507	1.6500	4.3114	5.0563	4.2530
WDUSA	0.0013	0.3117	0.1537	0.1720	7.7000
WTSSA	-0.0298	-1.0200	0.1571	0.2062	6.8079
WPPSA	0.8615	0.7129	40.613	50.149	11.677
WESA	-0.0094	.	0.1461	.	0.1834

The final criterion to determine the goodness-of-fit of the model is Theil's inequality coefficient, as presented in table 2. *U* can take on values between 0 and 1. If *U* = 0, there is a perfect fit, whereas, if *U* = 1, the predictive performance of the model is as bad as can be. With the highest value of 0.24181 for Wheat Exports (WESA), which is also the residual variable, these results also suggest that the *ex post* forecast of the model has performed well and consequently the model can be used for forecasting purposes as well as policy analyses.

Table 2: Theil's inequality Coefficients

Variable	Inequality Coefficient (U)
WSAHSA	0.0439
WWAHSA	0.0469
WPRODSA	0.0352
WENDSA	0.1384
WPCCSA	0.0388
WISA	0.2155
WDUSA	0.0379
WTSSA	0.0339
WPPSA	0.0428
WESA	0.2481

4. The Baseline

To facilitate the generation of a baseline, the model needs to be solved for a specific period in the future. Various assumptions are made regarding future values for the exogenous variables in the model. The baseline projections are considered as a commodity market outlook rather than as forecasts because they are produced conditional on a number of assumptions. These assumptions relate mainly to agricultural policies, the macroeconomic environment, and weather conditions.

The baseline assumes that no changes will take place in the agricultural policies currently in force. This implies that the policy on the import tariff will stay in place for the baseline period. Projections for the following macroeconomic variables were obtained from FAPRI's 2002 baseline:

the World Price of Wheat and Sunflower, the Exchange Rate, the Gross Domestic Product Deflator (GDPD), and Population. The wheat world price is projected to gradually increase to a level of $148.05/ton in 2008. The exchange rate is expected to consistently depreciate against the US dollar to a level of 1544 SA cents/USD in 2008. The population is assumed to decline at an increasing rate from 0.1 percent in 2003 to 1 percent in 2008. GDPD is projected to increase at a decreasing rate from 7.6 percent in 2001 to 3.5 percent in 2005. It will then again start to increase at an increasing rate up to 2008. The projected percentage change of the world price of sunflower was used to calculate the projected local sunflower producer price. The baseline projections also assume trend yields and normal weather conditions.

Table 3: Market Outlook for the South African Wheat Sector

Variable	Units	2002	2003	2004	2005	2006	2007	2008
Summer Area	mill. ha	0.510	0.480	0.491	0.514	0.547	0.587	0.643
Winter Area	mill. ha	0.410	0.445	0.462	0.469	0.471	0.472	0.475
Production	mill. tons	2.321	2.337	2.412	2.491	2.583	2.690	2.844
Ending Stock	mill. tons	0.631	0.638	0.667	0.716	0.785	0.875	0.996
Consumption	kg/capita	54.770	54.191	53.987	53.983	53.833	53.955	53.934
Domestic Use	mill. tons	2.494	2.466	2.448	2.434	2.410	2.394	2.370
Total Supply	mill. tons	3.273	3.277	3.330	3.417	3.524	3.675	3.895
Producer Price	R/ton	1588.464	1706.475	1782.003	1844.786	1928.167	2002.066	2036.327
Exports	mill. tons	0.148	0.174	0.214	0.266	0.330	0.405	0.528
Imports	mill. tons	0.304	0.374	0.322	0.309	0.280	0.259	0.226

Table 3 presents baseline projections for the South African wheat sector over the period 2002 to 2008. The wheat area harvested in the summer rainfall region decreases in 2003 but then gradually increases to a projected level of 643 000 hectares in 2008. The reason for the initial decrease in the area harvested is the impact of the high sunflower producer price. The wheat area harvested in the winter rainfall region increases consistently to reach 475 000 hectares in 2008. Despite a decline in the wheat imports per capita, the total supply of wheat increases to reach 3.8 million tons in 2008. This increase is a result of the higher levels of production. Higher levels of production also enhance exports over the projected period of time to reach a level of 528 000 tons in 2008. As the world price of wheat increases and the exchange rate depreciates, the import parity price increases, which will force the imports to decrease to 226 000 tons in 2008. Per capita consumption decreases over the projected period as the wheat producer price increases. The domestic use of wheat decreases at a faster rate than the wheat consumption per capita. This can be explained by the fact that the projected population declines at an increasing rate.

5. The Wheat Sector Outlook for a Shift in the Political Environment

The constructed model can now be used to make projections taking into account different policy shifts that will result in a change in the macroeconomic environment. Policy and business decisions can be assessed using a range of *"what if"* questions. Although various scenarios were simulated, only the results of one specific policy shift will be illustrated and discussed, namely, the elimination of the wheat import tariff. This shift in the political environment is introduced in 2003. The model is solved and the results are compared to the initial baseline, which was generated without any changes in policies, world markets and the production environment.

Import tariffs replaced quantitative import controls in 1995. These tariffs are usually implemented by means of a gliding scale where the international price drops below a level of $194/ton (Exchange rate R3.69 for $1 USA). It was not until February 1998, that the first import tariff was implemented. The import parity price of wheat dropped under R802 per ton and a R50 per ton import tariff was charged. In 1999, a new tariff structure for wheat was announced with a new reference price of $157 per ton. This tariff structure is still in place. The tariff is calculated according to the Hard Red Wheat (No.2) price in Kansas City on a weekly basis. If the current price deviates for three weeks by $10 per ton or more from the average price of $157 per ton, the tariff is adjusted. The wheat tariff is currently published at R196 per ton, which implies that it makes up almost ten percent of the current import parity price. It is, therefore, appropriate to consider the case where no import tariff is in place as a policy scenario. Results of this scenario are presented in Table 4 below.

Table 4 Impacts of the Elimination of the Import Tariff on the Wheat Sector

	2002	2003	2004	2005	2006	2007	2008
Summer Area Harvested							
Baseline	0.510	0.480	0.491	0.514	0.547	0.587	0.643
No Tariff	0.510	0.480	0.479	0.493	0.519	0.555	0.607
% Change	0.000	0.000	-2.494	-4.120	-5.068	-5.514	-5.581
Winter Area Harvested							
Baseline	0.410	0.445	0.462	0.469	0.471	0.472	0.475
No Tariff	0.410	0.445	0.457	0.462	0.464	0.465	0.469
% Change	0.000	0.000	-1.163	-1.422	-1.436	-1.378	-1.323
Production							
Baseline	2.321	2.337	2.412	2.491	2.583	2.690	2.844
No Tariff	2.321	2.337	2.367	2.421	2.495	2.591	2.736
% Change	0.000	0.000	-1.849	-2.833	-3.388	-3.671	-3.771
Supply							
Baseline	3.273	3.277	3.330	3.417	3.524	3.675	3.895
No Tariff	3.273	3.315	3.327	3.375	3.446	3.563	3.754
% Change	0.000	1.169	-0.090	-1.231	-2.231	-3.046	-3.626
Domestic Use							
Baseline	2.494	2.466	2.448	2.434	2.410	2.394	2.370
No Tariff	2.494	2.498	2.478	2.462	2.435	2.418	2.393
% Change	0.000	1.297	1.193	1.115	1.054	0.991	0.965
Producer Price							
Baseline	1588.464	1706.475	1782.003	1844.786	1928.167	2002.066	2036.327

No Tariff	1588.464	1640.671	1719.686	1784.502	1869.205	1943.986	1978.910
% Change	0.000	-3.856	-3.497	-3.268	-3.058	-2.901	-2.820
Exports							
Baseline	0.148	0.174	0.214	0.266	0.330	0.405	0.528
No Tariff	0.148	0.180	0.196	0.231	0.281	0.346	0.460
% Change	0.000	3.655	-8.345	-13.140	-14.677	-14.587	-12.876
Imports							
Baseline	0.3219	0.3088	0.2800	0.2586	0.2258	0.1998	0.1767
No Tariff	0.3219	0.3471	0.3216	0.3014	0.2688	0.2422	0.2192
% Change	0.000	12.408	14.854	16.562	19.070	21.264	24.069

The results indicate that the producer price of wheat immediately decreases by 3.85 percent in comparison to the baseline, which would affect the area harvested under wheat for the following production season (2004) because producers respond on the lagged producer prices. Compared to the baseline, the area harvested in the summer rainfall region decreases by 2.49 percent and the area in winter rainfall region decreases by 1.1 percent. The major impact on the wheat sector can however be seen on the imports of wheat. The imports of wheat will increase by 12.4 percent above the baseline in 2003. In 2008 wheat imports are projected to be 24 percent higher than the baseline projection at a level of 219 200 tons. Wheat exports reach a level of 460 000 tons in 2008. This is 12.8 percent lower than the projected level of the baseline.

6. Summary and Conclusion

In this paper the structure of the wheat sector in South Africa was analysed using economic theory and econometric modelling techniques. The estimated models were subjected to a range of statistical tests. Based on the results of these tests, it can be concluded that the estimated model provides reliable estimates of relevant variables and can thus be used for forecasting purposes. The model was used to make baseline projections regarding the supply and use of wheat in South Africa, and to analyse the impact of the elimination of the wheat tariff on the wheat sector for the period 2002 to 2008. Although the model developed in this study is for a South African specific case study and therefore, contributes significantly to the understanding of the South African wheat market, the model development is at a relative early stage. This model should ideally be integrated into a larger system of equations with the necessary interaction between the different commodity and livestock sectors.

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Appendix A: Explanations of Variable Names Used in the Estimations

WSAHSA	:Wheat Summer Area harvested, 1000 000ha
LAG(WSAHSA)	:Wheat Summer Area harvested lagged by one year, 1000 000ha
WPPSA	: Wheat Producer Price South Africa , R/ton
SPPSA	: Sunflower Producer Price South Africa, R/ton
RESA	: Requisites Index, 1995=100
PPIA	: Producer Price Index of Agricultural goods, 1995=100
RAIN	: Average Rainfall of Summer Wheat Production Area for first four months of production season (March, April, May, June) when the planting decision is taken.
WWAHSA	:Wheat Winter Area Harvested, 1000 000ha
LAG(WWAHSA)	:Wheat Winter Area Harvested lagged by one year, 1000 000ha
MPPSA	: Mutton Producer Price South Africa, c/kg
WPROSA	:Wheat Production in South Africa, 1000 000tons
WYSA	:Wheat Average Yield per Hectare, tons/ha
WISA	:Wheat Imports of South Africa, 1000 000tons
WESA	: Wheat Exports, 1000 000tons
WPPKC	: Kansas City Wheat Price, Hard Red no.2, $/ton
EXCH	: Exchange rate, SA cent/USD
POP	: Population in South Africa, 1000 000 people
WTSSA	:Wheat Total Supply of South Africa, 1000 000 tons
WBSSA	: Wheat Beginning Stock, 1000 000tons
WPCCSA	: Wheat per Capita Consumption, kg/capita/year
PRPSA	: Potatoes Retail Price, c/kg
PCGDP	: Per Capita Gross Domestic Product
WENDSA	: Wheat Ending Stocks in South Africa, 1000 000tons
WDUSA	: Wheat Domestic Use, 1000 000tons