FORECASTING THE MARKET OUTLOOK FOR THE SOUTH AFRICAN MAIZE AND SORGHUM SECTOR USING ECONOMETRIC MODELLING

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In this study, an econometric model of the South African maize and sorghum sector is estimated. Using the developed model, a market outlook for the two major grain sectors – maize and sorghum - for 1999/00 to 2006/07, is generated under the specified assumptions. Results indicate that for both maize and sorghum, consumption will gradually increase over time. In spite of varying areas of maize and sorghum being harvested, total production will also gradually increase over time due to increases in particularly yields.

1. INTRODUCTION

Agricultural commodity modelling is of special importance to many countries where agriculture plays a major role in the economy. Agricultural commodity markets reflect a complex of interrelationships between economic, technical, biological and institutional factors. The formulation and the application of agricultural commodity models have appeared since 1970 as a distinct area of research, which provides support for price and policy analysis of the agricultural markets. Development in econometric techniques, economic theory and computational capacity of computers have sparked the interest of economists and policy analysts to better understand and predict movements in prices, quantities demanded and supplied due to the changes in market conditions and policies. Commodity modelling is a methodological technique that provides a powerful analytical tool for examining the complexities of commodity markets. These models provide a systematic and comprehensive approach to analyse and forecast market behaviour. In fact, commodity models serve three important tasks namely, market analysis, forecasting of future market prices and quantities and finally policy analysis.

Due to the recent waves of change in both domestic and international agricultural markets, agricultural commodity modelling is of great importance for South Africa. South Africa is facing a major challenge to make its agricultural sector efficient and economically viable, as well as more market oriented. Globalisation, market liberalisation and regional market integration

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increase the need to understand the developments in agricultural commodity markets. Structural econometric models of the agricultural sector of South Africa will enhance and support the intermediate-term economic intelligence and forecasting ability, and will provide a means of evaluating and quantifying the impacts of alternative agricultural and macro economic policies.

This paper describes such a model for South Africa. It builds on work of the Food and Agricultural Policy Research Institute at the University of Missouri, Columbia, USA, as well as earlier research of Van Zyl (see for example, World Bank, 1995, for a summary of his work). The model in this study is a partial equilibrium model.

The paper is organised as follows: In the following section is a brief review of previous studies. Section 3 describes the structure of the model of the individual crop, using a flow chart and a P-Q space. Section 4 gives the framework of econometric modelling of the agricultural commodity markets, followed by a discussion of the data in section 5. In section 6, the estimation procedures, model validation and empirical results are provided. Finally, in section 7 is the summary and conclusion.

2. RESULTS FROM SOME PREVIOUS STUDIES

Van Zyl (1991) showed that the price of maize and its production substitutes do not play a major role in determining the annual area under maize. In general, the fits of the supply response equation for the Western Transvaal and North Western Free State were disappointing. This implied that no significant elasticities for these areas could be calculated. Significant elasticities could, however, be calculated for the Eastern Free State region. The price elasticity of supply for maize was relatively low, 0.026. Cleasby, Darroch and Ortmann (1993) found that climatic variation was the major determinant of export supply of yellow maize. Their results also 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.

Schimmelpfennig, Thirtle and Van Zyl (1996) used an error correction model to investigate South African supply response of maize and sorghum. They concluded that the maize area planted in the short run or the long run depends on two sets of variables. Maize production is influence by its own price, price of substitutes like sorghum and sunflowers, and intermediate input prices and rainfall. Sorghum is found to be a secondary crop dominated by expected changes in the maize variables, and the area planted depends simply on intermediate input prices and rainfall over both the short and long run.

3. STRUCTURE OF THE MODEL[1]

In this section, the structure of the model of each crop is discussed, using a flow chart and P-Q space. Each model is basically composed of three blocks: the supply block, the demand block and the price linkage block. Figure 1 represents a flow chart of the RSA maize.. Figure 2 gives the P-Q (price – quantity) space of the maize.. The left-hand side of figure 1 is the supply side and the right hand side represents the demand side. The flow chart (Figure 1) is a causal ordering of the Supply-Utilisation-Price structure. It facilitates the understanding of the nature of the economic and statistical relationships among variables that influence production and consumption. It also explains how the policy and other relevant variables influence production and the consumption of the commodity in consideration. It has been common in crop modelling to start with area planted, but due to unavailability of the data for area planted, area harvested which is a good proxy for the area planted and also is a reasonable indicator of planned production is used instead. Using area harvested in the determination of potential supply is not without its own problem since not all area planted is harvested. However, this may not be a serious problem in the case of the RSA, since farmers have fairly strong incentives to harvest the total crop.

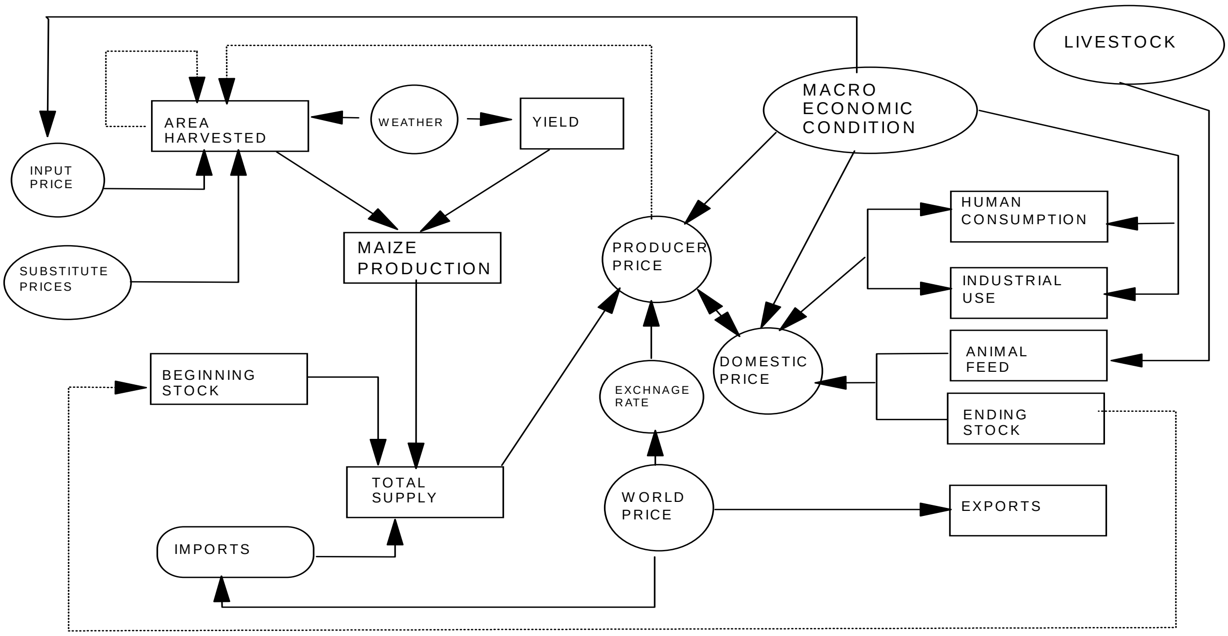

Figure 1: Flow chart of the South African maize/sorghum sector

In this model, it is assumed that area harvested is influenced by expected producer prices, input prices, competing crop price, weather, etc. Area harvested times yield gives total production. Total supply is equal to beginning stocks plus imports and total production. The domestic consumption is influence by the consumer price, substitute prices and income. The ending stock is a function of expected price and of expected production. Export is a function of world price, income of the importing country and the import tariff.

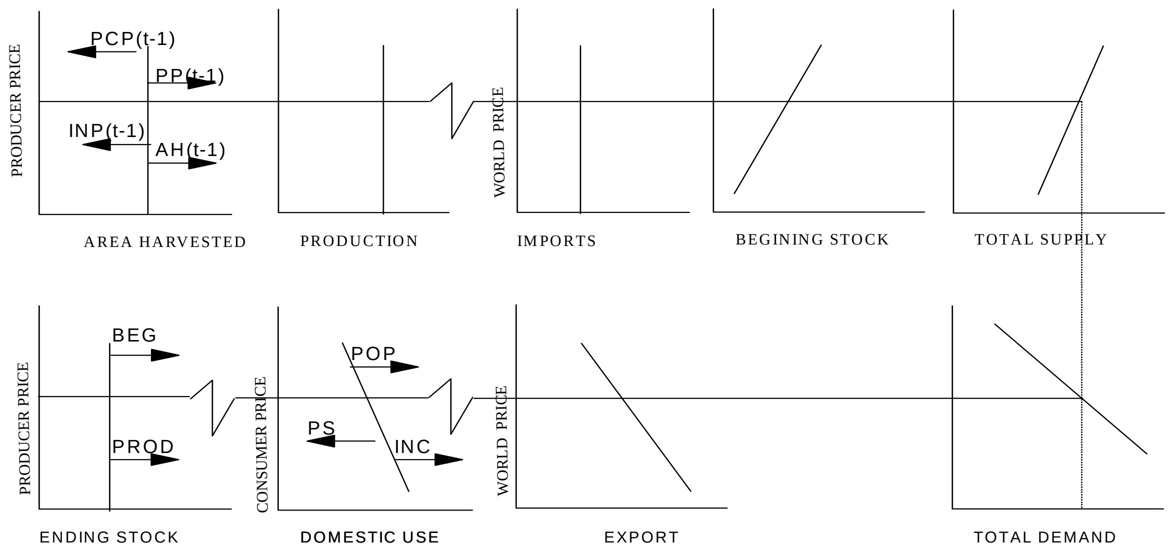

Figure 2: P-Q space of the RSA maize/sorghum sector

The P-Q space depicts the market at a specific point of time holding non-price factors constant. It reflects the economic relationships from the initial point of production to the final use of the product. The P-Q space is a convenient way of relating supply and utilisation by means of price. The flow chart and the P-Q space are closely linked. The first block represents the farm level, starting with area harvested times yield, which gives production. The arrows indicate the directional influence of the variables, i.e. the expected sign of the parameter associated with the variable in the estimated equation.

4. THEORETICAL FRAMEWORK

In this section, the conceptual model of domestic demand and supply, which reflects the general structure of the RSA maize and sorghum sectors, is developed. Each of the crop behavioural equations for supply and demand is specified according to the neo-classical producer and consumer theory. The model below builds on the *World Corn Model* of FAPRI (1990).

Supply Block

Following economic theory, the area harvested is expressed as a function of lagged area harvested, expected producer price, input prices, competing crop prices and policy variables. Yield times area harvested gives production. Total supply is equal to total production plus imports and beginning stock:

Area harvested: $AH_{i,t} = AH(AH_{i,t-1}, PS_{i,t-1}, PC_{i,t-1}, GP_{i,t}, Z_{i,t})$
Production: $PROD_{i,t} = AH_{i,t} * YLD_{i,t}$
Total Supply: $TS_{i,t} = PROD_{i,t} + IMP_{i,t} + BEGS_{i,t}$

where $AH_{i,t-1}$ is lagged area harvested, $PS_{i,t-1}$ is lagged producers price and $PC_{i,t-1}$ is lagged competing crop prices, $GP_{i,t-1}$ is a government policy variable, and $Z_{i,t}$ is a vector of other variables that affect the acreage harvested. Production is an identity, area harvested times yield. Total supply is also an identity, production plus imports plus beginning stock, while beginning stock is lagged ending stock. Yield is exogenous to the model.

Demand block

The concept specification for the demand block includes per capita consumption, which is a function of own price, competing prices and per capita income. Following Gallagher *et al.* (1981), ending stock is a function of the commodity own price, lagged ending stock and current production. Total human consumption is a function of real own price and real income:

Total Domestic Use: $TDU_{i,t} = DU(PD_{i,t}, PY_{i,t})$
Ending stock: $END_{i,t} = ED(PD_{it}, END_{i,t-1})$
Market Clearing Identity: $NET_{it} = TS_{it} – TFD_{it} - END_{it}$

Completing the model

Net trade is used to close the model. Domestic price is linked to world prices via a price linkage equation. Since RSA is an exporter of grains in the world market, and to reflect the endogeneity of world prices, a reduced form equation can be used to determine the world grain price as a function of net RSA grain exports. Exports depend on RSA net trade position in maize and sorghum. For the maize and sorghum, the equations of the world price linkage can be derived from FAPRI' s (1990) world feed grain model. Using this model, the short run flexibility is negative one, while the long run flexibility is approximately half that of the short run. The application of these results provides the following equations for maize and sorghum, respectively (see Appendix A for explanations of the variable names):

$$LOG(WPM) = -1.0* LOG(MEXPTZA-MIMPZA)_t + 0.46*LOG (MEXPTZA-MIMPZA)_{t-1} \quad (1)$$

$$LOG(WPS) =-1.0* LOG(SEXPTZA-SIMPZA)_t + 0.44*LOG (EXPTZA-RSASIMPZA)_{t-1} \quad (2)$$

The parameters of equation 1 and equation 2, reflects that the RSA export demand elasticity, both the long run and the short run.

5. DATA

The data used in this study are from various issues of the Abstract of Agricultural Statistics, the International Financial Statistics and the FAO database. The data covers the period 1978-1998.

6. ESTIMATION PROCEDURES, MODEL VALIDATION AND EMPIRICAL RESULTS

Although a single-equation approach may be used for initial estimation, considerable emphasis will be placed to ensure cross-equation and cross-commodity consistency. Supply equations, for example, must properly reflect competition for land and other resources. The equations in the model are estimated using the 2SLS estimation technique for the period 1976/77-1996/97. According to Johnston (1984), a necessary condition under which 3SLS is asymptotically more efficient than 2SLS is that the complete modelling system is correctly specified. Therefore, the possibility of misspecification would deny any advantage of 3SLS over 2SLS.

Following Kost's (1980) approach, the model is validated. For this purpose, the model is simulated over the historical period before any validation statistics are computed. Both static and dynamic simulations are used. For the static simulation, actual values of both exogenous and lagged endogenous variables are used to solve for the current variables over the historical period. The dynamic simulation uses the actual values of the exogenous variables and actual values of lagged endogenous variable for the first period only and then uses the solved values thereafter.

Four measures of goodness of fit are used: the mean absolute relative error (MARE), the root mean square error(RMSE), Thiel's inequality coefficient

(Thiel's U Statistics) and finally the percentage turning point(PTPE). The estimated equations in the model were subjected to a range of statistical tests. Based on the results of these tests, it can be concluded that the estimated econometric model provides reliable estimates of the RSA maize and sorghum supply and utilisation. For example, most of the percentages for the root mean squared error (RMSE) of both the static and dynamic models were less than 4 percent (although not reported here). The Thiel' s U statistics are in the range of 0.006 to 0.038. The fits of the area-harvested equations measured by R^2 are above 0.80. Some results of the tests are summarised in Table 1.

Table 1: Results of the validation tests

Variable	Mean Error	Mean Error %	Mean Abs. Error	RMSE	RMSE%
MAHZA	45.1245	1.02431	86.7981	94.56	2.453
SAHZA	-1.477	0.6578	78.7351	62.723	3.561
MDUZA	-122.07	-2.0569	116.75	122.65	4.021
SDUZA	1.477	0.4768	33.896	30.332	3.461

The relevant estimated equations are presented below (variable names are explained in Appendix A). In parenthesis are t-statistics.

Maize Area Harvested:

$$MAHZA = 2036.4 + \underset{(3.46)}{0.5341}\, LAG(MAHZA) + \underset{(2.56)}{1.890}\, (MPP1ZA/PPI) - 246.140SHIFT78 - 456.78D92$$

$R^2 = 0.891$ D.W = 1.89 D.H = 0.62

Maize Production:

$$MPRODZA = MAHZA*MYLD$$

Maize Total Supply:

$$MTSSZA = MPRODZA + MBEGZA + MIMPZA$$

Maize Domestic Use:

$$MDUZA = 6149.5 + \underset{(3.67)}{34.960}\, GDPZA/GDPDZA + 676.624(D81+D82) - \underset{(2.89)}{18.928}\, MPP1ZA/GDPDZA + 920.21SHIFT78$$

$R^2 = 0.801$ D.W = 1.76

Maize Ending Stock:

MENDZA = 13.465+ 0.275MPROZA – 6.345 MPP1ZA/GDPDZA
(12.65) (1.84)
+ 1382.82D80
(5.89)
R^2 = 0.862 D.W = 1.58

Maize Total Domestic Use:

MTDUZA= MDUZA + MENDZA

Maize area harvested is estimated as a function of real producer price, lag area harvested and a shift variable. The real producers price is computed as follows: MPP1ZA = (1-SHIFT94)*MPPZA +SHIFT94*LAG(MPPZA), where MPPZA is producer price of maize and SHIFT94 is equal to one after 94, and 0 otherwise. Short run supply elasticity is 0.12 and long run supply elasticity is 0.46. Maize yield is exogenous to the model. Domestic use is estimated as a function of real income, shift variables, and producer prices (the latter was used since retail prices were not available). The income elasticity is 0.281. The producer price of maize has a negative effect on ending stock, with an elasticity of –0.56, while the production of maize has a positive effect on ending stock.

Sorghum Area Harvested:

SAHZA = 217.646 + 0.019 SPPZA1/PPI – 0.011WPP1ZA/PPI –77.12SHIFT78
(6.17) (3.86) (2.40)
R^2 = 0.831 D.W = 1.69

Sorghum Production:

SPRODZA = SAHZA*SYLD

Sorghum Total Supply:

STSSZA= SPRODZA+ SBEGZA + SIMPZA

Sorghum Domestic Use:

SDUZA = 17.1 - 0.018 SPPZA1/GDPD +5.32GDP/GDPD
(2.12) (3.15)
+ 0.210 SPRODZA +133.729D80
(3.01) (2.72)
R^2 = 0.846 D.W = 1.86

Sorghum Ending Stock:

SENDZA = 17.56 + 0.326 SPRODZA - 0.005 SPPZA1/GDPD - 151.896 D83
(6.06) (1.90) (-3.85)
R^2 = 0.796 D.W = 2.41

Sorghum Total Domestic Use:

STDUZA= SDUZA + SENDZA

Sorghum area harvested is estimated as a function of real producer price and the shift variable. As for maize, the real producer price of sorghum is computed as follows:

SPPM1ZA= (1-SHIFT94)*SPPZA +SHIFT94*LAG(SPPZA),

where SPPZA is the producer price of sorghum and SHIFT94 is equal to one after 94, and 0 otherwise. Own price elasticity is 0.66 and cross price elasticity is –0.52. Sorghum yield is exogenous to the model. Domestic use is estimated as a function of real income, shift variables and producers price (since retail prices were not available, it was used instead). Demand elasticity is –0.29 and income elasticity is 0.23. Ending stocks are estimated as a function of real producer prices and production. Stock-price elasticity is –0.42. As in the case of maize, sorghum production has a positive effect on stocks.
The price linkage equations are as follows:

Maize Farm Price:

MPP1ZA = -13.642+56.127USCORPF*EXCUSZA – 33.210D84 -37.439*SHIFT92
(16.87) (2.68) (5.62)
R^2 = 0.921 D.W = 2.14

Sorghum Farm Price:

SPP1ZA= 1050.460+ 0.933USFP*EXCUSZA + 3983.52D82 +123.4SHIFT92
(10.27) (2.42) (1.91)
R^2 = 0.843 D.W = 1.94

Wheat Farm Price:

WPP1ZA = 1847.68 + 4471.02USWEPF EXCUSZA+5449.1(D80+D81+D82)
(9.74) (3.90)
R^2 = 0.783 D.W = 2.36

The RSA maize producer price is linked to US corn price. The price transmission elasticity is 1.19. Similarly, the RSA sorghum price is linked to US sorghum price, with a price transmission elasticity is 0.73. Also, the RSA wheat price is linked to the US wheat price, with a price transmission elasticity of 0.76. The market equilibrium identity for maize is:

NETMZA = MPRODZA+ MBEGZA- MTDUZA.

Similarly, for the sorghum it is:

NETSZA = SPRODZA+SBDEGZA-STDUZA.

6. USING THE MODEL FOR FORECASTING

Using the above model, a market outlook forecast for the period 2000/01 to 2006/7 is generated. The market outlook forecast can be considered as a plausible future market outlook, rather than a forecast *per se*, since the forecast is based on certain assumptions. It should be noted that different sets of assumptions would lead to different forecasting results. The main assumptions underlying the baseline forecast are briefly outlined before presenting and discussing the results under different scenarios. Values for the relevant macro variables over the projected period are from Wharton Econometrics Forecasting Associates (WEFA), February 2000. For yields, time trend equations were estimated for prediction purposes. It is also assumed that normal weather conditions would prevail during the forecast period. Table 2 reports the market outlook for RSA maize and Sorghum with respect to key variables over the next decade.

Table 2: Market Outlook for the RSA Maize and Sorghum Sectors

Item	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Area Harvested (million hectares)	3.29	3.27	3.32	3.31	3.30	3.32	3.32
Yield (tons per hectare)	2.63	2.69	2.71	2.80	2.86	2.89	2.92
Production (million tons)	8.65	8.80	9.00	9.30	9.44	9.60	9.70
Beginning stock (million tons)	1.40	1.36	1.38	1.40	1.43	1.43	1.45
Total Supply (million tons)	10.05	10.16	10.38	10.70	10.87	11.03	11.15
Domestic Consumption (million tons)	7.52	7.56	7.66	7.69	7.79	7.86	7.94
Ending Stock (million tons)	1.36	1.38	1.40	1.43	1.43	1.45	1.49
Total Domestic Use (million tons)	8.88	8.94	9.06	9.12	9.22	9.31	9.43
Net Trade (million tons)	1.17	1.22	1.32	1.60	1.65	1.72	1.72
Area Harvested (million hectares)	0.13	0.14	0.14	0.13	0.13	0.13	0.13
Yield (tons per hectare)	2.01	2.10	2.12	2.16	2.20	2.21	2.22
Production (million tons)	0.26	0.29	0.30	0.28	0.29	0.29	0.29

Item	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Beginning stock (million tons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Supply (million tons)	0.26	0.29	0.30	0.28	0.29	0.29	0.29
Domestic Consumption (million tons)	0.28	0.30	0.31	0.32	0.33	0.35	0.35
Ending Stock (million tons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Domestic Use (million tons)	0.28	0.30	0.31	0.32	0.33	0.35	0.35
Net Trade	-0.019	-0.006	-0.014	-0.040	-0.044	-0.063	-0.061

Results indicate that for both maize and sorghum, consumption will gradually increase over time. In spite of varying areas of maize and sorghum being harvested, total production will gradually increase over time due to increases in particularly yields.

7. SUMMARY AND CONCLUSION

In this paper a structural econometric model for both maize and sorghum in the South Africa is developed in order to generate a market outlook for the next decade. 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 parameters and can thus be used for forecasting purposes. While useful answers are derived that can be used in policy analysis, the model development is still at a relatively early stage of development at the Department of Agricultural Economics, University of Pretoria. In order to obtain more reliable results and better estimates on the maize and sorghum sectors, the model developed here should ideally be integrated into a larger model, which should incorporate many more policy variables. This will be a logical next step in this research.

NOTES

1. *The Sorghum sector will have a similar flow chart and P-Q spac.*

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APPENDIX A

MAHZA: Maize Area Harvested, 1000 ha
MPP1ZA: Maize Producer's Price (1-SHIFT94)*MPPZA +SHIFT94*LAG (MPPZA)
PPI: Producer Price Index
MPRODZA: Maize Production, 1000 mt
MYLD: Maize Yield Ton per Hectare
MTSSZA: Maize Total Supply, 1000 mt
MBEGZA: Maize Beginning Stock, 1000 mt
MIMPZA: Maize Imports, 1000mt
MDUZA: Maize Domestic Use, 1000 mt
MTDUZA: Maize Total Domestic Use, 1000 mt
GDPZA: Gross Domestic Product, Bil.Rand
GDPDZA: Gross Domestic Product Deflator, 1995=100
MENDZA: Maize Ending Stock, 1000 mt
SAHZA: Sorghum Area Harvested, 1000 ha
SPPZA1: Sorghum Producer's Price (1-SHIFT94)*SPPZA +SHIFT94*LAG (SPPZA)
SPPZA: Sorghum Producers' Price, Rand/MT
WPP1ZA: Wheat Producer's Price (1-SHIFT94)*WPPZA +SHIFT94*LAG (WPPZA)
SPRODZA: Sorghum Production, 1000 mt
SYLD: Sorghum Yield Ton per Hectare
STSSZA: Sorghum Total Supply, 1000 mt
SBEGZA: Sorghum Beginning Stock, 1000 mt
SIMPZA: Sorghum Imports, 1000 mt
STDUZA: Sorghum Domestic Use, 1000 mt
SENDZA: Sorghum Ending Stock, 1000 mt
USCORPF: US Corn Price
EXCUSZA: US Exchange Rate, Rand/ USD
USWEPF: US Wheat Price,
SHIFT78: one after 1978, 0 otherwise
SHIFT94: one after 1994, 0 otherwise
D92: 1 for 1992, 0 otherwise
D80: 1 for 1980, 0 otherwise
D81: 1 for 1981, 0 otherwise
D82: 1 for 1982, 0 otherwise