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CROP LEVEL SUPPLY RESPONSE IN SOUTH AFRICAN AGRICULTURE: AN ERROR CORRECTION APPROACH

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This article investigates South African supply response in agricultural production. It applies time series techniques to explain production planning decisions of the two dominant crops in the summer-rainfall grain area, maize and sorghum. After establishing the time series properties of the variables, cointegration is determined and used as the theoretical foundation for an error correction model (ECM). Maize area planted in the short run or the long run (or both), is found to depend on two sets of variables. One group changes the quantity or supply (area) of maize directly, like own price, the prices of substitutes like sorghum and sunflowers, and complementary intermediate input prices. The other variables change the supply environment, like rainfall, farmer education, R&D and cooperative extension. 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. These results further illustrate the dominance of maize and maize policies in production decisions in the summer-rainfall areas of South Africa.

1. INTRODUCTION

The most important agricultural crop in South Africa is maize. The marketing of maize in South Africa has been heavily regulated by the government since the mid-1940s, amongst others by guaranteed pan-territorial prices to producers, often at above market-clearing-levels, and a single-channel marketing system where the Maize Board acted as a monopsonist (Groenewald, 1989). Given the importance of maize in the South African agricultural economy and the heavy interventionist marketing regime followed over the past five decades, the response of maize and other crop farmers to institutional and market factors in South Africa is important. This has been analyzed by several authors (Langley and Du Toit, 1978; Armer, 1985; and Van Zyl, 1991). However, these analyses are mostly inconclusive and do not properly account for the time-series properties of the variables used. Therefore, the results obtained are unsatisfactory, open to criticism and have been viewed with some scepticism.

Nerlove (1958) formalized the dynamic approach to supply response where farmers are assumed to make expectations about the future price and to respond with lagged adjustments. This time series approach to agricultural supply analysis led Salmon (1982) and Nickell (1985) to consider if a specific type of time series model, the error correction model (ECM), could be derived from the dynamic optimizing behavior of economic agents. It could, and Hallam and Zanoli (1993) go on to show that the ECM avoids the partial adjustment model's unrealistic assumption of a fixed target supply based on stationary expectations. The ECM approach has been used to determine agricultural supply response by, among others, Hallam and Zanoli (1993). In Southern Africa, Townsend and Thirtle (1994) analyze supply response of maize and tobacco with an ECM model.

This article extends earlier work by considering for the first time, the South African supply response of maize and its relation to secondary crops, like sorghum, in the ECM framework. The next section discusses data sources, followed by a section which determines the time series properties of the variables and establishes cointegration between subsets of variables. These sections provide the basis for applying the ECM to the South African agricultural situation, which is done in the penultimate section. In that section, the ECM is used to distinguish between short run effects and deviations from the long run equilibrium path of area planted in maize and sorghum. The last section provides a summary and conclusions.

2. TIME SERIES ANALYSIS OF THE DATA

2.1 The data

The data are for the total agricultural sector of the Republic of South Africa, for the period 1956-93. The main source is the Abstract of Agricultural Statistics (Republic of South Africa, 1995), supplemented by South African Statistics (Republic of South Africa, 1994) and unpublished information from the Department of Agricultural Economics at the University of Pretoria and the Weather Bureau. These data have also been used for total factor productivity measurement (Thirtle et al.,1993) and estimation of a dual profit function (Khatri *et al.*, 1994).

The measures of farm output are the area planted in maize and sorghum (both in thousands of hectares). Area planted is preferred to production volume for the intended level of production given institutional and market conditions. The areas planted in other crops such as groundnuts (peanuts), sunflower seeds, and dry beans were considered as part of a system of equations with maize and sorghum, but the available explanatory variables (discussed below) do not adequately describe the number of hectares planted in these other crops. We find that maize is the crop that drives the agricultural system in the summer rainfall region in South Africa, with sorghum playing a smaller role as will be discussed. Future research may be able to uncover the subtle interactions between maize and sorghum supply response and these other crops.[2]

The average net producer price of maize, grain sorghum, sunflower seed and other substitution crops are all measured in Rands/ton (ZAR/t). The price index of intermediate goods as at January first each year is a weighted average price of fertilizer, fuel, dips and sprays, packing material, maintenance and repair work (1990=100). Variables that historically have changed the supply environment that farmers operate in are research and development expenditures that generate new technologies, extension expenditures that transmit the results to the farmers, so diffusing the technology, and the education level of the farmers, which affects both their own creative and managerial abilities, and their skill in appraising and adopting new technologies. These series are from (Thirtle and Van Zyl (1994).

Two additional rainfall variables capture the effect of precipitation on intended production: the sum of rainfall for August, September, October and November each year for Bothaville and Potchefstroom, which represent the two largest maize growing regions in the summer-rainfall areas, are averaged together to capture the effect of rainfall on maize production;[3] and annual rainfall on the Highveld (Johannesburg) captures the effect of rainfall on planned sorghum production. Rainfall for these months is used because the supply of summer grains in the Western Transvaal and the North Western Orange Free State has been shown to depend heavily on rainfall in the spring and early summer (Van Zyl, 1991).

2.2 Order of integration

Cointegration techniques are used to establish long-run equilibrium relationships between the variables. When variables have trends, one may spuriously explain variance in the other. If the variables are cointegrated, then deviations from the long run equilibrium path should be bounded. For this reason, cointegrated variables can with theoretical consistency be represented in a dynamic error correction framework (Engle and Granger, 1987), which is an ideal setting for the analysis of supply response because it avoids the spurious regression problem and explicitly represents short run adjustments to long run equilibrium. The approach here is to employ the Engle and Granger two-step procedure, first establishing if the variables are cointegrated and then reformulating the same variables in an error correction model (ECM). In simple cases, two conditions must be satisfied for variables to be cointegrated. First, the series for at least two of the individual variables should be integrated of the same order and second, a linear combination of all the variables must exist that is integrated an order one less than the original variables; that is, if the variables are integrated of order one (denoted I(1)), the error term from the cointegrating regression should be stationary (or I(0)) (Hansen and Juselius, 1995).

The time series properties of the variables, all in logarithms, are reported in Table 1. The standard Dickey-Fuller (Dickey and Fuller, 1981) (DF) and augmented Dickey-Fuller tests are used to determine the order of integration. It is possible for the order of integration of variables to vary depending on the assumed order of the autoregressive (AR) process. Column two shows that all the variables are first order autoregressive (AR) processes, indicating that the error terms in the DF tests are white noise, as required. This is confirmed using the Ljung and Box (1978) Q^* statistic which gives the probability of falsely rejecting the null hypothesis of no serial correlation. The small sample properties of this test are better than alternative tests for autocorrelation (Pesaran and Pesaran, 1991). In the next column, the DF test statistics indicate that all the variables--except rainfall--are non-stationary in the levels, with test statistics greater than the critical value of -2.93 (see Banerjee, et al., 1993, Table 4.2, p.103). This indicates that all the variables except rainfall are not I(0), as expected. We would not expect rainfall to have a unit root unless the climate in the summer-rainfall region of South Africa was undergoing long run change. If a variable is I(1), its first difference will be stationary. The same test carried out on the differences of all the variables--except rainfall--shows that all the DF test statistics are less than the same critical value of -2.93. The indicates that the first differences of all the variables except rainfall are stationary, indicating that all the variables are I(1), except rainfall which is I(0). The DF tests carried out with a trend term in the AR(1) equation gives the same results except for the area planted in maize and sorghum, and are reported in column four. To assess the significance of the trend terms for the variables, maize and sorghum acreage, Table III p.1062 in Dickey and Fuller (1981) is used. The results are reported in the last column. The trend is found to be insignificant at the 95% level for the acreage variables.

2.3 Cointegrating Relationships for Maize and Sorghum

Having established the order of integration of the variables, the next stage is to test for cointegrating vectors between groups of variables that we intend to include in an ECM. Cointegration implies that non-spurious long-run relationships exist, and that the ECM representation is a framework that is consistent theoretically with the previously determined time series properties of the variables. OLS results would have the desirable super-consistency property (Stock, 1987). These properties arise because cointegrated variables exhibit the characteristic that deviations from their long run equilibrium relationship are bounded. The variables may wander apart, but not very far or for very long. Table 1 showed that all the variables are I(1), except for rainfall in the maize and sorghum growing regions. Two groups of variables are tested for cointegration. The groups correspond to one equation each explaining the area planted in maize and in sorghum. At least two of the variables in each group are I(1) as required, and additional I(0) variables are included and separated from the group of I(1) variables by a forward slash in Table 2.

If a long run equilibrium relationship exists between the variables in each of these groups, then there should exist a linear combination of the variables that is integrated of order one less than the highest order of integration of the individual variables, which is I(1) in this case. It is clear now why an I(0) variable, like rainfall, can be included with two or more I(1) variables. We are looking for a linear combination of I(1) variables that is I(0), so including a variable that is already I(0) can not rule out the existence of such a relationship.

Three tests are used to determine if an I(0) linear combination exists among each of the groups of variables in Table 2. The DF test and the CRDW test (Sargan and Bhargava, 1983) are residual based tests and the Johansen procedure is a reduced rank test. The residual based tests determine if the residuals from OLS of area planted on the other variables are I(0). If these residuals are not stationary then a linear combination of the variables, which is what OLS vir ander bedrywe geld, in verskeie belangrike opsigte gewysig vir die landboubedryf (CAP-Monitor,1995). In parameter estimates are, could not be stationary either. The reasons why the maximum likelihood Johansen reduced rank test likewise establishes the existence of a stationary linear combination of variables in each group in Table 2 is less transparent and is discussed in.

Table 1: Testing the order of integration of the variables

Variable Name and Abbreviation	AR order	DF Test	DF Test with Trend	Trend only Test
LOG AREA PLANTED IN MAIZE (MZARE)	1	-2.70	-3.82	-1.72
D LOG AREA PLANTED IN MAIZE		-7.58		
LOG AREA PLANTED IN SORGHUM	1	-2.42	-3.64	-2.28
D LOG AREA PLANTED IN GRAIN SORGHUM		-7.15		
LOG NET PRODUCER PRICE OF YELLOW MZ (MZPRI)	1	1.66	-2.44	--
D LOG N.P.P. YELLOW MAIZE		-4.22		
LOG N.P.P. GRAIN SORGHUM (SRPRI)	1	-0.45	-2.02	--
D LOG N.P.P. GRAIN SORGHUM (SRPRI)		-5.55		
LOG N.P.P. SUNFLOWER SEED (SNPRI)	1	1.26	-2.87	--
D LOG N.P.P. SUNFLOWER SEED (SNPRI)		-4.72		
LOG PRICE INDEX OF INTERM. GOODS (INTPRI)	1	2.72	-2.31	--
D LOG PRICE INDEX OF INTERMEDIATE GOODS		-3.45		
LOG OF FARMER EDUCATION (FARMERED)	1	-0.39	-1.23	--
D LOG OF FARMER EDUCATION		-4.39		
LOG INDEX R&D EXPENDITURES (RDIND)	1	-1.01	-1.33	--
D LOG INDEX OF R&D EXPENDITURES		-5.67		
LOG INDEX EXTENSION EXPENDITURES (EXTIND)	1	-2.27	-2.15	--
D LOG INDEX OF EXTENSION EXPENDITURES		-9.01		
LOG OF MAIZE GROWING SEASON RAIN (BOPORAIN)	1	-4.61	-4.79	--
LOG OF RAINFALL ON HIGHVELD (SUMRAIN)	1	-6.64	-6.57	--
Critical values, 95% Confidence Level	All	-2.95	-3.54	-2.81

Table 2: Cointegration tests

Equations tested [1]	DF Test [2]	CRDW Test [2]	Johansen Model [2]	
			Eigenvalue Test	Trace Test
MZARE MZPRI SRPRI SNPRI INTPRI FARMERED RDIND EXTIND / BOPORAIN	-5.42 (<-4.4» -5.0) [3]	1.75 (0.5-3.0)	1) 122.48 (52.0) 2) 96.93 (46.5) 3) 71.78 (40.3) 4) 43.10 (34.4) 5) 29.68 (28.1) 6) 24.75 (22.0)	405.34 (165.6) 282.86 (131.7) 185.93 (102.1) 114.15 (76.1) 71.05 (53.1) 41.37 (34.9)
SRARE INTPRI / SUMRAIN	-4.06 (-3.73)	1.03 (0.7-1.7)	1) 16.56 (15.7)	20.0 (20.0)

Notes: [1] MZARE = area planted in maize (1000 ha), MZPRI = net producer price of yellow maize (Rands/ton), SRPRI = average net producer price of grain sorghum (Rands/ton), SNPRI = net producer price of sunflower seed (Rands/ton), INTPRI = price index of intermediate goods as at January first each year (fertilizer, fuel, dips and sprays, packing material, maintenance and repair work)(1990=100), FARMERED = farmer education, RDIND = index of research expenditures, EXTIND = index of extension expenditures, BOPORAIN = average of the sum of rainfall for August, September, October and November for Bothaville and Potchefstroom, SRARE = area planted in sorghum (1000 ha), SUMRAIN = annual rainfall on the Highveld (Johannesburg).
[2] Critical values in parenthesis are for the 95% significance level for all three tests.
[3] The critical value for a cointegrating regression with nine variables is not tabulated in Phillips and Ouliaris (1990), so the reported critical value is determined by interpolation with the tabulated critical values for four, five and six variables.

Johansen (1988) and Johansen and Juselius (1990)

The residual based tests are intuitively appealing because they apply the same DF test used to establish the time series properties of the levels and the differences of the variables. OLS ensures that the cointegrating regression will give results having the smallest possible sample variance, so critical values for the time series properties of the residuals must be adjusted (Townsend and Thirtle, 1994). Phillips and Ouliaris (1990) have tabulated critical values for this test to correct the test bias.

Unfortunately, when more than two variables are included in the OLS equation, the residual based tests are not able to establish if the cointegrating vector is unique. The Johansen test estimates all of the cointegrating vectors that span the cointegrating space, which means that these vectors are unique up to a linear transformation. Three cointegrating relationships, for example, describe a plane with uncertain edges, but we know the slope and orientation of the plane. This additional information provided by the Johansen test has led to its being used almost exclusively by practitioners.

Comparing the test statistics with the critical values (in parenthesis) shows that the maize acreage equation cointegrates according to all three tests. The Johansen test indicates the existence of six cointegrating vectors, persuasive evidence of a very strong and stable relationship between the area planted in maize and the variables that change the quantity supplied of maize over the shorter term (the own price, and the prices of the substitutes sorghum and sunflowers, and complementary intermediate input prices) and variables that shift the supply curve over the longer term (farmer education, R&D and extension). Although impossible to illustrate graphically, six cointegrating vectors span a six dimensional space providing stability to changes in many directions.

The sorghum acreage equation also cointegrates according to all three tests, but the Johansen test indicates the existence of only one cointegrating vector. This vector can be represented in two dimensions and provides additional information about the long run relationship between the area planted in sorghum and agricultural R&D and rainfall. Since the Johansen equation is an ECM, the results obtained from determining the cointegrating vector are similar to the results obtained from estimation of the sorghum equation as an ECM. The same can not be said of the maize equation because five cointegrating vectors were found, making it impossible to isolate the unique relationship tying together area planted and the supply response variables, except by direct estimation. This is discussed below.

3. ERROR CORRECTION MODELS OF SUPPLY RESPONSE

3.1 Estimation of the ECM

As mentioned above, the maximum likelihood approach to the determination of cointegrating relations following Johansen (1988) and Johansen and Juselius (1990) involves the estimation of an ECM. From Engle and Granger (1987) we know that when cointegration between the group of variables in the maize equation and also in the sorghum equation has been established, the ECM is a valid representation of the adjustment process to the long run equilibrium implied by cointegration. Having established the time series properties of the variables in Table 1 and that the maize and sorghum groups of variables are both cointegrated in Table 2, there is a non-spurious long run relationship between the area planted of each of the crops and the supply variables. Since this implies that the ECM is a valid representation of the relationship (Engle and Granger, 1987), we determine the ECM form for both the maize and sorghum equations directly,

$$
\begin{aligned}
\Delta \ln MZARE_t = {} & \phi_0 + \sum_{i=2}^{r} \phi_I \, \Delta \ln MZARE_{t-i} \\
& + \sum_{j=0}^{s} \phi_{Ij} \Delta \ln MZPRI_{t=j} + \sum_{k=0}^{u} \phi_k \Delta \ln SRPRI_{t=k} + \\
& \sum_{l=0}^{v} \phi_{;l} \Delta \ln SNPRII_{t=1} + \sum_{m=0}^{w} \phi_m \Delta \ln INTPRI_{t=m} + \\
& \sum_{n=0}^{x} \phi_n \Delta \ln FARMERED_{t-n} + \sum_{o=0}^{y} \phi_o \ln \Delta \, RDIND_{t-o} + \\
& \sum_{p=0}^{z} \phi_{pj} \Delta \ln EXTIND_{t=p} + \sum_{q=0}^{w} \phi_{qj} \Delta \ln BOPORAIN_{t=q} \\
& + \lambda[\ln MZARE - \alpha_1 \ln PMZPRI - \alpha_2 \ln SPRPRI - \\
& \alpha_3 \ln SNPRI - \alpha_4 \ln INTPRI - \alpha_5 \ln FARMERED - \\
& \alpha_6 \ln RDIND - \alpha_7 \ln EXTIND - \alpha_8 \ln BOPORAIN]_{t-1} \qquad (1)
\end{aligned}
$$

$$
\begin{aligned}
\Delta \ln MZARE_t = {} & \delta_0 + \sum_{f=2}^{\phi} \delta_f \, \Delta \ln SRARE_{t-F} \\
& + \sum_{g=0}^{v} \delta_g \Delta \ln INTPRI_{t-g} + \sum_{h=0}^{\tau} \delta_h \Delta \ln SUMRAIN_{t-h} \\
& + \lambda[\ln SRARE - \beta_1 \ln intpri - \beta_2 \ln SUMRAIN]_{t-1} \qquad (2)
\end{aligned}
$$

where MZARE = area planted in maize (1000 ha), MZPRI = net producer price of yellow maize (Rands/ton), SPRI = average net producer price of grain sorghum (Rands/ton), SNPRI = net producer price of sunflower seed (Rands/ton), INTPRI = price index of intermediate goods as at January first each year (fertilizer, fuel, dips and sprays, packing material, maintenance and repair work (1990 = 100), FARMERED = farmer education, RDINI = index of research expenditures, EXTIND = indes of extension expenditures, BORORAIN = average of the sum of rainfall for August, September, October and November for Bothaville and Potchefstroom, SRARE = area planted in sorghum (1000 ha), SUMRAIN = annual rainfall on the Highveld (Johannesburg).

Similar ECMs to equations (1) and (2) were developed for groundnuts, sunflower seed and dry beans, but did not produce satisfactory results. This is because maize is the dominant crop in the summer rainfall region of South Africa.[4] The variables that explain the planned production of these other crops are not evident at this time, but will be the subject of future research.

3.2 Results

The results for the ECMs, equations (1) and (2), are reported in Table 3, and were chosen on the criteria of goodness of fit (variance dominance), data coherence, parameter parsimony and consistency with theory (Hendry and Richard, 1982). The seemingly unrelated estimation procedure is considered at the end of the results section as an attempt to gain efficiency in estimation.

A cursory review of Table 3 reveals that the planned supply of maize in the summer rainfall region of South Africa is dictated by the set of factors that are customarily thought to influence supply; those that change the supply directly (the own price, and the prices of the substitutes sorghum and sunflowers, and complementary intermediate input prices) and factors that change the supply environment (farmer education, R&D and extension). The ECM allows the decomposition of those effects into short run and long run effects, represented by the difference and the levels terms respectively.

Reviewing the short run effects at the top of Table 3 first, the lagged maize area planted and the maize price are both positive and highly significant predictors of the current area planted. The price elasticity is 0.64 which is fairly inelastic as expected. The area is lagged two periods because differenced t-(t-1) area is the dependent variable, and differenced area lagged only one period (t-1)-(t-2) has (t-1) area in it. Therefore, including differenced area lagged one period as an explanatory variable puts the same variable, i.e. area (t-1), on both sides of the equal sign. Following the same logic, differenced area lagged two periods does not create this problem. The levels term for maize area is also only lagged one period, but is needed to capture the long run adjustment to equilibrium. The negative and highly significant sign on short run lagged maize price makes sense because the maize price in South Africa follows a step function. An increase in the price of maize in a previous period leads to a reduction in area planted in the following period, because farmer's expectations were that prices would not rise substantially (in real terms) immediately following a price increase, both during the controlled price era of 1970/71 1970/71 to 1987 and beyond. The Maize Board provides for a catching up period after a price increase, so a lagged increase in price leads to a reduction in current planned

Table 3: Unrestricted ECM Results

Variable Eq.(16)/Eq.(17)	Coefficient	$DMZARE_t$ Eq. (16)	Coefficient	$DSRARE_t$ Eq. (17)
SHORT RUN				
CONSTANT	F_0	4.40 (3.6)**	d_0	10.13 (2.9)**
$DMZARE_{t-2}$/ $DSRARE_{t-2}$	$F_{i=2}$	0.43 (3.7)**	$d_{f=2}$	NS
$DMZPRI_t$	$F_{j=0}$	0.64 (3.7)**		
$DMZPRI_{t-1}$	$F_{j=1}$	-0.59 (-4.0)**		
$DSRPRI_t$	$F_{k=0}$	0.09 (3.0)*		
$DSNPRI_t$	$F_{l=0}$	NS		
$DINTPRI_t$	$F_{m=0}$	0.39 (2.8)*	$d_{g=0}$	-1.11 (-1.9)*
$DINTPRI_{t-1}$	$F_{m=1}$	NS	$d_{g=1}$	NS
$DFARMERE_t$	$F_{n=0}$	-1.33 (-2.9)*		
$DFARMERE_{t-1}$	$F_{n=1}$	1.03 (1.6)		
$DRDIND_t$	$F_{o=0}$	-0.27 (-2.6)*		
$DRDIND_{t-1}$	$F_{o=1}$	-0.21 (-1.8)*		
$DEXTIND_t$	$F_{p=0}$	-0.32 (-3.0)*		
$DEXTIND_{t-1}$	$F_{p=1}$	-0.16 (-1.4)		
$DBOPORAIN_t$/ $DSUMRAIN_t$	$F_{q=0}$	0.03 (2.6)*	$d_{h=0}$ $d_{h=1}$	-0.59 (-2.8)** NS
LONG RUN				
$MZARE_{t-1}$/ $SRARE_{t-1}$	1	-0.59 (-4.4)**	1	-0.60 (-3.7)**
$MZPRI_{t-1}$	la_1	0.59 (3.0)*		
$SRPRI_{t-1}$	la_2	0.17 (5.2)**		
$SNPRI_{t-1}$	la_3	-0.57 (-3.0)*		
$INTPRI_{t-1}$	la_4	NS	$lß_1$	-0.12 (-1.8)*
$FARMERED_{t-1}$	la_5	NS		
$RDIND_{t-1}$	la_6	-0.78 (-6.1)**		
$EXTIND_{t-1}$	la_7	0.60 (4.0)**		
$BOPORAIN_{t-1}$/ $SUMRAIN_{t-1}$	la_8	0.12 (5.3)**	$lß_2$	-0.96 (-2.2)*
Adjusted R^2		0.89		0.43
DW		2.4		2.1

Notes: ** = significant at the ³99% level.
* = significant at the ³90% level.
Unstarred estimated coefficients are significant at the ³80% level.
NS = not significant.

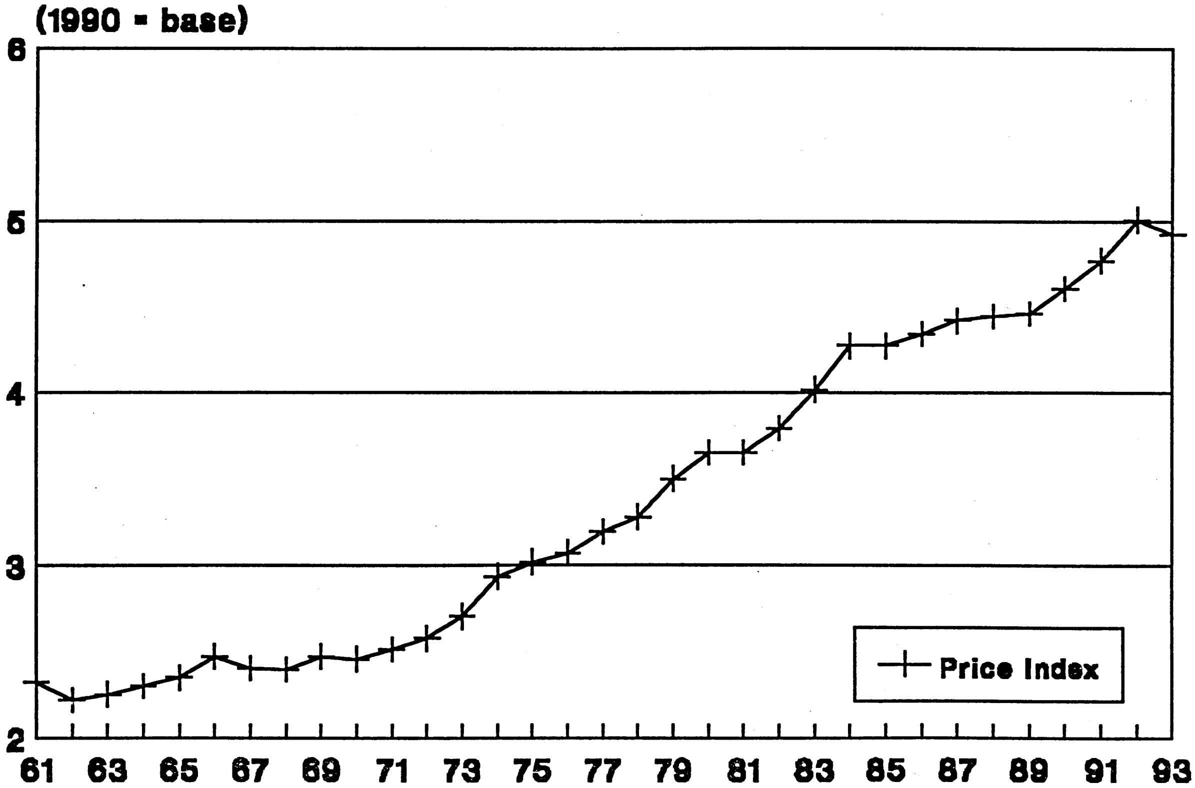

Figure 1: Net producer price index of maize (MZPRI) in natural logarithms

output, because the price is not expected to rise again for some time. This step characteristic of the maize price can be seen in Figure 1.

The short run sorghum price has a positive effect on maize area. As the area planted in maize increases the area in sorghum decreases and the sorghum price increases. The complementary input price index is positive as well. This is coming from the observation that the farming communities that grow maize derive 90 percent of their income from maize, and as the area planted expands, the local economy improves and prices rise. Also, due to the historical link between increases in the maize price and production costs (Groenewald, 1989; Van Zyl, 1991), farmers did not react to increases in input prices as expected. These results are counter to à priori expectations, shedding light on maize supply response in unforeseen ways. Rainfall in the Bothaville and Potchefstroom regions has the anticipated positive sign. The supply shift variables are mainly negative in the short run, indicating that it is necessary to look at the long run to make sense of these variables.

In the long run, the maize area error correction term is -0.59, indicating that adjustment occurs toward the long run equilibrium as expected with a 59 percent correction occurring in the current period. The maize and sorghum prices have the same sign in the long run as in the short run (current period), but the sunflower price is significant and negative, while it was not significant in the short run. Sunflowers therefore have a fundamentally different relationship to maize area planted than sorghum. Sunflowers are only substituted for maize when its price rises far enough and this substitution depends less on a short run rain supply response, like we saw for sorghum.[5]

The long run effect of extension is to increase the area planted in maize as expected, so the short run negative response could be coming from agents and cooperatives trying to persuade farmers not to produce more than what can be sold by the Maize Board in the domestic market without depressing prices too much. The long run and short run decrease in area planted in maize from additional R&D, then, is coming from improved varieties that produce more per acre, together with a limit on the quantity of maize that the Maize Board can sell profitably in the domestic market.[6] In addition, as R&D expenditures increased, particularly between 1981 and 1986, efforts were being funnelled toward alternatives to maize that further reduced by some small amount, the area planted in maize.[7]

The sorghum model is much simpler than the maize ECM. In the short run, an increase in intermediate input prices reduces the area planted in sorghum, a relationship that also holds in the long run, although with a much smaller elastically than would be expected. Rainfall on the Highveld has a negative sign because sorghum is mainly planted when there is not enough rainfall to plant maize and the rainfall measures are correlated. This relationship also holds for the long run. In the long run, the sorghum area error correction term is -0.60, almost identical to the maize area error correction term, again indicating that adjustment occurs toward the long run equilibrium in the sorghum equation with a 60 percent correction occurring in the current period.[8] As mentioned in an earlier section with

Table 4: Long Run Elasticities for the ECM

VARIABLE [1]	MZPRI	SRPRI	SNPRI	INTPRI	RDIND	EXTIND	RAIN
MZARE EQUATION	1.00	0.29	-0.97	-	-1.32	1.02	0.20
SRARE EQUATION	-	-	-	-0.20	-	-	-1.60

Note: [1] Variable definitions can be found following equations 1 and 2.

the estimation of the Johansen model, the maximum likelihood results obtained there are very similar to the results obtained here using OLS. The long run adjustment coefficient on SRARE from the Johansen model is -0.45 and on INTPRI it is -0.09, which is close to the -0.12 adjustment coefficient from Table 3.

Both the maize and sorghum equations have high adjusted R^2s and Durbin Watson statistics that indicate no serial correlation. This discussion of results highlights the fundamental differences that exists in the summer rainfall region in South Africa between determinants of the areas planted in maize and in sorghum. For this reason, system estimation of these two equations by SUR is detrimental. As confirmation, the residuals from the individual equations were found to have a correlation coefficient of -0.0098, or almost no correlation at all.

3.3 Long Run Elasticities and Supply Response

As discussed earlier, long run elasticities can be calculated from the results in Table 3 simply by dividing the long run coefficients by +l. These long run elasticities are reported in Table 4. In the sorghum equation, the long run response to rain is more elastic than the response to intermediate prices, where a 10 percent increase in intermediate prices eventually decreases the area planted in sorghum by 2 percent. This points to sorghum being a secondary (residual) crop that is mainly planted when rainfall conditions are unfavorable for maize. In the maize equation, the long run response is relatively sensitive to prices. In particular, elasticities of maize and sunflower prices, and R&D and extension expenditure, are relatively high, thereby illustrating the points made earlier. In particular, the relatively high negative supply elasticity of R&D expenditure illustrates the effects of increased maize supply on profitability within a relatively isolated market with domestic prices fixed at above market clearing levels.

4. CONCLUSION

This paper establishes factors that explain long run and short run supply response of South African maize and sorghum production. Within both institutional and market constraints, maize area planted is found to depend on two sets of variables, either in the short run or in the long run or both. Variables that change the quantity or supply of maize directly are own price and the prices of the substitutes sorghum and sunflowers, all except sunflowers operating in both the long run and the short run. Sunflowers have a long run effect only. Prices of a complement, intermediate input prices, matter in the short run. Another set of variables change the supply environment; farmer education matters in the short run, while R&D and cooperative extension (variables that generate and diffuse new technologies) and rainfall are important in both the long run and the short run. Sorghum, is found to be a secondary crop, and the area planted depends simply on intermediate input prices and rainfall over both the short and long run.

These relationships can be established even though all of the variables except rainfall are nonstationary, because cointegration is established between variables related to maize and between variables related to sorghum. Cointegration implies a long run equilibrium relationship that can be represented in terms of an error correction model (ECM). Subsequent estimation of the ECM allows individual variables to be considered for long and short run effects.

NOTES:

1. The views expressed are those of the authors' and do not necessary represent policies or views of the U.S. Department of Agriculture or any other institution.

2. Because maize is so dominant in the summer-rainfall grain area and maize prices are virtually guaranteed by government, most of cropping decisions with respect to other crops are dependant on movements of and expectations for the key variables of maize. It may therefore be appropriate to use price ratios of the individual crops to maize rather than the actual prices when specifying the supply of equation of other crops.

3. Langley and Du Toit (1978) and Armer (1985) illustrate the importance of rainfall in this period. Expected maize yields are up to 30 per cent lower when maize is planted after November 15 compared to when it is planted in the month of October.

4. See Groenewald (1989), Kirsten et al. (1994), Sartorius von Bach and Van Zyl (1994) and Van Zyl and Nel (1988) on the dominance of maize in the South African agricultural economy and particularly the summer-rainfall grain producing areas. This dominance is evident in most parameters - physical, financial and policy.

5. The general practice farmers follow is to plant maize if it has rained sufficiently before November 30. After that date, sunflowers are a better proposition (Armer, 1985).

6. Maize has been exported at a "loss" since the mid-1970s. Net receipts from exports do not cover production costs (see Groenewald, 1989 and World Bank, 1994, for an explanation of Maize Board pricing policies and their effects).

7. An example of this is the "Land Conversion Scheme" advocated by the government where farmers were encouraged to withdraw land from

maize production and research concentrated on finding viable alternatives for maize, particularly livestock on planted pastures (De Jager and Van Zyl, 1991).

8. The similarity of the magnitude of the error correction coefficients for maize and sorghum is according to *á priori* expectations. Both crops use the same equipment and infrastructure, and also have similar labour and managerial requirements. Thus, the similarity of the coefficients increases confidence in the results.

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