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THE IMPACTS OF MONETARY POLICY ON THE MAIZE AND BEEF SECTORS OF SOUTH AFRICA II: MODEL ESTIMATION AND SIMULATION RESULTS

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Abstract

A general equilibrium simultaneous equation model is constructed to analyse the impacts of monetary policy on the maize and beef sectors of South Africa. The model is estimated by three-stage least squares and used to simulate the dynamic impacts of an expansionary monetary policy (15 percent increase in money supply) from 1975 to 1987. In the short run, this causes real interest rates to fall, real income to rise, exchange rate to depreciate and prices to rise. Rising real incomes cause beef demand to increase and human maize consumption to fall. Depreciation of the exchange rate and higher domestic inflation raise real input prices. This impacts negatively on maize and beef supply. Higher beef prices encourage beef production, which causes animal maize demand to increase. Lower real interest rates impact positively on maize supply, negatively on beef supply, and stimulate real agricultural investment. The net effect is a decline in real gross farm income in the maize and beef sectors of South Africa.

Uittreksel
Die impak van monetêre beleid op die mielie- en beesvleis sektore van Suid-Afrika II: Modelraming en simulasie resultate

'n Algemene ewewig gelyktydige-vergelykingsmodel word opgestel om die impak van monetêre beleid op die mielie- en beesvleissektore van Suid-Afrika te ontleed. Die model word geraam volgens driestadium kleinste kwadrate en word gebruik om die dinamiese impak van 'n ekspansionistiese monetêre beleid (15 persent toename in geldvoorraad) vanaf 1975 tot 1987 te simuleer. Oor die korttermyn veroorsaak dit dat reële rentekoerse daal, reële inkomste styg, die wisselkoers depresieer, en pryse styg. Stygende reële inkomste veroorsaak dat die vraag na beesvleis toeneem en menslike mielieverbruik afneem. Depresiasie van die wisselkoers en hoër binnelandse inflasie laat reële insetpryse styg. Dit het 'n negatiewe impak op mielie- en beesvleisaanbod. Hoër beesvleispryse bevorder beesproduksie, wat veroorsaak dat die vraag na mielies vir diereverbruik styg. Laer reële rentekoerse het 'n positiewe impak op mielieaanbod, 'n negatiewe impak op beesvleisaanbod en dit stimuleer reële landboubelegging. Die netto effek is 'n afname in reële bruto plaasinkomste in die mielie- en beesvleissektore van Suid-Afrika.

1. Introduction

In this paper the general equilibrium simultaneous equations model specified in Paper I (Dushmanitch and Darroch, 1991) is estimated and used to dynamically simulate the impacts of an expansionary monetary policy on the maize and beef sectors of South Africa from 1975 to 1987. Two-stage (2SLS) and three-stage (3SLS) least squares are discussed as possible estimation techniques. The final model is estimated by 3SLS because there are sufficient degrees of freedom and 3SLS yields more efficient parameter estimates than 2SLS. The gain in efficiency is illustrated by comparing 3SLS and 2SLS parameter estimates for behavioural equations, specifying the maize and beef sectors in the model.

The impacts of monetary policy on the maize and beef sectors of South Africa are simulated by specifying interest rate, exchange rate, inflation and real income linkages through which monetary policy affects the two sectors. Annual data from 1960 to 1987 are used to construct 15 behavioural equations and 11 identities representing the maize, beef and manufacturing sectors, and money and foreign exchange markets. The exchange rate, inflation rate and real personal disposable income are determined endogenously within the model. The final form of the estimated model is used to simulate the dynamic impacts of an annual 15 percent increase in money supply from 1975 to 1987. Dynamic elasticities of the major endogenous variables with respect to a change in money supply are computed. Attention focuses on how the money supply expansion affects maize and beef supply, demand, prices and real gross farm income.

2. Model estimation

Estimation of model parameters by ordinary least squares (OLS) is inappropriate, because simultaneous equation bias arising from joint dependence among endogenous variables produces inconsistent OLS estimators. This problem is overcome by using simultaneous equations techniques such as 2SLS and 3SLS (Gujarati, 1982:368).

Estimators obtained by 2SLS are consistent and superior to OLS estimators. Two-stage least squares is termed a "single equation method" as each equation is estimated individually (provided it is identified). Single-equation methods are also termed "limited information" methods as they only utilise knowledge of the zero restrictions in the particular equation being estimated and therefore do not utilise all information available in the model (Kennedy, 1979:112; Pindyck and Rubinfeld, 1981:328).

The efficiency of 2SLS estimators can, however, be improved by employing a systems method like 3SLS. Systems methods estimate all identified structural equations together as a set, instead of estimating each equation individually. They are termed "full-information" methods because they utilise knowledge of all zero restrictions in the entire system, and thus make use of all information available in the model. This yields more efficient parameter estimates (Kennedy, 1979:116).

Three-stage least squares is a straightforward extension of 2SLS, in that it involves the application of least squares in three stages.

Briefly, the first two stages are the same as 2SLS, except that only the reduced form equations are used, with the 2SLS parameter estimates being discarded. The third stage involves the application of generalised least squares (GLS), that is, the application of least squares to a set of transformed equations, in which the transformation required is obtained from the reduced-form residuals of stage two. This transformation is necessary due to heteroscedasticity among the disturbance terms (Koutsoyiannis, 1977:475-477).

Disadvantages of 3SLS are large data requirements, high computational costs and sensitivity to specification bias. If the model is small, accuracy of the variable specification uncertain, and the possibility of uncorrelated error terms exists, then it is preferable to apply 2SLS (Koutsoyiannis, 1977:477-478).

The specified model was estimated by 3SLS (using the computer package RATS (Doan and Litterman, 1988)), because it is relatively large (26 equations), behavioural equations are supported by economic theory (Dushmanitch and Darroch, 1991) and 3SLS improves the efficiency of parameter estimates. Nonlinear 3SLS was used for final estimation as non-linearity can arise in the presence of auto-correlated error terms in a simultaneous equations system (Judge, *et al*, 1982:365).

3. Estimation results

All equations were first estimated individually by OLS and 2SLS to check for goodness of fit, correct variable specification and that coefficient signs agreed with *a priori* expectations. Some *a priori* specifications were changed during empirical estimation because of incorrect signs and/or non-significant parameter estimates. Once satisfactory results were obtained, the model was estimated as a complete set of equations by 3SLS.

The final form of the estimated model is presented in Appendix 1. The equations represent the best fit in terms of statistical significance and underlying theoretical foundations. Coefficient signs agree with *a priori* expectations, and most coefficients are significant at the five percent level or below. In most cases elasticities compare favourably with previous studies where comparisons were possible. Figures in the round and square brackets below each coefficient give the associated t-statistics and elasticities respectively. The $\bar{R}^2$ statistics are coefficients of determination adjusted for degrees of freedom, while Durbin h-statistics (h) are reported where lagged dependent variables appear as explanatory variables. All dependent variables are specified in terms of millions of rands to ensure homogeneity of units in the identities. The broad definition of money supply (M2) is used and all price variables are expressed as indices. Descriptions of, and data sources for, all model variables are given in Appendix 1 after the estimated equations.

3.1 Macro-sector

The three behavioural equations representing the manufacturing sector have good statistical fits, with all coefficients being significant at the five percent level and having the expected signs. Real money demand (RMd) is explained by RGDP, CPI, lagged CPI and lagged RMd. The grafted polynomial technique, developed by Fuller (1976:393), was used in which a grafted polynomial variable μ was used to differentiate between periods prior (1960-1980) and subsequent (1981-1987) to the monetary authorities adopting more market-orientated policy instruments recommended by the De Kock Commission (discount policy and open market operations). An excellent fit was obtained ($\bar{R}^2$ of 97,6 percent), with all coefficients being highly significant. The equation does not include the interest rate as the expected negative coefficient was not obtained. This supports findings of previous South African studies (Stadler, 1981; Contogiannis and Shahi, 1982) which could not establish a negative relationship between broadly defined money (M2) and the interest rate. Stadler (1981) hypothesises that this could be due to the definition of interest-bearing assets as broadly defined money.

The grafted polynomial variable was used to explain movements in the rand exchange rate during the three different exchange rate regimes between 1960-1987: fixed exchange rates (1960-1971), pegged exchange rates (1972-1978), and the managed float as recommended by the De Kock Commission (1979-1987). The grafted polynomial variable joins the three segments together to form a continuous function. Defined as zero in the period of fixed exchange rates, π explains movements in the exchange rate only after 1971. Prior to this, exchange rates were controlled directly by monetary authorities and exchange rate movements were therefore not a function of monetary variables.

The equation has an excellent fit ($\bar{R}^2$ of 98,5 percent) and coefficient signs agree with the monetarist view of exchange rate determination. According to the t-statistics which were adjusted for the reduced number of degrees of freedom, all coefficients are significant at the five percent level, except for the $r*\pi$ coefficient which is significant at the 10 percent level. The elasticity of the exchange rate with respect to the South African money supply (Ms) is 0,906. This implies that a one percent increase in Ms will lead to a 0,906 percent depreciation in the rand/standard drawing right (SDR) exchange rate.

The general price level (CPI) determination equation has an excellent statistical fit ($\bar{R}^2$ of 99,9 percent). Results indicated a strong relationship between the general level of prices and the ratio of money supply to real output (MsGDP), and lagged CPI. Inclusion of D1 in the equation improves the goodness of fit as it captures the substantially greater rate of increase in the inflation rate since 1973.

3.2 Agricultural sector

Real maize supply (RMZSS) was estimated as a function of lagged maize producer price deflated by the price of machinery and implements (RIMPPI), maize area planted (MAP), rainfall dummy (W), and real interest rate (RR). The price elasticity of RMZSS is 0,371, indicating an inelastic short-run response of RMZSS to changes in RIMPPI. Deflating the maize producer price by the price of machinery and implements (MIPI) simulates the inflation and exchange rate linkages. The prices of machinery and implements were used as a proxy for the maize input price because it produced the only statistically significant fit with the correct sign. Use of MIPI to simulate the inflation and exchange rate linkages is not unreasonable given that maize is a capital (machinery) intensive crop and a large proportion of machinery and implements are imported (Le Clus, 1979).

Real maize supply is inelastic (-0,059) with respect to RR. Devadoss (1985) obtained a similar result for the interest rate elasticity of real crop supply in the U.S. (-0,11). The negative sign indicates the cost effect of RR on RMZSS. The dummy variable, W, indicating years of good (W = 1) and bad (W = 0) rainfall, was constructed from rainfall data collated from a sample of 38 weather stations situated in the Maize Triangle by the Computing Centre for Water Research, University of Natal, Pietermaritzburg. The median rainfall was determined as the point differentiating between years of good rainfall and drought. The relatively high t-statistic (8,75) indicates that rainfall has a statistically significant effect on maize production.

Attempts to estimate a maize supply function using a Nerlove lag model were not successful. No statistically significant coefficients could be obtained using either lagged real maize price, lagged real returns per hectare or lagged real profit per hectare as explanatory variables. This result corresponds with that of Cadiz (1984) and may be explained by the very small year to year variation shown in the data on maize area planted.

Real *per capita* maize demand ($RPMZDH_t$) is estimated by the real maize price ($RMPPI_t$), real *per capita* disposable income ($RPCDY_t$) and lagged $RPMZDH_t$. The real bread price variable was dropped from the equation as its estimated coefficient was not statistically significant. The $RPCDY_t$ coefficient has a negative sign indicating that maize is an inferior good. This result agrees with the findings of Cadiz (1984) and Van Zyl (1986), and was supported by computing the income elasticity of demand for mealie-meal from cross-sectional data on consumption and expenditure patterns of Black, Coloured and Indian multiple households (Bureau of Market Research, University of South Africa). An income elasticity estimate of -0,158 was obtained which corresponds with the time-series estimate of -0,135. This elasticity is, however, smaller than those estimated by Cadiz (-0,38) and Van Zyl (-0,299).

The derived demand for maize as animal feed ($RMZDA_t$) depends upon the ratio of the maize producer price to the beef producer price ($RMBPI_t$). The estimated price elasticity of animal maize demand, -0,493, is lower than past estimates of -0,70 by Nieuwoudt (1973), and -1,29 by Van Zyl (1986), but similar to the -0,54 estimate by Cadiz (1984).

Real beef supply ($RBFSS_t$) is a function of the beef price deflated by price of dips and sprays (RIBAPI), herd size (CNW_t) and $RBFSS_t$, all lagged one year, and RR_t. The estimated price elasticity of $RBFSS_t$ is inelastic (0,30), in line with that reported by Devadoss (1985) for the price elasticity of livestock supply in the U.S. (0,22). The price of dips and sprays ($BIPI_t$) was selected as a suitable proxy for the beef input price as dips and sprays comprise a large proportion of inputs used in beef production and a significant percentage are imported (le Clus, 1979). The RR_t coefficient is significant and has a positive sign, indicating the stock effect of real interest rates on herd investment, and hence beef supply.

Real *per capita* beef demand ($RPBFDD_t$) was estimated by the real beef price ($RBAPI_t$), real poultry price ($RCHPI_t$), $RPCDY_t$, and the dummy variable $D1_t$. The price elasticity of $RPBFDD_t$ (-0,427) indicates an inelastic response of *per capita* beef demand to real beef price changes. The positive coefficient of $RPCDY_t$ indicates that beef is a normal good. The income elasticity of real *per capita* beef demand is 0,457, lower than that obtained by Hancock, *et al* (1984) of 0,96.

The significant positive $RCHPI_t$ coefficient supports the hypothesis that poultry and beef are substitutes in consumption. The dummy variable $D1_t$, is highly significant and the negative sign indicates the declining long term trend in *per capita* beef consumption. This could be due to increased awareness of the negative health aspects of excessive red meat consumption (Hancock,1983).

The maize and beef input demand equations have extremely good statistical fits (R^2 values of 99,90 percent and 99,60 percent respectively). All estimated coefficients are statistically significant at the five percent level or below, except for the XR_t coefficient in the maize input demand equation which is significant at the 15 percent level. This variable is retained as the t-statistic is greater than one and the coefficient has the correct sign.

Real agricultural investment (RAI_t) is inelastic with respect to RR_t (-0,07). Devadoss (1985) also reported an inelastic interest rate effect on U.S. agricultural investment (-0,05). Although the R^2 is low, the equation is retained due to the highly significant coefficient estimates.

3.3 Gain in efficiency associated with 3SLS

Table 1 compares 3SLS parameter estimates for maize and beef supply and demand equations with their 2SLS counterparts. The parameter estimates are of similar size and have the same sign, but the 3SLS estimates all have smaller variances. The gain in efficiency associated with 3SLS ranges from 36 percent for the real interest rate (RR_t) in the real maize supply equation ($RMZSS_t$) and to 87 percent for real livestock inventory (RLI_t) in the real animal maize demand ($RMZDA_t$) equation.

3.4 Model validation

Although individual regression equations may fit the data well (good R^2 and t-statistics), simulation results may be disappointing when the equations are combined into a simultaneous model (Pindyck and Rubinfeld, 1981:360-61). The model was therefore evaluated in terms of its simulation performance and forecasting properties.

The model was simulated over the entire study period to generate a set of base predictions of the endogenous variables. Actual and predicted values of these variables were then compared using mean percent errors (MPE), root-mean-square-percent-errors (RMSPE) and Theil's inequality coefficient (U). The turning point method was used to test the model's ability to track actual data. The closer MPE, RMSPE and U are to zero, the better is the predictive performance of the model. For a more detailed discussion of validation techniques, see Pindyck and Rubinfeld (1981:362-67).

Validation results showed that the model simulated the endogenous variables very well, except for real agricultural investment, real manufacturing supply and real net import demand for manufactured goods equations (U-statistics of 0,117, 0,179 and 0,173 respectively). The U-statistics of the remaining endogenous variables were less than 0,10. The simulation performance of the equations estimating real money demand, exchange rate, general price level, both input prices, real *per capita* maize and beef demand, and real beef supply are particularly good, with U-statistics all below 0,05. The model also predicted turning points of most key endogenous variables reasonably well. Validation results suggest that the model is a satisfactory basis for analysing the dynamic impacts of an expansionary monetary policy on the maize and beef sectors.

4. Policy analysis

An expansionary monetary policy is simulated by increasing money supply by 15 percent each year from 1975 to 1987. The focus is on the dynamic response (response over time) of the key endogenous variables to shocks originating in the money market and transmitted via the linkages to the maize and beef sectors. Dynamic simulations allow dynamic elasticities - which indicate how variables react over time in response to a change in another variable - to be calculated (Pindyck and Rubinfeld, 1981:395).

In the short run, an increase in money supply initially affects the general price level and exchange rate. The general price level will rise due to increases in real income which cause consumers to increase spending on domestic goods. The exchange rate depreciates in response to increased consumer demand for imported goods.

Inflation and exchange rate effects of the expansionary policy will be transmitted into the maize and beef sectors via impacts on agricultural input prices. Depreciation of the rand/SDR exchange rate will raise the cost of the imported component of machinery, implements, dips and sprays. As product/input price ratios decrease, maize and beef supply will decline as farmers react to the increased input prices relative to product prices. An expansionary monetary policy also lowers real interest rates which cause maize supply to increase (lower cost effect). Real beef supply will fall because lower real interest rates reduce the cost of holding stock on the farm and encourage herd investment (lower returns on interest bearing off-farm assets). Consumers react to higher real incomes by reducing real *per capita* maize demand and increasing real *per capita* beef demand. Table 2 reports the long-run dynamic elasticities of key endogenous variables with respect to a one percent increase in money supply.

Table 1: Three-stage and two-stage least squares parameter estimates

Equation	3SLS		2SLS			
	Coefficient estimate	Variance of coefficient estimate	Coefficient estimate		Variance of coefficient estimate	
Real maize supply: $RMZSS_t$						
$RIMPPI_{t-1}$	1,819	1,413	1,962		3,426	
MAP_t	1,173	0,249	1,080		0,850	
W_t	2,079	0,056	2,286		0,152	
RR_t	-0,128	-0,035	-0,119		-0,055	
Real *per capita* human maize demand: $RPMZDH_t$						
$RMPPI_t$	$-4,79x10^{-8}$	$-5,36x10^{-17}$		$-4,71x10^{-8}$		$-2,11x10^{-16}$
$RPCDY_t$	$-1,56x10^{-3}$	$-4,64x10^{-17}$		$-1,07x10^{-3}$		$-8,36x10^{-17}$
$RPMZDH_{t-1}$	0,427	$5,40x10^{-3}$	0,524		0,020	
Real animal maize demand: $RMZDA_t$						
$RMBPI_t$	-0,828	-0,022	-0,849		-0,050	
RLI_t	$7,57x10^{-3}$	$2,51x10^{-5}$	$7,12x10^{-3}$		$1,95x10^{-4}$	
$D1_t$	0,667	$5,72x10^{-3}$	0,699		0,011	
Real beef supply: $RBFSS_t$						
$RIBAPI_{t-1}$	0,940	0,011	0,764		0,023	
CNW_{t-1}	0,234	$2,59x10^{-3}$	0,206		$5,61x10^{-3}$	
$RBFSS_{t-1}$	0,228	$4,66x10^{-3}$	0,357		0,011	
RR_t	$7,08x10^{-2}$	$7,79x10^{-5}$	$7,0x10^{-2}$		$1,88x10^{-4}$	
Real *per capita* beef demand: $RPBFDD_t$						
$RBAPI_t$	$-1,09x10^{-7}$	$-1,34x10^{-16}$		$-1,21x10^{-7}$		$-5,99x10^{-16}$
$RCHPI_t$	$8,69x10^{-8}$	$1,40x10^{-16}$		$9,74x10^{-8}$		$6,82x10^{-16}$
$RPCDY_t$	$1,55x10^{-2}$	$7,61x10^{-6}$	$1,46x10^{-2}$		$2,13x10^{-5}$	
$D1_t$	$-1,94x10^{-8}$	$-2,52x10^{-17}$		$-1,39x10^{-8}$		$-5,58x10^{-17}$

The dynamic elasticities are calculated as average changes of the variable divided by average changes of the money supply, evaluated at the means over the period 1975 to 1987.The long run elasticity for CPI_t indicates that a one percent increase in the money supply results in an 0,355 percent increase in the general price level.

Table 2: Dynamic elasticities of the key endogenous variables with respect to a one percent change in money supply

Endogenous variable	Dynamic elasticity*
Consumer price index (CPI_t)	0,355
Exchange rate (XR_t)	1,343
Price of machinery and implements ($MIPI_t$)	0,668
Price of dips and sprays ($BIPI_t$)	0,444
Real maize supply ($RMZSS_t$)	-0,202
Real beef supply ($RBFSS_t$)	-1,376
Real per capita human maize demand ($RPMZDH_t$)	-0,208
Real per capita beef demand ($RPBFDD_t$)	0,755
Real animal maize demand ($RMZDA_t$)	0,679
Real agricultural income (maize and beef sectors)(RAY_t)	-0,666
Real agricultural investment (RAI_t)	-0,256

* calculated as the average change in the endogenous variable divided by the average change in the money supply, evaluated at the means over the period 1975 to 1987

This is similar to the 0,412 percent increase obtained by Devadoss in his U.S. study (1985).The positive sign supports the monetarist view of the quantity equation in which increases in the money supply raise the general price level.

The long run elasticity of the rand/SDR exchange rate with respect to a one percent money supply expansion is elastic at 1,343. An elastic response was also estimated for the $/SDR exchange rate by Devadoss (1985), although his estimate was larger (2,260). A possible reason for this could be the greater degree of South African Reserve Bank (SARB) management of the rand, and the existence of a dual currency (commercial and financial rand) system during part of the third exchange rate regime. Exchange rate fluctuations due to capital inflows and outflows would be reflected by changes in the financial rand exchange rate.

The long run elasticities of the maize ($MIPI_t$) and beef ($BIPI_t$) input prices associated with a one percent increase in money supply, reflect both inflation and exchange rate effects. The different elasticities (0,668 and 0,444 respectively) show that the combined impacts of the inflation and exchange rate effects are higher than the long run elasticity of the consumer price index. They also exceed the elasticities calculated by Devadoss (1985). As expected, both linkages show that an expansionary monetary policy puts upward pressure on farm input prices.

Real maize supply ($RMZSS_t$) shows a negative inelastic response (-0,202), indicating an inelastic response to increases in money supply, a result similar to that obtained by Devadoss

(1985). Real beef supply (RBFSS$_t$) also falls when money supply increases, but the response is elastic (-1,376). Stock effects of the lower real interest rate and cost effects of the higher price of dips and sprays reduce real beef supply.

The negative inelastic response (-0,208) of real *per capita* human maize demand (RPMZDH$_t$) supports the view that maize is an inferior good (as real *per capita* income rises in the short-run, real *per capita* demand for maize decreases). Real per capita beef demand increases when money supply expands (0,755) reflecting higher real income (normal good). The long-run elasticity of real animal maize demand (RMZDA$_t$) with respect to a one percent increase in money supply is positive (0,679), showing the increased demand for feed grain derived from increased demand for beef.

The long-run elasticity of the combined real gross farm incomes of the maize and beef sectors is -0,666, indicating that an expansionary monetary policy has negative effects on real gross incomes in these sectors. This elasticity estimate has a different sign from, and is smaller than, the 0,9 estimated by Devadoss (1985) for U.S. agriculture. The differences are probably due to his inclusion of trade effects of export demand for U.S. crops, whereas this model assumes maize and beef exports to be exogenous. Real agricultural investment (RAI$_t$) is inelastic with respect to a one percent increase in money supply. Falling gross farm incomes in the two sectors appear to outweigh reduced cost effects of lower real interest rates, thereby causing RAI$_t$ to fall.

5. Conclusions

The structural model successfully simulates linkages between monetary policy and the maize and beef sectors via the interest rate, general price level and exchange rate. Estimated coefficients for these variables have signs that agree with *a priori* expectations based on economic theory and are statistically significant. This evidence supports the hypothesis that changes in monetary policy can introduce further instability into the maize and beef sectors.

Negative estimated real interest rate coefficients in the real maize supply and real agricultural investment equations simulate cost effects of real interest rate changes on real maize supply and real agricultural investment. The positive relationship between the real interest rate and real beef supply shows the stock effect of real interest rates on herd investment, and hence real beef supply.

Positive estimated coefficients for the inflation and exchange rate variables in the inverted maize and beef input demand equations, simulate cost effects on input prices. Subsequent use of maize and beef input prices as deflators of the producer price variables in the real maize and beef supply equations respectively completes the inflation and exchange rate linkages.

The negative income elasticity of real *per capita* maize demand supports past findings that maize is an inferior good in South Africa. The positive income elasticity of real *per capita* beef demand indicates that beef is a normal good.

The efficiency of the model parameter estimates was markedly improved by using 3SLS. The gain in efficiency (reduced parameter variances) over 2SLS ranged from 36 percent to 87 percent for estimated maize and beef sector behavioural equation parameters.

The model simulates historical data well and accurately predicts most turning points in the endogenous variables over time. The model therefore provides a satisfactory basis for analysing the impacts of an expansionary policy on the maize and beef sectors in South Africa.

Dynamic simulation of a sustained 15 percent increase in money supply caused real interest rates to fall, the general price level to rise and the rand exchange rate to depreciate. Lower real interest rates decrease costs of short term debt (lower operating costs) and consequently increase real maize supply. Lower real interest rates also encourage beef herd investment (returns on off-farm interest bearing assets fall) and thus reduce real beef supply.

The effects of an expansionary monetary policy are transmitted to prices of machinery and implements and dips and sprays via the exchange rate and inflation linkages. Depreciation of the exchange rate causes the price of imports to rise. Higher prices of imported agricultural inputs, either in the form of raw materials or finished products, puts upward pressure on input prices. An increased domestic general price level raises input prices due to higher costs of raw materials and wage demands.

Higher input prices impact negatively on real supply in both sectors. In the maize sector, the increased cost effect of higher input prices offsets the reduced cost effect of lower real interest rates. In the beef sector, the increased cost effect of higher input prices and stock effect of lower real interest rates combine to reduce real beef supply.

Higher real consumer incomes impact positively on real *per capita* beef demand (normal good) and negatively on real *per capita* human maize demand (inferior good). Real animal maize demand, being derived from *per capita* beef demand, also increases.

The net effect of an expansionary monetary policy is lower real gross farm incomes in the maize and beef sectors. Policy makers therefore cannot ignore the effects of monetary policy changes when formulating agricultural policies, as these changes add to the instability faced by maize and beef farmers. The differential impact of the changes on product supply, demand, prices and incomes in each sector supports this conclusion.

Note

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Appendix 1: Three-stage least squares estimation results

MACRO-SECTOR

Money market

Real money demand

$$RMd_t = \underset{(4,52)}{32,58} - \underset{(-3,27)}{26,026}\mu_t + \underset{(21,10)}{0,244}(RGDP_t{*}\mu_t) - \underset{(-6,15)}{0,150}(CPI_t{*}\mu_t) + \underset{(5,98)}{9,04x10^{-2}}(CPI_{t-1}{*}\mu_{t-1}) + \underset{(7,10)}{0,200}(Md_{t-1}{*}\mu_{t-1})$$

$\bar{R}^2 = 0,976$ $h = -0,422$ $df = 22$

Money supply

$$Ms_t = m_t.B_t$$

Market equilibrium in the money market

$$Ms_t = (Md_t{*}CPI_t)$$

Foreign Exchange Market

Exchange rate determination equation

$$XR_t = \underset{\substack{(44,56)\\(28,18)}}{0,735} - \underset{\substack{(-7,55)\\(-4,78)\\[0,906]}}{1,791}\pi_t + \underset{\substack{(16,13)\\(10,20)}}{4,06x10^{-5}}(Ms_t{*}\pi_t) - \underset{\substack{(-11,98)\\(-7,58)}}{4,85x10^{-3}}(Ms'_t{*}\pi_t) + \underset{\substack{(2,44)\\(1,54)}}{4,72x10^{-3}}(r_t{*}\pi_t) - \underset{\substack{(-6,34)\\(-4,01)}}{3,49x10}(r'_t{*}\pi_t)$$

$$- \underset{\substack{(-3,74)\\(-2,36)}}{2,24x10^{-3}}(RGDP_t{*}\pi_t) + \underset{\substack{(9,91)\\(6,27)}}{2,85x10^{-2}}(RGDP'_t{*}\pi_t)$$

$\bar{R}^2 = 0,985$ $d = 2,79$ $df = 20$ adjusted $df = 8$

Real balance of payments

$$RBoP_t = RMZX_t - RBFM_t - RMANNM_t + RBoP'_t$$

General price level

$$CPI_t = \underset{(-5,78)}{-5,787} + \underset{\substack{(3,31)\\[0,051]}}{0,148}\, MsGDP_t + \underset{(43,18)}{1,099}\, CPI_{t-1} + \underset{(2,05)}{2,99}\, D1_t$$

$\bar{R}^2 = 0,999$ $h = 1,139$ $df = 24$

Manufacturing sector

Real *per capita* demand for manufactured goods

$$RPMAND_t = \underset{(7{,}60)}{4{,}29\times10^{5}} - \underset{\substack{(-8{,}29)\\ [-7{,}35]}}{4{,}39\times10^{5}}\, RMNPI_t + \underset{\substack{(9{,}70)\\ [1{,}252]}}{1{,}07}\, RPCDY_t$$

$\bar{R}^2 = 0{,}835$ $d = 0{,}80$ $df = 25$

Real net import demand for manufactured goods

$$RMANNM_t = \underset{(2{,}52)}{49{,}95} - \underset{\substack{(-2{,}05)\\ [-2{,}021]}}{45{,}24}\, RMMPI_t - \underset{\substack{(-3{,}01)\\ [-0{,}322]}}{5{,}886}\, XR_t + \underset{(3{,}29)}{6{,}32\times10^{2}}\, RGDP_t + \underset{(2{,}76)}{0{,}285}\, RMANNM_{t-1}$$

$\bar{R}^2 = 0{,}428$ $h = 1{,}023$ $df = 23$

Market equilibrium in the manufacturing sector

$$RMANSS_t + RMANNM_t = \{RPMAND_t * SAPOP_t\}$$

AGRICULTURAL SECTOR

Maize sector

Real maize supply

$$RMZSS_t = \underset{(-1{,}23)}{-2{,}674} + \underset{\substack{(1{,}53)\\ [0{,}371]}}{1{,}819}\, RIMPPI_{t-1} + \underset{(2{,}35)}{1{,}173}\, MAP_t + \underset{(8{,}75)}{2{,}079}\, W_t - \underset{\substack{(-3{,}63)\\ [-0{,}059]}}{0{,}128}\, RR_t$$

$\bar{R}^2 = 0{,}665$ $d = 1{,}946$ $df = 23$

Real *per capita* human maize demand

$$RPMZDH_t = \underset{(9{,}38)}{1{,}03\times10^{7}} - \underset{\substack{(-6{,}54)\\ [-0{,}605]}}{4{,}79\times10^{8}}\, RMPPI_t - \underset{\substack{(-2{,}29)\\ [-0{,}135]}}{1{,}56\times10^{3}}\, RPCDY_t + \underset{(5{,}81)}{0{,}427}\, RPMZDH_{t-1}$$

$\bar{R}^2 = 0{,}542$ $h = 2{,}601$ $df = 24$

Real animal maize demand

$$RMZDA_t = \underset{(5{,}11)}{2{,}238} - \underset{\substack{(-5{,}62)\\ [-0{,}493]}}{0{,}828}\, RMBPI_t + \underset{(1{,}51)}{7{,}57\times10^{3}}\, RLI_t + \underset{(8{,}82)}{0{,}667}\, D1_t$$

$\bar{R}^2 = 0{,}825$ $d = 0{,}963$ $df = 24$

Market equilibrium in the maize sector

$$RMZSS_t + RMZI_{t-1} = \{RPMZDH_t * SAPOP_t\} + RMZDA_t + RMZX_t + RMZI_t$$

Maize input demand

$$MIPI_t = \underset{(2{,}51)}{9{,}057} - \underset{(-5{,}75)}{5{,}641}\, RMZPT_t + \underset{(1{,}46)}{4{,}945}\, XR_t + \underset{(13{,}00)}{2{,}473}\, CPI_t - \underset{(-11{,}09)}{2{,}442}\, CPI_{t-1} + \underset{(14{,}16)}{0{,}833}\, MIPI_{t-1}$$

$\bar{R}^2 = 0{,}999$ $h = 1{,}316$ $df = 22$

Beef sector

Real beef supply

$$RBFSS_t = \underset{(-1{,}23)}{-0{,}554} + \underset{\substack{(8{,}84)\\ [0{,}30]}}{0{,}940}\, RIBAPI_{t-1} + \underset{(4{,}60)}{0{,}234}\, CNW_{t-1} + \underset{(3{,}34)}{0{,}228}\, RBFSS_{t-1} + \underset{\substack{(8{,}02)\\ [0{,}05]}}{7{,}08\times10^{2}}\, RR_t$$

$\bar{R}^2 = 0{,}787$ $h = -0{,}042$ $df = 23$

Real *per capita* beef demand

$$RPBFDD_t = \underset{(7{,}31)}{1{,}39\times10^{7}} - \underset{\substack{(-9{,}41)\\ [-0{,}427]}}{1{,}09\times10^{7}}\, RBAPI_t + \underset{\substack{(7{,}35)\\ [0{,}396]}}{8{,}69\times10^{8}}\, RCHPI_t + \underset{\substack{(5{,}62)\\ [0{,}457]}}{1{,}55\times10^{2}}\, RPCDY_t - \underset{(-3{,}86)}{1{,}94\times10^{8}}\, D1_t$$

$\bar{R}^2 = 0{,}486$ $d = 1{,}527$ $df = 23$

Market equilibrium in the beef sector

$$RBFSS_t + RBFM_t + RBFI_{t-1} = \{RPBFDD_t * SAPOP_t\} + RBFI_t$$

Beef input demand

$$BIPI_t = \underset{(6{,}70)}{13{,}39} - \underset{(-9{,}32)}{21{,}44}\, RBFPT_t + \underset{(31{,}54)}{0{,}715}\, CPI_t + \underset{(3{,}08)}{10{,}00}\, XR_t + \underset{(7{,}10)}{18{,}97}\, D1_t$$

$\bar{R}^2 = 0{,}996$ d = 1,79 df = 23

Real agricultural investment

$$RAI_t = 2{,}322 - 9{,}43x10^{-2}\, RR_t + 0{,}168\, RAY_t$$
$$(3{,}87)\ (-2{,}77)\ \ (2{,}40)$$
$$[-0{,}07]\ \ [0{,}391]$$

$\bar{R}^2 = 0{,}282$ d = 0,605 df = 25

Real income of the maize and beef sectors

$$RAY_t = RMZSS_t + RBFSS_t$$

National accounting identities

Real gross domestic product
$$RGDP_t = C_t + I_t + G_t + X_t$$

Real personal consumption expenditure
$$C_t = \{RPMZDH_t{*}SAPOP_t\} + RMZDA_t + \{RPBFDD_t{*}SAPOP_t\} + \{RPMAND_t{*}SAPOP_t\} + C'_t$$

Real gross domestic fixed investment
$$I_t = RAI_t + I'_t$$

Real net exports
$$X_t = RMZX_t + RBFM_t + RMANNM_t + X'_t$$

Real personal disposable income
$$RPDY_t = RGDP_t - RTD_t$$

Variable	Units	Variable description	Source
Endogenous variables			
Ms_t	R mil.	Nominal money supply M2	QB
RMd_t	R mil.	Real money demand M2 (CPI)	QB
CPI_t	Index	Consumer price index	AAS
$MsGDP_t$	R mil.	Ratio of nominal money supply to real gross domestic product	QB
XR_t	R/SDR	Exchange rate of the South African rand in terms of special drawing rights	IFS
$RBoP_t$	R mil.	Real balance of payments on the current account (CPI_t)	QB
$MNPI_t$	Index	Price of all consumer goods excluding food	SAS
$RMNPI_t$	Index	Real price of all consumer goods excluding food (CPI_t)	SAS
$RPMAND_t$	R mil.	Real per capita manufactured goods demand ($MNPI_t$)	SAS
$RMANSS_t$	R mil.	Real manufacturing supply ($MNPI_t$)	Calculated
$RMANNM_t$	R mil.	Real net import demand for manufactured goods ($MMPI_t$)	SAS
$MPPI_t$	Index	Maize producer price	AAS
$RMPPI_t$	Index	Real maize producer price (CPI_t)	AAS
$RIMPPI_t$	Index	Real maize producer price ($MIPI_t$)	AAS
$RMBPI_t$	Index	Ratio of $MPPI_t$ over $BAPI_t$	AAS
$RMZSS_t$	R mil.	Real maize supply ($MPPI_t$)	AAS
$RPMZDH_t$	R mil.	Real per capita human maize demand ($MPPI_t$)	MB
$RMZDA_t$	R mil.	Real animal maize demand ($MPPI_t$)	MB
$MIPI_t$	Index	Price of machinery and implements	AAS
$BAPI_t$	Index	Beef auction price on the hook	AAS
$RBAPI_t$	Index	Real beef auction price on the hook (CPI_t)	AAS
$RIBAPI_t$	Index	Real beef auction price on the hook ($BIPI_t$)	AAS
$RBFSS_t$	R mil.	Real beef supply ($BAPI_t$)	AAS
$RPBFDD_t$	R mil.	Real per capita beef demand ($BAPI_t$)	AAS
$BIPI_t$	Index	Price of dips and sprays	AAS
RAY_t	R mil.	Real gross farm income of maize and beef sectors	Calculated
RAI_t	R mil.	Real agricultural investment (CPI_t)	QB

C_t	R mil.	Real total personal consumption expenditure (CPI_t)	QB
I_t	R mil.	Real gross domestic fixed investment (CPI_t)	QB
X_t	R mil.	Real net exports of goods and services (CPI_t)	QB
$RGDP_t$	R mil.	Real gross domestic product (CPI_t)	QB
$RPDY_t$	R mil.	Real personal disposable income (CPI_t)	QB
$RPCDY_t$	R mil.	Per capita RPDYt	QB
Exogenous Variables			
B_t	R mil.	Monetary base	QB
m_t		Money multiplier	Calculated
r_t	Percent	Weighted average of major banks' prime overdraft rates	QB
Ms'_t	Index	Money supply in the world	IFS
r'_t	Percent	Treasury bill rate in the U.S.	IFS
$RGDP'_t$	Index	Real gross national product in the world	IFS
μ_t		0=1960-1971, Grafted polynomial variable connecting periods of different 1=1972-1978, exchange rate systems. 1960-1971 = fixed exchange rates, 2=1979-1987. 1972-1978 = floating exchange rates, 1979-1987 = managed floating exchange rates.	
π_t		1=1960-1980, Grafted polynomial variable connecting periods of different 2=1981-1987. monetary systems. 1960-1980 = quantitative and administrative controls, 1981-1987 = market oriented controls, i.e. Bank rate and open market operations	
$RBoP'_t$	R mil.	Real balance of payments on the current account not determined in model (CPI_t)	QB
$MMPI_t$	Index	Price of imported manufactured goods	SAS
$RMMPI_t$	Index	Real price of imported manufactured goods (CPI_t)	SAS
$SAPOP_t$	millions	Human population of South Africa	AAS
RR_t	percent	Real interest rate calculated as $RR_t = r_t-(CPI_t-CPI_{t-1})/CPI_{t-1}$	QB
MAP_t	mil. ha	Maize area planted	AAS
W_t	1=good yr, 0=bad yr	Dummy variable indicating years of good and bad rainfall	
$RMZPT_t$	R mil.	Real value of tractors, machinery and implements purchased ($MIPI_t$)	AAS
$RMZI_t$	R mil.	Real maize inventories ($MPPI_t$)	MB
$RMZX_t$	R mil.	Real maize net exports ($MPPI_t$)	MB
CNW_t	millions	Cattle numbers in white areas	AAS
$RBFPT_t$	R mil.	Real value of dips and sprays purchased ($BIPI_t$)	AAS
$RBFM_t$	R mil.	Real beef imports ($BAPI_t$)	AAS
$RBFI_t$	R mil.	Real beef inventories ($BAPI_t$)	Calculated
$D1_t$	0=1960-1972, 1=1973-1987	Dummy variable indicating period following oil price shock and subsequent double-digit inflation	
RLI_t	R mil.	Real livestock inventory (CPI_t)	AAS
$RCHPI_t$	Index	Real price of poultry products (CPI_t)	SAS
C'_t	R mil.	Real total personal consumption expenditure not determined in model (CPI_t)	QB
I'_t	R mil.	Real gross domestic fixed investment not determined in model (CPI_t)	QB
X'_t	R mil.	Real net exports of goods and services not determined in model (CPI_t)	QB
G_t	R mil.	Real government consumption expenditure (CPI_t)	QB
RTD_t	R mil.	Real taxes and deductions	Calculated

Note : variables appearing in brackets are deflators.

Sources : Directorate Agricultural Economic Trends (AAS), Central Statistical Service (SAS), Maize Board (MB), South African Reserve Bank (QB), International Monetary Fund (IFS).