AN ECONOMIC ANALYSIS OF THE IMPACTS OF MONETARY POLICY ON SOUTH AFRICAN AGRICULTURE

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Abstract

Following world wide trends, closer integration of agriculture into the macroeconomy has exposed farmers to the effects of changes in interest rates, exchange rates and prices that are associated with changes in monetary policy. In South Africa, farmers are faced with persistently high inflation, fluctuating interest rates and declining rand exchange rate. A general equilibrium simultaneous equation model was constructed to analyse the impacts of monetary policy on South African agriculture. Annual data (1960-1987) were used to estimate equations representing the field crop, horticultural, livestock and manufacturing sectors, and the money and foreign exchange markets. The interest, inflation, and exchange rates were determined endogenously and key macrolinkages whereby the impacts of monetary policy are transmitted to agriculture were simulated. Due to insufficient degrees of freedom, the model was estimated by two-stage principal components. The estimated model was used to simulate the dynamic impacts of an expansionary monetary policy on agriculture. In the short run, this causes the real interest rate to fall, exchange rate to depreciate, and general level of prices to rise. Depreciation of the exchange rate and higher domestic inflation raise input prices. Increased cost effects of higher input prices outweigh the reduced cost effects of lower real interest rates causing real field crop and horticultural supply to decrease. Increased stock effects of lower real interest rates and increased cost effects of higher input costs impact negatively on livestock supply. The resultant decrease in agricultural supply causes commodity prices to rise which lowers real demand for agricultural products. The net effect is a decline in real agricultural income for the sectors modeled.

Uittreksel

'n Ekonomiese analise van die impak van monetêre beleid op die Suid-Afrikaanse landbou

In navolging van wêreldwye neigings, het hegter integrasie van die landbou makro-ekonomie, boere blootgestel aan die gevolge van veranderinge in rentekoerse, wisselkoerse en pryse wat saamhang met veranderinge in monetêre beleid. In Suid-Afrika word boere gekonfronteer met voortgesette hoë inflasie, wisselende rentekoerse en 'n dalende rand-wisselkoers. 'n Algemene ewewigsmodel van gelyktydige vergelykings is saamgestel om die impak van monetêrebeleid op die Suid-Afrikaanse landbou te analiseer. Jaardata (1960-1987) is gebruik vir die raming van vergelykings om die akkerbou-, tuinbou-, lewendehawe- en vervaardigingsektore en die geld- en buitelandse valutamarkte te verteenwoordig. Die rente, inflasie en wisselkoerse is endogenies vasgestel en sleutel-makroskakels waardeur wisselkoerse die impak van monetêre beleid na die landbou oorgedra is, is gesimuleer. Weens onvoldoende grade van vryheid, is die model beraam deur tweede-vlak hoofkomponente. Die geraamde model is gebruik om die dinamiese inwerkings van 'n uitbreidende monetêre beleid op die landbou te simuleer. In die kort termyn het die reële rentekoers laat daal, die wisselkoers laat depresieer, en algemene prysvlakke laat styg. Depresiasie van die wisselkoers en hoër plaaslike inflasie het insetkoste laat styg. Verhoogde koste-effekte van hoër insetpryse weeg swaarder as die verlaagde koste-effekte van laer reële rentekoers en lei tot 'n afname in akkerbou- en tuinboutoevoer. Verhoogde vee-effekte weens die laer reële rentekoerse en verhoogde koste-effekte van hoër insetkoste, het 'n negatiewe invloed op lewendehawe-toevoer. Die gevolglike afname in landbou-toevoer veroorsaak dat kommoditeitspryse styg wat weer die reële vraag na landbouprodukte laat daal. Die netto-effek is 'n afname in die reële landbou-inkomste vir die sektore in die model bestudeer.

1. Introduction

Over the last fifteen years, considerable research effort has been devoted to the analysis of macroeconomic linkages through which changes in monetary policy impact on agriculture. Structural changes within the international economy, such as greater technological progress, monetary instability, adoption of floating exchange rates and increased capital and trade flows have facilitated the development of these macrolinkages and served to integrate agriculture into the macroeconomy (Schuh, 1976; 1979; 1984; 1985; McCalla, 1982). This has exposed farmers to the influences of monetary policy and increased the level of uncertainty, risk and instability in the farm sector. This trend has reinforced the need to move away from sectoral to general equilibrium analyses of the problems of agriculture (Gardner, 1981; Schuh, 1976).

Despite much controversy and contradictory evidence, the key macrovariables recognised as linking monetary policy changes to agriculture are the exchange rate, inflation rate, interest rate and real disposable income (Devadoss, 1985). Considerable argument exists in the literature concerning these linkages and the manner in which the macrovariables affect output, trade, prices, and ultimately, real income in the farm sector.

In the United States (U.S.), many economists view the dollar exchange rate as a major determinant of foreign demand for U.S. agricultural commodities and consequently, domestic commodity prices and farm incomes (Schuh 1974; Shei, 1978; Chambers, 1979; Chambers and Just, 1981; 1982). Others (Kost, 1976; Vellianitis-Fidas, 1976; and Johnson, *et al.*, 1977) attach more importance to variables taken from orthodox micro economic trade theory such as transport costs, foreign incomes and tariffs. Batten and Belongia (1984; 1986) argue that changes in money supply only have nominal effects and therefore monetary policy only affects nominal exchange rates.

As real and not nominal exchange rates affect real trade flows in the long run, this limits the role of monetary policy in promoting agricultural exports.

In South Africa a significant proportion of agricultural inputs are imported, either as raw materials or as finished goods (Le Clus, 1979). Depreciation of the rand exchange rate raises the cost of imported inputs relative to farm product prices adversely affecting South African farmers' terms of trade. The depreciation in the rand since 1985 has increased nominal returns from agricultural exports. Wool and fruit are among the major South African agricultural export orientated sectors to which increased nominal export earnings have accrued (Deciduous Fruit Board, Citrus Board, Wool Board).

Cost effects of inflation increase input costs, but inflation may also raise product prices. No definite conclusions have however been reached concerning the effects of inflation on real farm income. Starleaf, *et al.* (1985) and Devadoss (1985) contend that inflation benefits those with variable incomes, like farmers, at the expense of those with fixed incomes. Tweeten (1980a; 1980b), employing a more rigorous empirical analysis, concludes the opposite. Locally, Groenewald (1982; 1985) and le Clus (1979) attribute inflation in the farm sector partly to monopolies in the farm input manufacturing sector and tariff protection of local industries. Belongia and Fisher (1982) and Belongia (1985) point out that failure to distinguish between real and nominal effects, and relative and nominal price shifts have resulted in misidentification of the true causes and effects of inflation. An increase in input prices represents a change in relative prices with respect to prices received by farmers and not inflation which is a monetary phenomenon.

Interest rates impact on agriculture via cost and stock effects. Cost effects arise from the interest rate's role as a cost of debt. In South Africa and the U.S., high nominal interest rates have been identified as partial contributors to current liquidity and solvency problems (Louw, 1988; Van Zyl *et al*, 1987a; 1987b; Devadoss,1985). Stock effects influence inventory investment and have important implications for livestock owners. Higher real interest rates increase the marketing of animals as opportunity costs of herd investment on the farm increase with respect to investment in off-farm interest bearing assets (Rausser, 1985).

Real disposable income in the non-agricultural sector is an important determinant of demand for agricultural commodities. In the short run, an expansionary monetary policy increases real incomes and aggregate demand, *ceteris paribus*. This causes real prices and incomes to rise in the farm sector.

Since the early 1970's, South Africa has experienced persistently high inflation, fluctuating nominal and real interest rates, a decline in the rand exchange rate against major currencies and falling real per capita incomes (South African Reserve Bank). This study focuses on the impacts of these variables on the South African farm sector via changes in monetary policy. A general equilibrium simultaneous equations model is constructed and simulated to analyse how changes in monetary policy affect real gross and net farm income.

The paper first specifies behavioural equations for the macroeconomy, agriculture and major macrolinkages. The two-stage principal components estimation technique is then described and the estimated model discussed. After presenting results of the model validation, the dynamic impacts of an expansionary monetary policy on key endogenous variables are evaluated.

2. Model specification

Annual data from 1960 to 1987 were used to estimate 37 equations and 27 identities representing the field crop, horticultural, livestock and manufacturing sectors, and money and foreign exchange markets. The interest rate, exchange rate and inflation rate are determined endogenously to capture the influence of monetary policy on these variables. Linkages associated with these variables are simulated by specifying them in the relevant agricultural sector equations. This model extends the work by Dushmanitch and Darroch (1989) which examined monetary impacts on the maize and beef sectors in South Africa.

Specification of the agricultural and manufacturing sectors follows the structuralist approach. The agricultural sector is treated as being competitive, producing homogenous goods whose prices are flexible up and down. The manufacturing sector is viewed as being oligopolistic, producing heterogeneous goods whose prices are determined on a cost-plus basis and are inflexible downwards (Barnett, *et al.*, 1983). The money and foreign exchange markets are specified according to the monetarist approach which assigns money supply an active role in determining prices, the exchange rate and interest rates. Model specification shows how monetary shocks, which originate in the money market, impact on the agricultural sector.

2.1 Macrosector

The macrosector consists of the manufacturing sector and money and foreign exchange markets. The money market is the nucleus of the model from where all monetary shocks originate and is specified to endogenously determine nominal money supply, real money demand, the treasury bill rate and nominal and real prime overdraft rates.

Money supply (Ms_t) is determined as a multiple of the monetary base (B_t) and money multiplier (m_t) such that $Ms_t = m_t B_t$. Methodology used follows Oldham (1978) and Contogiannis (1979). The real money demand equation reflects Teigen's (1964) Keynesian specification. Transactions and speculative demand for money are represented by real income and the interest rate. Prices and price expectations are tested for inclusion as they have been identified as important determinants of real money demand in South Africa (Stadler, 1981; Contogiannis and Shahi, 1982).

Three interest rates are considered in the model. The discount rate is a policy variable manipulated directly by the South African Reserve Bank and is therefore treated exogenously. The treasury bill rate reflects conditions in the money and capital markets. It is determined endogenously as a function of money supply, real income and prices which capture the liquidity, income and price anticipation effects of monetary changes on interest rates (Friedman, 1972). Commercial banks adjust lending rates to changes in market rates. The prime overdraft rate represents the short-term lending rate and is specified as a distributed lag of the treasury bill rate. The real prime overdraft rate is defined as the nominal overdraft rate less the inflation rate (measured by the rate of increase in the consumer price index, CPI_t).

The foreign exchange market consists of a rand exchange rate determination equation and balance of payments identity. The exchange rate is specified according to the monetarist framework by which the principal determinants of nominal exchange rates are domestic and foreign money supplies, interest rates and real incomes. For example, country A's currency will depreciate against country B's if its money supply growth rate increases faster, interest rates rise faster or real output increases slower relative to country B (Humphrey and Keleher, 1982:248). The rand exchange rate is defined in terms of special drawing rights (SDR's), which gives a better indication of the overall competitive position of the rand and eliminates the need to construct an effective exchange rate index (Chambers, 1979).

Specification of the inflation rate equation follows the monetarist interpretation of the quantity theory of money which assigns money supply an active role in price level determination. The equation can be written as,

$$MV = PY \quad \text{(i)}$$

where M is the money stock, V is income velocity of circulation, P is the price level and Y is real income. Causation runs from left to right. An increase in M causes P to increase, given constant V and Y (Rogers, 1985). Rearranging the equation, the price level is determined as,

$$P = MV/Y \quad \text{(ii)}$$

The consumer price index (CPI), selected as a suitable proxy for the general price level, is specified as a function of the ratio of money supply to real gross domestic product and lagged CPI.

Endogenous determination of the treasury bill rate, prime overdraft rate, exchange rate and general price level as a function of appropriate policy variables simulates the macro-linkages associated with these variables and captures the effects of changes in monetary policy.

The manufacturing sector consists of a real *per capita* manufactured goods demand equation, real net import demand for manufactured goods equation and a market equilibrium identity. The structuralist approach specifies real supply of manufactured or industrial goods as a function of the percentage change in nominal wage rate and percentage change in productivity. A Philips curve equation relates percentage change in wages to unemployment and high powered money (Shei and Thompson, 1988:129). Paucity of reliable time-series of unemployment and wage rates in South Africa precludes the estimation of satisfactory manufacturing sector supply equations. Real supply is therefore estimated from the market equilibrium identity.

2.2 Agricultural sector

The agricultural sector is represented by 9 major products in the field crop (maize, sugar, and hay), horticultural (vegetables and potatoes) and livestock (beef, mutton, pork and poultry) sectors. These products were selected as they are major contributors to gross value of agricultural production. Export orientated products (deciduous fruit, citrus fruit and wool) are excluded from the reported model pending estimation of export demand equations which will be included in a later version.

Price determination and real demand equations are estimated for five major groups of agricultural inputs - fertilisers, dips and sprays, stock and poultry feed, fuel, and packing materials. Input prices are specified as a function of real quantity of inputs purchased, CPI and rand exchange rate. The CPI and exchange rate variables simulate the inflation and exchange rate linkages. The exchange rate is included because a significant percentage of non-farm produced inputs are imported into South Africa, either as raw materials or finished goods (Le Clus, 1979; Groenewald, 1982). Positive signs are hypothesised for these variables as an increase in CPI or depreciation in the rand exchange rate will raise input prices. Real demand for each input group is estimated to determine the real value of each input group purchased. Summation of individual input demand determines real variable costs of production.

All demand and supply equations are specified according to neoclassical theory. Real supply of each product is specified as a function of own real price, real input price, real price of substitutes in production (all lagged by one year to represent price expectations), real prime overdraft rate and external factors (weather, technology, areas planted and herd sizes).

Inclusion of real input prices in each real supply equation completes the inflation and exchange rate linkages. Inclusion of the real prime overdraft rate captures the effects of changes in the cost of short-term production loans on real supply and completes the interest rate linkage.

Real per capita demand for each product is specified as a function of real own price, real price of substitutes in consumption and real per capita disposable income. Real per capita disposable income simulates the real income linkage. As a large proportion of maize is consumed by livestock in South Africa real per capita human and real animal demand are estimated separately. Specification of the real animal maize demand equation reflects the derived demand for maize as animal feed (Nieuwoudt, 1973)

Real and nominal agricultural product prices are estimated from the market equilibrium identities. Identities estimate real income in the field crop, horticultural, red meat (beef, mutton and pork) and livestock sectors which are then summed to determine total real gross farm income. Real gross margin is determined by subtracting total variable costs from real gross farm income. Real gross margin less fixed costs gives real net farm income.

Real agricultural investment is specified as a function of the real price of capital goods, real interest rate and real net agricultural income. Four national accounting identities for real gross domestic product, real total personal consumption expenditure, real gross domestic fixed investment and real net exports close the system.

3. Model estimation

3.1 Estimation techniques

Simultaneous equations techniques such as two-stage (2SLS) and three-stage (3SLS) least squares are preferred to ordinary least squares when joint dependence among the endogenous variables (simultaneous equations bias) occurs. Application of OLS in the presence of simultaneous equations bias results in inconsistent estimators while 2SLS and 3SLS yield consistent estimators. Three-stage least squares was used by Dushmanitch and Darroch (1989) because 3SLS yields more efficient estimators than 2SLS.

The first stage of 2SLS and 3SLS estimates instrumental variables for each right-hand side endogenous variable by regressing each on all exogenous variables in the model. However, when the number of exogenous variables exceeds the number of observations, instruments cannot be estimated due to insufficient degrees of freedom. Two-stage least squares is therefore modified to reduce the number of exogenous variables used as explanatory variables in the first stage.

One method, initially proposed by Kloek and Mennes (1960), replaces the exogenous variables with a smaller number of principal components of the exogenous variables. Known as two-stage principal components (2SPC), this modification regresses the endogenous variables either on a set of principal components of all exogenous variables, or on the exogenous variables appearing explicitly in the structural equation being estimated and principal components of the remaining exogenous variables.

The first alternative is computationally fast and inexpensive (Mitchell, 1971), while the second is more demanding as a new set of principal components must be computed for each equation (Johnston, 1972:395). Although the second method ensures that 2SPC estimators are as consistent as 2SLS estimators

(McCarthy, 1971), multicollinearity between some of the exogenous variables and principal components may occur. In both cases, the number of principal components must be large enough to ensure identification, capture adequate variation in the exogenous variables, and small enough to overcome the degrees of freedom problem (Wonnacott and Wonnacott, 1979:512). No definite criteria exist regarding the number of principal components to include. Labys (1973:143) suggests selecting enough principal components to account for 90 percent of the variance. Coleman (1986) used enough components to account for 95 percent of the variance.

All equations were first estimated by OLS 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 insignificant parameter estimates. Once satisfactory results were obtained, principal components of all the exogenous variables were computed. To minimise computational costs and multicollinearity, the right hand side endogenous variables were regressed on enough principal components to account for 95 percent of the variation in the exogenous variables. All least squares equations were estimated using the computer package RATS (Doan and Litterman, 1988) and principal components were computed using the package GENSTAT.

3.2 Estimation results

The final form of the estimated model is reported in the appendix. Model equations represent the best fit in terms of statistical significance and underlying theoretical foundations. Coefficient signs agree with *a priori* expectations and most elasticities compare favourably with previous estimates where comparisons were possible. The round and square brackets beneath the estimated coefficients contain the corresponding t-statistics and elasticities respectively. R^2 statistics are adjusted for degrees of freedom and Durbin-Watson (DW) statistics are reported. Durbin h-statistics (h) are reported for equations which include a lagged dependent variable as an explanatory variable. Descriptions of, and data sources for, all variables are given in the appendix after the estimated equations.

3.2.1 Macrosector

Real money demand (RMd_t) is explained by real gross domestic product ($RGDP_t$), CPI_t and lagged CPI_{t-1}. The grafted polynomial technique (Fuller, 1976:393-398) was used to estimate RMd_t during the periods prior (1960-1980) and subsequent (1981-1987) to the adoption of the de Kock Commission recommendations. A grafted polynomial variable μ_t takes the value of one during 1960-1980 (quantitative and administrative monetary controls) and two during 1981-1987 (market orientated controls). The equation excludes the interest rate as the correct negative coefficient was not obtained. This supports findings of previous South African studies (Stadler, 1981; Contogiannis and Shahi, 1982) which were unable to establish a negative relationship between broadly defined money (M2) and the interest rate.

The treasury bill rate (TBR_t) is explained by Ms_t, $RGDP_t$ and lagged TBR_{t-1}. As a statistically significant coefficient with the correct positive sign could not be obtained for CPI_t it was dropped from the equation.

A grafted polynomial variable π_t was used to explain movements in the rand exchange rate (XR_t) during three different exchange rate regimes in effect during the study period: fixed exchange rates (1960-1971), flexible exchange rates (1972-1978), and managed float as recommended by the De Kock Commission (1979-1987). Defined as zero for the fixed exchange rate period, π_t 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 general price level (CPI_t) determination equation indicates a strong relationship between inflation and the ratio of Ms_t to $RGDP_t$. Inclusion of the dummy variable $D1_t$ (1960-1973=0, 1974-1987=1) in the equation improves goodness of fit as the variable captures the substantially greater rate of increase in the inflation rate since 1973.

Behavioural equations representing the manufacturing sector have good statistical fits, with all coefficients being statistically significant at the 5 percent level and having the correct signs.

3.2.2 Agricultural sector

The fertiliser ($PFERT_t$), dips and sprays ($PDIPS_t$) and farm feed ($PFEED_t$) price determination equations all include CPI_t and XR_t with positive signs. This correctly simulates the inflation and exchange rate linkages. An increase in CPI_t or depreciation in XR_t will raise input prices. The fuel ($PFUEL_t$) and packing materials ($PPACK_t$) price determination equations do not include XR_t due to wrong coefficient signs. Coefficients in the real input demand equations all have correct signs.

All real supply equations include lagged own producer prices deflated by the relevant input price. Input prices are used as deflators of producer prices rather than as separate regressors to reduce multicollinearity. This resulted in more significant coefficients with the correct signs. This specification simulates the inflation and exchange rate linkages, and captures the effects of changes in relative prices on real agricultural supply. Field and horticultural crop producer prices were deflated by $PFERT_t$. Beef, mutton and chicken meat price indices were deflated by $PDIPS_t$ and pork price index by $PFEED_t$. The input price indices reflect the primary input used in each sector, except for poultry where $PFEED_t$ produced the wrong sign, necessitating use of $PDIPS_t$.

All real supply equations, except for vegetables and chicken meat, contain the real prime overdraft rate (RR_t) with statistically significant coefficients and the correct signs. Real interest rate coefficients in the field crop and horticultural supply equations are negative, simulating cost effects of higher real short-term interest rates on crop supply. Real interest rate coefficients in the livestock supply equations have positive signs representing stock effects. Although RR_t elasticities are small (less than 0,10), all are statistically significant indicating that interest rate policy affects agriculture.

The real per capita disposable income ($RPCDY_t$) coefficient in the real per capita human maize demand ($RPCMZDH_t$) equation is negative, indicating that maize is an inferior good. This supports the findings of Van Zyl (1986) and Cadiz (1984). Coefficients of $RPCDY_t$ in all other per capita demand equations are positive (normal goods). The real per capita beef demand ($RPCBFDD_t$) equation has a statistically significant negative $D1_t$ coefficient and a statistically significant real chicken meat price ($RCHPI_t$) coefficient. This reflects falling per capita beef consumption and that poultry is a substitute in consumption. Inclusion of the real beef price in the real animal maize demand ($RMZDA_t$) equation reflects the importance of maize as animal feed in South Africa.

Real agricultural investment ($RAGINV_t$) is a function of the real price of capital goods ($RCAPI_t$), RR_t, total real net agricultural income ($RNAGINC_t$) and lagged $RAGINV_{t-1}$.

3.3 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). 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. Actual and predicted values were compared using a number of validation procedures which test ability to reproduce the data. The model was tested to check that it responded to economic shocks according to economic theory and *a priori* expectations.

The mean percent error (MPE), root-mean-square percent error (RMSPE) and Theil's U-statistic (including the bias, variance and covariance components) of each endogenous variable were calculated. The model was validated graphically to test its ability to duplicate turning points in the data. A 15 percent increase in money supply in 1972 tested model stability and that model response agreed with economic theory. For a more detailed discussion of validation techniques, see Pindyck and Rubinfeld (1981:362-67).

Validation results indicated that the model reproduces the actual data well and predicts turning points in the data satisfactorily. All except three endogenous variables have U-statistics less than 0,10 and most are less than 0,05 (U-statistics of zero indicate a perfect fit). Simulation results showed that the model was sufficiently stable for policy analysis.

4. Policy analysis

An expansionary monetary policy is simulated by increasing money supply by 15 percent each year from 1972 to 1987. The focus is on the dynamic response (response over time) of key endogenous variables to shocks originating in the money market and transmitted via the linkages to agriculture. Dynamic elasticities indicate how variables react over time in response to a change in another variable (Pindyck and Rubinfeld, 1981:395).

Table 1 reports the long-run dynamic elasticities of key endogenous variables in the model. The elasticities represent the percentage change in the endogenous variable with respect to a one percent change in money supply. Percentage changes were derived by comparing the simulated results with the base simulation.

The impacts on the monetary variables conform with *a priori* expectations. The positive long run elasticity of CPI_t indicates that the increase in money supply results in an 0,369 percent increase in the general price level. This is similar to the 0,412 percent increase obtained by Devadoss (1985) and conforms to the quantity theory of money by which the general price level is positively related to money supply.

The rand exchange rate depreciates by 1,208 percent per annum. Although elastic, this elasticity is smaller than that estimated by Devadoss (1985) for the U.S. dollar. This could be due to a greater degree of Reserve Bank management of the rand, and the existence of a dual currency system for much of the simulation period. The elasticity response of the financial rand, if estimated, would reflect the full effects of monetary policy on the exchange rate.

Positive long-run elasticities for input prices reflect the impacts of higher inflation and depreciated rand exchange rate on input prices. The different elasticities show that the combined impacts of inflation and exchange rate effects differ for each input price. Larger elasticities for $PFERT_t$ (0,480) and $PDIPS_t$ (0,465) reflect the effects of both linkages. The smaller $PFEED_t$ elasticity (0,298) could be due to farm feed being produced and fed to livestock on farm. Total real input demand declines by 0,576 percent.

Table 1. Long-run elasticities of the key endogenous variables with respect to a one percent change in money supply

Key Endogenous Variable	Long-run elasticity*
Consumer price index (CPI_t)	0,369
Exchange rate (XR_t)	1,208
Price of fertiliser ($PFERT_t$)	0,480
Price of dips and sprays ($PDIPS_t$)	0,465
Price of farm feed ($PFEED_t$)	0,298
Price of fuel ($PFUEL_t$)	0,442
Price of packaging ($PPACK_t$)	0,324
Real value of fertiliser purchased ($RQFERT_t$)	-0,627
Real value of dips and sprays purchased ($RQDIPS_t$)	-1,033
Real value of farm feed purchased ($RQFEED_t$)	-0,420
Real value of fuel purchased ($RQFUEL_t$)	-0,334
Real value of packaging purchased ($RQPACK_t$)	-0,298
Real maize supply ($RMZSS_t$)	-0,002
Real sugar supply ($RSCSS_t$)	-0,324
Real hay supply ($RHYSS_t$)	-0,831
Real gross farm income in field crop sector ($RFCINC_t$)	-0,206
Real vegetable supply ($RVGSS_t$)	-0,573
Real potato supply ($RPTSS_t$)	-0,522
Real gross farm income in horticultural sector ($RHTINC_t$)	-0,555
Real beef supply ($RBFSS_t$)	-0,509
Real mutton supply ($RMTSS_t$)	-1,879
Real pork supply ($RPKSS_t$)	-0,700
Real gross farm income in red meat sector ($RRMINC_t$)	-0,911
Real chicken supply ($RCHSS_t$)	-2,369
Real gross farm income in livestock sector ($RLVINC_t$)	-1,323
Real maize price ($RMZPI_t$)	0,178
Maize producer price ($MZPI_t$)	0,133
Real sugar price ($RSGPI_t$)	3,059
Sugar price ($SGPI_t$)	1,719
Real hay price ($RHYPI_t$)	2,286
Hay price ($HYPI_t$)	2,555
Real vegetable price ($RVGPI_t$)	0,747
Vegetable price ($VGPI_t$)	1,073
Real potato price ($RPTPI_t$)	0,956
Potato market price ($PTPI_t$)	1,096
Real beef auction price ($RBFPI_t$)	0,508
Beef auction price ($BFPI_t$)	1,016
Real mutton auction price ($RMTPI_t$)	1,372
Mutton auction price ($MTPI_t$)	2,009
Real pork auction price ($RPKPI_t$)	0,968
Pork auction price ($PKPI_t$)	1,453
Real chicken meat price ($RCHPI_t$)	0,529
Chicken meat price ($CHPI_t$)	0,216
Real per capita human maize demand ($RPCMZDH_t$)	-0.539
Real per capita sugar demand ($RPCSGDD_t$)	-1,182
Real hay demand ($RHYDD_t$)	-1,227
Real per capita vegetable demand ($RPCVGDD_t$)	-0.606
Real per capita potato demand ($RPCPTDD_t$)	-0,530
Real per capita beef demand ($RPCBFDD_t$)	-0,027
Real per capita mutton demand ($RPCMTDD_t$)	-1,287
Real per capita pork demand ($RPCPKDD_t$)	-0.418
Real per capita chicken meat demand ($RPCCHDD_t$)	-0,243
Real animal maize demand ($RMZDA_t$)	-0,199
Real total gross farm income ($RAGINC_t$)	-0,712
Real total value of inputs purchased ($RQINPUT_t$)	-0,576
Real total gross margin ($RGRSMGN_t$)	-0,376
Real net farm income ($RNTAGINC_t$)	-0,882
Real agricultural investment (RAI_t)	-0.188

* 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.

Real supply of all products decreases in the long run as a result of the money supply increase. The real maize (-0,002), sugar (-0,324), vegetable (-0,573) and potato (-0,522) supply responses are all inelastic. Real vegetable supply decreases the most since cost reducing effects of lower real interest rates are not captured. For maize, sugar, hay and potatoes, the increased cost effects of higher input prices offset the reduced cost effects of lower real interest rates. Real gross income in the field crop and horticultural sectors declines by 0,206 percent and 0,555 percent respectively.

For red meat products, stock effects of lower real interest rates reinforce increased cost effects of higher input prices causing red meat supply to decrease. Real beef supply decreases by 0,509 percent, mutton by 1,879 percent and pork by 0,700 percent. Real income of red meat producers declines by 0,911 percent. Real chicken meat supply decreases by 2,369 percent respectively. Real gross income in the livestock sectoris reduced by 1,323 percent.

Backward shifts in the supply curves raise real and nominal prices. The response of all real prices to the increase in money supply is inelastic, except for sugar (3,059), hay (2,286) and mutton (1,372). Higher real prices of all products cause real *per capita* demand for all products to decline. All elasticities of real *per capita* demand are less than one, except for sugar (-1,182), hay (-1,227) and mutton (-1,287). This is due to large increases in real prices of these products. The elastic response of real hay demand (-1,220) reflects the positive cross effects of higher real beef ($RBFPI_t$) and feed ($RPFEED_t$) prices which offset the the negative effects of a higher real hay price ($RHYPI_t$). The long-run elasticity of $RMZDA_t$ (-0,199) indicates that the increase in the real maize price ($RMZPI_t$) outweighs effects of the higher $RBFPI_t$.

The negative long-run elasticity of total real gross farm income ($RAGINC_t$) (-0,712) and real net farm income ($RNTAGINC_t$) (-0,882) indicates that an expansionary monetary policy has significant negative impacts on South Africa agriculture. Increased cost effects of the inflation and exchange rate linkages outweigh lower cost and increased stock effects of the interest rate linkage.

5. Summary and conclusions

Results show that the model successfully simulates links between money supply and the general price level, rand exchange rate and interest rate through the endogenous determination of these macrovariables. Inclusion of these macrovariables and real *per capita* disposable income in the agricultural sector equations simulates the linkages whereby the impacts of monetary policy are transmitted to South African agriculture.

Negative signs of the real interest rate coefficients in the real field crop and potato supply equations reflect cost effects of real interest rates on supply. The positive relationship between the real interest rate and real beef, mutton and pork supply shows the stock effect of real interest rates on herd investment, and hence red meat supply. The role of the real interest rate as a cost of capital is illustrated by its negative relationship with real agricultural investment.

Positive signs of the estimated coefficients of the inflation and exchange rate variables in the input price equations agree with *a priori* expectations. Use of input prices as deflators of the producer price variables in the real supply equations completes the inflation and exchange rate linkages.

The negative income elasticity of real *per capita* maize demand supports the view that maize is an inferior good in South Africa. Positive income elasticities of real *per capita* demand of all other products indicates that they are normal goods.

In the short run, an increase in money supply causes the real interest rate to fall, general price level to rise and rand exchange rate to depreciate.

Implications of lower real interest rates for the field crop and horticultural sectors are decreased real costs of short term debt which increase real supply. Lower real interest rates stimulate herd investment by beef, mutton and pork producers which decreases real red meat supply.

The effects of an expansionary monetary policy are transmitted to input prices via effects of money supply changes on the rand exchange rate and inflation. Depreciation of the rand exchange rate causes the price of imported inputs (either raw materials or finished products) to increase and put upward pressure on input prices.

Higher input prices impact negatively on real supply of all products. Cost effects of higher input prices offset reduced cost effects of lower real interest rates in the field crop and horticultural crop sectors. Cost effects of higher input prices and stock effect of lower real interest rates combine to reduce real red meat supply. Higher real prices caused by backward shifts in real supply result in reductions in real per capita demand for all products. Real animal maize demand decreases as the impact of higher maize price outweighs the impact of the higher real beef price.

The net effect of an expansionary monetary policy is lower real gross farm income, gross margin and net income for the modeled sectors. Policy implications are clear. Higher input costs, due to the effects of inflation or depreciation in the rand exchange rate, have negative consequences for these sectors. Higher input costs offset any positive impacts of lower real interest rates for all products.

Note

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APPENDIX

Two-stage principal components estimation results

Macrosector
Money market

Money supply

$$Ms_t = m_t * B_t$$

Treasury bill rate

$$TBR_t = \underset{(0,13)}{0,171} - \underset{(-2,84)\ [-0,267]}{1,277\times10^{-4}}\ Ms_t + \underset{(2,17)}{0,013}\ RGDP_t + \underset{(4,33)}{6,977}\ MD1_t + \underset{(3,55)}{0,546}\ TBR_{t-1}$$

$\bar{R}^2 = 0,838$ $\quad h = -2,02$ $\quad F_{4,23} = 31,19$ $\quad df = 23$

Prime overdraft rate

$$R_t = \underset{(3,63)}{2,290} + \underset{(10,49)\ [0,856]}{1,330}\ TBR_t - \underset{(-2,45)}{0,221}\ (TBR_t * MD1_t)$$

$\bar{R}^2 = 0,961$ $\quad DW = 1,38$ $\quad F_{2,25} = 315,93$ $\quad df = 25$

Real prime overdraft rate

$$RR_t = R_t - \{(CPI_t - CPI_{t-1})/CPI_{t-1}\}$$

Real money demand

$$RMd_t = \underset{(5,35)}{61,639} - \underset{(-4,18)}{51,795}\ \mu_t - \underset{(-1,50)}{7,938\times10^{-2}}\ (CPI_t * \mu_t) + \underset{(2,79)}{0,118}\ (CPI_{t-1} * \mu_{t-1}) + \underset{(10,70)}{0,241}\ (RGDP_t * \mu_t)$$

$\bar{R}^2 = 0,963$ $\quad DW = 2,25$ $\quad F_{4,23} = 152,88$ $\quad df = 23$

Market equilibrium in the money market

$Ms_t = (RMd_t * CPI_t)$

General price level

$CPI_t = -3,502 + 0,134\ MsGDP_t + 1,108\ CPI_{t-1} - 2,617\ D1_t$
(-1,20) (1,86) (27,03) (-1,26)
[0,046]
$\bar{R}^2 = 0,999$ h = 1,15 $F_{3,24} = 147,35$ df = 24

Foreign Exchange Market

Real balance of payments

$RBoP_t = RMZX_t - RMZM_t + RSGX_t - RSGM_t - RBFM_t - RMANNM_t + RBoP'_t$

Exchange rate determination equation

$XR_t = 71,978 - 147,961\ \pi_t + 3,935x10^{-3}\ (Ms_t * \pi_t) - 0,453\ (Ms^f_t * \pi_t) + 0,564\ (r_t * \pi_t)$
(34,37) (-3,45) (9,32) (-6,61) (1,89)
(21,74) (-2,18) (5,90) (-4,19) (0,97)
[0,894] [0,064]
$- 3,299\ (r^f_t * \pi_t) - 0,186\ (RGDP_t * \pi_t) + 2,436\ (RGDP^f_t * \pi_t)$
(-3,20) (-1,57) (4,68)
(-2,02) (-0,99) (3,97)
$\bar{R}^2 = 0,986$ DW = 2,72 $F_{7,20} = 192,27$ df = 20 adjusted df = 8

Manufacturing sector

Real per capita demand for manufactured goods

$RPCMNDD_t = 32,814 - 34,372\ RMNPI_t + 1,136\ RPCDY_t$
(3,10) (-3,58) (5,97)
[-6,16] [1,336]
$\bar{R}^2 = 0,842$ DW = 0,81 $F_{2,25} = 69,82$ df = 25

Real net import demand for manufactured goods

$RMANNM_t = 61,302 - 62,331\ RMMPI_t - 8,550x10^{-2}\ XR_t + 8,992x10^{-2}\ RGDP_t + 0,364\ RMANNM_{t-1}$
(1,99) (-1,80) (-3,01) (3,09) (2,22)
[-2,021] [-0,322]
$\bar{R}^2 = 0,463$ h = 0,82 $F_{4,23} = 5,93$ df = 23

Market equilibrium in the manufacturing sector

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

AGRICULTURAL SECTOR

Fertiliser price

$PFERT_t = 26,026 - 9,236\ RQFERT_t + 0,225\ XR_t + 0,806\ CPI_t - 28,517\ D1_t$
(1,33) (-1,15) (1,81) (10,94) (-2,99)
[0,184] [0,842]
$\bar{R}^2 = 0,990$ DW = 1,76 $F_{4,23} = 586,52$ df = 23

Dips and sprays price

$PDIPS_t = 31,232 - 21,255\ RQDIPS_t + 0,143\ XR_t + 0,691\ CPI_t - 19,336\ D1_t$
(3,67) (-2,82) (1,87) (12,20) (-3,31)
[0,134] [0,828]
$\bar{R}^2 = 0,996$ DW = 1,85 $F_{4,23} = 1302,21$ df = 23

Farm feed price

$PFEED_t = -12,947 - 4,858\ RQFEED_t + 0,195\ XR_t + 0,548\ CPI_t + 0,531\ HAYPI_t - 5,611\ D1_t$
(-1,70) (-1,23) (3,61) (10,16) (16,31) (-1,42)
[0,131] [0,471]
$\bar{R}^2 = 0,999$ DW = 2,17 $F_{5,22} = 4491,70$ df = 22

Fuel price

$PFUEL_t = 302,26 - 268,499\ RQFUEL_t + 1,523\ CPI_t - 70,825\ D1_t$
(2,13) (-1,72) (6,27) (-2,44)
[1,183]
$\bar{R}^2 = 0,924$ DW = 0,80 $F_{3,24} = 110,33$ df = 24

Packing material price

$PPACK_t = 90,585 - 179,699\ RQPACK_t + 0,819\ CPI_t + 0,183\ PPACK_{t-1}$
(3,19) (-3,37) (5,93) (1,02)
[0,820]
$\bar{R}^2 = 0,975$ h = 2,92 $F_{3,24} = 355,54$ df = 24

Fertiliser demand

$$RQFERT_t = 1{,}843 - 1{,}296\ RPFERT_t + 0{,}101\ RFCINC_t - 0{,}465\ D1_t$$
(2,04) (-1,74) [-0,042] (4,64) (-2,66)

$\bar{R}^2 = 0{,}832$ DW = 1,73 $F_{3,24} = 45{,}71$ df = 24

Dips and sprays demand

$$RQDIPS_t = 2{,}094 - 1{,}768\ RPDIPS_t + 5{,}885x10^{-2}\ RLVINC_t - 0{,}672\ D1_t$$
(2,12) (-3,09) [-0,349] (1,16) (5,77)

$\bar{R}^2 = 0{,}903$ DW = 0,90 $F_{3,24} = 84{,}76$ df = 24

Farm feed demand

$$RQFEED_t = -0{,}575 - 1{,}458\ RPFEED_t + 0{,}276\ RLVINC_t + 1{,}057\ RMZPI_t - 0{,}504\ D1_t$$
(-0,72) (-2,03) [-0,086] (5,24) (1,26) (-4,20)

$\bar{R}^2 = 0{,}875$ DW = 0,89 $F_{4,23} = 42{,}03$ df = 23

Fuel demand

$$RQFUEL_t = 0{,}952 - 0{,}231\ RPFUEL_t + 1{,}831x10^{-2}\ TRAGINC_t - 0{,}162\ D1_t$$
(3,04) (-2.03) [-0,176] (2,06) (-1,43)

$\bar{R}^2 = 0{,}408$ DW = 0,87 $F_{3,24} = 7{,}21$ df = 24

Packing material demand

$$RQPACK_t = 0{,}863 - 0{,}464\ RPPACK_t + 6{,}266x10^{-3}\ RFCINC_t + 8{,}530x10^{-2}\ D1_t$$
(6,28) (-4,96) [-0,108] (1,20) (2,95)

$\bar{R}^2 = 0{,}598$ DW = 0,93 $F_{3,24} = 14{,}41$ df = 24

Total real input demand

$$RQINPUT_t = RQFERT_t + RQDIPS_t + RQFEED_t + RQFUEL_t + RQPACK_t$$

Field crop sector

Real maize supply

$$RMZSS_t = -3{,}284 + 0{,}966\ MZFTPI_{t-1} - 6{,}994x10^{-2}\ RR_t + 1{,}520\ MAP_t + 2{,}093\ W_t - 0{,}440\ D1_t$$
(-0,78) (0,48) [0,210] (-1,05) [-0,032] (1,75) (4,31) (-0,97)

$\bar{R}^2 = 0{,}681$ DW = 2,25 $F_{5,22} = 11{,}39$ df = 22

Real per capita human maize demand

$$RPCMZDH_t = 7{,}578x10^{-2} - 3{,}485x10^{-2}\ RMZPI_t - 1{,}144x10^{-3}\ RPCDY_t + 0{,}546\ RPCMZDH_{t-1}$$
(3,32) (-1,91) [-0,441] (-1,22) [-0,010] (3,77)

$\bar{R}^2 = 0{,}540$ h = 2,63 $F_{3,24} = 11{,}56$ df = 24

Real animal maize demand

$$RMZDA_t = 0{,}395 - 1{,}726\ RMZPI_t + 0{,}621\ RBFPI_t + 1{,}107\ RPFEED_t + 0{,}677\ RMZDA_{t-1}$$
(0,80) (-2,98) [-1,168] (2,70) [0,383] (2,30) [0,856] (6,01)

$\bar{R}^2 = 0{,}931$ h = 0,39 $F_{4,23} = 79{,}60$ df = 23

Market equilibrium in the maize sector

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

Real sugar supply

$$RSCSS_t = -0{,}752 + 1{,}168\ SCFTPI_{t-1} - 4{,}715x10^{-2}\ RR_t + 5{,}460\ SCAM_t$$
(-2,48) (4,25) [0,007] (-3,84) [-0,044] (8,26)

$\bar{R}^2 = 0{,}816$ DW = 1,82 $F_{3,24} = 41{,}01$ df = 24

Real per capita sugar demand

$$RPCSGDD_t = 1{,}437x10^{-2} - 5{,}569x10^{-3}\ RSGPI_t + 2{,}365x10^{-3}\ RPCDY_t + 0{,}543\ RPCSGDD_{t-1}$$
(3,90) (-3,49) [-0,147] (5,19) [0,315] (5,61)

$\bar{R}^2 = 0{,}885$ h = 0,55 $F_{3,24} = 70{,}20$ df = 24

Market equilibrium in the sugar sector

$$\{RSCSS_t * SGSCR_t\} + RSGM_t + RSGI_{t-1} = \{RPCSGDD_t * SAPOP_t\} + RSGX_t + RSGI_t$$

Real hay supply

$$RHYSS_t = -0,213 + 0,806\ HYFTPI_{t-1} - 3,664x10^{-2}\ RR_t - 0,523\ D1_t + 0,528\ RHYSS_{t-1}$$
(-0,68) (2,69) (-2,04) (-2,82) (-3,24)
[1,074] [-0,082]

$R^2 = 0,858$ h = -2,49 $F_{4,23} = 36,24$ df = 23

Real hay demand

$$RHYDD_t = -1,503 - 0,954\ RHYPI_t + 2,586\ RPFEED_t + 0,507\ RBFPI_t + 0,362\ RHYDD_{t-1}$$
(-2,28) (-2,79) (3,11) (1,75) (1,87)
[-1,159] [1,230] [0,551]

$R^2 = 0,888$ DW = 1,91 $F_{4,23} = 47,35$ df = 23

Market equilibrium in the hay sector

$$RHYSS_t + RHYI_{t-1} = RHYDD_t + RHYI_t$$

Real income in field crop sector

$$RFCINC_t = RMZSS_t + RSCSS_t + RHYSS_t$$

Horticultural sector

Real vegetable supply

$$RVGSS_t = 0,410 + 0,238\ VGFTPI_{t-1} - 0,302\ RPTPI_{t-1} - 0,198\ D1_t + 0,773\ RVGSS_{t-1}$$
(1,26) (1,27) (-2,26) (-2,69) (5,72)
[0,194] [-0,225]

$R^2 = 0,858$ h = 0,68 $F_{4,23} = 36,40$ df = 23

Real per capita vegetable demand

$$RPCVGDD_t = 7,507x10^{-2} - 5,371x10^{-2}\ RVGPI_t + 2,293x10^{-3}\ RPCDY_t - 4,462x10^{-3}\ D1_t - 0,181\ RPCVGDD_{t-1}$$
(10,12) (-8,41) (4,24) (-2,94) (-1,76)
[-1,038] [0,467]

$R^2 = 0,898$ h = 1,43 $F_{4,23} = 52,56$ df = 23

Market equilibrium in the vegetable sector

$$RVGSS_t + RVGM_t + RVGI_{t-1} = \{RPCVGDD_t * SAPOP_t\} + RVGX_t + RVGI_t$$

Real potato supply

$$RPTSS_t = -0,506 + 0,472\ PTFTPI_{t-1} - 6,813x10^{-3}\ RR_t + 1,148x10^{-2}\ PAP_t + 0,359\ RPTSS_{t-1}$$
(-2,29) (2,30) (-0,64) (2,60) (1,72)
[0,623] [-0,023]

$R^2 = 0,571$ DW = 2,53 $F_{4,23} = 8,69$ df = 23

Real per capita potato demand

$$RPCPTDD_t = 1,629x10^{-2} - 2,218x10^{-2}\ RPTPI_t + 4,499x10^{-3}\ RPCDY_t - 0,216\ RPCPTDD_{t-1}$$
(3,22) (-5,22) (6,44) (-1,85)
[-0,765] [1,279]

$R^2 = 0,768$ h = 1,31 $F_{3,24} = 30,85$ df = 24

Market equilibrium in the potato sector

$$RPTSS_t + RPTM_t + RPTI_{t-1} = \{RPCPTDD_t * SAPOP_t\} + RPTX_t + RPTI_t$$

Real income in horticultural sector

$$RHTINC_t = RVGSS_t + RPTSS_t$$

Livestock sector

Real beef supply

$$RBFSS_t = -0,567 + 0,627\ BFDIPI_{t-1} + 7,773x10^{-2}\ RR_t + 0,145\ CNW_t - 0,240\ D1_t + 0,235\ RBFSS_{t-1}$$
(-0,52) (3,20) (4,76) (1,68) (-1,32) (1,70)
[0,195] [0,055]

$R^2 = 0,758$ h = -1,23 $F_{5,22} = 16,27$ df = 22

Real per capita beef demand

$$RPCBFDD_t = 0,125 - 0,130\ RBFPI_t + 1,486x10^{-3}\ RPCDY_t + 0,119\ RCHPI_t + 0,842\ D1_t$$
(3,69) (-4,87) (3,14) (4,08) (1,72)
[-0,508] [0,436] [0,486]

$R^2 = 0,496$ DW = 1,34 $F_{4,23} = 6,65$ df = 23

Market equilibrium in the beef sector

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

Real mutton supply

$$RMTSS_t = -1{,}452 + 0{,}601\ MTDIPI_{t-1} + 1{,}659\times10^{-2}\ RR_t + 3{,}517\times10^{-2}\ SNW_t + 0{,}842\ RMTSS_{t-1}$$
(-2,32) (3,81) (1,99) (2,98) (5,90)
[0,356] [0,025]

$\bar{R}^2 = 0{,}694$ h = 0,22 $F_{4,23} = 14{,}21$ df = 23

Real per capita mutton demand

$$RPCMTDD_t = 8{,}980\times10^{-2} - 9{,}488\times10^{-2}\ RMTPI_t + 1{,}020\times10^{-2}\ RPCDY_t + 2{,}098\times10^{-2}\ D1_t$$
(8,43) (-6,78) (5,16) (6,06)
[-0,805] [0,724]

$\bar{R}^2 = 0{,}734$ DW = 1,10 $F_{3,24} = 25{,}88$ df = 24

Market equilibrium in the mutton sector

$$RMTSS_t + RMTM_t + RMTI_{t-1} = \{RPCMTDD_t * SAPOP_t\} + RMTX_t + RMTI_t$$

Real pork supply

$$RPKSS_t = -0{,}379 + 0{,}328\ PKFDPI_{t-1} + 7{,}788\times10^{-3}\ RR_t + 3{,}878\times10^{-4}\ PNW_t + 0{,}552\ RPKSS_{t-1}$$
(-2,77) (2,70) (1,98) (3,16) (3,54)
[0,506] [0,034]

$\bar{R}^2 = 0{,}772$ h = 0,96 $F_{4,23} = 20{,}75$ df = 23

Real per capita pork demand

$$RPCPKDD_t = 1{,}788\times10^{-2} - 1{,}879\times10^{-2}\ RPKPI_t + 1{,}610\times10^{-3}\ RPCDY_t + 7{,}367\times10^{-3}\ RMTPI_t + 0{,}390\ RPCPKDD_{t-1}$$
(3,88) (-2,86) (2,79) (1,25) (2,30)
[-0,539] [0,357] [0,195]

$\bar{R}^2 = 0{,}724$ h = 1,08 $F_{4,23} = 16{,}26$ df = 23

Market equilibrium in the pork sector

$$RPKSS_t + RPKM_t + RPKI_{t-1} = \{RPCPKDD_t * SAPOP_t\} + RPKX_t + RPKI_t$$

Real income in red meat sector

$$RRMINC_t = RBFSS_t + RMTSS_t + RPKSS_t$$

Real chicken meat supply

$$RCHSS_t = -0{,}951 + 1{,}232\ CHDIPI_{t-1} + 0{,}836\ RCHSS_{t-1}$$
(-3,88) (4,54) (14,40)
[0,747]

$\bar{R}^2 = 0{,}945$ h = -1,14 $F_{2,25} = 227{,}86$ df = 25

Real per capita chicken meat demand

$$RPCCHDD_t = 8{,}543\times10^{-2} - 7{,}549\times10^{-2}\ RCHPI_t + 4{,}267\times10^{-3}\ RPCDY_t + 3{,}970\times10^{-2}\ RBFPI_t - 4{,}428\times10^{-2}\ D1_{t-1}$$
(2,31) (-2,38) (0,83) (1,36) (-5,36)
[-1,265] [0,512] [0,635]

$\bar{R}^2 = 0{,}790$ DW = 0,72 $F_{4,23} = 22{,}91$ df = 23

Market equilibrium in the poultry sector

$$RCHSS_t + RCHM_t + RCHI_{t-1} = \{RPCCHDD_t * SAPOP_t\} + RCHX_t + RCHI_t$$

Real gross income in livestock sector

$$RLVINC_t = RRMINC_t + RCHSS_t$$

Real gross income in agricultural sector

$$RAGINC_t = RFCINC_t + RHTINC_t + RLVINC_t$$

Total real gross income in agricultural sector

$$TRAGINC_t = RAGINC_t + RAGINC'_t$$

Total real gross margin in agricultural sector

$$RGRSMGN_t = TRAGINC_t - RQINPUT_t$$

Total real net income in agricultural sector

$$RNAGINC_t = RGRSMGN_t - RFIXCOST_t$$

Real agricultural investment

$$RAI_t = 1{,}650 - 1{,}524\ RCAPI_t - 5{,}532\times10^{-2}\ RR_t + 8{,}906\times10^{-2}\ RNAGINC_t + 0{,}763\ RAI_{t-1}$$
(1,65) (-1,89) (-1,36) (1,56) (6,68)
[-0,444] [-0,036] [0,613]

$\bar{R}^2 = 0{,}807$ h = -0,17 $F_{4,23} = 25{,}35$ df = 23

National accounting identities

Real gross domestic product

$$RGDP_t = C_t + I_t + G_t + X_t$$

Real personal consumption expenditure

$$C_t = \{RPCMZDH_t * SAPOP_t\} + \{RPCSGDD_t * SAPOP_t\} + \{RPCVGDD_t * SAPOP_t\} + \{RPCPTDD_t * SAPOP_t\} + \{RPCBFDD_t * SAPOP_t\} + \{RPCMTDD_t * SAPOP_t\} + \{RPCPKDD_t * SAPOP_t\} + \{RPCCIIDD_t * SAPOP_t\} + \{RPCMNDD_t * SAPOP_t\} + C'_t$$

Real gross domestic fixed investment

$$I_t = RAI_t + I'_t$$

Real net exports

$$X_t = RMZX_t - RMZM_t + RSGX_t - RSGM_t - RBFM_t - RMANNM_t + X'_t$$

Variable	Units	Variable description	Source
Endogenous variables			
Ms_t	R mil.	Nominal money supply (M2)	QB
RMd_t	R mil.	Real money demand (M2)	QB
TBR_t	Percent	Treasury bill rate	IFS
R_t	Percent	Prime overdraft rate	QB
RR_t	Percent	Real prime overdraft rate	Calculated
CPI_t	Index	Consumer price index	AAS
$MsGDP_t$	R mil.	Ratio of nominal money supply to real gross domestic product	
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	QB
C_t	R mil.	Real total personal consumption expenditure	QB
I_t	R mil.	Real gross domestic fixed investment	QB
X_t	R mil.	Real net exports of goods and services	QB
$RGDP_t$	R mil.	Real gross domestic product	QB
$RMANSS_t$	R mil.	Real manufacturing supply	Calculated
$RPCMNDD_t$	R mil.	Real per capita manufactured goods demand	SAS
$RMNPI_t$	Index	Real price of all consumer goods excluding food	SAS
$RMANNM_t$	R mil.	Real net import demand for manufactured goods	SAS
$PFERT_t$	Index	Price of fertilisers	AAS
$PDIPS_t$	Index	Price of dips and sprays	AAS
$PFEED_t$	Index	Price of stock and poultry feed	AAS
$PFUEL_t$	Index	Price of fuel	AAS
$PPACK_t$	Index	Price of packaging	AAS
$RPFERT_t$	Index	Real price of fertilisers	AAS
$RPDIPS_t$	Index	Real price of dips and sprays	AAS
$RPFEED_t$	Index	Real price of stock and poultry feed	AAS
$RPFUEL_t$	Index	Real price of fuel	AAS
$RPPACK_t$	Index	Real price of packaging	AAS
$RQFERT_t$	R mil.	Real value of fertilisers purchased	AAS
$RQDIPS_t$	R mil.	Real value of dips and sprays purchased	AAS
$RQFEED_t$	R mil.	Real value of stock and poultry feed purchased	AAS
$RQFUEL_t$	R mil.	Real value of fuel purchased	AAS
$RQPACK_t$	R mil.	Real value of packaging purchased	AAS
$RQINPUT_t$	R mil.	Total real value of inputs purchased	AAS
$RMZSS_t$	R mil.	Real maize supply	AAS
$MZFTPI_t$	Index	Maize producer price deflated by $PFERT_t$	AAS
$RPCMZDH_t$	R mil.	Real per capita human maize demand	MB
$RMZDA_t$	R mil.	Real animal maize demand	MB
$RMZPI_t$	Index	Real maize producer price	AAS
$RSCSS_t$	R mil.	Real sugarcane supply	AAS
$SCFTPI_t$	Index	Sucrose price deflated by $PFERT_t$	SASA
$RPCSGDD_t$	R mil.	Real per capita sugar demand	SASA
$RSGPI_t$	Index	Real sugar price	SASA
$RHYSS_t$	R mil.	Real hay supply	AAS
$HYFTPI_t$	Index	Hay price deflated by $PFERT_t$	AAS
$RHYDD_t$	R mil.	Real hay demand	AAS
$RHYPI_t$	Index	Real hay price	AAS
$RFCINC_t$	R mil.	Real income in the field crop sector	Calculated
$RVGSS_t$	R mil.	Real vegetable supply	AAS
$VGFTPI_t$	Index	Vegetable price deflated by $PFERT_t$	AAS
$RPCVGDD_t$	R mil.	Real per capita vegetable demand	AAS
$RVGPI_t$	Index	Real vegetable price	AAS
$RPTSS_t$	R mil.	Real potato supply	AAS
$PTFTPI_t$	Index	Potato price deflated by $PFERT_t$	AAS

$RPCPTDD_t$	R mil.	Real per capita potato demand	AAS
$RPTPI_t$	Index	Real potato price	AAS
$RHTINC_t$	Index	Real income in the horticultural sector	Calculated
$RBFSS_t$	R mil.	Real beef supply	AAS
$BFDIPI_t$	Index	Beef auction price deflated by $PDIPS_t$	AAS
$RPCBFDD_t$	R mil.	Real per capita beef demand	AAS
$RBFPI_t$	Index	Real beef auction price	AAS
$RMTSS_t$	R mil.	Real mutton supply	AAS
$MTDIPI_t$	Index	Mutton price deflated by $PDIPS_t$	AAS
$RPCMTDD_t$	R mil.	Real per capita mutton demand	AAS
$RMTPI_t$	Index	Real mutton price	AAS
$RPKSS_t$	R mil.	Real pork supply	AAS
$PKFDPI_t$	Index	Pork auction price deflated by $PFEED_t$	AAS
$RPCPKDD_t$	R mil.	Real per capita pork demand	AAS
$RPKPI_t$	Index	Real pork auction price	AAS
$RRMINC_t$	R mil.	Real income in the red meat sector	Calculated
$RCHSS_t$	R mil.	Real broiler supply	AAS
$CHDIPI_t$	Index	Broiler price deflated by $PDIPS_t$	AAS
$RPCCHDD_t$	R mil.	Real per capita broiler demand	AAS
$RCHPI_t$	Index	Real broiler price	AAS
$RLVINC_t$	R mil.	Real income in the livestock sector	Calculated
$RAGINC_t$	R mil.	Total real gross income of products in the sectors modelled	AAS
$TRAGINC_t$	R mil.	Total real gross income in agricultural sector	AAS
$RGRSMGN_t$	R mil.	Real gross margin	Calculated
$RNAGINC_t$	R mil.	Real net agricultural income in agricultural sector	Calculated
RAI_t	R mil.	Real agricultural investment	QB

Exogenous Variables

B_t	R mil.	Monetary base	QB
m_t		Money multiplier	Calculated
MD1	0 = 1960-1980, 1 = 1981-1987.	Dummy variable indicating periods of different monetary systems. 1960-1980 = quantitative and administrative money supply control, 1981-1987 = market oriented money supply control	
μ_t	1 = 1960-1980, 2 = 1981-1987.	Grafted polynomial variable connecting periods of different monetary systems. 1960-1980 = quantitative and administrative controls, 1981-1987 = market oriented controls	
π_t	0 = 1960-1971, 1 = 1972-1978, 2 = 1979-1987.	Grafted polynomial variable connecting periods of different exchange rate systems. 1960-1971 = fixed exchange rates, 1972-1978 = floating exchange rates, 1979-1987 = managed floating exchange rates.	
$D1_t$	0 = 1960-1973, 1 = 1974-1987.	Dummy variable indicating period following oil price shock and subsequent double-digit inflation	
$RBoP'_t$	R mil.	Real balance of payments on the current account not determined in model	
Ms^f_t	Index	Money supply in the world	IFS
r^f_t	Percent	Treasury bill rate in the U.S.	IFS
$RGDP^f_t$	Index	Real gross national product in the world	IFS
C'_t	R mil.	Real total personal consumption expenditure not determined in model	QB
I'_t	R mil.	Real gross domestic fixed investment not determined in model	QB
X'_t	R mil.	Real net exports of goods and services not determined in model	QB
G'_t	R mil.	Real government consumption expenditure	QB
$RPCDY_t$	R mil.	Per capita personal disposable income	QB
$RMMPI_t$	Index	Real price of imported manufactured goods	SAS
$SAPOP_t$	millions	Human population of South Africa	AAS
$RMZI_t$	R mil.	Real maize inventories	MB
$RMZX_t$	R mil.	Real maize exports	MB
$RMZM_t$	R mil.	Real maize imports	MB
$SGSCR_t$	Ratio	Sugar to sugar cane ratio	SASA
$RSGI_t$	R mil.	Real sugar inventories	SASA
$RSGX_t$	R mil.	Real sugar exports	SASA
$RSGM_t$	R mil.	Real sugar imports	SASA
$RHYI_t$	R mil.	Real hay inventories	Calculated
$RVGI_t$	R mil.	Real vegetable inventories	Calculated
$RVGX_t$	R mil.	Real vegetable exports	Calculated
$RVGM_t$	R mil.	Real vegetable imports	Calculated
$RPTI_t$	R mil.	Real potato inventories	Calculated
$RPTX_t$	R mil.	Real potato exports	Calculated
$RPTM_t$	R mil.	Real potato imports	Calculated
$RBFI_t$	R mil.	Real beef inventories	MTB
$RBFX_t$	R mil.	Real beef exports	MTB
$RBFM_t$	R mil.	Real beef imports	MTB
$RMTI_t$	R mil.	Real mutton inventories	MTB
$RMTX_t$	R mil.	Real mutton exports	MTB
$RMTM_t$	R mil.	Real mutton imports	MTB
$RPKI_t$	R mil.	Real pork inventories	MTB
$RPKX_t$	R mil.	Real pork exports	MTB

$RPKM_t$	R mil.	Real pork imports	MTB
$RCHI_t$	R mil.	Real broiler inventories	Calculated
$RCHX_t$	R mil.	Real broiler exports	Calculated
$RCHM_t$	R mil.	Real broiler imports	Calculated
$RAGINC_t$	R mil.	Real gross income not determined in model	Calculated
$RFIXCOST_t$	R mil.	Real fixed costs (depreciation, salaries and wages, interest and rent paid)	AAS
W_t	1=good year 0=bad year	Dummy variable indicating years of good and bad rainfall in maize growing areas	
MAP_t	mil. ha	Maize area planted	AAS
$SCAM_t$	mil. ha	Area of sugar cane harvested for milling	SASA
PAP_t	mil. ha	Potato area planted	PB
CNW_t	millions	Cattle numbers in white areas	AAS
SNW_t	millions	Sheep numbers in white areas	AAS
PNW_t	millions	Pig numbers in white areas	AAS
$RBNPI_t$	Index	Real banana price	SAS
$RCAPI_t$	Index	Real price of capital goods	AAS

Sources : Directorate Agricultural Economic Trends (AAS), Central Statistical Service (SAS), Maize Board (MB), South African Sugar Association (SASA), Potato Board (PB), Meat Board (MTB), South African Reserve Bank (QB), International Monetary Fund (IFS).