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

By

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I certify that the work reported in this thesis is my own original and unaided work except where specific acknowledgement is made.

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ABSTRACT

A general equilibrium, simultaneous equations model was constructed to analyse the impacts of monetary policy on South African agriculture via the interest rate, exchange rate, inflation and real income. 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 rate, general price level and exchange rate were determined endogenously to capture the effects of monetary policy on these variables. Macrolinkages whereby the impacts of monetary policy are transmitted to agriculture were simulated. Due to insufficient degrees of freedom, the final model was estimated by two-stage principal components.

Dynamic simulations of an expansionary monetary policy suggest that such policy action has important implications for South African agriculture. In the short run, an increase in money supply causes the real interest rate to fall, general price level to rise and exchange rate to depreciate.

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. Stock effects of lower real interest rates and cost effects of higher input costs impact negatively on livestock supply. The resultant decrease in real agricultural supply causes product prices to rise which lowers real per capita quantiy demanded for agricultural products. The net effect is a decline in total real gross farm income for the sectors modelled.

Dynamic simulations of the separate impacts of changes in the interest rate, general price level and exchange rate on agriculture support these conclusions. Inflationary impacts of monetary policy changes were larger than interest rate and exchange rate impacts, which were generally similar in magnitude.

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INTRODUCTION

Since the early 1970's, South African farmers have been exposed to persistent double-digit inflation and fluctuating nominal and real interest rates. More recently, the rand exchange rate has declined against major currencies and real per capita incomes have fallen (South African Reserve Bank). Structural changes in South African monetary policy have contributed to instability and uncertainty in the agricultural sector. In January 1979, the South African Reserve Bank implemented a managed float system for the exchange rate, and in 1980 the interest rate replaced strict quantitative controls, such as reserve asset requirements, as the principal policy instrument of monetary control. Lack of adequate restraints placed on the growth rate of monetary aggregates by the monetary authorities has contributed to general inflation (De Kock Commission, 1988, p.145). Acknowledgment of the importance of monetary policy for agriculture has created an increased awareness of the need to establish and understand the nature of the linkages between the macrosector and agriculture in South Africa.

Prior to the early 1970's, low inflation, unemployment and interest rates, and stable exchange rates had contributed to a period of economic stability and growth. Little significance was attached to the effects of these variables on agriculture. This resulted in agriculture being regarded as immune to the impacts of macroeconomic policies, and studies treated agriculture in isolation from the macroeconomy (Schuh, 1976; 1984; Lamm, 1980; Gardner, 1981; Freebairn, *et al.*, 1982). However, 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 contributed to increased instability, risk and uncertainty in the farm sector.

The key macrovariables recognised as linking monetary policy to agriculture are the exchange rate, inflation rate, interest rate and real disposable income (Chambers and Just, 1982; Chambers, 1985; Devadoss, 1985; Josling, 1985; Rausser, 1985). Inflation raises farm operating costs both directly and indirectly through its effect on factor costs in the agricultural and input manufacturing sectors respectively (Tweeten, 1980a; 1980b; Groenewald, 1982; 1985; van Zyl, 1986b). Movements in the exchange rate may alter the competitive position of domestic farmers on world agricultural commodity markets (Schuh, 1974; Shei, 1978; Chambers and Just, 1981; 1982) and affect the cost of imported inputs (le Clus, 1979; Groenewald, 1982). In South Africa and the United States, high nominal interest

rates have contributed partly to current liquidity problems experienced by farmers (Louw, 1988; van Zyl *et al.*, 1987a; 1987b; Devadoss, 1985). Real disposable income in the non-agricultural sector is an important determinant of demand for agricultural commodities.

The objective of this study is to empirically investigate the nature and strength of the macrolinkages that exist between monetary policy and agriculture in South Africa. Macrolinkages between South African agriculture and the macrosector are specified within a general equilibrium simultaneous equations model. Annual data from 1960 to 1987 are used to estimate 41 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 general price level are determined endogenously to capture the influence of monetary policy on these variables. Linkages to agriculture associated with these variables are simulated by specifying them in the relevant agricultural sector equations.

Individual equations are estimated by ordinary least squares and two-stage least squares regression to check for specification bias, statistical significance, and that coefficient signs agree with economic theory. Due to insufficient degrees of freedom, the final model is estimated by two-stage principal components. Model simulation performance is evaluated and validated using statistical and graphical techniques. The model is simulated dynamically to analyse the impacts of changes in South African monetary policy on South African agriculture - particularly on real supply, demand and prices of representative field crop, horticultural and livestock products. Long-run dynamic elasticities of these agricultural variables with respect to changes in the key macrovariables are computed.

The study is presented as follows: Chapter 1 discusses the evolution of South African monetary policy during the study period and the implications of these changes for the empirical analysis. Chapter 2 reviews literature on the four key macrovariables identified as major linkages between monetary policy and agriculture - exchange rate, inflation, interest rate and real income. Chapter 3 presents the model specification. Chapter 4 discusses estimation techniques, two-stage principal components estimation results, validation techniques and results. Results of the dynamic simulations and policy analysis are presented in Chapter 5. Policy implications of the study are discussed in the conclusion.

CHAPTER 1

MONETARY POLICY IN SOUTH AFRICA

1.1 Introduction

This chapter outlines the aims, objectives, operational variables and policy instruments of the South African Reserve Bank (SARB). Important features of the South African monetary system and monetary policy are discussed, with particular reference to three major changes which have occurred during the study period (1960-1987): the passing of the Banks Act in 1965; abandonment of the Bretton Woods System of fixed exchange rates in 1971; and implementation of the recommendations of the Commission of Inquiry into the Monetary System and Monetary Policy in South Africa[1] from 1979 onwards. These changes have had wide ranging implications for agriculture and must be considered in the empirical analysis.

1.2 Aims and objectives

The main aim of monetary policy in South Africa is to control the domestic money stock and protect the value of the national currency (du Plessis, 1979; Goedhuys, 1980). Others maintain that the primary concern of monetary policy is not simply the control of the domestic money stock as the name implies. Regulation of the level and structure of domestic interest rates, control of the amount and expansion of credit, and management of the exchange rate are important responsibilities of monetary policy (Meijer, 1988, p.493).

In South Africa, the primary or ultimate objectives of monetary policy are given as the attainment of;

i) a high degree of stability of the value of money,

ii) a high and stable level of employment,

iii) an acceptable growth rate for the economy, and,

iv) the maintenance of a satisfactory balance of payments, foreign reserve and exchange rate position (du Plessis, 1979; Meijer, 1988, p.499).

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[1] Hereafter referred to as the De Kock Commission, after Dr. G.P. de Kock, Governor of the South African Reserve Bank, who chaired the Commission.

Meijer (1988, p.501) lists four "second order objectives" as;

i) improvements in the distribution of wealth and income,

ii) protection and promotion of certain local industries deemed to be important to the national interest,

iii) improvements in the pattern of private consumption, and,

iv) ensuring security of supply.

Although these "second order" objectives are not the direct responsibility of the SARB, it may be called on by government to assist in attaining one or more of these objectives.

1.3 Operational variables

Operational variables are variables over which the SARB has statutory control. They are used to create conditions conducive to attaining the objectives of monetary policy. Their use derives from the inability of the SARB to simply achieve an objective in a dictatorial manner, e.g., the use of price and wage controls to control inflation (Meijer, 1988, p.497).

Examples of commonly used operational variables are interest rates and reserve asset requirements. The SARB attempts to attain its objectives by directing interest rates to a level at which the non-bank public desire to hold money. The ultimate objective is the control of aggregate demand, spending and domestic inflation. Changes in operational variables are effected by using any one of a number of policy instruments at the disposal of the SARB.

1.4 Policy instruments

Policy instruments fall into two broad categories - non-market-orientated and market-orientated. Non-market-orientated policy instruments were used extensively before 1980. These have been replaced by more market-orientated instruments following gradual implementation of the recommendations of the De Kock Commission.

1.4.1 Non-market-orientated policy instruments

Non-market-orientated policy instruments are direct instructions from the SARB to banking and financial institutions. Examples of direct controls that were commonly used in South Africa are;

i) quantitative restrictions on bank lending,

ii) selective credit controls,

iii) deposit and lending interest rate controls,

iv) moral suasion,

v) variations in terms of conditions of hire-purchase and instalment credit, and,

vi) exchange control regulations.

For a detailed description of these policy instruments, see Meijer (1988, pp.527-547).

Although their use is presently avoided, they were used extensively when market-orientated instruments proved ineffective. They permit the SARB greater control of the banking sector and increase its influence over the level and structure of market interest rates. More importantly, the SARB retains direct quantitative control over the level of credit. These measures are, however, considered undesirable due to considerable economic inefficiencies and inequalities associated with their use (Goedhuys, 1980; de Kock, 1981).

1.4.1 Market-orientated policy instruments

Market-orientated policy instruments are designed to be coercive and guide banking and financial institutions into a desired lending and borrowing behaviour which would otherwise have been imposed in an authoritative manner. These measures act as incentives to which banking institutions will respond voluntarily and spontaneously. The most commonly used instruments in South Africa are;

i) public debt management - management of the size, composition, maturity structure, ownership and changes of public sector debt, minimisation of interest costs and optimisation of repayments,

ii) open market operations - the sale and purchase of domestic securities in order to decrease or increase the supply of cash reserves to the banking system,

iii) discount policy - the extension of credit to banks to enable them to satisfy their immediate cash reserve needs and make good a reserve asset deficiency that arises from a statutory minimum cash reserve requirement. This is the SARB's most effective policy tool as it can set the level of market interest rates by setting the discount rate at a predetermined level. In being obliged to comply with a minimum cash reserve requirement, the banks approach what is termed the "discount window" and seek "accommodation". On being approached, the SARB rediscounts assets at a "penalty" rate. This penalty or discount rate sets the level and structure of interest rates at which the non-banking private sector can borrow money. The

SARB is obliged to unconditionally and without question meet any request for cash reserves. Only the price of these cash reserves, i.e. the interest rate, is altered,

iv) intervention in the spot and forward exchange markets, and,

v) variation of reserve asset requirements - this semi-market-orientated method is used only in exceptional circumstances. These are imposed on all banks and force them to maintain, as cash or liquid reserves, a certain percentage of their total liabilities. By varying these requirements, the SARB can restrict the banking sector's lending activities (Meijer, 1988, pp. 512-531; De Kock Commission, 1988, pp.159-160).

Implementation of the recommendations of the De Kock Commission since 1979 has significantly changed the South African monetary system and the conduct of monetary policy. Implications of these changes with respect to agriculture are discussed below, drawing mainly from de Kock (1981).

1.5 Monetary policy before the De Kock Commission

Monetary policy between 1945 and 1980 reflected the limited structure of domestic money and financial markets, and prevailing economic theories, especially with regard to money. Prior to the early 1960's, money was regarded as a unique financial asset which could only be created by the SARB and commercial banks. Monetary policy was therefore directed primarily at controlling the commercial banking sector's activities.

Policies of the SARB were heavily influenced by Keynesian economics and consequently focused on demand management. Although the link between money supply and expenditure, income, prices, and interest rates (and hence investment and consumption) was recognised, little importance was attached to measuring and publishing monetary aggregates (M1, M2, cash base, etc.). Greater emphasis was placed on the national accounts and other economic indicators.

Acknowledgement of the existence of "near money" and recognition of the importance of alternative banking institutions (discount houses, and merchant, hire-purchase and general banks) in the early 1960's resulted in the passing of the Banks Act in 1965. The Act brought the entire banking sector under the control of the SARB and subjected all banking institutions to the same set of legal requirements. Emphasis was placed on control of banks' cash reserves and liquid assets through use of public debt management, open market operations, rediscount policy and variable liquid asset requirements - in other words, market-orientated instruments.

These policy measures were, however, never fully implemented. The SARB increasingly utilised direct or non-market-orientated methods of control. Market-orientated measures proved totally ineffective in restraining the totally unexpected increase in credit demand. Open market operations and discount policy were restricted by the undeveloped nature of South Africa's financial markets. It was only in the late 1970's that these markets developed to the level at which they could be used effectively (Franzsen, 1983).

The primary reason for the failure of South African monetary policy was the inadequate recognition given to the importance of these markets, particularly for short term financial assets. Too much attention was directed at controlling the activities of the banks and financial institutions themselves. Control measures were too administrative, classificatory and rigid and were unable to adapt to the ever changing and evolving financial system (Goedhuys, 1980).

The De Kock Commission was appointed in 1977 to investigate current monetary policy and recommend suitable changes. The Commission identified four main deficiencies to be addressed;

i) rates of increase in the monetary aggregates were not adequately moderated and stabilised,

ii) control measures led to abnormal "disintermediation and reintermediation" which caused marked fluctuations in income velocity,

iii) interest rates were prevented from increasing to required levels, and,

iv) spot and forward exchange rates were not allowed to adjust to levels reconcilable with the appropriate level of aggregate monetary demand (De Kock Commission, 1988, pp.144-147).

1.6 Monetary policy after the De Kock Commission

The De Kock Commission recommended a market related approach to monetary policy which would allow the newly developed financial system to operate more freely and competitively. All policy instruments that bypassed financial markets were to be avoided and replaced by market-orientated policy instruments. The primary aim was to promote stability in the growth of monetary aggregates, increase control over disintermediation, and encourage market interest rates and spot and forward exchange rates (De Kock Commission, 1988, pp.153-160).

In January 1979, a managed floating exchange rate system was adopted. In March 1980, deposit rate controls were abolished and emphasis was placed on banks' cash reserve requirements rather than liquid asset requirements. In September 1980, bank credit ceilings were abolished. In February 1982, the clearing banks' prime rate was freed from its link to the SARB's Bank rate. Between March and

September 1982, the banks' cash reserve and liquid asset requirements were reduced. Throughout this period, interest rates were allowed to rise to more realistic market related levels (Meijer, 1984).

For the purposes of this study, what is important is the method of monetary control selected by the Commission. The Commission recommended the adoption of monetary targeting (de Wet, 1986). The main argument against interest rate targeting was that decision makers are guided by real, and not nominal interest rates (Botha, 1986). Monetary targeting should not be confused with the adoption of a rigid and overriding "money rule". It represents the choice of flexible targets that fall between certain ranges that are reviewed and revised in response to changing economic conditions (Moore and Smit, 1986).

In establishing a monetary target, the authorities attempt to direct the interest rate and exchange rate towards levels considered appropriate to achieving chosen objectives, given prevailing economic conditions. The money supply thereby becomes an endogenous variable (Moore and Smit, 1986). This method of monetary control is known as the Classical system. The Classical system differs from the alternative American system in a number of important respects.

The American system endorses the monetarist specification of money supply. Money supply, Ms, is a multiple of the money multiplier, m, and the monetary base, B, such that,

$$Ms = m.B \tag{1.1}$$

Emphasis is placed on direct control of the amount of cash reserves in the banking system. Money supply is controlled through open market operations rather than by discount policy, and market forces are left to determine the level of interest rates. The monetary authorities determine the quantity and rate of growth of the money supply by manipulating the monetary base, assuming a constant multiplier. Growth in the money supply determines the rate of growth of nominal incomes, prices and wages (Moore and Smit, 1986).

In direct contrast, the Classical system involves the use of variable cash reserve requirements and to a lesser extent liquid asset requirements to control the cash reserve base of the banking sector. The SARB does not control the monetary base directly, but uses open market operations to drive the banks to the discount window. Bank reserves held at the SARB in terms of the statutory requirements bear no interest, and therefore banks hold negligible excess reserves above required reserves. When faced

with additional demands for credit, banks are forced to seek accommodation at the discount window where they are subjected to a penal discount rate (Whittaker and Theunissen, 1987).

The SARB is obliged to meet all requests for accommodation and the banking sector is therefore able to obtain all their cash requirements. The discount rate sets the cost of these reserves, and by increasing this cost, the SARB strives to restrict any excess demand for credit and consequently excessive growth of the money supply. The SARB is also able to directly affect the market level of interest rates which serve to act upon the volume of bank credit thus causing the money supply to become a derived quantity (de Wet, 1986).

The discount rate is not market determined, but is an exogenous variable under the direct control of the SARB. The money stock is not restricted quantitatively, but is free to expand to the level that satisfies credit demand. The money stock in South Africa can therefore be regarded as being demand-determined and credit driven (Moore and Smit, 1986). Investors and consumers can obtain as much credit as they like as long as they are prepared to pay for it. The SARB has indicated its willingness and ability to raise interest rates to whatever level it considers necessary to restrain credit demand. Evidence of this can be seen in the overdraft rate rising to a peak of 27 percent in August 1984 (Botha, 1986).

The primary advantage of the Classical system is that the money stock can expand on demand to finance investment and real growth. Unlike the case of commodity money, growth is not restricted by an inadequate money stock. Expansion of the money supply in response to an increase in the demand for credit can however, be inflationary as the banking system is unable to distinguish between nominal and real growth. Endogeneity of the money supply accommodates an increase in wages and prices just as readily as an increase in output and employment (Rogers, 1986).

These developments within the South African monetary sector must be considered in the empirical analysis. During the study period, monetary policy can be divided into three distinct periods - the period before the Banks Act of 1965 (1960-1964); the period characterised by use of non-market-orientated policy instruments (1965-1980); and the period following adoption of the De Kock Commission recommendations (1981-1987). The period 1960-1964 poses problems for specification and estimation of functions which require data for certain monetary aggregates which were not measured prior to 1965. Implementation of the De Kock Commission recommendations from 1980 onwards transformed money supply from an exogenous to an endogenous variable. This poses problems for selecting a

suitable specification of a money supply function that accurately reflects the money supply process throughout the study period.

Adoption of the interest rate as a key instrumental variable in 1980 has had important implications for South African agriculture. Direct manipulation of the discount rate by the SARB has a direct bearing on lending rates which impact on agriculture. The interest rate impacts on agriculture via its role as a cost-of-capital which directly affects the cost of credit, investment and savings (du Plessis, 1979). Indirectly, input prices increase as interest charges are built into cost structures by manufacturers. These factors impact negatively on agricultural output and incomes and ultimately the financial and cash-flow position of the farming sector (van Zyl, *et al.*, 1987b).

Changes to exchange rate policy must also be incorporated into the empirical analysis. Until the abandonment of the Bretton Woods fixed exchange rate system in 1971, monetary policy was divorced from the needs of managing a floating exchange rate. This provided the authorities with a state of independence not available under a system of freely or managed floating exchange rates. Floating exchange rates have contributed to instability and uncertainty due to the adoption of certain policies not consistent with the internal needs of the economy (Meijer, 1988, p.355).

The transition from fixed to floating (albeit managed) exchange rates transformed the exchange rate from an exogenous into an endogenous variable. This poses problems for the specification and estimation of an exchange rate function which adequately reflects exchange rate determination in both periods.

To be useful for policy analysis and forecasting, the empirical model must be representative of real world behaviour. The model must capture macroeconomic linkages and simulate monetary impacts on agriculture. Specification of the model equations, and measures taken to incorporate structural changes in the monetary and real sectors are described in Chapter 3.

Chapter 2 discusses structural changes in the international economy which prompted research into the closer integration of United States agriculture into the world macroeconomy. It highlights key macrovariables and linkages through which changes in monetary policy impact on agriculture. Linkages in the South African context are also discussed.

CHAPTER 2

IMPORTANT MACROLINKAGES AND KEY MACROVARIABLES

2.1 Introduction

Over the last fifteen years, considerable research has been devoted to analysing macroeconomic linkages through which changes in monetary policy impact on agriculture. Structural changes within the international economy 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 reinforced the need to move away from sectoral to general equilibrium analyses of the problems of agriculture (Gardner, 1981; Schuh, 1976).

Key macrovariables identified as linking monetary policy to agriculture are the exchange rate, inflation rate, interest rate and real income (Devadoss, 1985; Josling, 1985). Considerable debate exists in the literature concerning these linkages and the manner in which certain macrovariables affect agricultural output, trade, prices, and ultimately, real income in the farm sector.

This chapter reviews literature on macroeconomic linkages and key macrovariables through which impacts of changes in macroeconomic policies are transmitted to the agricultural sector. Important linkages between agriculture and the macroeconomy are first discussed, followed by a review of empirical and theoretical studies on the impacts of the exchange rate, inflation, interest rate and real income on agriculture.

2.2 Linkages with the farm sector

Just (1977) pointed out the poor record of agricultural sector models in predicting future trends in macroeconomic variables. This is due to poor specification of exogenous and endogenous variables and non-recognition of important macrolinkages or interfaces. These involve the interaction of;

i) general price and income levels, agricultural marketing costs and agricultural prices in domestic demand for agricultural products,

ii) agricultural input markets with the supply side of the agricultural sector, and,

iii) international trade in agricultural and non-agricultural goods which has an effect on the trade balance, exchange rate and export demand.

Josling (1985) identifies five important macroeconomic linkages which expose agriculture to events in the macroeconomy.

2.2.1 Purchase of non-farm inputs

The purchase of inputs such as machinery, fertiliser, chemicals, fuel, etc., exposes agriculture to both inflation and real price changes in these input markets. Effects of exchange rate changes are also transmitted through this market.

2.2.2 Hiring of factors

The need to hire factors of production (labour and capital) links agriculture to the macroeconomy, the strength of this linkage depending on the degree of integration between rural and urban markets.

2.2.3 Value of assets

Farmers own real assets (land, buildings and livestock) and incur debts. Asset values reflect farm sector demand and non-farm valuations, which are in turn affected by inflation. Effects on farm liabilities and real asset values may be asymmetric to the benefit of the farmer, especially those in debt.

2.2.4 Sale of produce

Agricultural product prices are a combination of consumer (private) and government created (public) demand. Private demand is more heavily influenced by changes in real incomes and relative prices than by monetary effects. Public demand, on the other hand, may react to the nominal component of price changes. In times of inflation the government may use agricultural policy to hold down food prices. This decreases real farm product prices, which adversely affects the welfare of farmers.

2.2.5 Purchase of consumption goods

The need to purchase non-farm produced consumption goods for farm-family consumption provides another linkage between the two markets. This exposes the farm household to inflation in the non-farm sector.

2.3 Forward and backward linkages

Rausser (1985) describes forward and backward linkages which must be taken into account when attempting to determine the different effects of macroeconomic and agricultural policies on agriculture.

2.3.1 Forward linkages

The most important linkages are observed in acreage, yield, demand, and inventory behaviour. These linkages should include interest rates, personal income, non-food and general inflation rates, and energy costs.

Interest rates form a sizeable component of operating costs for many farmers. Rising interest rates increase production costs of agricultural inputs. This causes decreased crop production and decreases in the size of breeding herds as it becomes more costly (opportunity costs) to hold animals on the farm.

Changes in inflation affect consumer demand for agricultural commodities. The magnitude of this effect depends on the rate at which wages increase relative to inflation. Constant real wages will have no impact on demand. If wages change at a different rate to inflation, real incomes change causing consumer spending to change. The impact on the demand for agricultural products of this change depends on the size and sign product of income elasticities of demand.

2.3.2 Backward linkages

Backward linkages originate in the agricultural sector and are evident in the consumer price index (CPI), endogenous deficits, and effects on the trade balance.

As the CPI includes food prices, any increases in agricultural commodity prices will be incorporated into the general inflation rate. Recognition of the food price-CPI linkage is important because the CPI is used to deflate nominal economic variables and is included in equations as an explanatory variable.

Government expenditure links agriculture to the macroeconomy. Subsidies, floor prices, drought relief, etc. provide avenues through which government actions impact on agriculture. Government expenditure is an important component of gross domestic product (GDP).

The third linkage exists in export demand for agricultural produce which affects a country's balance of payments, GDP, and ultimately that country's exchange rate.

2.4 International monetary linkages

Several linkages exist between agriculture and domestic and foreign monetary policies. Foreign monetary policies affect foreign prices, interest rates, and incomes. The interaction of domestic and foreign monetary policies affects international financial and commodity markets. Impacts of these changes link domestic agriculture to foreign monetary policies.

McCalla (1982) outlines several international linkages which have had important implications for agricultural trade and development. Greater technological progress, increased 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. These are discussed in detail by McCalla (1982) and Schuh (1976; 1979; 1984; 1985).

The emergence of international monetary linkages has contributed to global economic instability and volatility. Effects of unstable domestic monetary policies are transmitted from major economies such as the U.S to developed economies, and ultimately to economies of centrally planned and less developed countries.

This period has witnessed the development of linkages between primary commodity, financial and capital markets. International liquidity contributes to primary commodity price variability. This in turn affects holdings of storable commodities, aggregate demand for agricultural commodities, and real prices. Linkages between global macrovariables such as the exchange rate, international commodity markets, and domestic and foreign monetary policies affect agricultural trade which impact on the net trade position of major importers and exporters of agricultural produce.

This has important implications for South Africa which, like most typical non-OPEC developing countries, is heavily dependent on the export of primary commodities for foreign exchange earnings. Links between economic development and economic performance in the agricultural sector mean that

instability in these commodity markets can adversely affect development plans. Lower world commodity prices increase the cost of retail food subsidies and raise relative costs of domestically produced food to imported food.

It is apparent that a network of strong domestic and international linkages has emerged in response to structural changes in the world economy since the early 1970's. This has increasingly integrated agriculture into both the domestic and world macroeconomies. Farmers are no longer able to divorce themselves from the effects of both domestic and foreign monetary policies. As Schuh (1984, p.243) points out, "as an economy becomes increasingly open, it becomes increasingly beyond the reach of domestic policies".

2.5 Exchange rate

In the 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, 1975; 1976; and Johnson, *et al.*, 1977) attach more importance to variables taken from orthodox microeconomic trade theory such as transport costs, foreign incomes and tariffs. Batten and Belongia (1984; 1986) argue that as changes in money supply only have nominal effects, 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 addition, concern has been expressed over discrepancies in the results yielded by different measures of the exchange rate indices (Belongia, 1986; Batten and Belongia, 1987; Dutton and Grennes, 1987; Ott, 1987).

The debate can be broadly divided into the consensus view (Batten and Belongia, 1986) which holds that the major impact is on the agricultural trade balance via price and export effects, and the monetarist view which maintains that exchange rate changes can only have monetary effects and hence cause portfolio adjustments without seriously affecting the trade balance (Chambers, 1981). Studies which address these questions are discussed below.

2.5.1 Impacts of the exchange rate on agricultural exports

The debate was initiated by Schuh (1974) when he drew attention to the effects of the exchange rate on agricultural trade, prices, and real farm income. He used a theoretical partial equilibrium analysis to argue that low agricultural commodity prices and incomes could be attributed to an overvalued dollar. The overvalued dollar raised commodity prices in terms of foreign currency which lowered foreign demand for U.S. farm products. This depressed domestic commodity prices and real farm income.

Schuh linked the dramatic rise in agricultural commodity prices in the early 1970's to successive devaluations in the dollar which occurred at that time. The improved competitive position of the U.S. on world agricultural commodity markets increased demand for U.S. products raising prices, export earnings and real incomes.

Schuh was criticised by Grennes (1975), Vellianitis-Fidas (1975; 1976) and Kost (1976). Grennes (1975) and Vellianitis-Fidas (1975) questioned his evidence that the dollar was overvalued, and also the importance of the exchange rate relative to other contributing factors. Vellianitis-Fidas (1976) used both cross-sectional and time series analysis to test this hypothesis and found that the exchange rate variable coefficient was either insignificant or had a sign that did not comply with theory. It was concluded that agricultural export variation could not be explained by fluctuations in the exchange rate as agricultural commodity price rises exceeded the size of the devaluations.

Kost (1976) used a neo-classical microeconomic trade model consisting of a two-country perfectly competitive market for one homogeneous commodity. He conceded that a devaluation of an exporter's currency would raise import demand and export supply. However, changes in prices and quantities depend on the elasticities of export supply and import demand and would be limited to the extent of the exchange rate devaluation.

Kost (1976) concluded that impacts of exchange rate changes on agricultural trade and balance-of-payments are lessened when the assumption of free trade is dropped. Given that the elasticities of supply and demand for agricultural goods are regarded as being very small, and that tariffs, quotas and stocks are present, impacts of the exchange rate are diminished considerably. Prices, rather than quantity, are affected, and price changes are limited to the percentage change in the exchange rate.

Johnson, *et al.* (1977) tested Schuh's hypothesis using a world trade model for U.S. wheat to analyse the separate effects of variables other than the exchange rate. Variables taken from orthodox trade theory (tariffs, export taxes, import levies and transport costs) and the exchange rate were included in the model. The exchange rate was found to exert no greater an influence on U.S. wheat exports and prices than these variables.

Shei (1978) recognised the limitations of partial equilibrium analysis and estimated a general equilibrium model to examine monetary impacts on U.S. agriculture. Simulation results indicated that the dollar devaluation of the early 1970's contributed significantly to increased crop export demand, although monetary expansion may have contributed more to higher crop prices.

Chambers and Just (1981; 1982) used an expanded partial equilibrium analysis to study the dynamic impacts of exchange rate changes on U.S. corn, soya bean and wheat exports. Exchange rate adjustments were treated as monetary effects and model specification was flexible, as they considered that many studies of this nature had been overly restrictive in variable selection. Results indicated that exchange rate fluctuations had significant real impacts on agricultural markets. The adjustment process was complex and each crop adjusted differently to these fluctuations but, in the long term, export volumes and prices increased following the exchange rate depreciation. The important conclusion drawn was that exchange rate elasticities of price are not restricted to the range between zero and -1. However, as Dutton and Grennes (1988, p.106) point out, use of separate price and exchange rate variables, and the use of the nominal $/SDR rate to represent the exchange rate, may explain their high exchange rate and low price elasticities.

Their results indicated important implications of monetary policy for agriculture via the exchange rate. Monetary policy has a significant effect on interest rates which affect international capital flows. These flows are an important determinant of the exchange rate and consequently agricultural trade and prices.

A number of studies dispute these conclusions. Batten and Belongia (1984) found no consistent relationship between the real exchange rate and the volume of U.S. agricultural exports. They estimated a real export demand function to isolate the marginal effects of the real dollar exchange rate, real U.S. agricultural prices and real foreign incomes. Their results indicated that while the real exchange rate may have contributed to increased agricultural exports, there was no evidence that the real exchange rate influenced export demand more than real commodity prices and foreign real incomes.

Batten and Belongia's conclusions are supported by Childs and Hammig (1989). They found no statistically significant link between the real exchange rate and agricultural exports. Real per capita income levels in less-developed countries were identified as the most important determinant of foreign demand for U.S. agriculture as export demand was found to be price inelastic.

While these studies focused on the impacts of exchange rate changes on U.S. agricultural exports and prices, little attention was paid to the role of the exchange rate as a link between monetary policy and agriculture. Within the partial equilibrium framework, the exchange rate was treated as an exogenous variable. Links between monetary variables and the exchange rate were ignored. However, recognition of the role of money, interest rates and capital flows in exchange rate determination during the mid-1970's highlighted the implications of monetary policy for agriculture.

2.5.2 Role of the exchange rate as a linkage

The consensus view in the literature (Schuh, 1974; Chambers, 1979; 1981; Chambers and Just, 1981; 1982; Rausser, 1985; Devadoss, 1985) is that increases in domestic money supply will lower the value of the domestic currency and increase exports. Under a floating exchange rate regime, domestic currencies are directly influenced by forces in international money markets, the most important of which are derived from relative changes in domestic and foreign interest rates. Higher relative real interest rates cause capital inflows into a country raising the value of its currency. This causes exports to become less competitive on world markets and real domestic farm incomes decline. Exclusion of the endogenous determination of the exchange rate from empirical models led to the linkage between monetary policy and the exchange rate being ignored. The exchange rate provides a direct link between monetary policy and agriculture (Chambers, 1981; Chambers and Just, 1981; 1982).

A number of studies have disputed the importance of this role. Batten and Luttrell (1982), and Batten and Belongia (1984; 1986) argue that as real and not nominal exchange rates influence real trade flows in the long run, the exchange rate does not provide a link between monetary policy and agricultural trade. Their empirical evidence does not support a significant correlation between changes in any of the money growth variables and the real interest differential and hence the real exchange rate. The lack of a statistically significant relationship between monetary shocks and changes in the real exchange rate does not indicate a role for the exchange rate as a link between agriculture to monetary policy. It is recognised however, that under certain circumstances, monetary policy can have real effects in the short-run. Nominal exchange rate are often affected by factors other than price level differences

across countries. Short-run changes in real exchange rate may be attributed to monetary factors under conditions of differing price flexibilities.

2.5.3 Exchange rate measurement problem

The debate has been complicated by discrepancies in the results yielded by different measures of the exchange rate (Belongia, 1986; Dutton and Grennes, 1987; Batten and Belongia, 1987; Ott, 1987). Certain important theoretical issues are often ignored in empirical studies. The distinction between real and nominal exchange rates and bilateral and effective exchange rates must be made.

On theoretical grounds, real trade flows are affected by the real exchange rate rather than the nominal rate as supply and demand respond to changes in relative prices and not absolute prices. In addition, effective, and not bilateral, exchange rate indices should be used when assessing the effect of exchange rate movements on trade flows. Difficulties arise regarding the selection of the base period, weighting scheme and mathematical form of the index and data availability. A number of notable references deal with this topic and should be referred to (e.g. Rhomberg, 1976; Maciejewski, 1983). Decisions regarding selection of these criteria have been shown to affect results, with considerable cause for concern when results are used for policy prescription.

Belongia (1986) illustrated the effect of alternative effective exchange rate indices on the results obtained from the same export demand function. Five effective exchange rate measures calculated from different trade weights were included separately in the same U.S. agricultural export demand function. Percentage of variance accounted for, significance and signs of the coefficients in each function were broadly similar. However, elasticities of the real exchange rate differed markedly. Ott (1987) examined the effects of alternative weighting mechanisms on the same index constructed from the same currencies and found no significant difference in the results obtained. This should not be seen as a contradiction of Belongia as only the weighting mechanism was changed and not the currencies included in each index.

2.5.4 Importance of the exchange rate for South African agriculture

Literature on this topic is limited. However, Control Board annual reports show that since 1984/85, the lower exchange value of the rand has impacted positively on nominal gross proceeds of major South African agricultural exports (South African Wool Board, Deciduous Fruit Board, Citrus Board). These

Control Boards report that volumes of exports are a function of local supply conditions (weather, plantings) and foreign demand and market conditions (incomes, export prices of competitors).

The rand exchange rate has major implications for the South African farmer through demand for imported inputs. A significant percentage of the fuel, fertilisers, chemicals and capital equipment used in South Africa are imported, either as raw materials, or as finished goods (le Clus, 1979). Depreciation of the rand exchange rate causes input prices to increase. This can reduce crop and livestock production and decrease real agricultural incomes.

2.6 Inflation

There is much debate in the literature regarding the causes of inflation and its effects on agriculture. In particular, no definite conclusions have been reached concerning the effects of inflation on real farm income.

Inflation can be defined as a sustained upward movement in nominal prices that is widely shared by the basic components of the GNP deflator (Belongia and Fisher, 1982). Inflation is not;

i) a once-and-for-all increase in the average level of prices which would be an increase in the absolute price, or

ii) a temporary increase in the average level of prices (Klinefelter, *et al.*, 1980), or

iii) a one-time increase in the price of an individual commodity caused by an isolated shift in the supply and/or demand function (Belongia and Fisher, 1982).

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. For example, 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.

2.6.1 Money supply and nominal agricultural prices

A study of the effects of inflation on agriculture requires an understanding of the mechanism underlying the behaviour of nominal agricultural prices. It is argued that both real and monetary factors contribute to agricultural price increases. Broadly speaking, these explanations can be divided into two categories - the structuralist and monetary approach (Barnett, *et al.*, 1983).

2.6.1.1 Structuralist approach

This approach sees inflation as being caused by real shocks such as crop failures, changes in consumption patterns, etc. The money supply adopts a passive role and merely accommodates price level changes that occur in the non-agricultural sector. The agricultural sector is considered to be perfectly competitive, producing homogeneous goods whose prices are completely flexible. The industrial sector is viewed as being oligopolistic, producing heterogeneous goods under increasing returns to scale. Prices are set on a cost-plus basis and lack flexibility.

If all prices were perfectly flexible and have the same adjustment rates, real shocks have no impact on the general price level in the long run. Relative prices change, and inflation is constant as an increase in one price is offset by a decrease in another. In the real world, however, prices move at different rates and tend to be inflexible downwards. Real shocks therefore affect the relative prices of agricultural commodities and are viewed as the main cause of inflation. Monetary policy plays a passive role in price determination, with money supply accommodating any changes in relative prices. This assumption is central to the structuralist approach.

2.6.1.2 Monetarist approach

The monetarist approach assigns monetary policy an active role. The money supply is controlled directly by the monetary authorities. Prices rise when money supply exceeds desired real cash balances due to cash-holders increasing their spending in an attempt to rid themselves of excess cash. Monetarists recognise the existence of real shocks which change relative prices, but assume a greater degree of price flexibility and less imperfect competition.

The growth rate in money supply in excess of productivity is seen as the direct cause of inflation. If a real shock occurs that causes nominal agricultural prices to increase, the general price level increases causing real balances to fall. Real incomes fall causing demand to fall, thus reducing spending and lowering prices to their original level. This only occurs if the money stock is kept at a fixed level. Without monetary accommodation, a rise in nominal agricultural prices causes lower nominal prices in other sectors and the general price level remains unchanged.

The two differing viewpoints can be illustrated using the quantity equation,

$$MV = PY \tag{3.1}$$

where M is the money stock, V the velocity of circulation, P the price level, and Y real income. Monetarists maintain that the direction of causation runs from left to right. An increase in the money stock causes actual real cash balances to exceed desired cash balances. This causes cash holders to increase expenditure thus raising the price level, given constant V and Y. The structuralist approach views the relationship in the opposite direction. The money stock only expands in response to an increase in the general price level (Rogers, 1985). It is important to note however that this analysis applies to frictionless world and must be modified to account for lags in the transmission of information and wage-price inflexibilities (Bordo and Choudhri, 1982).

Although monetarists claim that inflation is a monetary phenomenon, the monetary authorities are not solely responsible for inflation. Real shocks may alter prices but inflation can only occur when accommodated by monetary expansion, as the money supply is "the sole known stimulus that can occur continuously without upper bounds on its quantity" (Belongia and Fisher, 1982:119). All other stimuli, such as wage demands, cannot occur continuously without monetary accommodation and therefore inflation - the sustained increase in nominal prices - can only occur when accommodated by monetary expansion.

Both approaches recognise the importance of monetary policy in controlling inflation. These approaches provide a useful basis on which to investigate some of the causes of inflation in South African agriculture.

2.6.2 Causes of inflation in South African agriculture

Table 2.1 shows relative percentage changes in food, product and input price series in South Africa between 1960-1987. Inflation, as measured by the general consumer price index, has exceeded 10 percent since 1973-74. Except for 1979-80 and 1980-81, producers' prices of farm products rose more slowly than those of the other three groups. The two exceptions, 1979-80 and 1980-81, were characterised by record yields of many crops (van Zyl, 1986b).

Groenewald (1985) contends that South African farmers face cost-push inflation as they have no control over the price they pay for inputs. In South Africa, the structure and protection of the local input manufacturing industry has contributed to higher agricultural input costs. He (1982) cites le Clus who maintained that in 1982 the price of inputs produced by protected industries exceeded the price at which they could be imported by between 34 and 74 percent.

Table 2.1 Annual percentage changes in certain prices, Republic of South Africa, 1960-1987

Period	Consumer prices		Producer prices of all agricultural products	Farming requisites
	All items	Food		
1960-61	2,1	2,0	2,3	-0,2
1961-62	1,4	0,0	-2,0	1,9
1962-63	1,2	0,4	3,0	1,0
1963-64	2,5	4,6	6,0	1,6
1964-65	3,6	5,9	2,9	1,4
1965-66	3,5	3,8	4,5	2,2
1966-67	3,4	3,4	-0,2	0,8
1967-68	1,7	1,7	-0,1	0,8
1968-69	2,9	1,6	3,7	1,7
1969-70	5,3	4,5	3,6	2,8
1970-71	6,1	4,8	3,3	5,4
1971-72	6,5	7,0	14,3	7,5
1972-73	9,4	15,4	26,0	10,7
1973-74	11,7	14,9	12,3	18,3
1974-75	13,4	14,9	9,4	21,8
1975-76	11,1	7,5	8,6	15,6
1976-77	11,3	10,2	8,8	12,7
1977-78	10,9	12,9	6,3	13,5
1978-79	13,2	15,7	19,1	20,6
1979-80	13,8	18,9	18,5	16,3
1980-81	15,2	22,1	12,1	11,0
1981-82	14,7	11,2	13,4	17,7
1982-83	12,3	11,7	11,1	13,8
1983-84	11,8	11,0	12,2	18,9
1984-85	16,2	12,0	9,1	19,3
1985-86	18,6	20,3	10,2	19,4
1986-87	16,1	22,8	11,1	11,9

Source: Figures processed from data published by the Directorate of Agricultural Economic Trends (1989).

In addition, the agricultural input industry contains monopolistic elements, a good example being the fertiliser industry. Economic concentration and monopoly power are seen as some of the most pressing problems in need of attention by policy makers. The small number of manufacturers and importers of farm machinery and chemicals, and the monopoly powers enjoyed by the manufacturers of tractor engines and the South African Transport Services are cause for concern (Groenewald, 1985).

Groenewald suggests that farmers may have contributed to demand-pull inflation. Farmers have not responded rationally to relative price changes and reduced expenditure on inputs. Demand-pull inflation has thus added to cost-push inflation.

Given that South African farmers are price takers, both domestically and internationally, rapid increases in input prices combined with their weak bargaining position, have meant that many are operating at stress levels that even above-average managers find it difficult to operate at economically (Groenewald, 1985). Efforts have been made to improve farmer bargaining power by means of special legislation, control and support measures. There are presently 21 control boards administering marketing schemes, with several taking on the characteristics of statutory monopolies. This has lead to price rigidities, inefficiencies and consequently inflation. Abattoir location is an example of inefficient decision making that has resulted in producers incurring increased transport costs and levies. Consumers have also been disadvantaged.

Autonomous increases in wages and salaries in excess of increases in labour productivity are said to be an important factor underlying inflation in this country (Moore and Smit, 1986). Accommodation by the money supply has resulted in persistent inflation. Increased wages and salaries put upward pressure on prices as these are built into the cost structure of manufactured goods. As the agricultural sector derives a significant percentage of its inputs from the non-agricultural sector, this provides an important passthrough of inflation into the agricultural sector.

Although inflation in the South African agricultural sector is attributed to structural, cost-push and, to a lesser extent, demand-pull causes, it could not have occurred without monetary accommodation. In accordance with the structuralist view, the industrial sector can be regarded as oligopolistic, conducting its pricing policy on a cost-plus basis with significant barriers to entry. The agricultural sector, while not being perfectly competitive, contains certain sectors that can be regarded as having some characteristics of a perfectly competitive market. A good example is the horticultural industry whose prices are determined on domestic fresh produce markets.

Batten (1980) and Belongia and Fisher (1982) criticise the use of cost-push theory to explain inflationary impacts on agriculture. They contend that the lag of product price increases behind input price increases represents a change in relative prices, not inflation. The change is neither sustained, nor is it shared by a wide range of commodities.

Inflation can only occur persistently under an expansionary monetary policy. The South African monetary authorities have not been successful in restraining growth rates of the monetary aggregates. Money supply has accommodated increased aggregate demand and wages (Moore and Smit, 1986). Care must therefore be taken in naming the causes of inflation in South Africa. Although the factors

discussed above may have contributed to increased prices, inflation could not have occurred if they had not been accompanied by monetary expansion.

While much debate centres on the causes of inflation, policy makers should be aware of the effects of inflation on the agricultural sector. The following discussion examines the effects of inflation on agriculture and discusses the neutrality of inflation with respect to agriculture.

2.6.3 Effects of inflation on agriculture

Any analysis of the impacts of inflation rests on acceptance or rejection of the neutrality of money and real effects of monetary policy. Many authors contend that inflationary impacts on agriculture are non-neutral, particularly in the short-run. Ruttan (1979) maintains that inflation underlies low productivity growth in U.S. agriculture, while Johnson (1980) concludes that inflation has had little or no impact on agricultural productivity. Inflation has major distributional effects due to different price flexibilities which affect factor price ratios and land prices (Robinson, 1979; Johnson, 1980). According to neo-classical economic theory, monetary shocks do not have real impacts in the long-run. Short-run impacts however arise when the following conditions for money neutrality are not met;

i) complete price and wage flexibility in all markets,
ii) no money illusion in expenditure or money demand,
iii) no distributional effects caused by changes in the absolute price level,
iv) elasticity of price expectations is unity,
v) all money is outside money, and,
vi) no interest-bearing government debt is outstanding (Boorman and Havrilesky, 1972, p.375).

Much debate centres on whether farmers gain or lose according to the terms of trade, as measured by the ratio of prices received for products to prices paid for inputs (Freebairn, 1981; Chambers, 1985; Tweeten, 1986; Daouli and Demoussis, 1989). Farmers may gain in times of inflation if product prices increase faster than input prices due to their greater flexibility. This enables them to respond more quickly to inflationary pressures. Conversely, farmers may lose if the input sector is imperfectly competitive and practices cost-plus pricing, since higher input prices are passed on to farmers who cannot pass on increased costs as they have no control over product prices.

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) concluded the oppo-

site and found that farmers face a cost-price squeeze as increases in input prices exceed agricultural product price increases.

Starleaf, *et al.* (1985) contend that farmers are net beneficiaries in times of inflation and suffer losses in terms of trade when inflation declines. Any unanticipated rise in the rate of inflation benefits those with flexible money incomes, i.e. farmers, at the expense of those with fixed incomes. Belongia (1985), however points out that Starleaf, *et al.* (1985) fail to distinguish between relative "price changes" and "inflation" and therefore arrive at the wrong conclusions. Changes in agricultural prices consist of two components;

i) a relative component caused by shifts in the supply and demand schedules, and,

ii) a nominal component which associated with the trend rate of growth in the money supply.

Starleaf, *et al.* (1985) ignore factors responsible for changes in the relative component (which are not associated with the cause and effects of inflation). By failing to control for them, it becomes impossible to determine the cause of inflation and distinguish between the effects of the two components. Any analysis into the causes of inflation must include a relative component (demand and supply shifters) and a monetary component (Belongia, 1985).

Inflation impacts on cash-flow stress. The problem arises when land is purchased but the capital gain can only be realised when land is sold. Interest payments must, however, be made from the date of purchase and this constitutes a cash drain to the farmer (Belongia and Fisher, 1982). Under conditions of zero inflation, when the rate of return to land exceeds or equals the mortgage rate, no cash-flow problem arises. However, inflation causes nominal interest rates to rise and cash-flow stress increases (Tweeten, 1983).

Inflation has important implications for financial markets (Klinefelter, *et al.*, 1980). Unanticipated inflation due to unstable growth in money supply leads to wealth transfers from lenders to borrowers, increased interest rate volatility and interest rate risk. Land prices are determined by expected, rather than current inflation when land values and returns are expected to increase. If inflation increases, investors may find themselves unable to meet loan repayments, and cash reserves or overdraft facilities have to be used which exacerbates cash-flow problem (Lins and Duncan, 1980).

Farmers who are net debtors having entered into long term contracts with fixed interest obligations, benefit from inflation. Real wealth is transferred from lenders to borrowers. Recently however, U.S. creditors have refused to enter into long term contracts in which the interest rate is fixed and instead

have resorted to higher interest rates, or flexible rates tied to the rate of inflation (Klinefelter *et al.*, 1980; Tweeten, 1983).

With land being regarded as a good hedge against inflation, the price of farm land increase in nominal terms. Long term owners of land benefit in terms of real wealth gains, while new entrants find it increasingly difficult to enter the farm sector in times of inflation (Johnson, 1980).

Lins and Duncan (1980) contend that inflation does not lead to an increase in the real value of land; it is the increase in real returns to land that is responsible. If real returns are adversely affected by inflation, lower real farm values result.

In South Africa, farm sizes have increased as the number of farmers has declined (Directorate Agricultural Economic Trends). Inflation impacts on farm structure in three ways;

i) fewer and larger farms - well established farmers buy land from less successful counterparts. As income variability and financial risk increases, larger farm size contributes to lessening risk (Lins and Duncan, 1980). The incidence of small part-time farmers is increasing, with farmers augmenting incomes from non-farm sources (Tweeten, 1983),

ii) corporate agriculture - large industrial firms enter agriculture and establish large efficient enterprises. The effects of inflation, economies of scale and tax policies have caused increases in corporate forms of business in agriculture (Lins and Duncan, 1980). With farm and non-farm sources of income, debt and equity capital, the enterprise is better equipped to withstand cash-flow stress, risk and instability (Tweeten, 1983), and,

iii) integration and coordination - risk and income variability are reduced by vertical and horizontal integration. Greater participation by the farmer in input procurement and marketing offers benefits of reduced costs. Diversification and development of off-farm sources of income are useful strategies in combating inflation and risk (Lins and Duncan, 1980).

The above discussion indicates that inflation directly affects agriculture. Policy makers and the monetary authorities can better understand how inflation impacts on agriculture by clarifying the theoretical issues underlying the causes and effects of inflation. Indiscriminate use of the interest rate has contributed to the susceptibility of agriculture to the business cycle and added to uncertainty (Tweeten, 1986). This highlights the importance for agriculture of sound monetary policy.

2.7 Interest rate

Adoption of the interest rate as the key instrumental variable in monetary policy has important implications for agricultural debt servicing. The interest rate is seen as a major contributor to farm financial problems in South Africa (van Zyl *et al.*, 1987a; 1987b; Louw, 1988) and the U.S. (Devadoss, 1985; Bullock, 1985; Tweeten, 1985; Penson and Gardner, 1988; Snape, 1989). With farm debt in South Africa standing at 13,582 billion rands at the end of 1988, an increase of 10 billion rands since 1980 (Directorate of Agricultural Economic Trends, 1990), the interest rate linkage between monetary policy and agriculture demands the highest attention from policy makers and the monetary authorities. However, as Bullock cautions, high interest rates should not be seen as the sole cause of farm financial problems, but as one of many contributing factors.

Van Zyl, *et al.* (1987b) found the real agricultural debt burden to be highly elastic with respect to interest rates. Van Zyl, *et al.* (1987a) found that interest rates have a significant effect on farm financial results. High interest rates add to liquidity problems, reduce debt repayment capacities, land values, and credit reserve capacities.

Interest rates impact on agriculture primarily through cost and stock effects (Devadoss, 1985). Cost effects impact on agricultural output through the interest rate's role as the cost of short-term production loans. Indirect effects arise when input manufacturers build increased interest rate charges into input prices. Investment is also adversely affected by high real interest rates.

Stock effects impact on inventory behaviour. Higher interest rates raise the cost of holding stocks causing stock holders to run down inventories. Rausser (1985) points out the impacts of higher interest rates on the livestock industry. Slaughterings increase as the cost of holding animals on the farm increases due to higher production costs and the increased opportunity cost of non-farm investment in interest bearing assets, e.g. savings deposits.

Interest rates play a key role in linking agriculture to monetary policy through the effect of interest rates on capital flows, exchange rates and ultimately agricultural prices. Tight monetary policy creates deflationary expectations and raises real interest rates. Capital inflows increase as off-shore borrowing increases and foreign investment is attracted by higher real rates of return on assets. Subsequent increase in the value of the domestic currency reduces the competitiveness of domestic agriculture and pushes down agricultural prices (Chambers, 1981; 1984; 1985; Snape, 1989).

Real interest rates impact directly on land values as capitalisation rates for future returns (rents) to land (Nieuwoudt, 1980; Tweeten, 1985, pp.95-100; Penson and Gardner, 1988), as shown by the following relationship,

$$PV = \frac{Ro}{i} \tag{3.2}$$

where PV is the present value of land, Ro is the constant annual real rent and i is the real interest (capitalisation) rate. Higher real interest rates may also impact negatively on land values by reducing annual real rents. This reduces real wealth and collateral for loans adding to financial stress in the farm sector (Tweeten, 1985, p.97)

2.8 Real income

Monetary policy impacts on agriculture via the effect of money supply on real income and aggregate demand for agricultural produce. Monetary impacts on real output and income are short run. An increase in money supply raises aggregate demand as cash-holders increase spending in an attempt to rid themselves of excess money. Real income rises as long as prices rise at a rate slower than that of money supply. Real output increases if wages rise slower than the rate of increase in money supply. Increases in real output are sustained by the increase in real income. Monetary policy is neutral in the long run as prices increase until the proportionate increase in prices, wages and money supply is equal. Real output and income return to pre-monetary shock levels (Dornbusch and Fischer, 1981, pp.407-409).

Effect of changes in real income are commodity specific. As incomes increase the demand for commodities with higher income elasticities (e.g. red meats, fruit) increases, and the demand for inferior commodities (e.g. maize (Cadiz, 1984; Devadoss, 1985; van Zyl, 1986a) falls.

2.9 Summary

Literature covering important macrolinkages between agriculture and monetary policy has been reviewed emphasising the impacts of the exchange rate, inflation, interest rates and real income. In the next chapter, the impacts of monetary policy on South African agriculture are analysed by specifying these linkages within a general equilibrium simultaneous equations model. Economic theory underlying specification of the model equations is also discussed.

CHAPTER 3

MODEL SPECIFICATION

3.1 Introduction

The model described in this chapter contributes to the growing number of econometric models which have attempted to analyse macrolinkages with agriculture. It draws upon a number of previous theoretical and empirical models (Chambers and Just, 1982; Lamm, 1981; Rausser, 1985; Devadoss, 1985; Shei and Thompson, 1988). The model is specified within a general equilibrium framework to capture linkages between agriculture and the macroeconomy.

The model comprises a macrosector and agricultural sector. The macrosector contains two monetary sectors - money and foreign exchange markets - and one real sector - the manufacturing sector. The agricultural sector consists of three real sectors - the field crop, horticultural crop and livestock sectors.

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 more flexible than those in the non-agricultural sector. The manufacturing sector is viewed as being oligopolistic, producing heterogenous goods whose prices are determined on a cost-plus basis and are inflexible downwards (Barnett, *et al.*, 1983; Shei and Thompson, 1988). 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.

The model is specified to indicate how monetary shocks, which originate in the money market, impact on the agricultural sector via interest rate, exchange rate and inflation linkages. 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. Theoretical foundations underlying specification of the model equations are discussed. Variables in each equation are selected in accordance with *a priori* expectations.

All quantitative variables are expressed in monetary units - South African rands. This preserves uniformity of measurement throughout the components of the identities. All variables are expressed in real terms to account for changes in purchasing power and the value of money. Dependent variables expressed in rands are converted into real terms by deflating with the corresponding price index, and all other quantitative variables are deflated by the consumer price index (CPI). All prices are expressed as indices with a base year of 1975, and are deflated by the CPI. The expected signs of the coefficients of each variable are shown in parenthesis above the variables where applicable.

3.2 Macrosector

This section specifies behavioural equations and identities for the money market, foreign exchange market, manufacturing sector, and general price level.

3.2.1 Money market

The money market is the nucleus of the model from where all monetary shocks originate. Structural equations for estimating nominal money supply, real money demand, the treasury bill rate, and nominal and real prime overdraft rates are specified.

Money supply

The money supply function should represent the actions of the various groups and authorities that influence the money supply (Oldham, 1978). The function follows the modified form of the Brunner-Meltzer nonlinear money supply hypothesis developed by Contogiannis (1979) and simplified by Oldham (1978). This hypothesis expresses the money stock as a product of the monetary base and money multiplier.

The monetarist specification was selected as it represents the money supply determination process for most of the study period, 1960-1980. In 1980, strict quantitative controls on money supply money were replaced by market-orientated policy instruments - discount policy and open market operations. This transformed money supply from an exogenously determined variable controlled directly by the SARB, to an endogenous variable determined by real and monetary variables outside direct control of the monetary authorities.

Examples of specifications for an endogenous money supply controlled using discount rates are given by Fand (1972), Bordo, *et al.* (1987) and Dean (1988). Money supply (*Ms*) is generally determined as,

$$Ms = f(X, r, T, Y, W) \tag{3.1}$$

where X is a vector of monetary policy instruments (monetary base, reserve requirements, discount rate); r is a vector of endogenous financial assets (Treasury bill rate, time deposits, short-term, medium-term and long-term rates); T are close substitutes for money and demand deposits (time deposits, shares); Y is a vector of real variables; and W is wealth (Fand, 1972, pp.92-93; Bordo, *et al.*, 1987).

This describes South African monetary policy after 1980 and only represents monetary policy for the last 7 years of the study period. This period is insufficient to test the dynamic properties of the model, as use of the model for historic policy analysis and calculation of long-run dynamic elasticities requires a longer simulation period. For this reason, an alternative monetarist specification of broadly defined money supply (M2 - money plus near money as defined by the SARB) is used for the whole study period.

Money supply is the sum of currency outside the banks, C, demand deposits, D, and near money deposits, N,

$$M2 = C + D + N. \tag{3.1a}$$

The monetary base, B, is the sum of currency outside the banks, plus required liquid assets, RLA, plus excess liquid assets (reserve assets), ELA,

$$B = C + RLA + ELA \tag{3.1b}$$

Required liquid assets held in the form of reserve assets reflect the public's demand for different types of assets such as currency, demand deposits, near-money, long term deposits, L, and acceptances, A. Liquid asset requirements reflect these preferences,

$$RLA = r_1D + r_2N + r_3L + r_4X \tag{3.1c}$$

where r_1, r_2, r_3 and r_4 represent the respective required reserve ratios. The r_3 and r_4 ratios were not usually varied by the authorities and can be ignored. The definition of B is adjusted such that,

$$B' = B - r_3L - r_4A$$

or,

$$B' = C + RLA' + ELA \tag{3.1d}$$

where $RLA' = dD + nN$.

The public's preferences for money are expressed as fractions of the money supply,

$$c = \frac{C}{D} \tag{3.1e}$$

$$d = \frac{N}{D} \tag{3.1f}$$

where c and d are the ratios of currency and near money to demand deposits.

To represent the manner in which the monetary authorities and the private banks behave,

$$rr = \frac{LAR'}{D + N} \tag{3.1g}$$

where rr is the average required reserve ratio and expresses the way in which the authorities vary the required liquid asset ratio, and,

$$re = \frac{ELA}{D + N} \tag{3.1h}$$

where re is the excess reserve ratio and represents the portfolio behaviour of the banks.

Substituting (3.1e), (3.1f), (3.1g), (3.1h), (3.1a) and (3.1d) into (3.1a) gives,

$$M2 = D(1 + c + n) \tag{3.1i}$$

and

$$B2 = D\{c + (1 + n)(rr + re)\}. \tag{3.1j}$$

Combining (3.1i) and (3.1j) gives,

$$M2 = \left[\frac{1 + c + n}{c + (1 + n)(rr + re)}\right] B2 \qquad (3.1k)$$

which can be rewritten as

$$M2 = m.B2 \qquad (3.1l)$$

or,

$$Ms = m.B \qquad (3.1)$$

Although beyond the scope of this thesis, the elasticity of the multiplier with respect to its components can be computed to give an idea of portfolio adjustments made by the banks and the public. In this study m and B are treated as being exogenously determined since the focus is on the impacts of monetary policy on agriculture, not the specific behaviour of the monetary authorities.

Real money demand

Specification of real money demand is based on Tobin (1956), Friedman (1956), Teigen (1964) and work by Stadler (1981), and Contogiannis and Shahi (1982) on real money demand in South Africa.

Keynesian liquidity preference theory is the most widely used theoretical paradigm underlying real money demand. In a simple economy whose only liquid assets are money and bonds, the demand for money arises from two of money's properties: its role as a medium of exchange (transaction demand), and as a store of value over time (asset or investment demand). The asset demand for money arises due to expectations regarding future movements in the interest rate. In the real world, however, money is not the only liquid asset. Other assets are available which are just as liquid, free from risk of capital loss and have the added advantage of earning a positive return, e.g, savings deposits. For this reason, money cannot be assumed to hold a permanent place in the portfolios of asset holders, and therefore only transactions demand exists.

Money's role as a unique means of payment, and the imperfect synchronisation between the flow of income into the household or firm, and these units' requirements for payments, gives rise to the transactions demand for money. Not all money is required for transactions at one time. It is possible to

earn a return until the money is needed by investing in liquid interest-yielding assets, i.e. bonds. This behaviour has been summarised into the square-root inventory formula for transactions demand derived by Tobin (1956).

The individual receives his annual income, Y_i, in f equal instalments. His income at the beginning of every period, y_i, is Y_i/f which is spent at a constant rate over the payment period, with all being spent by the beginning of the next period. If the expense of converting cash into bonds is high relative to the return so that no conversions take place, the ith individual's money-demand function can be derived as,

$$C_i = \frac{y_i}{2} = \frac{Y_i}{2f} \tag{3.2a}$$

where C is the average money holdings during the payment period. If n transactions occur, the demand function is,

$$C_i = \frac{y_i}{2n} = \frac{Y_i}{2fn} \tag{3.2b}$$

For a given rate of return on bonds, r, and fixed charge per transaction, a, the optimal number of transactions into and out of bonds, n^*, can be approximated as,

$$n^* \approx \frac{1}{f}\left[\frac{Y_i r}{2a}\right]^{\frac{1}{2}} \tag{3.2c}$$

Equation (3.2b) may be rewritten as follows,

$$C_i = \frac{Y_i}{2fn^*} \approx \left[\frac{Y_i a}{2r}\right]^{\frac{1}{2}} \tag{3.2d}$$

Equations (3.2a) and (3.2d) form the basis for the derivation of a suitable description of aggregate behaviour. As the money-holding behaviour of an individual economic unit over time can be governed by either or both of these rules, depending on the level of the interest rate compared to transactions costs, such behaviour can be approximated by,

$$C_i = \epsilon_0 r^{\epsilon 1} Y_i^{\epsilon 2} \tag{3.2e}$$

By summing over all individual units an aggregate money demand function can be formulated in which money is demanded for transactions purposes,

$$\Sigma C_i = Md = \tau_0 r^{\tau 1} Y^{\tau 2} \tag{3.2f}$$

Results obtained by Stadler (1981) and Contogiannis and Shahi (1982) fail to establish a negative relationship between real money demand and the interest rate in South Africa. Courakis (1984) and Whittaker (1985) estimate real money demand functions that exclude the interest rate and concentrate on expectations and measures of permanent income and prices. This reflects Friedman's restatement of the quantity theory of money which specified the demand for real money balances as,

$$\frac{Md}{P} = f\left[r_b,\ r_e,\ \frac{1}{P}\frac{dP}{dt},\ w,\ \frac{Y}{P},\ u\right] \tag{3.2g}$$

where Md/P is the real quantity of money demanded; r_b is the rate of return on bonds; r_e is the rate of return on equities; P is an index of the general price level; $1/P\ dP/dt$ is the rate of change in P over time, t; w is the ratio of non-human to human wealth; Y/P is real income; and u are tastes and preferences (Friedman, 1956, pp.8-11).

Friedman's view of real demand for money departs from the traditional Keynesian specification in a number of important respects. The demand for money is assumed to be stable; the demand for money is not divided among different components; and money is regarded as one of many financial assets in which wealth might be held. The elasticity of real money demand with respect to interest rates are minimal and no statistical significance is attached to them (Friedman, 1959).

Empirically, the number of variables may be reduced to single measures of income (wealth), price expectations and interest rates. Real money demand in the model is specified as a function of real gross domestic product, treasury bill rate, and current and lagged price level. Expected coefficient signs are indicated above the explanatory variables.

$$\left[\frac{Md}{CPI}\right]_t = f_2\left[\overset{(-)}{TBR_t},\ \overset{(+)}{\left[\frac{GDP}{CPI}\right]_t},\ \overset{(-)}{CPI_t},\ CPI_{t-1},\ e_{2,t}\right] \tag{3.2}$$

where
Md_t = nominal demand for money (money plus near money),
CPI_t = consumer price index,
TBR_t = treasury bill rate,
GDP_t = nominal gross domestic product, and,
e_t = stochastic error term.

Treasury bill rate

Three interest rates are considered in the model - the SARB discount rate, treasury bill rate, and prime overdraft rate - to simulate the interest rate linkage.

The discount rate is a policy variable manipulated directly by the SARB and is therefore treated as exogenous. The treasury bill rate is used as a proxy to reflect conditions in the money and capital markets. The prime overdraft rate represents the short-term lending rate of commercial banks for production loans.

Specification of the treasury bill rate equation follows Friedman (1972, pp.200-218). Interest rates are affected by liquidity, income and price anticipations effects. No link between the discount rate and the treasury bill rate is specified due to lack of sufficient theoretical support for the relationship between the discount rate and money market rates (Thornton, 1982; 1986).

The liquidity effect of money supply impacts negatively on interest rates. As money supply increases, spending increases as cash-holders attempt to rid themselves of excess cash. In order to induce them to hold money, interest rates must fall.

The income effect reflects the impact of higher real incomes on the demand for loanable funds. Rising real incomes cause the liquidity preference curve to shift to the right. Holding prices constant, this raises interest rates.

If prices rise, the cost of holding cash rises. This gives rise to the price anticipations effect which causes cash-holders to rid themselves of cash-holdings and forces interest rates down.

The treasury bill rate is therefore specified as a function of money supply, real gross domestic product (real income) and CPI (inflation). Inclusion of the money supply variable captures the impacts of changes in money supply on interest rate and simulates the first part of the interest rate linkage.

$$TBR_t = f_3 \left[\overset{(-)}{Ms_t}, \overset{(+)}{\left[\frac{GDP}{CPI} \right]_t}, \overset{(-)}{CPI_t}, CPI_{t-1}, e_{3,t} \right] \qquad (3.3)$$

Nominal prime overdraft rate

The prime overdraft rate completes the interest rate linkage and is used as a proxy for the cost of short-term production loans. Commercial banks adjust their lending rates in accordance with changes in market rates, passing the cost of borrowing on to customers. The nominal prime overdraft rate is therefore specified as function of the treasury bill rate,

$$R_t = f_4[TBR_t, TBR_{t-1}, e_{4,t}] \tag{3.4}$$

where R_t = nominal prime overdraft rate of major commercial banks.

Real prime overdraft rate

Since 1960, South African real interest rates have fluctuated markedly due to variations in monetary policy and inflation (refer Chapter 1). Inflation reduces the real cost of borrowing by discounting future repayments of fixed-debt obligations (Barry, *et al.*, 1979, p.311). Conversely, lower inflation increases the purchasing power of money and increases the real cost of borrowing. Farmers borrowing decisions are therefore influenced by the real interest rate. The nominal prime overdraft rate is expressed in real terms by subtracting the inflation rate,

$$RR_t = R_t - ((CPI_t - CPI_{t-1})/CPI_{t-1}) \tag{3.5}$$

Market equilibrium condition for money

The money market is closed by an equilibrium condition which equates nominal money supply to nominal money demand,

$$Ms_t = \left[\frac{Md}{CPI}\right]_t * CPI_t \tag{3.6}$$

3.2.2 Foreign exchange market

The foreign exchange market comprises an exchange rate determination equation and a balance of payments identity.

Exchange rate

The monetary approach is used to determine the exchange rate, which is seen as the relative price of two assets (moneys). The equilibrium exchange rate exists when stocks of moneys are held willingly. This approach views the balance of payments and the exchange rate as monetary phenomena which are determined by the supply and demand for national moneys (Mussa, 1976). The role of money is emphasised in determining the balance of payments when the exchange rate is fixed, and the exchange rate when it is flexible (Frenkel, 1976). This approach therefore provides a useful analysis of the impacts of monetary variables on the exchange rate.

The theoretical model discussed below draws on Bilson (1978), and Humphrey and Keleher (1982, pp.247-264). There are six key propositions central to the monetary approach to exchange rate determination;

i) the quantity theory of money,
ii) the purchasing power parity doctrine,
iii) the real interest rate parity concept,
iv) the Fisher relationship between nominal and real interest rates,
v) a monetarist rational expectations hypothesis, and,
vi) the efficient markets hypothesis.

The model consists of two hypothetical national economies - a domestic and foreign economy. Each have a nominal money stock, M, and a demand-adjusted rate of money growth, m, which is the difference in growth rates of the nominal money supply and the real demand for money. This difference is equal to the rate of price inflation. D represents the real demand for money, Y the level of real income, i and v, nominal and real rates of interest, e the exchange rate, P the price level and pe and me, the expected future rates of price inflation and demand adjusted money growth.

Monetary equilibrium is attained in each country when,

$$P = \frac{M}{D} \quad \text{and} \quad P^* = \frac{M^*}{D^*} \tag{3.7a}$$

where the asterisks represent the foreign country. These equations can be rewritten as $D = M/P$ to show the adjustment of the price level which brings the real value of the money supply in line with demand for real money balances, thus clearing the money market. Any increase in the nominal money

supply will lead to increased spending as cash holders attempt to rid themselves of excess cash-holdings. This drives up prices and reduces the real value of money.

The public's demand for real cash balances is a function of a fixed constant, K, real income and nominal interest rates,

$$D = KYi^{-a} \text{ and } D^* = K^*Y^*i^{*-a} \tag{3.7b}$$

Real income represents the transactions demand for money, and the interest rate represents the opportunity cost of holding money rather than interest bearing assets. The parameter $-a$ represents the interest elasticity of demand for money. The negative sign indicates the inverse relationship between the demand for money and the interest rate.

The purchasing power parity doctrine equalises prices in both countries via the exchange rate,

$$P = eP^* \tag{3.7c}$$

This equation illustrates the proposition that one unit of the domestic country's currency can buy the same quantity of goods and services in the foreign country when the domestic currency is converted into the foreign currency at the equilibrium exchange rate. This condition is necessary to maintain monetary equilibrium in each country. If purchasing powers were unequal, demand for the high purchasing power currency would increase, and for the low purchasing power currency decrease. This would force the exchange rate to adjust until parity was achieved and the advantage in converting from one currency to another would disappear.

The Fisher relationship defines the nominal interest rate as the sum of the real rate of interest and expected future rate of inflation,

$$i = r + pe \text{ and } i^* = r^* + pe^* \tag{3.7d}$$

The real interest rate parity condition states that the real rate of return on capital assets tends to be the same everywhere and independent of the currency denomination of the assets,

$$r = r^* = r_w \tag{3.7e}$$

where r_w is a given constant world real interest rate. This equation reflects the existence of a highly integrated efficient world capital market where capital is internationally mobile. This leads to the real rates of interest in both countries being the same, and these being equal to r_w.

Expectations with respect to prices and future money growth complete the model,

$$pe = me \quad \text{and} \quad pe^* = me^* \tag{3.7f}$$

where,

$$me = me\,(m, I) \quad \text{and} \quad me^* = me^*\,(m^*, I^*).$$

Expectations play an important role in exchange rate determination via the impact of inflationary expectations on nominal interest rates which determine domestic and foreign money demand functions. Inflationary expectations are based on expectations of future money growth. The assumption of rational expectations ensures that the formation of inflationary expectations is consistent with how price inflation is actually generated. Thus knowledge of past increases in money supply lead to inflationary expectations, with expectations of future money growth being dependent on actual growth rates and other information, I. The assumption that people use all available information to formulate their expectations rationally is therefore included in the model.

Combining these relationships into a model constitutes the monetary approach to exchange rate determination. The causal chain is as follows: if expectations are that the future demand-adjusted money growth rate will rise, price expectations rise causing the nominal interest rate to rise. The demand for real cash balances decreases, i.e. money supply exceeds money demand. This causes spending to increase and therefore domestic prices rise relative to foreign prices. In order to restore purchasing power parity, the exchange rate rises (depreciates) as the demand for the foreign currency increases due to increased demand for relatively cheaper foreign goods. Thus, prices and the exchange rate will continue to adjust until the real value of the nominal money supply is deflated to the level people desire to hold and monetary equilibrium is established.

The determination of the exchange rate hence runs from actual and expected money supply through real incomes and prices as,

$$e = f\left[\frac{K^*}{K}, \frac{M^*}{M}, \frac{Y^*}{Y}, \left[\frac{r + me(m, I)}{r^* + me^*(m^*, I^*)}\right]^a\right] \tag{3.7g}$$

Disregarding the constants, the determinants can be categorised into three groups; relative money supplies, relative real incomes, and relative nominal interest rates (real rate plus price expectations). The first group captures monetary influences, the second, real influences, and the third, expectations.

The need to use an effective exchange rate index was discussed in the previous chapter. The exchange rate is therefore defined in terms of special drawing rights, which gives a better indication of the overall competitive position of the rand and eliminates the need to construct a basket index of exchange rates (Chambers, 1979). The equation is specified as,

$$XR_t = f_7 \left[\underset{(+)}{Ms_t}, \underset{(-)}{Ms_t^f}, \underset{(+)}{TBR_t}, \underset{(-)}{TBR_t^f}, \underset{(-)}{\left[\frac{GDP}{CPI}\right]_t}, \underset{(+)}{\left[\frac{GDP^f}{CPI^f}\right]_t}, e_{7,t} \right] \tag{3.7}$$

where Ms_t^f = nominal money supply in the rest of the world (ROW),

GDP_t^f = nominal gross national product in ROW,

CPI_t^f = consumer price index in ROW, and,

TBR_t^f = nominal interest rate in ROW.

The expected signs indicate the effect of each determinant. The country with the faster monetary growth will find its currency depreciating relative to that of the foreign country. The country whose level of real income increases at a relatively faster rate will experience an increase in the real demand for money and therefore its exchange rate will appreciate. This is in direct contrast to more conventional approaches to exchange rate determination which maintain that increases in real incomes cause increases in the demand for imports, and therefore reduce the value of the domestic currency. While monetarists accept this, they contend that real growth increased the demand for that countries' money thereby generating a capital account surplus which more than offsets the current account deficit. The nominal interest rate reflects inflationary expectations, and rising inflationary expectations will cause the exchange rate to depreciate. This is due to people wishing to hold less of a currency whose value is declining, and trade taking place using the currency whose value is expected to depreciate the least.

Difficulties in estimating the exchange rate arise due to three distinctly different exchange rate regimes during the study period. Exchange rates were fixed until 1971 when the Bretton Woods system collapsed, bringing about a period of flexible exchange rates. In 1979, South Africa adopted a managed float, as recommended by the De Kock Commission. To account for this, the grafted polyno-

mial technique developed by Fuller (1976) is used to estimate equation (3.7). The technique is described in chapter 4.

Real balance of payments

The real balance of payments on the current account is determined as real net exports of five important agricultural export products included in the model (maize, sugar, deciduous fruit, citrus fruit and wool) less real net imports of manufactured goods plus balance of payments items not determined endogenously in the model.

$$\left[\frac{BoP}{CPI}\right]_t = \left[\frac{MZNX}{MZPI}\right]_t + \left[\frac{SGNX}{SCPI}\right]_t + \left[\frac{DFNX}{DFPI}\right]_t + \left[\frac{CFNX}{CFPI}\right]_t + \left[\frac{WLNX}{WLPI}\right]_t - \left[\frac{MANNM}{MNMPI}\right]_t + \left[\frac{BoP'}{CPI}\right]_t \tag{3.8}$$

where BoP_t = South African balance of payments on the current account,
$MZNX_t$ = gross value of maize net exports,
$MZPI_t$ = maize price index,
$SGNX_t$ = gross value of sugar net exports,
$SCPI_t$ = sugar price index,
$DFNX_t$ = gross value of deciduous fruit net exports,
$DFPI_t$ = deciduous fruit price index,
$CFNX_t$ = gross value of citrus fruit net exports,
$CFPI_t$ = citrus fruit price index,
$WLNX_t$ = gross value of wool net exports,
$WLPI_t$ = wool price index,
BoP' = balance of payments items not endogenously determined in the model.

3.2.3 General price level

The general price level is estimated from the quantity equation,

$$MV = PY \tag{3.9a}$$

which is rearranged such that,

$$P = \frac{MV}{Y} \tag{3.9b}$$

This reflects the relationship between the money supply, M, and general price level, P. An increase in the money supply increases actual holdings of real cash balances above desired cash-holdings, which leads to an increase in expenditure as cash-holders rid themselves of excess cash. This increase in expenditure relative to output in the economy, i.e. real incomes, puts upward pressure on the general price level. This relationship is represented as,

$$CPI_t = f_9\left[\left(\frac{Ms}{RGDP}\right)^{(+)}_t, \left(\frac{Ms}{RGDP}\right)_{t-1}, CPI_{t-1}, e_{9,t}\right] \tag{3.9}$$

where $RGDP_t$ = real gross domestic product.

3.2.4 Manufacturing sector

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.

Real manufactured goods supply

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, p.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.

Real per capita manufactured goods demand

Real per capita demand for manufactured goods is specified as a function of real manufactured goods price and real per capita personal disposable income.

$$\left(\frac{MANDD}{MANPI}\right) = f_{10}\left[\left(\frac{MANPI}{CPI}\right)^{(-)}_t, \left(\frac{PDY}{CPI}\right)^{(+)}_t, e_{10,t}\right] \tag{3.10}$$

where $MANDD_t$ = gross value of per capita manufactured goods demand,
$MANPI_t$ = manufactured goods price index, and,
PDY_t = per capita personal disposable income.

Real net import demand for manufactured goods

South Africa is a net importer of manufactured goods. Real net import demand for manufactured goods is specified as a function of the real price of imported goods, real exchange rate, and level of domestic economic activity.

$$\left[\frac{MANNM}{MNMPI}\right]_t = f_{11}\left[\left[\frac{MNMPI}{CPI}\right]_t^{(-)}, RXR_t^{(-)}, \left[\frac{GDP}{CPI}\right]_t^{(+)}, e_{11,t}\right] \qquad (3.11)$$

Market equilibrium condition for the manufacturing sector

The manufacturing sector is closed by a market equilibrium condition from which real manufactured goods supply is determined.

$$\left[\frac{MANSS}{MANPI}\right]_t = \left[\frac{MANDD}{MANPI}\right]_t - \left[\frac{MANNM}{MNMPI}\right]_t \qquad (3.12)$$

3.2.5 Input price and real demand equations

Price determination (equations (3.13) to (3.17)) and real demand (equations (3.18) to (3.22))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). Higher production costs arising from domestic inflation and depreciation of the rand raise input prices. Positive signs are hypothesised for CPI_t and XR_t.

$$INPIi_t = f_i\left[\left[\frac{INPTi}{INPIi}\right]_t^{(-)}, CPI_t^{(+)}, XR_t^{(+)}, INPI_{t-1}, e_{i,t}\right] \qquad (3.13 \text{ to } 3.17)$$

where $INPIi_t$ = input price index, (i = fertilisers ($FTPI_t$), dips and sprays ($DSPI_t$), stock and poultry feed ($FDPI_t$), fuel ($FLPI_t$), and packing materials ($PMPI_t$)), and,

$INPTi_t$ = gross value of inputs purchased, (i = fertilisers ($QFERT_t$), dips and sprays ($QDIPS_t$), stock and poultry feed ($QFEED_t$), fuel ($QFUEL_t$), and packing materials ($QPACK_t$)).

Real demand for each input group is estimated to determine the real value of each input group purchased. Real input demand equations are specified as a function of real input price and total real gross farm income in the sectors modelled.

$$\left[\frac{INPTi}{INPIi}\right]_t = f_i\left[\left[\frac{INPIi}{CPI}\right]_t^{(-)}, \left[\frac{AGINC}{AGPI}\right]_t^{(+)}, e_{i,t}\right] \qquad (3.18 \text{ to } 3.22)$$

where $AGINC_t$ = total gross farm income in the sectors modelled.

Total real input demand

Summation of individual input demand determines total real input demand.

$$\left[\frac{TINPT}{TINPI}\right]_t = \left[\frac{QFERT}{FTPI}\right]_t + \left[\frac{QDIPS}{DSPI}\right]_t + \left[\frac{QFEED}{FDPI}\right]_t + \left[\frac{QFUEL}{FLPI}\right]_t + \left[\frac{QPACK}{PMPI}\right]_t \qquad (3.23)$$

where $TINPT_t$ = total gross value of inputs purchased, and,

$TINPI_t$ = aggregate input price index.

3.3 Agricultural sector

The agricultural sector consists of field crop, horticultural crop and livestock sectors. Each sector is represented by products which are major contributors to gross value of production. The field crop sector is represented by maize, sugar cane and hay. The horticultural crop sector is represented by deciduous fruit, citrus fruit, vegetables and potatoes. The livestock sector is represented by beef, mutton, pork, poultry (chicken meat) and wool.

Real supply, real per capita demand and real export demand functions are estimated for each product. Theoretical foundations underlying specification of these equations are discussed firstly. As the theo-

retical foundations underlying the variable specification of these equations is broadly similar for each product, real supply, real per capita demand and real export demand equations for all products are discussed together, to avoid repetition. Individual product equations in each sector are then specified.

3.3.1 Specification of real supply

Farmers' decisions about production depend on expected prices. As prices are unobservable at time of planting, expectations are based on previous year's prices. Real supply is therefore specified as a function of the lagged own real producer price, lagged real input price, lagged real price of major substitutes in production, real prime overdraft rate, and other exogenous factors relevant to the particular product (e.g., areas planted and harvested, weather, technology, herd sizes, etc.).

Inclusion of a real input price variable in each real supply equation completes the inflation and exchange rate linkages. An increase in inflation or depreciation of the rand causes input prices to rise. An increase in the real input price impacts negatively on real supply. A negative sign is therefore hypothesised for this variable.

Inclusion of the real prime overdraft rate completes the interest rate linkage. A negative sign is hypothesised for this variable in the real field crop and horticultural crop supply equations. The negative sign reflects the cost effects of changes in the interest rate. An increase in the real interest rate raises the cost of short-term production loans and causes real supply to decrease.

A positive sign is expected for the real interest rate variable in the beef, mutton and pork real supply equations. This simulates the stock effects of the real interest rate on livestock supply. Higher real interest rates raise the opportunity costs of keeping animals on the farm causing supply to increase.

3.3.2 Specification of real demand

Specification of the real per capita demand functions follows neoclassical demand theory. Quantity demanded of a particular commodity depends on the commodity's own real price, real price of substitutes in consumption, real per capita personal disposable income and tastes. Demand is expressed in per capita terms to account for changes in population.

Inclusion of real per capita personal disposable income in each demand equation simulates the real income linkage. Positive signs are expected for the estimated coefficients of this variable in all demand

equations except maize. Past studies of maize demand for human consumption have found maize to be an inferior good in South Africa (Cadiz, 1984; van Zyl, 1986a). The real per capita disposable income coefficient should therefore have a negative sign in the real per capita human maize demand equation.

3.3.3 Specification of real export demand

Real export demand for maize, sugar, wool, and deciduous and citrus fruit is considered. These sectors are surplus producers and export large proportions of output (Maize Board, South African Sugar Association, South African Wool Board, Deciduous Fruit Board, Citrus Board, various years).

This study analyses the relationship between foreign demand for South African agricultural exports and the rand exchange rate. Specification of real export demand equations must reflect real world behaviour. South Africa is a minor exporter in terms of world market shares. Being a price taker on world agricultural commodity markets, South Africa faces a perfectly elastic demand curve. This is similar to the situation faced by many non-oil exporting less developed countries whose principal exports are primary products. This contrasts with the position of the U.S. which, for instance, commands significant market shares in world grain markets where prices are denominated in U.S. dollars.

Specifying real export demand for South African agricultural commodities based on methodology used in studies by Chambers and Just (1981; 1982) and Batten and Belongia (1984; 1986) is inappropriate. Bond's (1985) specification of export demand equations for groups of non-oil exporting developing countries is more suitable. Small country characteristics such as perfectly elastic demand curves are recognised. She indicates, however, that demand may be less than perfectly elastic when exports are differentiated by place of origin and/or countries export as a group. Bond specifies export demand as,

$$XD_{pq} = a_o\, GNP^{a1}{}_q\, (PX_{pq}/PC_q)^{a2}\, (PX_{pq}/PD_q)^{a3}\, e^{a4t}$$

where XD_{pq} is country q's demand for country p's exports; GNP_q is real gross national product in country q; PX_{pq} is country p's price in the qth market; PC_q is country p's competitors prices in country q; PD_q is the domestic price in the qth market; and t is the trend term which accounts for factors affecting allocation of country q's imports from country p over time. In addition,

$$PX_{pq} = PX_p/E_p$$

where PX_p is country p's domestic price; and E_p is a unit of country p's currency per U.S. dollar.

It is inappropriate to use this specification to describe demand for South African agricultural commodities as trade is independent of the South African domestic price, PX_p. Real world observations of South African maize, sugar, deciduous fruit, citrus fruit and wool trade reveals that foreign demand for these products is independent of the South African domestic price. Maize and sugar are traded at world market prices which reflect prices on futures markets (Hardy, 1990). Wool is traded at a world price that strongly reflects the Australian wool price (Bornman, 1990). Deciduous and citrus fruit are traded mainly on European markets. Prices reflect local market conditions (real incomes, tastes, prices of substitute fruits), fruit quality and prices of fruit from competing countries (Ferrandi, 1990; Kruger, 1990). All prices are independent of the South African domestic price.

The demand for South African deciduous and citrus fruit can be regarded as less than perfectly elastic due to significant market shares (albeit diminishing) on European fruit markets (Deciduous Fruit Board, Citrus Board). Analysis of real world behaviour indicates that the exchange rate does not influence the buying decisions of foreign consumers. All fruit is sold at prices determined by local market conditions. The exchange rate therefore does not affect fruit prices prior to sale. The exchange rate affects South African producers when sales proceeds are repatriated to South Africa. The exchange rate affects gross realisation from exports and hence the rand price received by South African producers. This can be illustrated using the relation taken from Johnson, *et al.* (1977) expressed in Bond's notation. A consumer price PX_{pq} for the exporting country p's good in the importing country q is,

$$PX_{pq} = ePX_p + t_{pq}$$

where PX_p is the supply price of country p; t_{pq},s are exogenous shifters that affect the difference between the origin price and ultimate consumer price; and e is the exchange rate between country q and country p. This represents the case where supply is exogenous and consumer prices in the importing country are a function of supply prices determined outside the importing country. South African fruit is not traded at a supply price determined outside of the European or world market. This can be illustrated by rearranging the relation such that,

$$PX_p = PX_{pq}/e - t_{pq}.$$

Prices received by South African fruit exporters, PX_p, are a function of the consumer price in the importing country, PX_{pq}, converted into South African rands at the exchange rate, e, less certain deduc-

tions such as transport, marketing and packing costs, t_{pq}. A depreciated rand exchange rate impacts positively on prices received by South African farmers. If these price increases are perceived as being permanent, farmers will increase production. Fruit tree plantings and flock investment in wool bearing sheep will increase. Maize and sugar farmers receive fixed prices above world prices and therefore will not be affected by exchange rate movements in the short-run, unless world prices should exceed domestic prices.

Real exports of maize, sugar, deciduous fruit, citrus fruit and wool are determined from the market equilibrium identities. The gross rand value of exports is determined as the foreign currency value of exports multiplied by the rand/SDR exchange rate deflated by the respective price indices. Specified as such, real exports are treated as a residual of domestic production net of domestic consumption. Effects of fluctuations in the rand exchange rate on the rand value of exports are captured.

3.3.4 Field crop sector

The field crop sector is represented by maize, sugar cane and hay. Together these crops accounted for almost 63 percent of the gross value of production in the field crop sector in 1987 (Directorate Agricultural Economic Trends).

3.3.4.1 Maize

Maize is the single most important agricultural commodity produced in South Africa in terms of gross value of production (Directorate Agricultural Economic Trends). It is important for human and animal consumption, and is a major export crop (Maize Board).

Real maize supply

All real supply equations (except for deciduous and citrus fruit) follow the specification of the real maize supply equation. Real own prices, real input prices and real prices of major substitutes in production, the real interest rate and other factors such as area planted, weather and technology are tested for inclusion.

$$\left[\frac{MZSS}{MZPI}\right]_t = f_{24}\left[\left[\frac{MZPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{MSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, MAP_t^{(+)}, W_t^{(+)}, T_t^{(+)}, e_{24,t}\right] \quad (3.24)$$

where $MZSS_t$ = gross value of maize production,

$MZPI_t$ = maize producer price index,

$MSPIi_t$ = producer price indices of major substitutes in production, (i = soybeans, groundnuts, sunflowers, and sorghum),

MAP_t = maize area planted,

W_t = dummy variable indicating good rainfall years (1=good rainfall year, 0=drought year), and,

T_t = technology.

Farmers' decisions to plant can be better captured by using acreage planted as the dependent variable rather than maize supply which is affected by the weather (Nieuwoudt, 1985). This specification follows the Nerlove lag model which is based on the hypothesis that "farmers react, not to last year's price, but rather to the price they expect, and this expected price depends only to a limited extent on what last year's price was" (Nerlove, 1956).

As expected prices are unobservable, past prices are used to represent expected prices, the more recent the past price, the greater the influence it has on current price expectations, and therefore the greater the weight attached to it. Expected prices can therefore be represented as a weighted moving average of past prices in which the weights decline for each year further back in time. A special case of the model, used more frequently, represents expected price by price lagged by one year, with a weight of one being attached to that lagged year's price, and zero to all other preceding years.

Maize area planted is therefore specified as a function of maize area planted lagged by one year and either real maize price, profits per hectare or returns per hectare, all lagged by one year. Returns per hectare, which is the product of producer price and yield per hectare, takes into account the increase in yields due to technology (Nieuwoudt, 1985)

$$MAP_t = f_{24a}\left[\left[\frac{MZPRi}{CPI}\right]_{t-1}^{(+)}, MAP_{t-1}^{(+)}, e_{24a,t}\right] \qquad (3.24a)$$

where $MZPRi_t$ = maize price (i = 1), profits per hectare (i = 2) or gross returns per hectare (i = 3).

Real per capita human maize demand

In South Africa human maize consumption is a major component of maize demand. Animal and human maize demand are therefore estimated separately as different factors affect each component of demand (van Zyl, 1986a).

$$\left[\frac{MZDH}{MZPI}\right]_t = f_{25}\left[\left[\frac{MZPI}{CPI}\right]_t^{(-)}, \left[\frac{MCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{25,t}\right] \tag{3.25}$$

where $MZDH_t$ = gross value of per capita human maize consumption, and

$MCPIi_t$ = price indices of major substitutes in consumption, (i = bread, potatoes and rice).

Real animal maize demand

Animal demand for maize feed is derived from the demand for animal products and constitutes the major source of animal feed (Nieuwoudt, 1973). Inclusion of real auction prices for beef, mutton, pork and poultry together with the real maize price captures the effect of relative price changes on animal maize demand. The livestock inventory variable captures the effect of increasing animal numbers on animal maize demand. The real price of major feed substitutes is also tested for inclusion.

$$\left[\frac{MZDA}{MZPI}\right]_t = f_{26}\left[\left[\frac{MZPI}{CPI}\right]_t^{(-)}, \left[\frac{MFPIi}{CPI}\right]_t^{(+)}, \left[\frac{LVPIi}{CPI}\right]_t^{(+)}, \left[\frac{LI}{CPI}\right]_t^{(+)}, e_{26,t}\right] \tag{3.26}$$

where $MZDA_t$ = gross value of animal maize consumption,

$MFPIi_t$ = price indices of major feed substitutes, (i = hay, and stock and poultry feed),

$LVPIi_t$ = producer price indices of livestock products, (i = beef, mutton, pork and poultry), and,

LI_t = gross value of livestock inventory.

Market equilibrium condition for maize

The source and usage of each agricultural product is equated by a market equilibrium condition. In each case, real per capita demand is multiplied by the South African human population to give total real demand. The gross foreign currency value of maize exports is converted into rand terms by the exchange rate. Equilibrium conditions are used to endogenously determine real and nominal product prices.

$$\left[\frac{MZSS}{MZPI}\right]_t + \left[\frac{MZM}{MZPI}\right]_t + \left[\frac{MZI}{MZPI}\right]_{t-1} = \left[\left[\frac{MZDH}{MZPI}\right]_t * SAPOP_t\right] + \left[\frac{MZDA}{MZPI}\right]_t + \left[\frac{MZX * XR}{MZXPI}\right]_t + \left[\frac{MZI}{MZPI}\right]_t \quad (3.27)$$

where MZI_t = gross value of maize stocks

MZM_t = gross value of maize imports,

MZX_t = gross foreign currency value of maize exports,

$MZXPI_t$ = maize export price index, and,

$SAPOP_t$ = human population of South Africa.

3.3.4.2 Sugar cane

Real sugar cane supply and real per capita sugar demand are estimated. Sugar cane production is regulated by quotas and therefore an extremely small supply elasticity is expected. Raw sugar is manufactured from sugar cane for domestic consumption, export and storage.

Real sugar cane supply

Sugar cane growers respond to the expected sucrose price as they are paid according to the sucrose content of cane.

$$\left[\frac{SCSS}{SCPI}\right]_t = f_{28}\left[\left[\frac{SCPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, SCAP_t^{(-)}, W_t, T_t, e_{28,t}^{(+)(+)}\right] \quad (3.28)$$

where $SCSS_t$ = gross value of sugar cane production,

$SCPI_t$ = sucrose price index,

$SCAP_t$ = sugar cane area planted.

Real per capita sugar demand

Real per capita demand for sugar is estimated in aggregate and not by different use (sweets, confectionary, sweet drinks, etc.) as,

$$\left[\frac{SGDD}{SCPI}\right]_t = f_{29}\left[\left[\frac{SCPI}{CPI}\right]_t^{(-)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{29,t}\right] \tag{3.29}$$

where $SGDD_t$ = gross value of per capita sugar consumption.

Market equilibrium condition for sugar

Real sugar cane supply is converted into a raw sugar equivalent by the conversion factor $SGSCR_t$ in the market equilibrium condition.

$$\left[\left[\frac{SCSS}{SCPI}\right]_t * SGSCR_t\right] + \left[\frac{SGM}{SCPI}\right]_t + \left[\frac{SGI}{SCPI}\right]_{t-1} = \left[\left[\frac{SGDD}{SCPI}\right]_t * SAPOP_t\right] + \left[\frac{SGX * XR}{SCXPI}\right]_t + \left[\frac{SGI}{SCPI}\right]_t \tag{3.30}$$

where $SGSCR_t$ = sugar to sugar cane ratio,
SGI_t = gross value of sugar stocks
SGM_t = gross value of sugar imports,
SGX_t = gross foreign currency value of sugar exports, and,
$SGXPI_t$ = sugar export price index.

3.3.4.3 Hay

Hay is the largest field crop in terms of gross value of production after maize and wheat. It is an important winter feed and maize substitute in livestock production.

Real hay supply

$$\left[\frac{HYSS}{HYPI}\right]_t = f_{31}\left[\left[\frac{HYPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{HSPIi}{CPI}\right]_{t-1}^{(+)}, RR_t^{(-)}, W_t^{(+)}, T_t^{(+)}, e_{31,t}\right] \tag{3.31}$$

where $HYSS_t$ = gross value of hay production,

$HYPI_t$ = hay price index, and,

$HSPIi_t$ = producer price indices of major hay substitutes, (i = maize).

Real hay demand

As an important livestock feed, real hay demand, like maize, is derived from the demand for animal products. A large number of animal price indices are tested for inclusion to reflect this. Price indices of maize, and stock and poultry feed are included in the demand equation as they are important feed substitutes.

$$\left[\frac{HYDD}{HYPI}\right]_t = f_{32}\left[\left[\frac{HYPI}{CPI}\right]_t^{(-)}, \left[\frac{HCPIi}{CPI}\right]_t^{(+)}, \left[\frac{LVPIi}{CPI}\right]_t^{(+)}, \left[\frac{LI}{CPI}\right]_t^{(+)}, e_{32,t}\right] \tag{3.32}$$

where $HYDD_t$ = gross value of hay consumption, and,

$HCPIi_t$ = price indices of major substitutes in consumption, (i = maize, stock and poultry feed).

Market equilibrium condition for hay

Real imports and exports are not considered for hay.

$$\left[\frac{HYSS}{HYPI}\right]_t + \left[\frac{HYI}{HYPI}\right]_{t-1} = \left[\frac{HYDD}{HYPI}\right]_t + \left[\frac{HYI}{HYPI}\right]_t \tag{3.33}$$

where HYI_t = gross value of hay stocks.

Total real gross farm income in the field crop sector

Total real gross income at the farm level in the field crop sector is derived as the sum of the real gross income for maize, sugar cane and hay.

$$\left[\frac{FCINC}{FCPI}\right]_t = \left[\frac{MZSS}{MZPI}\right]_t + \left[\frac{SCSS}{SCPI}\right]_t + \left[\frac{HYSS}{HYPI}\right]_t \tag{3.34}$$

where $FCINC_t$ = total gross farm income in the field crop sector, and,

$FCPI_t$ = field crop price index.

3.3.5 Horticultural sector

The horticultural sector is represented by deciduous fruit, citrus fruit, vegetables and potatoes. These four crops comprise, on average, approximately 65 percent of the gross value of horticultural production. Deciduous fruit is the single most important crop in the sector (Directorate Agricultural Economic Trends). Deciduous and citrus fruit are major export crops. Fruit not exported is marketed domestically for fresh consumption and juice extraction, drying and canning.

3.3.5.1 Deciduous fruit

Major South African deciduous fruits are apples, pears, apricots, peaches, plums and table grapes. In this study, real demand for deciduous fruits in aggregate is estimated.

Real deciduous fruit supply

Deciduous fruits are perennial crops. Significant time lags occur between planting and harvest, and harvest continues for an extended period from time of planting. Annual perennial crop output should therefore estimated by two relationships. The first is a planting relationship which specifies annual tree plantings as a function of factors that underlie farmers' decisions. The second is an output relationship which is an identity that determines output as a multiple of yield times area or number of trees planted (Labys, 1973, p.42).

Annual fruit tree plantings would be specified as a function of real own price, real input price, real price of major substitutes and the real interest rate. The output identity estimates output as a multiple of yield per tree and trees planted.

Due to the lack of reliable time series on tree numbers and plantings, real deciduous fruit supply is determined from the market equilibrium condition in this study.

Real per capita deciduous fruit demand

Deciduous fruit sold on national fresh produce markets for fresh consumption is considered in this study. Prices are not controlled and therefore reflect supply and demand conditions.

$$\left[\frac{DFDD}{DFPI}\right]_t = f_{35}\left[\left[\frac{DFPI}{CPI}\right]_t^{(-)}, \left[\frac{DCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{35,t}\right] \tag{3.35}$$

where $DFDD_t$ = gross value of per capita deciduous fruit consumption,

$DFPI_t$ = deciduous fruit market price index, and,

$DCPIi_t$ = price indices of major substitutes in consumption, (i = citrus fruit and sub-tropical fruit).

Market equilibrium condition for deciduous fruit

$$\left[\frac{DFSS}{DFPI}\right]_t + \left[\frac{DFM}{DFPI}\right]_t + \left[\frac{DFI}{DFPI}\right]_{t-1} = \left[\left[\frac{DFDD}{DFPI}\right]_t * SAPOP_t\right] + \left[\frac{DFX * XR}{DFXPI}\right]_t + \left[\frac{DFI}{DFPI}\right]_t \tag{3.36}$$

where DFI_t = gross value of deciduous fruit stocks

DFM_t = gross value of deciduous fruit imports,

DFX_t = gross foreign currency value of deciduous fruit exports, and,

$DFXPI_t$ = deciduous fruit export price index.

3.3.5.2 Citrus fruit

Oranges, lemons, grapefruit and naartjies comprise the major citrus fruits grown in South Africa.

Real citrus fruit supply

Citrus fruit is a perennial crop and real supply of citrus fruit is specified in the same way as real deciduous fruit supply.

Real per capita citrus fruit demand

Citrus fruit is marketed in a similar way to deciduous fruit.

$$\left[\frac{CFDD}{CFPI}\right]_t = f_{37}\left[\left[\frac{CFPI}{CPI}\right]_t^{(-)}, \left[\frac{CCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{37,t}\right] \tag{3.37}$$

where $CFDD_t$ = gross value of per capita citrus fruit consumption,
$CFPI_t$ = citrus fruit market price index, and,
$CCPIi_t$ = price indices of major substitutes in consumption, (i = deciduous fruit and sub-tropical fruit.

Market equilibrium condition for citrus fruit

$$\left[\frac{CFSS}{CFPI}\right]_t + \left[\frac{CFM}{CFPI}\right]_t + \left[\frac{CFI}{CFPI}\right]_{t-1} = \left[\left[\frac{CFDD}{CFPI}\right]_t * SAPOP_t\right] + \left[\frac{CFX * XR}{CFXPI}\right]_t + \left[\frac{CFI}{CFPI}\right]_t \quad (3.38)$$

where CFI_t = gross value of citrus fruit stocks,
CFM_t = gross value of citrus fruit imports, and,
CFX_t = gross foreign currency value of citrus fruit exports, and,
$CFXPI_t$ = citrus fruit export price index.

3.3.5.3 Vegetables

Vegetable production is not regulated by Control Boards. Fresh vegetables are sold on 14 national fresh produce markets throughout South Africa. The remainder is sold to retailers and canners. Prices are not controlled and are determined through the interaction of supply and demand. As a large number of different vegetables are grown in South Africa, this study estimates real vegetable supply and demand functions in aggregate.

Potatoes are treated separately from fresh vegetables in this study due to their importance as a staple food in South Africa. Potatoes comprise 40 to 50 percent of the gross value of vegetable production (Directorate Agricultural Economic Trends). Real potato supply and demand equations are specified after the real vegetable supply and demand equations.

Real vegetable supply

$$\left[\frac{VGSS}{VGPI}\right]_t = f_{39}\left[\left[\frac{VGPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{VSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, T_t^{(+)}, e_{39,t}\right] \quad (3.39)$$

where $VGSS_t$ = gross value of vegetable production,

$VGPI_t$ = vegetable market price index, and,

$VSPIi_t$ = price indices of major substitutes in production, (i = potatoes, maize).

Real per capita vegetable demand

$$\left[\frac{VGDD}{VGPI}\right]_t = f_{40}\left[\left[\frac{VGPI}{CPI}\right]_t^{(-)}, \left[\frac{VCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{40,t}\right] \quad (3.40)$$

where $VGDD_t$ = gross value of per capita vegetable consumption,

$VCPIi_t$ = price indices of major substitutes in consumption, (i = potatoes, maize, deciduous, citrus and sub-tropical fruits).

Market equilibrium condition for vegetables

$$\left[\frac{VGSS}{VGPI}\right]_t + \left[\frac{VGM}{VGPI}\right]_t + \left[\frac{VGI}{VGPI}\right]_{t-1} = \left[\left[\frac{VGDD}{VGPI}\right]_t * SAPOP_t\right] + \left[\frac{VGX}{VGPI}\right]_t + \left[\frac{VGI}{VGPI}\right]_t \quad (3.41)$$

where VGI_t = gross value of vegetable stocks

VGM_t = gross value of vegetable imports, and,

VGX_t = gross value of vegetable exports.

3.3.5.4 Potatoes

Potatoes are marketed by the Potato Board as a "Surplus Removal Scheme" (Potato Board) and are sold mainly on the national fresh produce markets where prices are determined by market supply and demand.

Real potato supply

$$\left[\frac{PTSS}{PTPI}\right]_t = f_{42}\left[\left[\frac{PTPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{PSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, PAP_t^{(+)}, T_t^{(+)}, e_{42,t}\right] \quad (3.42)$$

where $PTSS_t$ = gross value of potato production,

$PTPI_t$ = potato market price index,

$PSPIi_t$ = prices of major substitutes in production, (i = vegetables, maize, and,

PAP_t = potato area planted.

Real per capita potato demand

Specification of the real per capita potato demand equation reflects the importance of potatoes as a substitute staple food. Prices of maize, rice and bread are tested for inclusion in the equation.

$$\left[\frac{PTDD}{PTPI}\right]_t = f_{43}\left[\overset{(-)}{\left[\frac{PTPI}{CPI}\right]_t}, \overset{(+)}{\left[\frac{PCPIi}{CPI}\right]_t}, \overset{(+)}{\left[\frac{PDY}{CPI}\right]_t}, e_{43,t}\right] \tag{3.43}$$

where $PTDD_t$ = gross value of per capita potato consumption,

$PCPIi_t$ = prices of major substitutes in consumption, (i = maize, rice and bread).

Market equilibrium condition for potatoes

$$\left[\frac{PTSS}{PTPI}\right]_t + \left[\frac{PTM}{PTPI}\right]_t + \left[\frac{PTI}{PTPI}\right]_{t-1} = \left[\left[\frac{PTDD}{PTPI}\right]_t * SAPOP_t\right] + \left[\frac{PTX}{PTPI}\right]_t + \left[\frac{PTI}{PTPI}\right]_t \tag{3.44}$$

where PTI_t = gross value of potato stocks

PTM_t = gross value of potato imports,

PTX_t = gross value of potato exports.

Total real gross farm income in the horticultural sector

$$\left[\frac{HTINC}{HTPI}\right]_t = \left[\frac{DFSS}{DFPI}\right]_t + \left[\frac{CFSS}{CFPI}\right]_t + \left[\frac{VGSS}{VGPI}\right]_t + \left[\frac{PTSS}{PTPI}\right]_t \tag{3.45}$$

where $HTINC_t$ = total real farm income in the horticultural sector, and,

$HTPI_t$ = horticultural crop price index.

3.3.6 Livestock sector

The livestock sector is represented by beef, mutton, pork, chicken meat and wool. Beef, mutton and pork are red meats, while chicken is the predominant white meat.

Important structural changes have occurred in the South African livestock sector during the study period. Annual per capita red meat consumption has fallen consistently from 39,33 kg in 1960 to 24,86 kg in 1987. Annual per capita chicken meat consumption has increased from 2,37 kg per annum in 1960 to 15,00 kg per annum in 1987 (Directorate Agricultural Economic Trends).

3.3.6.1 Beef

Beef is the most important product in the livestock sector, contributing almost 25 percent of gross value of production in the livestock sector (Directorate Agricultural Economic Trends).

Real beef supply

$$\left[\frac{BFSS}{BFPI}\right]_t = f_{46}\left[\left[\frac{BFPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{BSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(+)}, CNW_t^{(+)}, e_{46,t}\right] \tag{3.46}$$

where $BFSS_t$ = gross value of beef and calf production,

$BFPI_t$ = beef auction price index,

$BSPIi_t$ = producer price indices of major substitutes in production, (i = maize and mutton),

CNW_t = national beef cattle numbers.

Real per capita beef demand

$$\left[\frac{BFDD}{BFPI}\right]_t = f_{47}\left[\left[\frac{BFPI}{CPI}\right]_t^{(-)}, \left[\frac{BCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{47,t}\right] \tag{3.47}$$

where $BFDD_t$ = gross value of per capita beef demand.

$BCPIi_t$ = price indices of major substitutes in consumption, (i = mutton, pork and chicken meat).

Market equilibrium condition for beef

Real beef imports, exports and stocks are treated as exogenous variables. Beef imports arise due to periodic shortfalls in domestic production.

$$\left[\frac{BFSS}{BFPI}\right]_t + \left[\frac{BFM}{BFPI}\right]_t + \left[\frac{BFI}{BFPI}\right]_{t-1} = \left[\left[\frac{BFDD}{BFPI}\right]_t * SAPOP_t\right] + \left[\frac{BFX}{BFPI}\right]_t + \left[\frac{BFI}{BFPI}\right]_t \quad (3.48)$$

where BFM_t = gross value of beef imports,

BFX_t = gross value of beef exports, and,

BFI_t = gross value of beef stocks.

3.3.6.2 Mutton

Real mutton supply

$$\left[\frac{MTSS}{MTPI}\right]_t = f_{49}\left[\left[\frac{MTPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{MSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(+)}, SNW_t^{(+)}, e_{49,t}\right] \quad (3.49)$$

where $MTSS_t$ = gross value of mutton production,

$MTPI_t$ = mutton auction price index,

$MSPIi_t$ = price indices of major mutton substitutes in production, (i = beef and maize), and,

SNW_t = national sheep numbers.

Real per capita mutton demand

$$\left[\frac{MTDD}{MTPI}\right]_t = f_{50}\left[\left[\frac{MTPI}{CPI}\right]_t^{(-)}, \left[\frac{MCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{50,t}\right] \quad (3.50)$$

where $MTDD_t$ = gross value of per capita mutton consumption,

$MCPIi_t$ = price of major substitutes in consumption, (i = beef, pork and chicken meat).

Market equilibrium condition for mutton

$$\left[\frac{MTSS}{MTPI}\right]_t + \left[\frac{MTM}{MTPI}\right]_t + \left[\frac{MTI}{MTPI}\right]_{t-1} = \left[\left[\frac{MTDD}{MTPI}\right]_t * SAPOP_t\right] + \left[\frac{MTX}{MTPI}\right]_t + \left[\frac{MTI}{MTPI}\right]_t \quad (3.51)$$

where MTM_t = gross value of mutton imports,

MTX_t = gross value of mutton exports, and,

MTI_t = gross value of mutton stocks.

3.3.6.3 Pork

Real pork supply

$$\left[\frac{PKSS}{PKPI}\right]_t = f_{52}\left[\left[\frac{PKPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, RRt^{(+)}, PNW_t^{(+)}, e_{52,t}\right] \quad (3.52)$$

where $PKSS_t$ = gross value of pork production,

$PKPI_t$ = pork producer price index, and,

PNW_t = national pig numbers.

Real per capita pork demand

$$\left[\frac{PKDD}{PKPI}\right]_t = f_{53}\left[\left[\frac{PKPI}{CPI}\right]_t^{(-)}, \left[\frac{PCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{53,t}\right] \quad (3.53)$$

where $PKDD_t$ = gross value of per capita pork consumption,

$PCPIi_t$ = prices indices of major substitutes in pork consumption, (i = beef, mutton and chicken meat).

Market equilibrium condition for pork

$$\left[\frac{PKSS}{PKPI}\right]_t + \left[\frac{PKM}{PKPI}\right]_t + \left[\frac{PKI}{PKPI}\right]_{t-1} = \left[\left[\frac{PKDD}{PKPI}\right]_t * SAPOP_t\right] + \left[\frac{PKX}{PKPI}\right]_t + \left[\frac{PKI}{PKPI}\right]_t \quad (3.54)$$

where PKM_t = gross value of pork imports,

PKX_t = gross value of pork exports, and,

PKI_t = gross value of pork stocks.

Total real gross farm income for red meats

Real income for red meats is derived by summing real gross income for beef, mutton and pork.

$$\left[\frac{RMINC}{RMPI}\right]_t = \left[\frac{BFSS}{BFPI}\right]_t + \left[\frac{MTSS}{MTPI}\right]_t + \left[\frac{PKSS}{PKPI}\right]_t \qquad (3.55)$$

where $RMINC_t$ = total gross income for red meats, and,

$RMPI_t$ = red meat price index.

3.3.6.4 Chicken meat

As indicated previously, chicken meat has become a major substitute for red meat in South Africa.

Real chicken meat supply

$$\left[\frac{CHSS}{CHPI}\right]_t = f_{56}\left[\left[\frac{CHPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, T_t^{(+)}, e_{56,t}\right] \qquad (3.56)$$

where $CHSS_t$ = gross value of chicken meat production, and,

$CHPI_t$ = chicken price index.

Real per capita chicken meat demand

$$\left[\frac{CHDD}{CHPI}\right]_t = f_{57}\left[\left[\frac{CHPI}{CPI}\right]_t^{(-)}, \left[\frac{CCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{57,t}\right] \qquad (3.57)$$

where $CHDD_t$ = gross value of per capita chicken meat demand, and,

$CCPIi_t$ = price indices of major substitutes in chicken meat consumption (i = mutton, pork and chicken meat).

Market equilibrium condition for chicken

$$\left[\frac{CHSS}{CHPI}\right]_t + \left[\frac{CHM}{CHPI}\right]_t + \left[\frac{CHI}{CHPI}\right]_{t-1} = \left[\left[\frac{CHDD}{CHPI}\right]_t * SAPOP_t\right] + \left[\frac{CHX}{CHPI}\right]_t + \left[\frac{CHI}{CHPI}\right]_t \qquad (3.58)$$

where CHI_t = gross value of chicken meat stocks,
CHM_t = gross value of chicken meat imports, and,
CHX_t = gross value of chicken meat exports.

3.3.6.5 Wool

Wool is an important livestock product in South Africa as it is often produced in arid areas unsuited to crop production. It constitutes an extremely important export product as a very high proportion of the annual clip is sold to foreign buyers. Wool is marketed by the South African Wool Board which sets reserve auction prices for each grade. South African auction prices closely reflect world wool prices (Bornman, 1990; South African Wool Board).

Real wool supply

$$\left[\frac{WLSS}{WLPI}\right]_t = f_{59}\left[\left[\frac{WLPI}{CPI}\right]_{t-1}^{(+)}, \left[\frac{INPI}{CPI}\right]_{t-1}^{(-)}, \left[\frac{WSPIi}{CPI}\right]_{t-1}^{(-)}, RR_t^{(-)}, WSNW_t^{(+)}, T_t^{(+)}, e_{59,t}\right] \quad (3.59)$$

where $WLSS_t$ = gross value of wool production,
$WLPI_t$ = wool auction price index,
$WSPIi_t$ = producer price indices of major substitutes in wool production, (i = mutton), and,
$WSNW_t$ = national wool sheep numbers.

Real per capita wool demand

$$\left[\frac{WLDD}{WLPI}\right]_t = f_{60}\left[\left[\frac{WLPI}{CPI}\right]_t^{(-)}, \left[\frac{WCPIi}{CPI}\right]_t^{(+)}, \left[\frac{PDY}{CPI}\right]_t^{(+)}, e_{60,t}\right] \quad (3.60)$$

where $WLDD_t$ = gross value of per capita wool consumption,
$WCPIi_t$ = price indices of major substitutes in wool consumption, (i = cotton, synthetics).

Market equilibrium condition for wool

$$\left[\frac{WLSS}{WLPI}\right]_t + \left[\frac{WLM}{WLPI}\right]_t + \left[\frac{WLI}{WLPI}\right]_{t-1} = \left[\left[\frac{WLDD}{WLPI}\right]_t * SAPOP_t\right] + \left[\frac{WLX}{WLPI}\right]_t + \left[\frac{WLI}{WLPI}\right]_t \quad (3.61)$$

where WLI_t = gross value of wool stocks,
WLM_t = gross value of wool imports, and,
WLX_t = gross value of wool exports.

Total real gross farm income in the livestock sector

Total real gross income in the livestock sector is the sum of the real gross farm income for red meats plus real gross farm income for chicken meat and wool.

$$\left[\frac{LVINC}{LVPI}\right]_t = \left[\frac{RMINC}{RMPI}\right]_t + \left[\frac{CHSS}{CHPI}\right]_t + \left[\frac{WLSS}{WLPI}\right]_t \quad (3.62)$$

where $LVINC_t$ = total real farm income in the livestock sector, and,
$LVPI_t$ = livestock price index.

Total real gross farm income in the sectors modelled

Real gross farm income in the field crop, horticultural and livestock sectors is summed to obtain total real gross farm income in the sectors modelled.

$$\left[\frac{AGINC}{AGPI}\right]_t = \left[\frac{FCINC}{FCPI}\right]_t + \left[\frac{HTINC}{HTPI}\right]_t + \left[\frac{LVINC}{LVPI}\right]_t \quad (3.63)$$

where $AGINC_t$ = total gross farm income in the sectors modelled sectors.

Total nominal gross farm income in the sectors modelled

Total nominal gross farm income is determined by multiplying total real gross farm income by the agricultural price index.

$$AGINC_t = \left[\frac{AGINC}{AGPI}\right]_t * AGPI_t \quad (3.64)$$

Agricultural product price determination

Agricultural product prices are determined from the identities which equate the source and usage of each product. The agricultural price index is endogenously determined as a weighted average of the product prices. Weights are determined according to contribution to total real gross farm income.

Real agricultural investment

Real agricultural investment is specified as a function of the real price of agricultural capital goods (machinery and implements, and building materials), real interest rate and total real gross farm income in the sectors modelled.

$$\left[\frac{AGINV}{AIPI}\right]_t = f_{65}\left[\left[\frac{AIPI}{CPI}\right]_t^{(-)}, \left[\frac{AGINC}{AGPI}\right]_t^{(+)}, RR_t^{(+)}, e_{65,t}\right] \tag{3.65}$$

where $AGINV_t$ = gross value of agricultural investment, and,

$AIPI_t$ = price index of agricultural capital goods.

3.4 National accounting identities

To close the system of equations, standard national accounting identities are specified for real total personal consumption expenditure, real gross domestic fixed investment, real net exports and real gross domestic product.

Real total personal consumption expenditure

$$\begin{aligned}\left[\frac{TPCE}{CPI}\right]_t = {} & \left[\frac{MANDD}{MANPI}\right]_t + \left[\frac{MZDH}{MZPI}\right]_t + \left[\frac{SGDD}{SCPI}\right]_t + \left[\frac{DFDD}{DFPI}\right]_t + \left[\frac{CFDD}{CFPI}\right]_t + \\ & \left[\frac{VGDD}{VGPI}\right]_t + \left[\frac{PTDD}{PTPI}\right]_t + \left[\frac{BFDD}{BFPI}\right]_t + \left[\frac{MTDD}{MTPI}\right]_t + \left[\frac{PKDD}{PKPI}\right]_t + \\ & \left[\frac{WLDD}{WLDD}\right]_t + \left[\frac{CHDD}{CHPI}\right]_t + \left[\frac{TPCE'}{CPI}\right]_t\end{aligned} \tag{3.66}$$

Real gross domestic fixed investment

$$\left[\frac{GDFI}{CPI}\right]_t = \left[\frac{AGINV}{AIPI}\right]_t + \left[\frac{GDFI'}{CPI}\right]_t \tag{3.67}$$

Real net exports

$$\left[\frac{NXPT}{CPI}\right]_t = \left[\frac{MZNX}{MZPI}\right]_t + \left[\frac{SGNX}{SCPI}\right]_t + \left[\frac{DFNX}{DFPI}\right]_t + \left[\frac{CFNX}{CFPI}\right]_t + \left[\frac{WLNX}{WLPI}\right]_t - \left[\frac{MANNM}{MNMPI}\right]_t + \left[\frac{NXPT'}{CPI}\right]_t \quad (3.68)$$

Real gross domestic product

$$\left[\frac{GDP}{CPI}\right]_t = \left[\frac{TPCE}{CPI}\right]_t + \left[\frac{GDFI}{CPI}\right]_t + \left[\frac{GOVT}{CPI}\right]_t + \left[\frac{NXPT}{CPI}\right]_t \quad (3.69)$$

where $TPCE_t$ = total private consumption expenditure,

$GDFI_t$ = gross domestic fixed investment,

$GOVT_t$ = government consumption expenditure,

$NXPT_t$ = net exports,

$TPCE'_t$ = total private consumption expenditure not determined in the model,

$GDFI'_t$ = gross domestic fixed investment not determined in the model,

$NXPT'_t$ = net exports not determined in the model.

3.5 Summary

The model reflects macrolinkages between agriculture and the macrosector in South Africa. The interest rate, exchange rate and general price level are linked to money supply. Money supply impacts on market interest rates, represented by the treasury bill rate. The prime overdraft rate simulates the cost of short-term debt and reflects market interest rates. The exchange rate is determined according to the monetarist approach to capture effects of monetary variables on the exchange rate. Specification of the general price level reflects the monetarist view of the quantity equation in which money supply plays a direct causal role in price determination.

The interest rate linkage with agriculture is simulated by including the real prime overdraft rate in the real product supply equations. The inflation and exchange rate linkages impact on agriculture via the purchase of inputs. An increase in the domestic price level and depreciation of the rand exchange rate causes input prices to increase. The impact of these changes on product supply is modelled by including real input prices in the product supply equations. Given South Africa's position as price taker on world commodity markets, changes in the rand exchange rate do not effect foreign demand for

domestic produce. The effect of the exchange on prices received by South African farmers is modelled. The effect of real non-agricultural income on agriculture is represented by real per capita personal disposable income as a determinant of real per capita product demand equations.

The model offers a framework for studying the impacts of monetary policy changes on agriculture. Simulation of the four macrolinkages and the endogenous determination of the exchange rate, inflation and real income makes the model a useful tool for policy analysis. Model estimation and validation techniques and results are reported in Chapter 4.

CHAPTER 4

EMPIRICAL ESTIMATION OF THE MODEL

4.1 Introduction

This chapter discusses model estimation and validation techniques, and presents empirical results. Ordinary least squares (OLS), two-stage least squares (2SLS), three-stage least squares (3SLS) and two-stage principal components (2SPC) were all used as estimating techniques during model construction. However, due to insufficient degrees of freedom, the final model was estimated using 2SPC. For the sake of brevity, only 2SPC estimation results are reported. The model's simulation performance was tested using a variety of statistical and graphical techniques. These tests are necessary to determine the model's suitability for policy analysis.

4.2 Simultaneous equations techniques

Use of OLS to estimate a simultaneous equations model is inappropriate. Ordinary least squares can only be applied to single-equation regression models in which a unidirectional cause-and-effect relationship exists between the dependent and explanatory variables. In economics, relationships are often bi-directional in which the explanatory variable is determined to some extent by the dependent variable and the distinction between dependent and independent variables becomes invalid. These variables are termed jointly dependent variables (Gujarati, 1982, p.335).

Estimation of a relationship with joint dependence among the variables requires a wider system of equations, with one equation for each jointly dependent or endogenous variable. A set of these equations is called a system of simultaneous equations (Koutsoyiannis, 1977, p.331). Use of OLS to estimate an equation that is part of a simultaneous equations system violates the OLS assumption that the explanatory variables are either nonstochastic, or if stochastic, distributed independently of the stochastic disturbance term. If these assumptions are violated, the resulting least-squares estimators are biased and inconsistent. This bias is known as simultaneous equation bias (for proof, see Gujarati, 1982, pp.342-344).

Many relationships in the model are not unidirectional making OLS inappropriate for estimating model parameters. More suitable techniques include single equation and systems methods.

4.2.1 Single equation methods

Two-stage least squares is the simplest and most inexpensive method of eliminating simultaneous equation bias. It is termed a "single-equation" method as each equation in the system is estimated individually, provided it is identified. Single-equation methods are termed "limited information" methods as they only utilise knowledge of the zero restrictions in the particular equation being estimated, and therefore do not use all the information available in the model (Kennedy, 1979, p.112).

Estimators obtained by 2SLS are consistent and thus superior to OLS estimators. The 2SLS estimators can be made more efficient by using systems methods which utilise all information available in the system of equations.

4.2.2 Systems methods

Systems methods estimate all identified structural equations together as a set, instead of estimating the parameters of each equation individually. They are termed "full-information" methods because they utilise knowledge of all zero restrictions in the entire system, making use of all information available in the model (Kennedy, 1979, p.116).

Three-stage least squares is a commonly used systems method. It is 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. In the third stage, generalised least squares (GLS) is applied to a set of transformed equations in which the transformation required is obtained from the reduced-form residuals in stage two. This transformation is necessary due to the presence of heteroscedasticity among the disturbance terms (Koutsoyiannis, 1977, pp.475-477).

Three-stage least squares estimators are biased but consistent, and more efficient than 2SLS estimators since they utilise more information. Systems methods improve efficiency by incorporating all available information into parameter estimates and take into account cross-equation correlation (Pindyck and Rubinfeld, 1981, p.335). This results in smaller asymptotic variance-covariance matrices for each parameter, provided there is no specification bias. If the system is misspecified, all parameter esti-

mates are affected, rather than just the estimates of one equation, as in the case of single equation estimation methods (Kennedy, 1979, p.116). Disadvantages are large data requirements, high computational costs and high sensitivity to specification bias. One specification error is transmitted to all system equations due to the simultaneous estimation of the equations. If the model is very small, accuracy of the specification of the equations is uncertain and there is a possibility that the disturbance terms are uncorrelated, then it is preferable to apply 2SLS (Koutsoyiannis, 1977, pp.477-478).

In the preliminary stages of estimation, OLS, 2SLS and 3SLS were used to estimate a model which analysed the impacts of monetary policy on the maize and beef sectors of South Africa (Dushmanitch and Darroch, 1989). As additional equations for other sectors were added to the model, the number of exogenous variables in the model exceeded the number of observations resulting in insufficient degrees of freedom. This meant that the complete model had to be estimated by two-stage principal components rather than 2SLS or 3SLS as described in the following section.

4.2.3 Large model methods

The first stage of 2SLS and 3SLS estimates instrumental variables for each right-hand side endogenous variable by regressing each of those variables on all exogenous variables in the model. 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, p.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, p.512). No definite criteria exist

regarding the number of principal components to include. Labys (1973, p.143) suggests selecting enough principal components to account for 90 percent of the variance. Coleman (1986) used the second method with enough components to account for 95 percent of the variance. In this study, the first alternative is followed.

4.3 Estimation results

The final form of the estimated model is reported in Table 4.1. Model equations represent the best fit in terms of statistical significance and underlying economic theory. Coefficient signs agree with *a priori* expectations and most elasticities compare favourably with previous estimates where comparisons were possible. Some *a priori* specifications were changed during empirical estimation because of incorrect signs and/or insignificant parameter estimates.

All equations were first estimated by OLS and 2SLS to check for goodness of fit, correct variable specification, and that coefficient signs agreed with *a priori* expectations. Once satisfactory results were obtained, principal components of all exogenous variables were computed. To minimise computational costs and multicollinearity, all right hand side endogenous variables were regressed on enough principal components to account for 95 percent of the variance of all the exogenous variables in the system. All least squares equations were estimated using the computer package RATS (Doan and Litterman, 1988) and principal components were computed using the package GENSTAT.

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 (d) statistics are reported. Durbin h-statistics (h) are reported for equations which include a lagged dependent variable as an explanatory variable. Autocorrelation was corrected using procedures described by Kelejian and Oates (1981, pp.276-279). Where tests proved inconclusive, estimation results were retained. Descriptions of, and data sources for, all variables are given in Table 4.1.

4.3.1 Macrosector

4.3.1.1 Money market

Real money demand is explained by real gross domestic product, general price level and lagged price level. The equation does not include the interest rate as the correct negative coefficient could not be

Table 4.1 Two-stage principal components estimation results

MACROSECTOR

Money market

Money supply

$$Ms_t = m_t * B_t \qquad (4.1)$$

Real money demand

$$\left(\frac{Md}{CPI}\right)_t = \underset{(5,35)}{61,639} - \underset{(-4,18)}{7,938\times10^{-2}}\ CPI_t + \underset{(2,79)}{0,118}\ CPI_{t-1} + \underset{(10,70)}{0,241}\left(\frac{GDP}{CPI}\right)_t \qquad (4.2)$$

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

Treasury bill rate

$$TBR_t = \underset{(0,13)}{0,171} - \underset{(-2,84)\ [-0,267]}{1,277\times10^{-4}}\ Ms_t + \underset{(2,17)}{0,013}\left(\frac{GDP}{CPI}\right)_t + \underset{(4,33)}{6,977}\ MD1_t + \underset{(3,55)}{0,546}\ TBR_{t-1} \qquad (4.3)$$

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

Prime overdraft rate

$$R_t = \underset{(3,63)}{2,290} + \underset{(10,49)\ [0,856]}{1,330}\ TBR_t - \underset{(-2,45)}{0,221}\ (TBR_t * MD1_t) \qquad (4.4)$$

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

Real prime overdraft rate

$$RR_t = R_t - \{(CPI_t - CPI_{t-1})/CPI_{t-1}\} \qquad (4.5)$$

Market equilibrium in the money market

$$Ms_t = \left(\left(\frac{Md}{CPI}\right)_t * CPI_t\right) \qquad (4.6)$$

Table 4.1 continued

Foreign Exchange Market

Exchange rate

$$XR_t = \underset{(34,37)\ (21,74)}{71,978} - \underset{(-3,45)\ (-2,18)}{147,961}\,\pi_t + \underset{(9,32)\ (5,90)\ [0,894]}{3,935\text{x}10^{-3}}\,(Ms_t*\pi_t) - \underset{(-6,61)\ (-4,19)}{0,453}\,(Ms^f{}_t*\pi_t) +$$

$$\underset{(1,89)\ (0,97)\ [0,064]}{0,564}\,(TBR_t*\pi_t) - \underset{(-3,20)\ (-2,02)}{3,299}\,(TBR^f{}_t*\pi_t) - \underset{(-1,57)\ (-0,99)}{0,186}\left(\left(\frac{GDP}{CPI}\right)_t*\pi_t\right) + \underset{(4,68)\ (3,97)}{2,436}\left(\left(\frac{GDP^f}{CPI^f}\right)_t*\pi_t\right) \quad (4.7)$$

$\bar{R}^2 = 0,986$ d = 2,72 $F_{7,20} = 192,27$ df = 20 adjusted df = 8

Real balance of payments

$$\left(\frac{BoP}{CPI}\right)_t = \left(\frac{MZNX}{MZPI}\right)_t + \left(\frac{SGNX}{SCPI}\right)_t + \left(\frac{DFNX}{DFPI}\right)_t + \left(\frac{CFNX}{CFPI}\right)_t + \left(\frac{WLNX}{WLPI}\right)_t - \left(\frac{MANNM}{MNMPI}\right)_t + \left(\frac{BoP'}{CPI}\right)_t \quad (4.8)$$

General price level

$$CPI_t = \underset{(-1,20)}{-3,502} + \underset{(1,86)\ [0,046]}{0,134}\left(\frac{Ms}{RGDP}\right)_t + \underset{(27,03)}{1,108}\,CPI_{t-1} - \underset{(-1,26)}{2,617}\,D1_t \quad (4.9)$$

$\bar{R}^2 = 0,999$ h = 1,15 $F_{3,24} = 147,35$ df = 24

Manufacturing sector

Real per capita demand for manufactured goods

$$\left(\frac{MANDD}{MANPI}\right)_t = \underset{(3,10)}{32,814} - \underset{(-3,58)\ [-6,16]}{34,372}\left(\frac{MANPI}{CPI}\right)_t + \underset{(5,97)\ [1,336]}{1,136}\left(\frac{PDY}{CPI}\right)_t \quad (4.10)$$

$\bar{R}^2 = 0,842$ d = 1,43 $F_{2,25} = 69,82$ df = 25

Table 4.1 continued

Real net import demand for manufactured goods

$$\left(\frac{MANNM}{MNMPI}\right)_t = \underset{(1,99)}{61,302} - \underset{(-1,80)\ [-2,021]}{62,331}\left(\frac{MNMPI}{CPI}\right)_t - \underset{(-3,01)\ [-0,322]}{8,550\times10^{-2}}\ XR_t + \underset{(3,09)}{8,992\times10^{-2}}\left(\frac{GDP}{CPI}\right)_t + \underset{(2,22)}{0,364}\left(\frac{MANNM}{MNMPI}\right)_t \quad (4.11)$$

$\bar{R}^2 = 0,463$ $\quad h = 0,82$ $\quad F_{4,23} = 5,93$ $\quad df = 23$

Market equilibrium in the manufacturing sector

$$\left(\frac{MANSS}{MANPI}\right)_t = \left(\frac{MANNM}{MNMPI}\right)_t + \left\{\left(\frac{MANDD}{MANPI}\right)_t * SAPOP_t\right\} \quad (4.12)$$

AGRICULTURAL SECTOR

Fertiliser price index

$$FTPI_t = \underset{(1,33)}{26,026} - \underset{(-1,15)}{9,236}\left(\frac{QFERT}{FTPI}\right)_t + \underset{(1,81)\ [0,184]}{0,225}\ XR_t + \underset{(10,94)\ [0,842]}{0,806}\ CPI_t - \underset{(-2,99)}{28,517}\ D1_t \quad (4.13)$$

$\bar{R}^2 = 0,990$ $\quad d = 1,76$ $\quad F_{4,23} = 586,52$ $\quad df = 23$

Dips and sprays price index

$$DSPI_t = \underset{(3,67)}{31,232} - \underset{(-2,82)}{21,255}\left(\frac{QDIPS}{DSPI}\right)_t + \underset{(1,87)\ [0,134]}{0,143}\ XR_t + \underset{(12,20)\ [0,828]}{0,691}\ CPI_t - \underset{(-3,31)}{19,336}\ D1_t \quad (4.14)$$

$\bar{R}^2 = 0,996$ $\quad d = 1,85$ $\quad F_{4,23} = 1302,21$ $\quad df = 23$

Stock and poultry feed price index

$$FDPI_t = \underset{(-1,70)}{-12,947} - \underset{(-1,23)}{4,858}\left(\frac{QFEED}{FDPI}\right)_t + \underset{(3,61)\ [0,131]}{0,195}\ XR_t + \underset{(10,16)\ [0,471]}{0,548}\ CPI_t + \underset{(16,31)}{0,531}\ HYPI_t - \underset{(-1,42)}{5,611}\ D1_t \quad (4.15)$$

$\bar{R}^2 = 0,999$ $\quad d = 2,17$ $\quad F_{5,22} = 4491,70$ $\quad df = 22$

Table 4.1 continued

Fuel price index

$$FLPI_t = \underset{(2,13)}{302,26} - \underset{(-1,72)}{268,499}\left(\frac{QFUEL}{FLPI}\right)_t + \underset{(6,27)\ [1,183]}{1,523\ CPI_t} - \underset{(-2,44)}{70,825\ D1_t} \qquad (4.16)$$

$\bar{R}^2 = 0,924$ $\quad d = 0,80$ $\quad F_{3,24} = 110,33$ $\quad df = 24$

Packing materials price index

$$PMPI_t = \underset{(3,19)}{90,585} - \underset{(-3,37)}{179,699}\left(\frac{QPACK}{PMPI}\right)_t + \underset{(5,93)\ [1,323]}{0,819\ CPI_t} + \underset{(1,02)}{0,183\ PMPI_{t-1}} \qquad (4.17)$$

$\bar{R}^2 = 0,975$ $\quad h = 2,92$ $\quad F_{3,24} = 355,54$ $\quad df = 24$

Real fertiliser demand

$$\left(\frac{QFERT}{FTPI}\right)_t = \underset{(2,04)}{1,843} - \underset{(-1,74)\ [-0,042]}{1,296}\left(\frac{FTPI}{CPI}\right)_t + \underset{(4,64)}{0,101}\left(\frac{FCINC}{FCPI}\right)_t - \underset{(-2,66)}{0,465\ D1_t} \qquad (4.18)$$

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

Real dips and sprays demand

$$\left(\frac{QDIPS}{DSPI}\right)_t = \underset{(2,12)}{2,094} - \underset{(-3,09)\ [-0,349]}{1,768}\left(\frac{DSPI}{CPI}\right)_t + \underset{(1,16)}{5,885x10^{-2}}\left(\frac{LVINC}{LVPI}\right)_t - \underset{(-5,77)}{0,672\ D1_t} \qquad (4.19)$$

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

Real stock and poultry feed demand

$$\left(\frac{QFEED}{FDPI}\right)_t = \underset{(-0,72)}{-\ 0,575} - \underset{(-2,03)\ [-0,086]}{1,458}\left(\frac{FDPI}{CPI}\right)_t + \underset{(5,24)}{0,276}\left(\frac{LVINC}{LVPI}\right)_t + \underset{(1,26)}{1,057}\left(\frac{MZPI}{CPI}\right)_t - \underset{(-4,20)}{0,504\ D1_t} \qquad (4.20)$$

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

Real fuel demand

$$\left(\frac{QFUEL}{FLPI}\right)_t = \underset{(3,04)}{0,952} - \underset{(-2.03)\ [-0,176]}{0,231}\left(\frac{FLPI}{CPI}\right)_t + \underset{(2,06)}{1,831x10^{-2}}\left(\frac{AGINC}{AGPI}\right)_t - \underset{(-1,43)}{0,162\ D1_t} \qquad (4.21)$$

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

Table 4.1 continued

Real packing materials demand

$$\left(\frac{QPACK}{PMPI}\right)_t = \underset{(6,28)}{0,863} - \underset{\substack{(-4,96)\\[-0,108]}}{0,464}\left(\frac{PMPI}{CPI}\right)_t + \underset{(1,20)}{6,266\text{x}10^{-3}}\left(\frac{FCINC}{FCPI}\right)_t + \underset{(2,95)}{8,530\text{x}10^{-2}}\ D1_t \qquad (4.22)$$

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

Total real input demand

$$\left(\frac{TINPT}{TINPI}\right)_t = \left(\frac{QFERT}{FTPI}\right)_t + \left(\frac{QDIPS}{DSPI}\right)_t + \left(\frac{QFEED}{FDPI}\right)_t + \left(\frac{QFUEL}{FLPI}\right)_t + \left(\frac{QPACK}{PMPI}\right)_t \qquad (4.23)$$

Field crop sector

Real maize supply

$$\left(\frac{MZSS}{MZPI}\right)_t = \underset{(-0,78)}{-\ 3,284} + \underset{\substack{(0,48)\\[0,210]}}{0,966}\left(\frac{MZPI}{CPI}\right)_{t-1} \underset{\substack{(-1,05)\\[-0,032]}}{-\ 6,994\text{x}10^{-2}}\ RR_t + \underset{(1,75)}{1,520}\ MAP_t + \underset{(4,31)}{2,093}\ W_t -$$

$$\underset{(-0,97)}{0,440}\ D1_t \qquad (4.24)$$

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

Real per capita human maize demand

$$\left(\frac{MZDH}{MZPI}\right)_t = \underset{(3,32)}{7,578\text{x}10^{-2}} - \underset{\substack{(-1,91)\\[-0,441]}}{3,485\text{x}10^{-2}}\left(\frac{MZPI}{CPI}\right)_t \underset{(-1,22)}{-\ 1,144\text{x}10^{-3}}\left(\frac{PDY}{CPI}\right)_t + \underset{(3,77)}{0,546}\left(\frac{MZDH}{MZPI}\right)_{t-1} \qquad (4.25)$$

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

Real animal maize demand

$$\left(\frac{MZDA}{MZPI}\right)_t = \underset{(0,80)}{0,395} - \underset{\substack{(-2,98)\\[-1,168]}}{1,726}\left(\frac{MZPI}{CPI}\right)_t + \underset{\substack{(2,70)\\[0,383]}}{0,621}\left(\frac{BFPI}{CPI}\right)_t + \underset{\substack{(2,30)\\[0,856]}}{1,107}\left(\frac{FDPI}{CPI}\right)_t + \underset{(6,01)}{0,677}\left(\frac{MZDA}{MZPI}\right)_{t-1} \qquad (4.26)$$

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

Market equilibrium condition for maize

$$\left(\frac{MZSS}{MZPI}\right)_t + \left(\frac{MZM}{MZPI}\right)_t + \left(\frac{MZI}{MZPI}\right)_{t-1} = \left\{\left(\frac{MZDH}{MZPI}\right)_t * SAPOP_t\right\} + \left(\frac{MZDA}{MZPI}\right)_t + \left(\frac{MZX*XR}{MZXPI}\right)_t + \left(\frac{MZI}{MZPI}\right)_t \qquad (4.27)$$

Table 4.1 continued

Real sugar cane supply

$$\left(\frac{SCSS}{SCPI}\right)_t = -0,752 + 1,168\left(\frac{SCPI}{FTPI}\right)_{t-1} - 4,715x10^{-2}\,RR_t + 5,460\,SCAM_t \qquad (4.28)$$

(-2,48) (4,25) (-3,84) (8,26)
[0,007] [-0,044]

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

Real per capita sugar demand

$$\left(\frac{SGDD}{SCPI}\right)_t = 1,437x10^{-2} - 5,569x10^{-3}\left(\frac{SCPI}{CPI}\right)_t + 2,365x10^{-3}\left(\frac{PDY}{CPI}\right)_t + 0,543\left(\frac{SGDD}{SCPI}\right)_{t-1} \qquad (4.29)$$

(3,90) (-3,49) (5,19) (5,61)
[-0,147] [0,315]

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

Market equilibrium condition for sugar

$$\left\{\left(\frac{SCSS}{SCPI}\right)_t * SGSCR_t\right\} + \left(\frac{SGM}{SCPI}\right)_t + \left(\frac{SGI}{SCPI}\right)_{t-1} = \left\{\left(\frac{SGDD}{SCPI}\right)_t * SAPOP_t\right\} + \left(\frac{SGX*XR}{SGXPI}\right)_t + \left(\frac{SGI}{SCPI}\right)_t \qquad (4.30)$$

Real hay supply

$$\left(\frac{HYSS}{HYPI}\right)_t = -0,213 + 0,806\left(\frac{HYPI}{FTPI}\right)_{t-1} - 3,664x10^{-2}\,RR_t - 0,523\,D1_t + 0,528\left(\frac{HYSS}{HYPI}\right)_{t-1} \qquad (4.31)$$

(-0,68) (2,69) (-2,04) (-2,82) (-3,24)
[1,074] [-0,082]

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

Real hay demand

$$\left(\frac{HYDD}{HYPI}\right)_t = -1,503 - 0,954\left(\frac{HYPI}{CPI}\right)_t + 2,586\left(\frac{FDPI}{CPI}\right)_t + 0,507\left(\frac{BFPI}{CPI}\right)_t + 0,362\left(\frac{HYDD}{HYPI}\right)_{t-1} \qquad (4.32)$$

(-2,28) (-2,79) (3,11) (1,75) (1,87)
[-1,159] [1,230] [0,551]

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

Market equilibrium condition for hay

$$\left(\frac{HYSS}{HYPI}\right)_t + \left(\frac{HYI}{HYPI}\right)_{t-1} = \left(\frac{HYDD}{HYPI}\right)_t + \left(\frac{HYI}{HYPI}\right)_t \qquad (4.33)$$

Total real gross farm income in field crop sector

$$\left(\frac{FCINC}{FCPI}\right)_t = \left(\frac{MZSS}{MZPI}\right)_t + \left(\frac{SCSS}{SCPI}\right)_t + \left(\frac{HYSS}{HYPI}\right)_t \qquad (4.34)$$

Table 4.1 continued

Horticultural sector

Real per capita deciduous fruit demand

$$\left(\frac{DFDD}{DFPI}\right)_t = \underset{(5,75)}{4,906\text{x}10^{-2}} - \underset{(-8,95)\ [-0,865]}{6,067\text{x}10^{-2}}\left(\frac{DFPI}{CPI}\right)_t + \underset{(10,26)\ [2,110]}{6,487\text{x}10^{-3}}\left(\frac{STPI}{CPI}\right)_t + \underset{(2,41)\ [0,773]}{1,106\text{x}10^{-2}}\left(\frac{PDY}{CPI}\right)_t \quad (4.35)$$

$\bar{R}^2 = 0,908$ $\quad d = 2,05$ $\quad F3_{,24} = 78,74$ $\quad df = 24$

Market equilibrium condition for deciduous fruit

$$\left(\frac{DFSS}{DFPI}\right)_t + \left(\frac{DFM}{DFPI}\right)_t + \left(\frac{DFI}{DFPI}\right)_{t-1} = \left\{\left(\frac{DFDD}{DFPI}\right)_t * SAPOP_t\right\} + \left(\frac{DFX*XR}{DFXPI}\right)_t + \left(\frac{DFI}{DFPI}\right)_t \quad (4.36)$$

Real per capita citrus fruit demand

$$\left(\frac{CFDD}{CFPI}\right)_t = \underset{(4,47)}{1,192\text{x}10^{-2}} - \underset{(-2,59)\ [-1,093]}{8,854\text{x}10^{-3}}\left(\frac{CFPI}{CPI}\right)_t + \underset{(2,87)\ [0,752]}{1,008\text{x}10^{-3}}\left(\frac{PDY}{CPI}\right)_t \quad (4.37)$$

$\bar{R}^2 = 0,192$ $\quad d = 1,58$ $\quad F_{4,23} = 2,84$ $\quad df = 23$

Market equilibrium condition for citrus fruit

$$\left(\frac{CFSS}{CFPI}\right)_t + \left(\frac{CFM}{CFPI}\right)_t + \left(\frac{CFI}{CFPI}\right)_{t-1} = \left\{\left(\frac{CFDD}{CFPI}\right)_t * SAPOP_t\right\} + \left(\frac{CFX*XR}{CFXPI}\right)_t + \left(\frac{CFI}{CFPI}\right)_t \quad (4.38)$$

Real vegetable supply

$$\left(\frac{VGSS}{VGPI}\right)_t = \underset{(1,26)}{0,410} + \underset{(1,27)\ [0,194]}{0,238}\left(\frac{VGPI}{CPI}\right)_{t-1} - \underset{(-2,26)\ [-0,225]}{0,302}\left(\frac{PTPI}{CPI}\right)_t - \underset{(-2,69)}{0,198}\ D1_t + \underset{(5,72)}{0,773}\left(\frac{VGSS}{VGPI}\right)_{t-1} \quad (4.39)$$

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

Real per capita vegetable demand

$$\left(\frac{VGDD}{VGPI}\right)_t = \underset{(10,12)}{7,507\text{x}10^{-2}} - \underset{(-8,41)\ [-1,038]}{5,371\text{x}10^{-2}}\left(\frac{VGPI}{CPI}\right)_t + \underset{(4,24)\ [0,467]}{2,293\text{x}10^{-3}}\left(\frac{PDY}{CPI}\right)_t - \underset{(-2,94)}{4,462\text{x}10^{-3}}\ D1_t - \underset{(-1,76)}{0,181}\left(\frac{VGDD}{VGPI}\right)_{t-1} \quad (4.40)$$

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

Table 4.1 continued

Market equilibrium condition for vegetables

$$\left(\frac{VGSS}{VGPI}\right)_t + \left(\frac{VGM}{VGPI}\right)_t + \left(\frac{VGI}{VGPI}\right)_{t-1} = \left\{\left(\frac{VGDD}{VGPI}\right)_t * SAPOP_t\right\} + \left(\frac{VGX}{VGPI}\right)_t + \left(\frac{VGI}{VGPI}\right)_t \qquad (4.41)$$

Real potato supply

$$\left(\frac{PTSS}{PTPI}\right)_t = \underset{(-2,29)}{-\ 0,506} + \underset{\substack{(2,30)\\[0,623]}}{0,472}\left(\frac{VGPI}{FTPI}\right)_{t-1} \underset{\substack{(-0,64)\\[-0,023]}}{-\ 6,813\times10^{-3}\ RR_t} + \underset{(2,60)}{1,148\times10^{-2}\ PAP_t} +$$

$$\underset{(1,72)}{0,359}\left(\frac{PTSS}{PTPI}\right)_{t-1} \qquad (4.42)$$

$\bar{R}^2 = 0,571 \qquad d = 2,53 \qquad F_{4,23} = 8,69 \qquad df = 23$

Real per capita potato demand

$$\left(\frac{PTDD}{PTPI}\right)_t = \underset{(3,22)}{1,629\times10^{-2}} \underset{\substack{(-5,22)\\[-0,765]}}{-\ 2,218\times10^{-2}}\left(\frac{PTPI}{CPI}\right)_t + \underset{\substack{(6,44)\\[1,279]}}{4,499\times10^{-3}}\left(\frac{PDY}{CPI}\right)_t \underset{(-1,85)}{-\ 0,216}\left(\frac{PTDD}{PTPI}\right)_{t-1} \qquad (4.43)$$

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

Market equilibrium condition for potatoes

$$\left(\frac{PTSS}{PTPI}\right)_t + \left(\frac{PTM}{PTPI}\right)_t + \left(\frac{PTI}{PTPI}\right)_{t-1} = \left\{\left(\frac{PTDD}{PTPI}\right)_t * SAPOP_t\right\} + \left(\frac{PTX}{PTPI}\right)_t + \left(\frac{PTI}{PTPI}\right)_t \qquad (4.44)$$

Total real gross farm income in horticultural sector

$$\left(\frac{HTINC}{HTPI}\right)_t = \left(\frac{DFSS}{DFPI}\right)_t + \left(\frac{CFSS}{CFPI}\right)_t + \left(\frac{VGSS}{VGPI}\right)_t + \left(\frac{PTSS}{PTPI}\right)_t \qquad (4.45)$$

Livestock sector

Real beef supply

$$\left(\frac{BFSS}{BFPI}\right)_t = \underset{(-0,52)}{-\ 0,567} + \underset{\substack{(3,20)\\[0,195]}}{0,627}\left(\frac{BFPI}{DSPI}\right)_{t-1} + \underset{\substack{(4,76)\\[0,055]}}{7,773\times10^{-2}\ RR_t} + \underset{(1,68)}{0,145\ CNW_t} \underset{(-1,32)}{-\ 0,240\ D1_t} +$$

$$\underset{(1,70)}{0,235}\left(\frac{BFSS}{BFPI}\right)_{t-1} \qquad (4.46)$$

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

Table 4.1 continued

Real per capita beef demand

$$\left(\frac{BFDD}{BFPI}\right)_t = \underset{(3,69)}{0,125} - \underset{(-4,87)\ [-0,508]}{0,130}\left(\frac{BFPI}{CPI}\right)_t + \underset{(3,14)\ [0,436]}{1,486\times10^{-3}}\left(\frac{PDY}{CPI}\right)_t + \underset{(4,08)\ [0,486]}{0,119}\left(\frac{CHPI}{CPI}\right)_t + \underset{(1,72)}{0,842}\ D1_t \qquad (4.47)$$

$\bar{R}^2 = 0,496$ $\quad d = 1,34$ $\quad F_{4,23} = 6,65$ $\quad df = 23$

Market equilibrium condition for beef

$$\left(\frac{BFSS}{BFPI}\right)_t + \left(\frac{BFM}{BFPI}\right)_t + \left(\frac{BFI}{BFPI}\right)_{t-1} = \left\{\left(\frac{BFDD}{BFPI}\right)_t * SAPOP_t\right\} + \left(\frac{BFX}{BFPI}\right)_t + \left(\frac{BFI}{BFPI}\right)_t \qquad (4.48)$$

Real mutton supply

$$\left(\frac{MTSS}{MTPI}\right)_t = \underset{(-2,32)}{-1,452} + \underset{(3,81)\ [0,356]}{0,601}\left(\frac{MTPI}{DSPI}\right)_{t-1} + \underset{(1,99)\ [0,025]}{1,659\times10^{-2}}\ RR_t + \underset{(2,98)}{3,517\times10^{-2}}\ SNW_t +$$

$$\underset{(5,90)}{0,842}\left(\frac{MTSS}{MTPI}\right)_{t-1} \qquad (4.49)$$

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

Real per capita mutton demand

$$\left(\frac{MTDD}{MTPI}\right)_t = \underset{(8,43)}{8,980\times10^{-2}} - \underset{(-6,78)\ [-0,805]}{9,488\times10^{-2}}\left(\frac{MTPI}{CPI}\right)_t + \underset{(5,16)\ [0,724]}{1,020\times10^{-2}}\left(\frac{PDY}{CPI}\right)_t + \underset{(6,06)}{2,098\times10^{-2}}\ D1_t \qquad (4.50)$$

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

Market equilibrium condition for mutton

$$\left(\frac{MTSS}{MTPI}\right)_t + \left(\frac{MTM}{MTPI}\right)_t + \left(\frac{MTI}{MTPI}\right)_{t-1} = \left\{\left(\frac{MTDD}{MTPI}\right)_t * SAPOP_t\right\} + \left(\frac{MTX}{MTPI}\right)_t + \left(\frac{MTI}{MTPI}\right)_t \qquad (4.51)$$

Real pork supply

$$\left(\frac{PKSS}{PKPI}\right)_t = \underset{(-2,77)}{-0,379} + \underset{(2,70)\ [0,506]}{0,328}\left(\frac{PKPI}{FDPI}\right)_{t-1} + \underset{(1,98)\ [0,034]}{7,788\times10^{-3}}\ RR_t + \underset{(3,16)}{3,878\times10^{-4}}\ PNW_t +$$

$$\underset{(3,54)}{0,552}\left(\frac{PKSS}{PKPI}\right)_{t-1} \qquad (4.52)$$

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

Table 4.1 continued

Real per capita pork demand

$$\left(\frac{PKDD}{PKPI}\right)_t = \underset{(3,88)}{1,788\text{x}10^{-2}} - \underset{\substack{(-2,86)\\[-0,539]}}{1,879\text{x}10^{-2}}\left(\frac{PKPI}{CPI}\right)_t + \underset{\substack{(2,79)\\[0,357]}}{1,610\text{x}10^{-3}}\left(\frac{PDY}{CPI}\right)_t + \underset{\substack{(1,25)\\[0,195]}}{7,367\text{x}10^{-3}}\left(\frac{MTPI}{CPI}\right)_t + \underset{(2,30)}{0,390}\left(\frac{PKDD}{PKPI}\right)_{t-1} \quad (4.53)$$

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

Market equilibrium condition for pork

$$\left(\frac{PKSS}{PKPI}\right)_t + \left(\frac{PKM}{PKPI}\right)_t + \left(\frac{PKI}{PKPI}\right)_{t-1} = \left\{\left(\frac{PKDD}{PKPI}\right)_t * SAPOP_t\right\} + \left(\frac{PKX}{PKPI}\right)_t + \left(\frac{PKI}{PKPI}\right)_t \quad (4.54)$$

Total real gross farm income in red meat sector

$$\left(\frac{RMINC}{RMPI}\right)_t = \left(\frac{BFSS}{BFPI}\right)_t + \left(\frac{MTSS}{MTPI}\right)_t + \left(\frac{PKSS}{PKPI}\right)_t \quad (4.55)$$

Real chicken meat supply

$$\left(\frac{CHSS}{CHPI}\right)_t = \underset{(-3,88)}{-0,951} + \underset{\substack{(4,54)\\[0,747]}}{1,232}\left(\frac{CHPI}{DSPI}\right)_{t-1} + \underset{(14,40)}{0,836}\left(\frac{CHSS}{CHPI}\right)_{t-1} \quad (4.56)$$

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

Real per capita chicken meat demand

$$\left(\frac{CHDD}{CHPI}\right)_t = \underset{(2,31)}{8,543\text{x}10^{-2}} - \underset{\substack{(-2,38)\\[-1,265]}}{7,549\text{x}10^{-2}}\left(\frac{CHPI}{CPI}\right)_t + \underset{\substack{(0,83)\\[0,512]}}{4,267\text{x}10^{-3}}\left(\frac{PDY}{CPI}\right)_t + \underset{\substack{(1,36)\\[0,635]}}{3,970\text{x}10^{-2}}\left(\frac{BFPI}{CPI}\right)_t - \underset{(-5,36)}{4,428\text{x}10^{-2}}\,D1_t \quad (4.57)$$

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

Market equilibrium condition for chicken meat

$$\left(\frac{CHSS}{CHPI}\right)_t + \left(\frac{CHM}{CHPI}\right)_t + \left(\frac{CHI}{CHPI}\right)_{t-1} = \left\{\left(\frac{CHDD}{CHPI}\right)_t * SAPOP_t\right\} + \left(\frac{CHX}{CHPI}\right)_t + \left(\frac{CHI}{CHPI}\right)_t \quad (4.58)$$

Table 4.1 continued

Real wool supply

$$\left(\frac{WLSS}{WLPI}\right)_t = \underset{(-2,31)}{-0,870} + \underset{(3,11)\ [0,312]}{0,328}\left(\frac{WLPI}{DSPI}\right)_{t-1} \underset{(-3,51)\ [-0,602]}{-0,946}\left(\frac{MTPI}{CPI}\right)_t + \underset{(5,76)}{6,611\times10^{-2}}\ WSNW_t +$$

$$\underset{(1,98)}{0,271}\left(\frac{WLSS}{WLPI}\right)_{t-1} \qquad (4.59)$$

$\bar{R}^2 = 0,891$ $\quad h = 1,26$ $\quad F_{4,23} = 40,78$ $\quad df = 23$

Real per capita wool demand

$$\left(\frac{WLDD}{WLPI}\right)_t = \underset{(2,47)}{3,311\times10^{-2}} \underset{(-2,82)\ [-1,093]}{-2,961\times10^{-2}}\left(\frac{WLPI}{CPI}\right)_t \underset{(-4,56)}{-0,936}\left(\frac{WLDD}{WLPI}\right)_{t-1} \qquad (4.60)$$

$\bar{R}^2 = 0,918$ $\quad h = 1,13$ $\quad F_{4,23} = 87,86$ $\quad df = 23$

Market equilibrium condition for wool

$$\left(\frac{WLSS}{WLPI}\right)_t + \left(\frac{WLM}{WLPI}\right)_t + \left(\frac{WLI}{WLPI}\right)_{t-1} = \left\{\left(\frac{WLDD}{WLPI}\right)_t * SAPOP_t\right\} + \left(\frac{WLX*XR}{WLXPI}\right)_t + \left(\frac{WLI}{WLPI}\right)_t \qquad (4.61)$$

Total real gross farm income in livestock sector

$$\left(\frac{LVINC}{LVPI}\right)_t = \left(\frac{RMINC}{RMPI}\right)_t + \left(\frac{CHSS}{CHPI}\right)_t + \left(\frac{WLSS}{WLPI}\right)_t \qquad (4.62)$$

Total real gross farm income in the sectors modelled

$$\left(\frac{AGINC}{AGPI}\right)_t = \left(\frac{FCINC}{FCPI}\right)_t + \left(\frac{HTINC}{HTPI}\right)_t + \left(\frac{LVINC}{LVPI}\right)_t \qquad (4.63)$$

Total nominal gross farm income in the sectors modelled

$$AGINC_t = \left(\frac{AGINC}{AGPI}\right)_t * AGPI_t \qquad (4.64)$$

Real agricultural investment

$$\left(\frac{AGINV}{AIPI}\right)_t = \underset{(1,65)}{1,650} \underset{(-1,89)\ [-0,444]}{-1,524}\left(\frac{AIPI}{CPI}\right)_t \underset{(-1,36)\ [-0,036]}{-5,532\times10^{-2}}\ RR_t + \underset{(1,56)\ [0,613]}{8,906\times10^{-2}}\left(\frac{AGINC}{AGPI}\right)_t +$$

$$\underset{(6,68)}{0,763}\left(\frac{AGINV}{AIPI}\right)_{t-1} \qquad (4.65)$$

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

Table 4.1 continued

National accounting identities

Real total personal consumption expenditure

$$\left(\frac{TPCE}{CPI}\right)_t = \left\{\left(\frac{MANDD}{MANPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{MZDD}{MZPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{SGDD}{SCPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{DFDD}{DFPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{CFDD}{CFPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{VGDD}{VGPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{PTDD}{PTPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{BFDD}{BFPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{MTDD}{MTPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{PKDD}{PKPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{CHDD}{CHPI}\right)_t * SAPOP_t\right\} + \left\{\left(\frac{WLDD}{WLPI}\right)_t * SAPOP_t\right\} + \left(\frac{TPCE}{CPI}\right)'_t \quad (4.66)$$

Real gross domestic fixed investment

$$\left(\frac{GDFI}{CPI}\right)_t = \left(\frac{AGINV}{AIPI}\right)_t + \left(\frac{GDFI}{CPI}\right)'_t \quad (4.67)$$

Real net exports

$$\left(\frac{NXPT}{CPI}\right)_t = \left(\frac{MZNX}{MZPI}\right)_t + \left(\frac{SGNX}{SCPI}\right)_t + \left(\frac{DFNX}{DFPI}\right)_t + \left(\frac{CFNX}{CFPI}\right)_t + \left(\frac{WLNX}{WLPI}\right)_t - \left(\frac{MANNM}{MNMPI}\right)_t + \left(\frac{NXPT}{CPI}\right)'_t \quad (4.68)$$

Real gross domestic product

$$\left(\frac{GDP}{CPI}\right)_t = \left(\frac{TPCE}{CPI}\right)_t + \left(\frac{GDFI}{CPI}\right)_t + \left(\frac{GOVT}{CPI}\right)_t + \left(\frac{NXPT}{CPI}\right)_t \quad (4.69)$$

Variable	Units	Variable description	Source
		Endogenous variables	
Ms_t	R mil.	Nominal money supply (M2)	SARB
Md_t	R mil.	Nominal money demand (M2)	SARB
TBR_t	Percent	Treasury bill rate	IFS
R_t	Percent	Prime overdraft rate of major commercial banks	SARB
RR_t	percent	Real prime overdraft rate	Calculated
CPI_t	Index	Consumer price index	AAS
XR_t	R/SDR	Exchange rate of the South African rand in terms of special drawing rights	IFS
BoP_t	R mil.	Balance of payments on the current account	SARB
GDP_t	R mil.	Gross domestic product	SARB
$RGDP_t$	R mil.	Real gross domestic product	SARB
$TPCE_t$	R mil.	Total personal consumption expenditure	SARB
$GDFI_t$	R mil.	Gross domestic fixed investment	SARB

Table 4.1 continued

Variable	Units	Variable description	Source
$NXPT_t$	R mil.	Net exports of goods and services	SARB
$MANSS_t$	R mil.	Gross value of manufacturing supply	Calculated
$MANDD_t$	R mil.	Gross value of per capita manufactured goods demand	SAS
$MANPI_t$	Index	Price index of all consumer goods excluding food	SAS
$MANNM_t$	R mil.	Gross value of net import demand for manufactured goods	SAS
$FTPI_t$	Index	Fertiliser price index	AAS
$DSPI_t$	Index	Dips and sprays price index	AAS
$FDPI_t$	Index	Stock and poultry feed price index	AAS
$FLPI_t$	Index	Fuel price index	AAS
$PMPI_t$	Index	Packing materials price index	AAS
$QFERT_t$	R mil.	Gross value of fertilisers purchased	AAS
$QDIPS_t$	R mil.	Gross value of dips and sprays purchased	AAS
$QFEED_t$	R mil.	Gross value of stock and poultry feed purchased	AAS
$QFUEL_t$	R mil.	Gross value of fuel purchased	AAS
$QPACK_t$	R mil.	Gross value of packaging purchased	AAS
$TINPT_t$	R mil.	Total gross value of inputs purchased	AAS
$TINPI_t$	Index	Aggregate input price index	AAS
$MZSS_t$	R mil.	Gross value of maize production	AAS
$MZDH_t$	R mil.	Gross value of per capita human maize consumption	MB
$MZDA_t$	R mil.	Gross value of animal maize consumption	MB
$MZPI_t$	Index	Maize producer price index	AAS
$SCSS_t$	R mil.	Gross value of sugarcane production	AAS
$SGDD_t$	R mil.	Gross value of per capita sugar consumption	SASA
$SCPI_t$	Index	Sucrose price index	SASA
$HYSS_t$	R mil.	Gross value of hay production	AAS
$HYDD_t$	R mil.	Gross value of hay consumption	AAS
$HYPI_t$	Index	Hay price index	AAS
$FCINC_t$	R mil.	Total gross farm income in the field crop sector	Calculated
$VGSS_t$	R mil.	Gross value of vegetable production	AAS
$VGDD_t$	R mil.	Gross value of per capita vegetable consumption	AAS
$VGPI_t$	Index	Vegetable market price index	AAS
$PTSS_t$	R mil.	Gross value of potato production	AAS
$PTDD_t$	R mil.	Gross value of per capita potato consumption	AAS
$PTPI_t$	Index	Potato market price index	AAS
$HTINC_t$	Index	Total gross farm income in the horticultural sector	Calculated
$BFSS_t$	R mil.	Gross value of beef production	AAS
$BFDD_t$	R mil.	Gross value of per capita beef consumption	AAS
$BFPI_t$	Index	Beef auction price index	AAS
$MTSS_t$	R mil.	Gross value of mutton production	AAS
$MTDD_t$	R mil.	Gross value of per capita mutton consumption	AAS
$MTPI_t$	Index	Mutton auction price index	AAS
$PKSS_t$	R mil.	Gross value of pork production	AAS
$PKDD_t$	R mil.	Gross value of per capita pork consumption	AAS
$PKPI_t$	Index	Pork auction price index	AAS
$RMINC_t$	R mil.	Total gross farm income in the red meat sector	Calculated
$CHSS_t$	R mil.	Gross value of chicken meat production	AAS
$CHDD_t$	R mil.	Gross value of per capita chicken meat consumption	AAS

Table 4.1 continued

Variable	Units	Variable description	Source
$CHPI_t$	Index	Chicken meat price	AAS
$WLSS_t$	R mil.	Gross value of wool production	AAS
$WLDD_t$	R mil.	Gross value of per capita wool consumption	AAS
$WLPI_t$	Index	Wool auction price index	AAS
$LVINC_t$	R mil.	Total gross farm income in the livestock sector	Calculated
$AGINC_t$	R mil.	Total gross farm income in the sectors modelled	AAS
$AGINV_t$	R mil.	Gross value of agricultural investment	SARB
		Exogenous Variables	
B_t	R mil.	Monetary base	SARB
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	
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	
BoP'_t	R mil.	Balance of payments on the current account not determined in model	
Ms^f_t	Index	Money supply in the rest of the world	IFS
TBR^f_t	Percent	Treasury bill rate in the U.S.	IFS
GDP^f_t	Index	Real gross national product in the world	IFS
$TPCE'_t$	R mil.	Real total personal consumption expenditure not determined in model	SARB
$GDFI'_t$	R mil.	Real gross domestic fixed investment not determined in model	SARB
$NXPT'_t$	R mil.	Real net exports of goods and services not determined in model	SARB
$GOVT_t$	R mil.	Real government consumption expenditure	SARB
PDY_t	R mil.	Per capita personal disposable income	SARB
$MNMPI_t$	Index	Price index of imported manufactured goods	SAS
$SAPOP_t$	millions	Human population of South Africa	AAS
MZI_t	R mil.	Gross value of maize inventories	MB
MZX_t	R mil./XR_t	Gross foreign currency value of maize exports	MB
$MZNX_t$	R mil.	Gross value of maize net exports	MB
MZM_t	R mil.	Gross value of maize imports	MB
$MZXPI_t$	Index	Maize export price (unit value) index	MB
$SGSCR_t$	Ratio	Sugar to sugar cane ratio	SASA
SGI_t	R mil.	Gross value of sugar inventories	SASA
SGX_t	R mil./XR_t	Gross value foreign currency value of sugar exports	SASA
$SGNX_t$	R mil.	Gross value of sugar net exports	SASA
SGM_t	R mil.	Gross value of sugar imports	SASA
$SGXPI_t$	Index	Sugar export price (unit value) index	SASA
HYI_t	R mil.	Gross value of hay inventories	Calculated
DFI_t	R mil.	Gross value of deciduous fruit inventories	DFB

Table 4.1 continued

Variable	Units	Variable description	Source
DFX_t	R mil./XR_t	Gross foreign currency value of deciduous fruit exports	DFB
$DFNX_t$	R mil.	Gross value of deciduous fruit net exports	DFB
DFM_t	R mil.	Gross value of deciduous fruit imports	DFB
$DFXPI_t$	Index	Deciduous fruit export (unit value) price index	DFB
CFI_t	R mil.	Gross value of citrus fruit inventories	CFB
CFX_t	R mil./XR_t	Gross foreign currency value of citrus fruit exports	CFB
$CFNX_t$	R mil.	Gross value of citrus fruit net exports	CFB
CFM_t	R mil.	Gross value of citrus fruit imports	CFB
CFXPIt	Index	Citrus fruit export price (unit value) index	CFB
VGI_t	R mil.	Gross value of vegetable inventories	Calculated
VGX_t	R mil.	Gross value of vegetable exports	Calculated
VGM_t	R mil.	Gross value of vegetable imports	Calculated
PTI_t	R mil.	Gross value of potato inventories	Calculated
PTX_t	R mil.	Gross value of potato exports	Calculated
PTM_t	R mil.	Gross value of potato imports	Calculated
BFI_t	R mil.	Gross value of beef inventories	MTB
BFX_t	R mil.	Gross value of beef exports	MTB
BFM_t	R mil.	Gross value of beef imports	MTB
MTI_t	R mil.	Gross value of mutton inventories	MTB
MTX_t	R mil.	Gross value of mutton exports	MTB
MTM_t	R mil.	Gross value of mutton imports	MTB
PKI_t	R mil.	Gross value of pork inventories	MTB
PKX_t	R mil.	Gross value of pork exports	MTB
PKM_t	R mil.	Gross value of pork imports	MTB
CHI_t	R mil.	Gross value of chicken meat inventories	Calculated
CHX_t	R mil.	Gross value of chicken meat exports	Calculated
CHM_t	R mil.	Gross value of chicken meat imports	Calculated
WLI_t	R mil.	Gross value of wool inventories	SAWB
WLX_t	R mil./XR_t	Gross foreign currency value of wool exports	SAWB
$WLNX_t$	R mil.	Gross value of wool net exports	SAWB
WLM_t	R mil.	Gross value of wool imports	SAWB
$WLXPI_t$	Index	Wool export price index	SAWB
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
$STPI_t$	Index	Price index of sub-tropical fruits	SAS
PAP_t	mil. ha	Potato area planted	PB
CNW_t	millions	National cattle numbers on commercial farms	AAS
SNW_t	millions	National sheep numbers on commercial farms	AAS
PNW_t	millions	National pig numbers on commercial farms	AAS
$WSNW_t$	millions	National wool sheep numbers on commercial farms	AAS
$AIPI_t$	Index	Price index of agricultural capital goods	AAS

Sources: Directorate Agricultural Economic Trends (AAS), Central Statistical Service (SAS), Maize Board (MB), South African Sugar Association (SASA), Deciduous Fruit Board (DFB), Citrus Fruit Board (CFB), Potato Board (PB), Meat Board (MTB), South African Wool Board (SAWB), South African Reserve Bank (SARB), International Monetary Fund (IFS).

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 hypothesises that the reason for this has been the emergence of a growing number of alternative interest bearing liquid assets. This, combined with increased inflation, has caused money-holders to reduce money-holdings and invest in interest-bearing liquid assets. The holding of money just sufficient to cover transaction requirements neutralises the effect of the interest rate on the transactions demand for money. In addition, monetary policy which has maintained negative real interest rates and allowed liquidity to increase may have led to interest rates having no discernable effect on money demand. This may be responsible for the price level and real income playing a more important role in determining the demand for real money balances.

The treasury bill rate equation achieves a good statistical fit. The $\overline{R}^2$ is 83,8 percent and all coefficients are significant at the five percent level. The treasury bill rate is explained by money supply, real gross domestic product, dummy variable $MD1_t$ and lagged treasury bill rate. The dummy variable $MD1_t$ differentiates between the periods before and after the adoption of the De Kock Commission recommendations. The general price level was dropped from the equation as the correct positive sign could not be obtained. The elasticity of treasury bill rate with respect to money supply is inelastic (-0,267). This supports the conclusion that the relationship between interest rates and money supply in South Africa is weak.

The nominal prime overdraft rate is estimated as a function of a distributed lag of the treasury bill rate. The lagged treasury bill rate is contained in an interaction term with $MD1_t$. The elasticity of overdraft rate with respect to treasury bill rate is 0,856 indicating that the overdraft rate follows market interest rates closely.

4.3.1.2 Foreign exchange market.

Estimation of the rand exchange rate must describe exchange rate movements during the period of fixed exchange rates (1960-1971) and flexible/managed float exchange rates (1972-1987). To capture these different exchange rate regimes in one behavioural equation, the rand exchange rate was estimated using the grafted polynomial technique developed by Fuller (1976, pp.393-397).

The grafted polynomial technique is employed when the use of higher order polynomials is to be avoided. Higher order polynomials may produce a good statistical fit, but the function may be unsatisfactory in that it contains a large number of changes in the sign of the derivative. Instead of approximating different segments of the function with higher order polynomials, these segments are approximated by low order polynomials and these segments are then joined together so that a continuous line is obtained. The function is then called a grafted polynomial.

The technique is used to explain movements in the exchange rate over three different time periods,

i) 1960 - 1971: fixed exchange rate,

ii) 1972 - 1978: flexible/pegged exchange rates, and,

iii) 1979 - 1987: managed float as recommended by the De Kock Commission.

A grafted polynomial variable, π_t , joins the three segments together to form a continuous function. Values assigned to π_t for each period were,

1960 - 1971, $\pi_t = 0$,

1972 - 1978, $\pi_t = 1$, and,

1979 - 1987, $\pi_t = 2$.

Defined as zero in the period of fixed exchange rates, π_t explains movements in the rand exchange rate only after 1971. Movements in each period are explained when π_t is included as a separate regressor and all explanatory variables are multiplied by π_t. The rand exchange rate, XR_t, is estimated as,

$$XR_t = f_7\left[\pi_t,\ Ms_t * \pi_t,\ Ms_t^f * \pi_t,\ TBR_t * \pi_t,\ TBR_t^f * \pi_t,\ \left[\frac{GDP}{CPI}\right]_t * \pi_t,\ \left[\frac{GDP^f}{CPI^f}\right]_t * \pi_t,\ e_{7,t}\right] \quad (4.1)$$

Results show that all coefficient signs agree with the monetarist specification and are significant at the five percent level except for domestic real gross domestic product which is significant at the 13 percent level.

Actual t-statistics are adjusted for degrees of freedom as all explanatory variables have zero values for the period 1960-1971. Each t-statistics is adjusted by the factor $\sqrt{(n_1\text{-}k_1/n\text{-}k)}$, where (n-k) is the original degrees of freedom, and $(n_1\text{-}k_1)$ is the adjusted degrees of freedom. The adjusted and adjusted degrees of freedom are 20 and 8 respectively, as $n = 28$, $n_1 = 16$, $k = 8$ and $k_1 = 8$.

Adjusted t-statistics are reported below the actual t-statistics in table 4.1. The adjusted t-statistics show that all coefficients are significant at the five percent level except for those of the domestic interest rate and gross domestic product variables.

The elasticity of the rand exchange rate with respect to money supply is 0,894. This implies that a one percent increase in domestic money supply will lead to a 0,894 percent depreciation in the value of the rand against the SDR.

4.3.1.3 General price level

The general price level equation has an excellent statistical fit ($\overline{R}^2$ of 99,9 percent). Results indicate a strong relationship between the general price level and ratio of money supply to real income. This simulates the linkage between monetary policy and the general price level. Inclusion of the dummy variable *D1*, (1960-1973=0, 1974-1987=1) in the equation improves goodness of fit as the variable captures the substantially greater rate of increase in prices since 1973.

4.3.1.4 Manufacturing sector

The two behavioural equations representing the manufacturing sector have good statistical fits. All coefficients are significant at the five percent level and have the correct signs.

The price variable used in the real per capita manufactured goods demand equation is the consumer price index of all items excluding food. Attempts to fit the manufactured goods and production price indices published by the Central Statistical Service were not successful.

Real per capita manufactured goods demand is represented by real gross value of sales of manufactured goods divided by total South African population. The equation fits the data well ($\overline{R}^2$ of 83,48 percent), and the coefficients are all highly significant.

Real net import demand for manufactured goods is explained by the real price of imported manufactured production goods, exchange rate, real gross domestic product, and lagged real net import demand for manufactured goods. Although the $\overline{R}^2$ is only 42,13 percent, all coefficients are significant at the one percent level except for real price, which is significant at the five percent level.

The negative exchange rate coefficient shows the effect of a depreciating exchange rate on the price of imports, and resulting reduction in demand. Inclusion of real gross domestic product shows how increasing real incomes raise import demand. This reflects the monetarist view that in the short run, an expansionary monetary policy causes real incomes to rise, which causes consumer spending on domestic and imported goods to increase. This puts upward pressure on prices, causing them to rise relative to foreign prices, and thus causing the exchange rate to depreciate. Increased demand for foreign goods causes the exchange rate to depreciate as cash-holders convert domestic currency into foreign currency in order to make cheaper purchases abroad (Humphrey and Keleher, 1982, p.256).

4.3.1.5 Input price and real demand equations

The input price equations achieve good statistical fit as evidenced by high $\bar{R}^2$ statistics. Most coefficients are significant at the one percent level. The fertiliser, dips and sprays, and stock and poultry feed price determination equations all include the general price level and rand exchange rate with positive signs. This correctly simulates the inflation and exchange rate linkages. An increase in the general price or depreciation of the exchange rate will raise input prices. The fuel and packing materials price determination equations do not include the exchange rate due to wrong coefficient signs.

Coefficients in the real input demand equations all have correct signs. Real demand for each input is a function of real own price and real income in the sector which mainly uses the input. Difficulties in obtaining statistically significant coefficients for total real farm income necessitated use of real gross farm income in individual sectors. Real demand for fertiliser and packing materials are a function of real income in the field crop sector. Real demand for dips and sprays and stock and poultry feed are a function of real income in the livestock sector.

4.3.2 Agricultural sector

All real supply equations include indices of lagged own producer prices deflated by the relevant input price. Input price indices are used as deflators of producer price indices rather than as separate regressors to reduce multicollinearity. Generally, this resulted in more significant coefficients together with the correct sign. 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 price indices were deflated by the fertiliser price index. Beef, mutton and chicken meat price indices were deflated by the dips and sprays price index and pork price

index by the stock and poultry feed price index. The input price indices reflect the primary input used in each sector, except for poultry where the stock and poultry feed price index yielded the wrong sign, necessitating use of the dips and sprays price index.

All real supply equations, except for vegetables, chicken meat and wool, contain the real prime overdraft rate 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 beef, mutton and pork supply equations have positive signs representing stock effects of real short-term interest rates. All real interest rate elasticities are small (less than 0,10).

All real per capita demand equations, except for wool, include real per capita personal disposable income. This simulates the impact of real income on agricultural product demand. The income coefficient in the real per capita wool demand equation was negative and therefore dropped from the equation. The inability to establish the correct positive relationship between real per capita wool demand and real income is not totally unexpected given that most of the South African wool clip is purchased by foreigns buyers and therefore influenced very little by domestic demand.

4.3.2.1 Field crop sector

The best real maize supply equation fit was obtained with lagged maize producer price index (deflated by the fertiliser price index), maize area planted, a rainfall dummy (W_t) and real interest rate. The real price elasticity of real maize supply is 0,210, indicating an inelastic response of maize production to changes in the real maize producer price. The real interest rate elasticity of real maize supply is inelastic (-0,059). Devadoss (1985) obtained a similar result for U.S. crop supply (-0,11). The real interest rate coefficient is significant at the one percent level.

The dummy variable W_t indicating years of good and bad rainfall was constructed from data provided by the Computing Centre for Water Research, University of Natal, Pietermaritzburg. The critical growth period for maize occurs during the months of December and January. To counter the problem of annual rainfall data not reflecting distribution throughout the year, rainfall data for these two months was used to construct W_t. Rainfall data was collated from a sample of 38 weather stations situated in major maize growing areas. The median rainfall for the two months was determined as the point differentiating between good (above median) and drought (below median) years. The t-statistic (4,31) indicates that rainfall has a statistically significant impact on maize production.

Attempts to include real price indices of substitute crops (soya beans, groundnuts, sunflowers and sorghum) as determinants of real maize supply were not successful. This supports the findings of Cadiz (1984).

An alternative maize supply function specifying planning decisions of maize farmers in terms of the Nerlove lag model was not successful. No statistically significant coefficients were obtained using either lagged real maize prices, returns per hectare or profit per hectare as explanatory variables. This finding agrees with that of Cadiz (1984). Maize area planted data showed very little year to year variation, which may explain why statistically significant coefficients could not be estimated.

The best fitting real per capita human maize demand equation included the real maize price index, real per capita disposable income and lagged real per capita human maize demand. Coefficients of the real bread, rice and potato price indices were not significant and these variables were therefore dropped from the equation. The real per capita disposable income coefficient is negative, indicating that maize is an inferior good. This supports the findings of van Zyl (1986a) and Cadiz (1984). The price elasticity of demand estimate is -0,441 which is similar to estimates reported by Cadiz (-0,38) and van Zyl (-0,299).

Some 83,1 percent of the variation is explained by the selected variables. Inclusion of the real beef price index simulates the derived demand for maize as animal feed. The estimated price elasticity of animal maize demand is -1,17 which is similar to those obtained by Nieuwoudt (-0,70 to -1,76) and van Zyl (-1,29 to -1,56). The real stock and poultry feed price index has statistically significant positive influence on real animal maize demand, indicating it is a substitute feed source.

The very small estimated price elasticity of real sugar supply of 0,007 is expected as sugar cane is grown under quota. The real interest rate elasticity is -0,044. The price and income elasticities of real per capita sugar demand (-0,147 and 0,315 respectively) are smaller than the price (-0,30 to -0,47) and income (0,40 to 0,80) elasticities estimated by Oosthuisen (1980). The income elasticity (0,315) is relatively low indicating that sugar is both a necessity and a normal good.

The real price and interest rate elasticities of real hay supply are 1,074 and -0,082 respectively. The real own price, substitute feed and beef price elasticities of real hay demand are -1,159, 1,230 and 0,551 respectively. The large own and substitute price elasticities indicate that farmers are responsive to changes in relative feed prices.

4.3.2.2 Horticultural sector

The real vegetable supply equation is the best fit in terms of statistical significance and economic theory. The estimated real price elasticity of real vegetable supply is low at 0,194. This may be smaller than expected for vegetables given the comparatively short growing seasons for most vegetables. However, vegetables are aggregated in the model which may mask substitution between alternative vegetable crops. The statistically significant positive real potato price index coefficient indicates the potatoes are a substitute in production. The price and income elasticities of real per capita vegetable demand are -1,038 and 0,467.

The price and interest rate elasticities of real potato supply are 0,623 and -0,023 respectively. The price and income elasticities of real per capita potato demand are -0,765 and 1,279 respectively, both higher than the price (-0,42) and income (0,84) elasticities estimated by Ortmann (1982).

4.3.2.3 Livestock sector

All real supply equations represent the best statistical fit possible given the underlying economic theory. Real beef supply is a function of the lagged beef auction price index (deflated by the dips and sprays price index), herd size, real interest rate and lagged real beef supply.

Price elasticities of real supply for all meats are inelastic; beef (0,195), mutton (0,356), pork (0,506) and chicken meat (0,747). This reflects the relatively long adjustment periods that occur in livestock production. Livestock production involves long-term expectations with adjustments to price signals occurring with considerable lags due to time taken to increase herd sizes. The relatively higher real supply elasticity for chicken meat is expected, as chicken production uses less specialised resources.

The real interest rate coefficient in the real beef, mutton and pork supply equations are all significant and have the expected positive signs. This indicates significant stock effects of real interest rates on real red meat supply. As the interest rate (opportunity of holding livestock) increases it becomes more profitable to reduce herd sizes, and therefore real red meat supply increases. All interest rate elasticities are small; 0,055 (beef), 0,025 (mutton) and 0,034 (pork).

Price elasticities of real per capita beef, mutton, pork and chicken meat demand are -0,508, -0,805, -0,539 and -1,265 respectively. These are lower than those estimated by Hancock, *et al.*, (1984). A

possible explanation may be that Hancock, *et al*. used quarterly data and consequently captured more variation in the data.

Real price indices of substitutes whose coefficients had the wrong sign and/or were statistically insignificant were dropped from the estimated equations. Inclusion of the real chicken meat price index in the real per capita beef demand equation reflects the increasing importance of chicken meat as a substitute in red meat consumption. This is due to the decrease in the real price of white meat relative to the real price of red meat and changing tastes as a result of the negative health aspects of excessive red meat consumption. The real mutton price index was successfully included in the real per capita pork demand equation and the real beef price index was included in the real per capita chicken meat demand equation. This reflects the importance of these products as substitutes in consumption.

The dummy variable $D1_t$ in the real per capita beef demand equation is highly significant and has a negative sign which indicates the effect of faster rising beef prices which have led to declining real per capita beef demand. This trend has serious implications for beef producers who have zero opportunity costs of production (operate in areas not suitable for other enterprises).

The estimated price elasticity of real wool supply is 0,312, reflecting long adjustment periods in wool production. Mutton is identified as a substitute in production by the significant real mutton price index coefficient and real mutton cross-price elasticity of -0,602. The real interest rate was dropped from the equation due to the coefficient having the wrong sign.

Real agricultural investment is inelastic with respect to the real interest rate (-0,02), a result similar to that obtained by Devadoss (-0,05). The elasticity of real agricultural investment with respect to the real price index of capital goods is also inelastic (-0,25). This could be due to the tax system relating to agriculture. Prior to the adoption of the Margo Commission's proposals in 1988, the full value of farm capital items could be written off against taxable farming income in the year of purchase. This incentive to invest in capital goods to reduce tax payments could induce investment despite the interest charges and prices of capital items.

With the individual equations having been satisfactorily estimated, the model's simulation performance is evaluated in Section 4.4 which covers model validation techniques and results. If the model is to be used for policy analysis, the researcher must be confident of its ability to simulate historical data well. Simple inspection of the R^2 and t-statistics does not reveal this ability and therefore alternative techniques have been developed for model validation.

4.4 Model validation

When individual regression equations, which may fit the data well (good R^2 and t-statistics), are combined to form a simultaneous model, simulation results may be disappointing (Pindyck and Rubinfeld, 1981, p.355). Conversely, individual equations with a poor statistical fit may approximate the data very well when combined into a simulation model. The model must therefore be evaluated in terms of its simulation performance and forecasting properties.

Model simulations are undertaken to test and evaluate simulation performance so that the model can be used for historical policy analysis and forecasting. The simulation may be performed over different time horizons depending on the objective of the simulation. This is explained using figure 4.1.

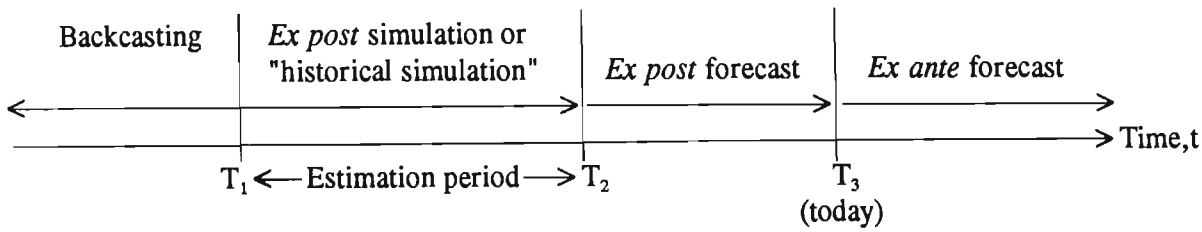

Figure 4.1 Simulation time horizons
Source: (Pindyck and Rubinfeld, 1981, p.359).

T_1 to T_2 represents the period of the study and T_3 represents "today". *Ex post* or historical simulations are undertaken over the period T_1 to T_2 to test model validity by comparing actual with predicted endogenous variable values. Actual values of the endogenous and exogenous variables are known and are not changed. *Ex post* simulations are used for policy analysis. By changing parameter values or the values of exogenous policy variables, the researcher can evaluate the effect on endogenous variables of different policies, e.g. the effects of changes in the level of government spending or money supply.

Forecasting involves a simulation of the model beyond the time period covered by the estimation period. Time series of all exogenous variables for the whole forecast period must be available. In the case of *ex post* forecasting, in which the forecast period runs from T_2 to T_3, data will be available and the forecast performance of the model can be checked. *Ex ante* forecasts, however, are a projection beyond "today", and therefore hypothetical data must be used. The researcher must have confidence in the models forecasting ability, as there is no actual data against which to compare predicted values.

In this study, *ex post* simulations are conducted for model validation and policy analysis. Techniques for model validation are discussed in the following section.

4.4.1 Model validation techniques

As outlined above, the simulation performance of a multi-equation simulation model cannot be judged according to the goodness of fit of the individual equations. The model must be judged with respect to the purpose for which it was built, e.g. forecasting, hypothesis testing or elasticity measurement.

Simultaneous-equations models have a complicated dynamic structure and different criteria are required to validate simultaneous-equations simulation models. These are analogous to the statistical tests used to evaluate single-equation regression models.

4.4.1.1 Root-mean-square and root-mean-square percent errors

The measure most often used is the root-mean-square simulation error (*RMSE*) which is defined as,

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^s - Y_t^a\right)^2} \tag{4.2}$$

where Y'_t = simulated value of Y_t,
Y_t = actual value, and,
T = number of periods t in the simulation.

The *RMSE* is a measure of deviations of simulated variable values from actual values.

Another simulation error statistic is the root-mean-square percent error (*RMSPE*) which is defined as,

$$RMSPE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{Y_t^s - Y_t^a}{Y_t^a}\right)^2} \tag{4.3}$$

This is a measure of *RMSE* in percentage terms, and obviates the need to compare the magnitude of the *RMSE* with the mean of the variable that is being tested.

4.4.1.2 Mean and mean percent errors

Mean errors (*ME*) and mean percent errors (*MPE*) are also used to evaluate simulation performance. These are defined as,

$$ME = \frac{1}{T}\sum_{t=1}^{T}\left(Y_t^s - Y_t^a\right) \tag{4.4}$$

and,

$$MPE = \frac{1}{T}\sum_{t=1}^{T}\frac{Y_t^s - Y_t^a}{Y_t^a} \tag{4.5}$$

Mean errors may give erroneous answers if large positive errors cancel out large negative errors. The *ME* may therefore be close to the desired value of zero, but the *RMSE* may be large. The *RMSE* and *RMSPE* are thus more suitable measures of simulation performance.

4.4.1.3 Theil's inequality coefficient

The most useful simulation statistic is Theil's inequality coefficient (U), defined as,

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^s - Y_t^a\right)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^s\right)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^a\right)^2}} \tag{4.6}$$

The numerator of U is simply the *RMSE*. The scaling of the denominator is such that U will always lie between O and 1. If U = O, $Y'_t = Y_t$ for all t and the fit is perfect. When U = 1, the fit is the worst possible.

Theil's inequality coefficient can be broken down into three so called 'proportions of inequality'. From the denominator, it can be shown that,

$$\frac{1}{T}\sum\left(Y_t^s - Y_t^a\right)^2 = \left(\bar{Y}^s - \bar{Y}^a\right)^2 + \left(\sigma_s - \sigma_a\right)^2 + 2(1-\rho)\rho_s\rho_a \tag{4.7}$$

where Y', Y, σ' and σ are the means and standard deviations of the series Y'_t and Y_t respectively and ρ is their correlation coefficient.

The proportions of inequality are defined as,

$$U^M = \frac{(\bar{Y}^s - \bar{Y}^a)^2}{(1/T)\sum (Y_t^s - Y_t^a)^2} \tag{4.8}$$

$$U^S = \frac{(\rho_s - \rho_a)^2}{(1/T)\sum (Y_t^s - Y_t^a)^2} \tag{4.9}$$

and,

$$U^C = \frac{2(1-\rho)\rho_s\rho_a}{(1/T)\sum (Y_t^s - Y_t^a)^2} \tag{4.10}$$

U^M, U^S and U^C are called the bias, variance and covariance proportions respectively. They allow the simulation error to be broken down into its characteristic sources. Note from equation 4.7 that $U^M + U^S + U^C = 1$.

The bias proportion, U^M, indicates systematic error since it measures the extent to which the average values of the actual and predicted series deviate from each other. Ideally, U^M should be zero. If the U^M is large, the predicted values do not match the actual values accurately.

The variance proportion, U^S, indicates the ability of the model to replicate the degree of variability in the variable of interest. If U^S is large, then the actual series has shown a high degree of fluctuation, with the simulated series exhibiting no fluctuation, or vice versa. A large U^S value hence indicates that turning points have not been well duplicated.

The covariance proportion, U^C, measures the unsystematic error which represents the remaining error after deviations from average values and average variabilities have been accounted for. As predicted and actual values rarely, if ever, coincide, this component is less important and a value of 1 would not be undesirable. The ideal distribution of inequality over the three sources is, $U^M = U^S = 0$, and, $U^C = 1$.

4.4.1.4 Turning point method

This is a very simple and commonly used model validation method. Plots of the predicted versus actual values of endogenous variables indicate visually how well the model has simulated the historical data. The model should be able to predict fluctuations in the data without a lag. As models with good

statistical fits may fail to predict turning points, a comparison of actual and predicted values of endogenous variables provides a useful check on model simulation ability.

4.4.2 Model validation results

Table 4.2 reports *MPE*, *RMSPE* and *U* statistics derived to validate the model. *ME* and *RMSE* statistics are not reported as they are unit dependent and require comparison with variable means.

All *U* statistics of endogenous macrosector variables are below 0,10, except those for the real prime overdraft rate and real net import demand for manufactured goods (0,35616 and 0,11503 respectively). The *U* statistic of the real prime overdraft rate is the largest in the model. The majority of *MPE* and *RMSPE* values are less than 0,10 and 0,20 respectively. The small *MPE*, *RMSPE* and *U* statistics indicate that the model has successfully replicated the actual data. The simulation performance of the exchange rate, general price level and input price indices is particularly encouraging as this study focuses on their role in linking the agricultural sector to monetary policy.

Low values of the *MPE*, *RMSPE* and *U* statistics for the endogenous agricultural sector variables indicate good simulation performance, particularly for product price indices. All *U* statistics are below 0,10 except for real exports of maize (0,29814), sugar (0,12482), and wool (0,14625).

The small *U* statistic for real gross domestic product (0,03612) is encouraging given that real gross domestic product is the summation of total personal consumption expenditure, gross domestic fixed investment and net exports and therefore captures simulation errors of these variables which in turn have captured the simulation errors of variables of which they are a summation.

Table 4.3 reports the bias (U^M), variance (U^S) and covariance (U^C) proportions of *U* statistics for the endogenous variables. The model has successfully simulated the short and long-term variability in most monetary, real per capita demand and real supply variables. This is evidenced by the high U^C values which are close to the desired value of 1, and correspondingly low values of U^M and U^S for these variables.

Exceptions are the general price level, manufactured goods price index and agricultural product price indices. Large U^M values for these variables indicate that predicted values systematically diverge from actual values. The long-term trend in the data is captured but the predicted values are consistently

Table 4.2 Mean percent errors (*MPE*), root-mean-square percent errors (*RMSPE*) and Theil's inequality coefficients (*U*) of the endogenous variables.

Endogenous variable	*MPE*	*RMSPE*	*U*
Real money demand (Md_t/CPI_t)	0,09457	0,07380	0,03546
Treasury bill rate (TBR_t)	0,03744	0,26548	0,09524
Prime overdraft rate (R_t)	0,01740	0,15281	0,08612
Real prime overdraft rate (RR_t)	-0,71112	1,35910	0,35616
Exchange rate (XR_t)	0,00361	0,05241	0,02468
Real balance of payments (BoP_t/CPI_t)	0,33453	0,14601	0,23157
Consumer price index (CPI_t)	0,07965	0,08869	0,03494
Real manufactured goods supply ($MANSS_t/MANPI_t$)	0,02538	0,13454	0,08311
Real per capita manufactured goods demand ($MANDD_t/MANPI_t$)	0,01230	0,11643	0,06733
Real net import demand for manufactured goods ($MANNM_t/MNMPI_t$)	0,04434	0,27736	0,11503
Real manufactured goods price index ($MNPI_t/CPI_t$)	0,00000	0,00000	0,00000
Manufactured goods price ($MNPI_t$)	0,07966	0,08867	0,03515
Price of fertiliser ($FTPI_t$)	0,07730	0,11341	0,04044
Price of dips and sprays ($DSPI_t$)	0,06048	0,07141	0,03628
Price of farm feed ($FDPI_t$)	0,04202	0,06641	0,01896
Price of fuel ($FLPI_t$)	0,14192	0,23315	0,09451
Price of packaging ($PMPI_t$)	0,08302	0,11880	0,05906
Real fertiliser demand ($QFERT_t/FTPI_t$)	0,01785	0,12577	0,05831
Real dips and sprays demand ($QDIPS_t/DSPI_t$)	-0,03939	0,56254	0,09243
Real stock and poultry feed demand ($QFEED_t/FDPI_t$)	0,01992	0,14026	0,05498
Real fuel demand ($QFUEL_t/FLPI_t$)	0,01191	0,10974	0,05437
Real packing materials demand ($QPACK_t/PMPI_t$)	0,00835	0,10022	0,04499
Real total value of inputs purchased ($TINPT_t/TINPI_t$)	0,00413	0,06176	0,02883
Real maize supply ($MZSS_t/MZPI_t$)	0,02858	0,15549	0,08832
Real per capita human maize demand ($MZDH_t/MZPI_t$)	-0,00070	0,08259	0,04088
Real animal maize demand ($MZDA_t/MZPI_t$)	0,01954	0,13501	0,05339
Real maize exports ($MZX_t*XR_t/MZXPI_t$)	0,08109	0,68692	0,29814
Real maize producer price ($MZPI_t/CPI_t$)	0,01693	0,09327	0,04593
Maize producer price ($MZPI_t$)	0,09745	0,14025	0,06418
Real sugar cane supply ($SCSS_t/SCPI_t$)	0,02399	0,12471	0,05618
Real per capita sugar demand ($SGDD_t/SCPI_t$)	0,00015	0,03492	0,01746
Real sugar exports ($SGX_t*XR_t/SGXPI_t$)	0,42487	0,21140	0,12482
Real sucrose price index ($SCPI_t/CPI_t$)	0,00150	0,12146	0,06311
Sucrose price index ($SCPI_t$)	0,07966	0,14702	0,10064
Real hay supply ($HYSS_t/HYPI_t$)	0,06317	0,24742	0,08670
Real hay demand ($HYDD_t/HYPI_t$)	0,04907	0,25641	0,07499
Real hay price index ($HYPI_t/CPI_t$)	0,00206	0,05529	0,02565
Hay price index ($HYPI_t$)	0,08295	0,12011	0,04739
Total real gross farm income in field crop sector ($FCINC_t/FCPI_t$)	0,02079	0,12054	0,06669
Real deciduous fruit supply ($DFSS_t/DFPI_t$)	0,00116	0,03702	0,01623
Real per capita deciduous fruit demand ($DFDD_t/DFPI_t$)	0,00227	0,05993	0,02774
Real deciduous fruit exports ($DFX_t*XR_t/DFXPI_t$)	0,00378	0,05372	0,03058
Real deciduous fruit market price index ($DFPI_t/CPI_t$)	0,00000	0,00000	0,00000
Deciduous fruit market price index ($DFPI_t$)	0,07966	0,08869	0,03606
Real citrus fruit supply ($CFSS_t/CFPI_t$)	-0,00439	0,06576	0,03001

Table 4.2 continued

Endogenous variable	*MPE*	*RMSPE*	*U*
Real per capita citrus fruit demand ($CFDD_t/CFPI_t$)	0,02402	0,17195	0,07908
Real citrus fruit exports ($CFX_t*XR_t/CFXPI_t$)	0,00378	0,05373	0,02803
Real citrus fruit market price index ($CFPI_t/CPI_t$)	-0,00000	0,00000	0,00000
Citrus fruit market price index ($CFPI_t$)	0,07966	0,08869	0,03508
Real vegetable supply ($VGSS_t/VGPI_t$)	0,01721	0,18066	0,08571
Real per capita vegetable demand ($VGDD_t/VGPI_t$)	0,00058	0,05074	0,02526
Real vegetable market price index ($VGPI_t/CPI_t$)	-0,00039	0,00974	0,00442
Vegetable market price index ($VGPI_t$)	-0,00039	0,00974	0,00442
Real potato supply ($PTSS_t/PTPI_t$)	0,03460	0,21175	0,09881
Real per capita potato demand ($PTDD_t/PTPI_t$)	0,00950	0,13708	0,06201
Real potato market price index ($PTPI_t/CPI_t$)	-0,00084	0,04057	0,01769
Potato market price index ($PTPI_t$)	0,07875	0,09838	0,03807
Total real gross farm income in the horticultural sector ($HTINC_t/HTPI_t$)	0,00380	0,04775	0,02568
Real beef supply ($BFSS_t/BFPI_t$)	-0,00243	0,09602	0,04877
Real per capita beef demand ($BFDD_t/BFPI_t$)	0,00272	0,05756	0,02802
Real beef auction price index ($BFPI_t/CPI_t$)	0,00000	0,00000	0,00000
Beef auction price index ($BFPI_t$)	0,07966	0,08869	0,03389
Real mutton supply ($MTSS_t/MTPI_t$)	0,00583	0,11091	0,05147
Real per capita mutton demand ($MTDD_t/MTPI_t$)	0,00329	0,06151	0,02949
Real mutton auction price index ($MTPI_t/CPI_t$)	0,00000	0,00000	0,00000
Mutton auction price index ($MTPI_t$)	0,07966	0,08869	0,03494
Real pork supply ($PKSS_t/PKPI_t$)	0,00576	0,12833	0,06335
Real per capita pork demand ($PKDD_t/PKPI_t$)	0,00299	0,06969	0,03384
Real pork auction price index ($PKPI_t/CPI_t$)	0,00494	0,16835	0,82671
Pork auction price index ($PKPI_t$)	0,08298	0,11369	0,04553
Total real gross farm income for red meats ($RMINC_t/RMPI_t$)	-0,00149	0,08082	0,03994
Real chicken meat supply ($CHSS_t/CHPI_t$)	0,07442	0,27546	0,06766
Real per capita broiler demand ($CHDD_t/CHPI_t$)	0,02555	0,29353	0,10913
Real chicken meat price index ($CHPI_t/CPI_t$)	-0,00000	0,00000	0,00000
Chicken meat price index ($CHPI_t$)	0,07965	0,08869	0,03476
Real wool supply ($WLSS_t/WLPI_t$)	0,00874	0,10155	0,04527
Real per capita wool demand ($WLDD_t/WLPI_t$)	-0,05702	0,67299	0,06663
Real wool exports ($WLX_t*XR_t/WLXPI_t$)	0,06064	0,45227	0,14625
Real wool auction price index ($WLPI_t/CPI_t$)	0,00137	0,10462	0,04255
Wool auction price index ($WLPI_t$)	0,08929	0,16249	0,51684
Total real gross farm income in the livestock sector ($LVINC_t/LVPI_t$)	0,00421	0,06458	0,03187
Total real gross farm income in the sectors modelled ($AGINC_t/AGPI_t$)	0,00538	0,04582	0,02303
Total nominal gross farm income in the sectors modelled ($AGINC_t$)	0,00352	0,03277	0,01648
Real agricultural investment ($AGINV_t/AIPI_t$)	0,02736	0,12427	0,06640
Real total personal consumption expenditure ($TPCE_t/CPI_t$)	-0,00137	0,12234	0,06628
Real gross domestic fixed investment ($GDFI_t/CPI_t$)	0,00116	0,00772	0,00365
Real net exports ($NXPT_t/CPI_t$)	0,24416	0,18382	0,15749
Real gross domestic product (GDP_t/CPI_t)	0,00240	0,06469	0,03612

Table 4.3 Bias (U^M), variance (U^S) and covariance proportions (U^C) of the inequality coefficients (U) of the endogenous variables.

Endogenous variable	U^M	U^S	U^C
Real money demand (Md_t/CPI_t)	0,00000	0,01079	0,98921
Treasury bill rate (TBR_t)	0,00104	0,02433	0,97462
Prime overdraft rate (R_t)	0,00110	0,03186	0,96703
Real prime overdraft rate (RR_t)	0,00899	0,06976	0,92125
Exchange rate (XR_t)	0,00000	0,00268	0,99732
Real balance of payments (BoP_t/CPI_t)	0,00021	0,06835	0,93144
General price level (CPI_t)	0,64261	0,30970	0,04768
Real manufactured goods supply ($MANSS_t/MANPI_t$)	0,00000	0,03399	0,96599
Real per capita manufactured goods demand ($MANDD_t/MANPI_t$)	0,00000	0,04395	0,95605
Real net import demand for manufactured goods ($MANNM_t/MNMPI_t$)	0,00013	0,06402	0,93585
Real manufactured goods price index ($MNPI_t/CPI_t$)	0,00000	0,00000	1,00000
Manufactured goods price index ($MNPI_t$)	0,65308	0,29647	0,05045
Fertiliser price index ($FTPI_t$)	0,33376	0,10716	0,55908
Dips and sprays price index ($DSPI_t$)	0,45327	0,27457	0,27216
Stock and poultry feed price index ($FDPI_t$)	0,47279	0,21219	0,31502
Fuel price index ($FLPI_t$)	0,09897	0,11696	0,78408
Packing materials price index ($PMPI_t$)	0,23721	0,01095	0,75184
Real fertiliser demand ($QFERT_t/FTPI_t$)	0,00000	0,05236	0,94764
Real dips and sprays demand ($QDIPS_t/DSPI_t$)	0,00000	0,02692	0,97308
Real stock and poultry feed demand ($QFEED_t/FDPI_t$)	0,00000	0,01563	0,98437
Real fuel demand ($QFUEL_t/FLPI_t$)	0,00016	0,15777	0,84207
Real packing materials demand ($QPACK_t/PMPI_t$)	0,00000	0,06183	0,93817
Total real input demand ($TINPT_t/TINPI_t$)	0,00002	0,01714	0,98284
Real maize supply ($MZSS_t/MZPI_t$)	0,00041	0,07137	0,92822
Real per capita human maize demand ($MZDH_t/MZPI_t$)	0,00808	0,24273	0,74919
Real animal maize demand ($MZDA_t/MZPI_t$)	0,00195	0,18845	0,80959
Real maize exports ($MZX_t*XR_t/MZXPI_t$)	0,00375	0,01605	0,98020
Real maize producer price index ($MZPI_t/CPI_t$)	0,03213	0,21638	0,75149
Maize producer price index ($MZPI_t$)	0,35946	0,22673	0,41381
Real sugar cane supply ($SCSS_t/SCPI_t$)	0,00539	0,01838	0,97622
Real per capita sugar demand ($SGDD_t/SCPI_t$)	0,00039	0,00437	0,99524
Real sugar exports ($SGX_t*XR_t/SGXPI_t$)	0,04449	0,00258	0,95293
Real sucrose price index ($SCPI_t/CPI_t$)	0,00134	0,19852	0,80014
Sucrose price index ($SCPI_t$)	0,17722	0,65919	0,16359
Real hay supply ($HYSS_t/HYPI_t$)	0,01043	0,04655	0,94302
Real hay demand ($HYDD_t/HYPI_t$)	0,00011	0,04403	0,95586
Real hay price index ($HYPI_t/CPI_t$)	0,00087	0,00837	0,99077
Hay price index ($HYPI_t$)	0,43143	0,26230	0,30626
Total real gross farm income in field crop sector ($FCINC_t/FCPI_t$)	0,00247	0,03123	0,96631
Real deciduous fruit supply ($DFSS_t/DFPI_t$)	0,00004	0,01279	0,09871
Real per capita deciduous fruit demand ($DFDD_t/DFPI_t$)	0,00000	0,00713	0,99287
Real deciduous fruit exports ($DFX_t*XR_t/DFXPI_t$)	0,00001	0,00025	0,99974
Real deciduous fruit market price index ($DFPI_t/CPI_t$)	0,18178	0,00071	0,81751
Deciduous fruit market price index ($DFPI_t$)	0,71230	0,22422	0,06348
Real citrus fruit supply ($CFSS_t/CFPI_t$)	0,00006	0,09925	0,90068

Table 4.3 continued

Endogenous variable	U^M	U^S	U^C
Real per capita citrus fruit demand ($CFDD_t/CFPI_t$)	0,00000	0,24054	0,75946
Real citrus fruit exports ($CFX_t*XR_t/CFXPI_t$)	0,00361	0,02976	0,96663
Real citrus fruit market price index ($CFPI_t/CPI_t$)	0,01544	0,06412	0,92044
Citrus fruit market price index ($CFPI_t$)	0,60498	0,35328	0,04174
Real vegetable supply ($VGSS_t/VGPI_t$)	0,00323	0,00429	0,99248
Real per capita vegetable demand ($VGDD_t/VGPI_t$)	0,00000	0,00013	0,99987
Real vegetable market price index ($VGPI_t/CPI_t$)	0,00055	0,06216	0,93778
Vegetable market price index ($VGPI_t$)	0,69406	0,20751	0,09843
Real potato supply ($PTSS_t/PTPI_t$)	0,00083	0,07728	0,92190
Real per capita potato demand ($PTDD_t/PTPI_t$)	0,00000	0,04655	0,95345
Real potato market price index ($PTPI_t/CPI_t$)	0,00005	0,02448	0,97546
Potato market price index ($PTPI_t$)	0,48055	0,17845	0,34099
Total real gross farm income in the horticultural sector ($HTINC_t/HTPI_t$)	0,00412	0,00012	0,99576
Real beef supply ($BFSS_t/BFPI_t$)	0,00762	0,01413	0,97825
Real per capita beef demand ($BFDD_t/BFPI_t$)	0,00000	0,05297	0,94703
Real beef auction price index ($BFPI_t/CPI_t$)	0,00000	0,00000	1,00000
Beef auction price index ($BFPI_t$)	0,61309	0,35164	0,03527
Real mutton supply ($MTSS_t/MTPI_t$)	0,00014	0,02155	0,97831
Real per capita mutton demand ($MTDD_t/MTPI_t$)	0,00000	0,07726	0,92274
Real mutton auction price index ($MTPI_t/CPI_t$)	0,00000	0,00000	1,00000
Mutton auction price index ($MTPI_t$)	0,64379	0,31112	0,04509
Real pork supply ($PKSS_t/PKPI_t$)	0,00004	0,01374	0,99862
Real per capita pork demand ($PKDD_t/PKPI_t$)	0,00071	0,11471	0,88458
Real pork auction price index ($PKPI_t/CPI_t$)	0,00494	0,16835	0,82671
Pork auction price index ($PKPI_t$)	0,37569	0,14859	0,47572
Total real gross farm income for red meats ($RMINC_t/RMPI_t$)	0,00501	0,01850	0,97649
Real chicken meat supply ($CHSS_t/CHPI_t$)	0,04168	0,03272	0,92561
Real per capita broiler demand ($CHDD_t/CHPI_t$)	0,00000	0,04663	0,95337
Real chicken meat price index ($CHPI_t/CPI_t$)	0,70000	0,35123	0,04877
Chicken meat price index ($CHPI_t$)	0,65033	0,30248	0,04719
Real wool supply ($WLSS_t/WLPI_t$)	0,00011	0,02358	0,97632
Real per capita wool demand ($WLDD_t/WLPI_t$)	0,00166	0,05366	0,94468
Real wool exports ($WLX_t*XR_t/WLXPI_t$)	0,01641	0,15533	0,82826
Real wool auction price index ($WLPI_t/CPI_t$)	0,00956	0,14163	0,84881
Wool auction price index ($WLPI_t$)	0,20875	0,31219	0,47905
Total real gross farm income in the livestock sector ($LVINC_t/LVPI_t$)	0,00124	0,00013	0,99864
Total real gross farm income in the sectors modelled ($AGINC_t/AGPI_t$)	0,00822	0,00085	0,99094
Total nominal gross farm income in the sectors modelled ($AGINC_t$)	0,70048	0,16769	0,13183
Real agricultural investment ($AGINV_t/AIPI_t$)	0,01796	0,01486	0,96718
Real total personal consumption expenditure ($TPCE_t/CPI_t$)	0,00000	0,07100	0,92900
Real gross domestic fixed investment ($GDFI_t/CPI_t$)	0,01796	0,05430	0,92775
Real net exports ($NXPT_t/CPI_t$)	0,00021	0,04796	0,95183
Real gross domestic product (GDP_t/CPI_t)	0,00007	0,00577	0,99416

biased up or down. The high U^S value for the sucrose price index indicates that the short-term variability has not been captured.

Figures 4.2 to 4.77 are plots of predicted versus actual values of key endogenous variables. They provide a visual analysis of the model's simulation performance and ability to duplicate turning points in the actual data. The plots show that generally long-term trends in the data have been captured and the majority of turning points have been duplicated.

In the macrosector, the model simulates real money demand (figure 4.2), the rand/SDR exchange rate (figure 4.6), real balance of payments (figure 4.7) and general price level (figure 4.8) very well. The model has captured long-term trends in the treasury bill rate (figure 4.3), and nominal (figure 4.4) and real prime (figure 4.5) overdraft rates, but had difficulty simulating large short-term fluctuations in these variables, particularly from 1973 to 1986.

Short term movements in the rand/SDR exchange rate of the rand (figure 4.6) have been simulated extremely well. The horizontal line from 1960 to 1971 indicates the period of fixed exchange rates. Short term movements during the period of floating exchange rates (1972-1987) have been captured. The sustained depreciation from 1980 to 1985, slight appreciation in 1986 and depreciation in 1987 have been well duplicated.

Figure 4.8 illustrates how a large U^M value is derived for the general price level, and for most nominal price indices. The long-term trend in the general price level is accurately reflected, but the predicted values have a consistent upward bias resulting in a high U^M value.

The real manufactured goods supply function (figure 4.9) captures the trends in the data but is seriously underestimated from 1975 onwards. The turning points are duplicated, but at a much lower level. The long-term upward trend in real per capita manufactured goods demand (figure 4.10) has been simulated, with most of the turning points being duplicated (except for 1972 and 1977-1981). Large fluctuations in real net import demand for manufactured goods (figure 4.11) are not duplicated although the long-term trend is captured. The price index of manufactured goods (figure 4.12) has been simulated extremely well.

The plot of actual versus predicted values of real net import demand for manufactured goods illustrates how functions with significant variables and high R^2 statistics can simulate historical data poorly when

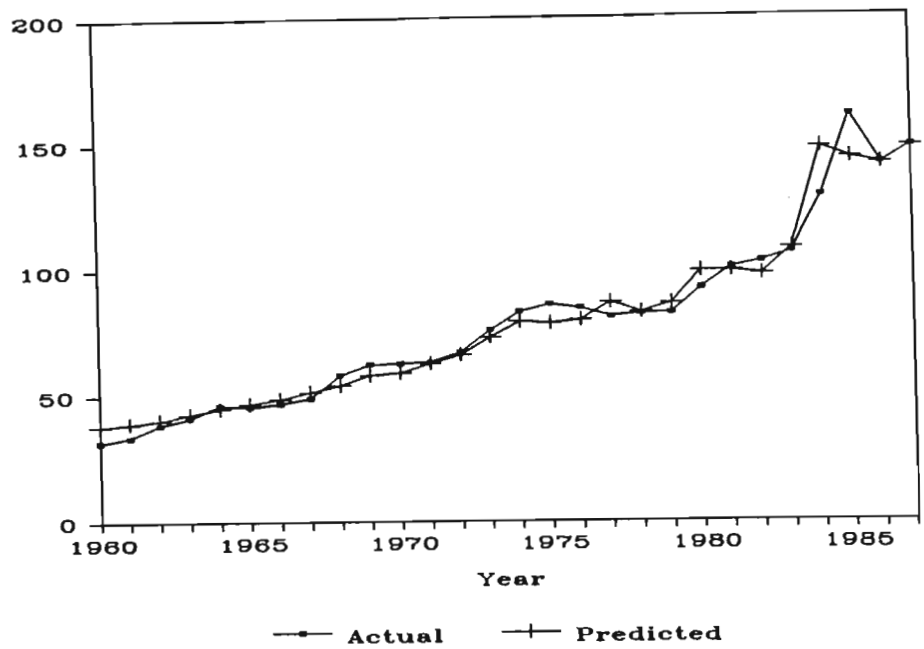

Figure 4.2 Plot of actual versus predicted values of real money demand (R 100 million)

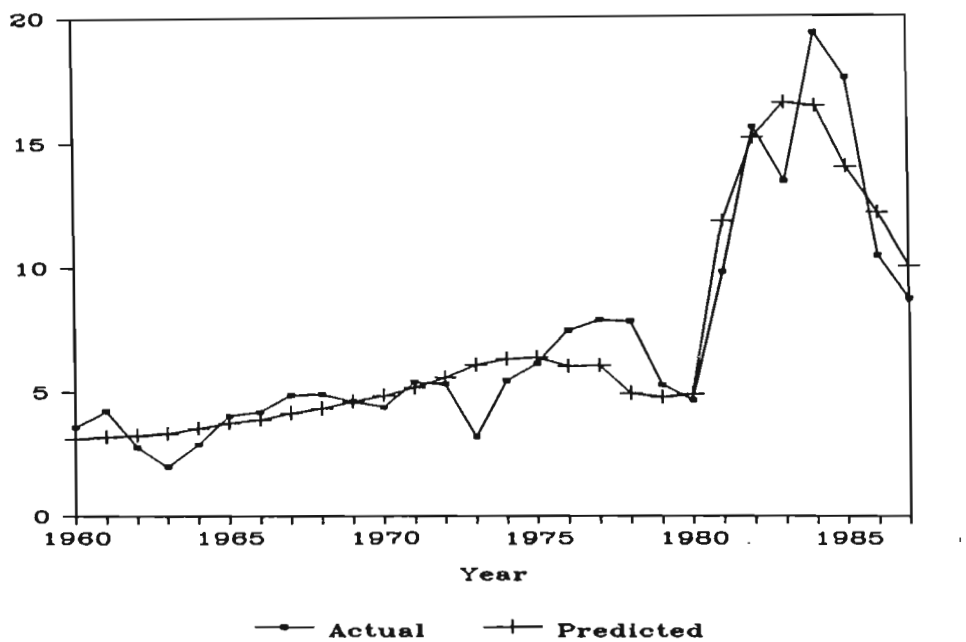

Figure 4.3 Plot of actual versus predicted values of the treasury bill rate (percent)

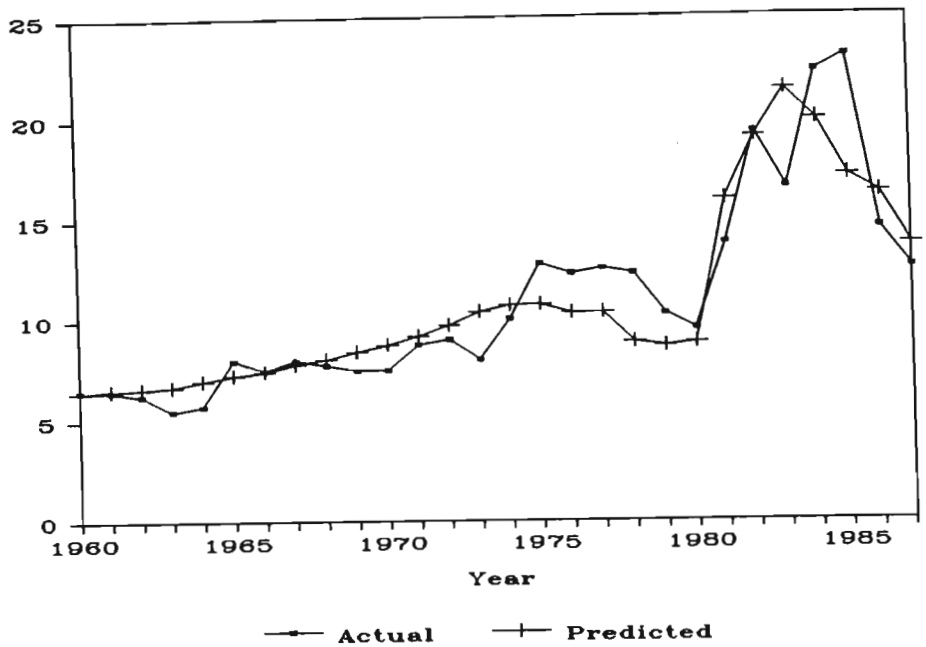

Figure 4.4 Plot of actual versus predicted values of the nominal prime overdraft rate (percent)

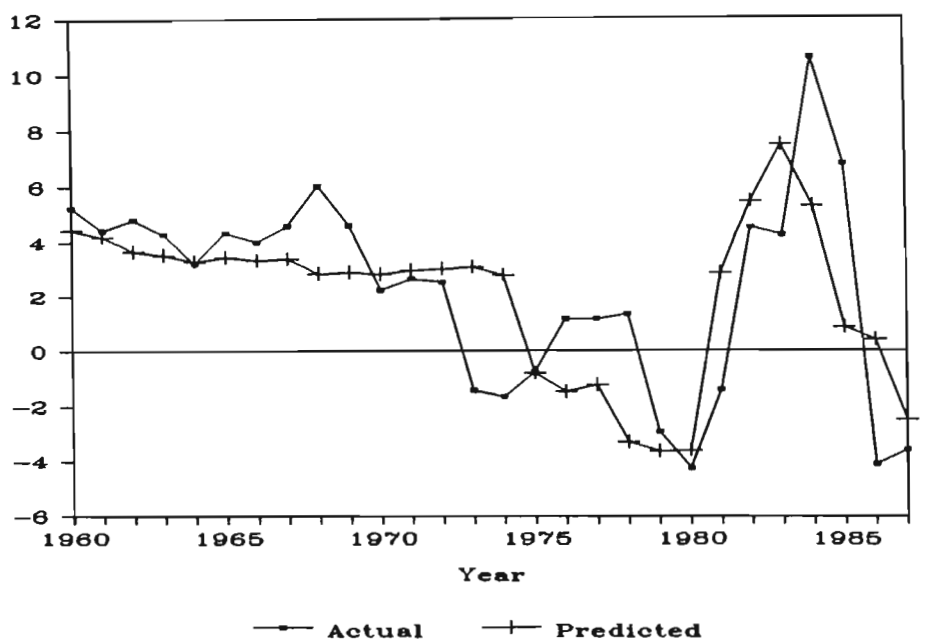

Figure 4.5 Plot of actual versus predicted values of real prime overdraft rate (percent)

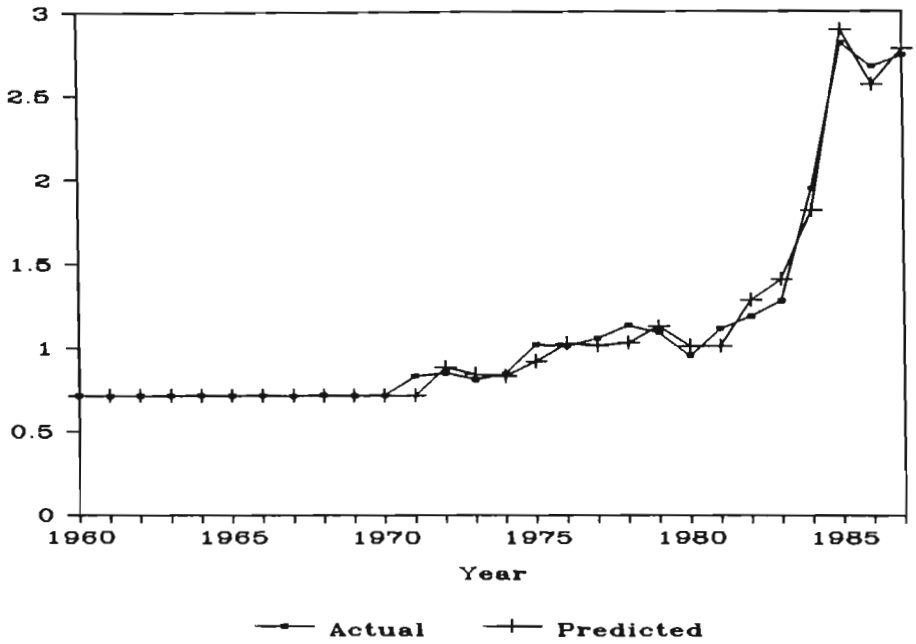

Figure 4.6 Plot of actual versus predicted values of the rand exchange rate (R/SDR)

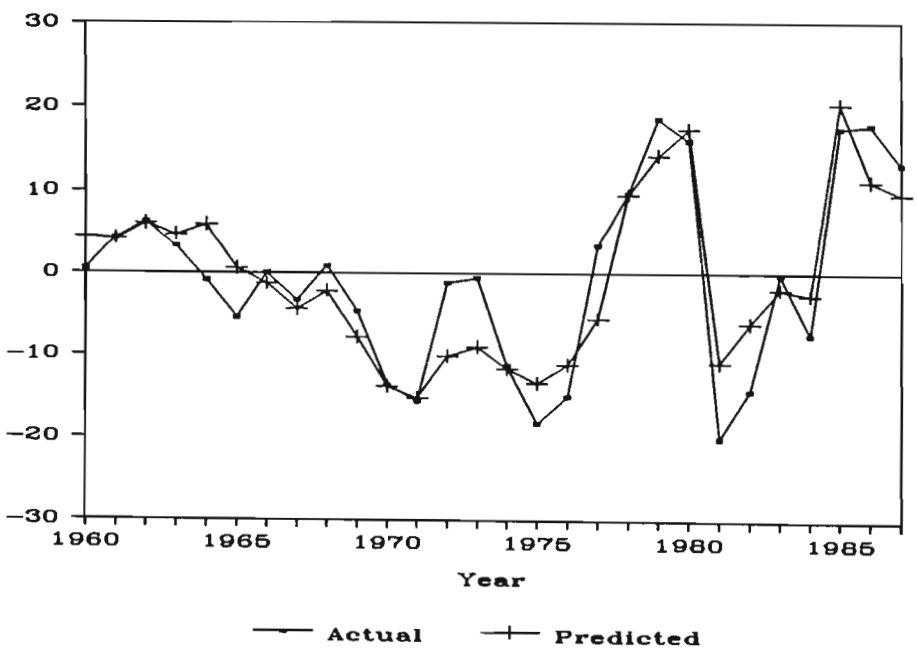

Figure 4.7 Plot of actual versus predicted values of the real balance of payments (R 100 million, base year = 1975)

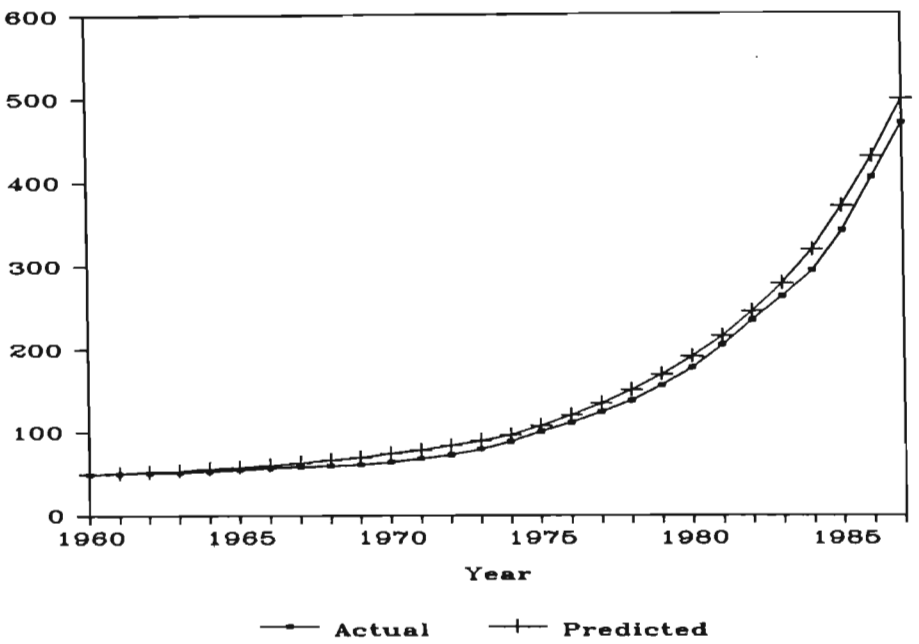

Figure 4.8 Plot of actual versus predicted values of the general price level (index, 1975=100)

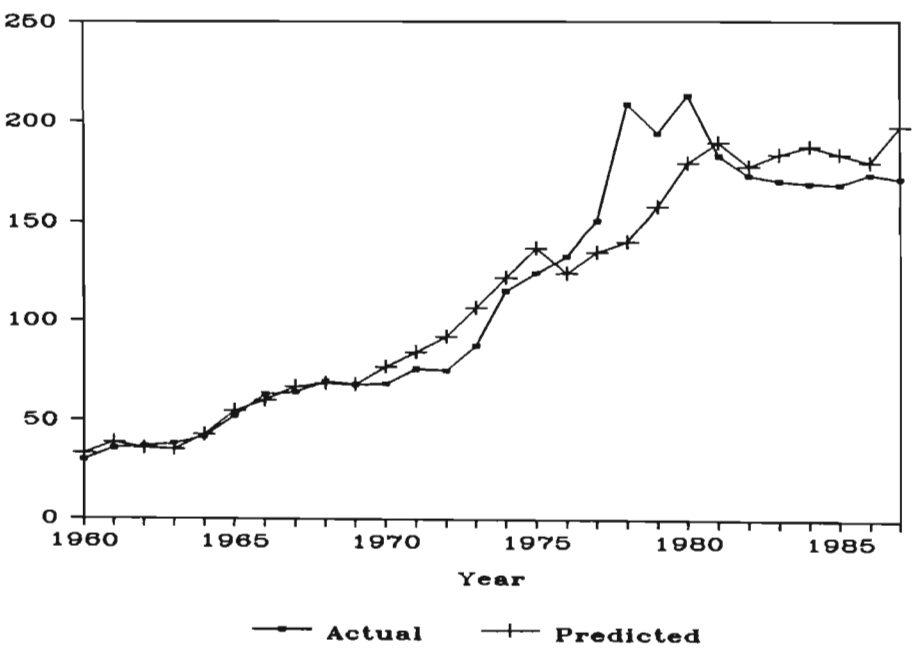

Figure 4.9 Plot of actual versus predicted values of real manufacturing supply (R 100 million, base year = 1975)

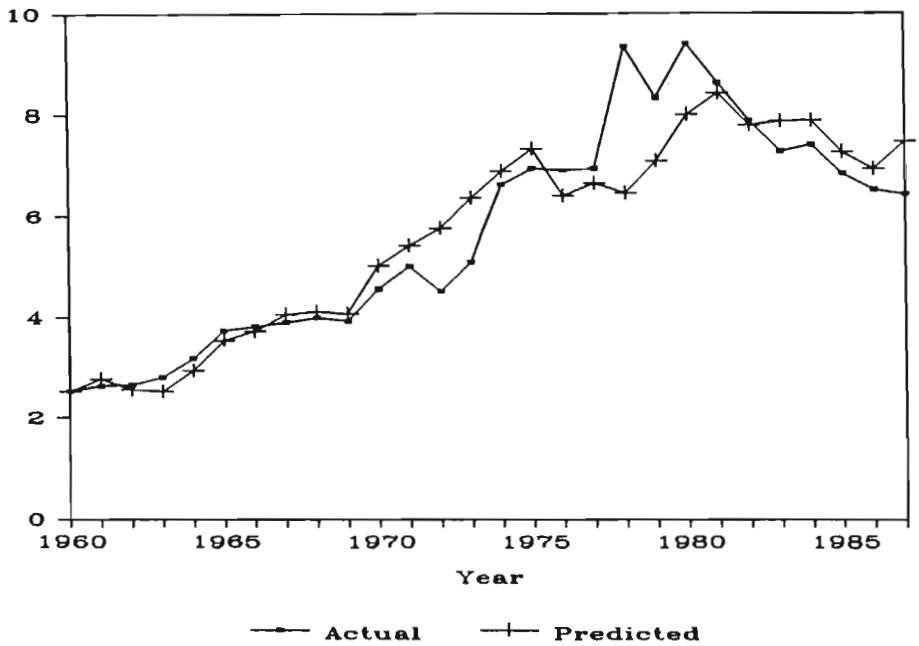

Figure 4.10 Plot of actual versus predicted values of real per capita manufactured goods demand (R 100 million, base year=1975)

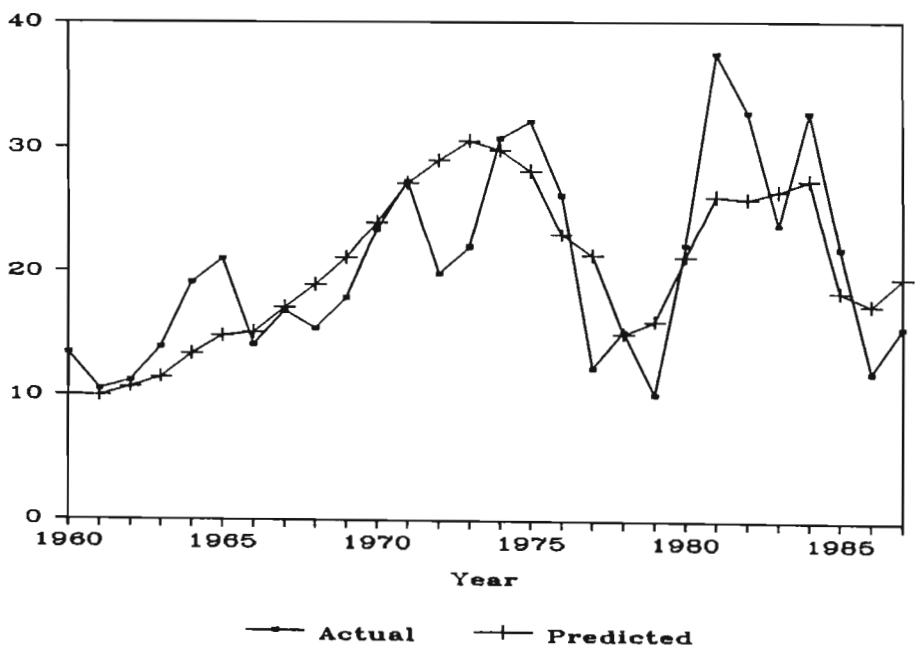

Figure 4.11 Plot of actual versus predicted values of real net import demand for manufactured goods (R 100 million, base year=1975)

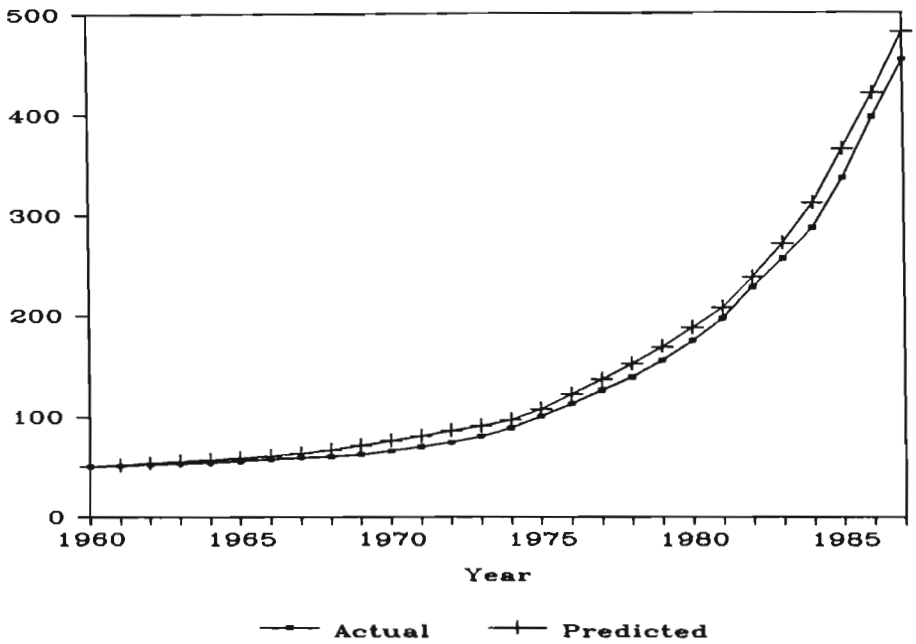

Figure 4.12 Plot of actual versus predicted values of the manufactured goods price index (1975=100)

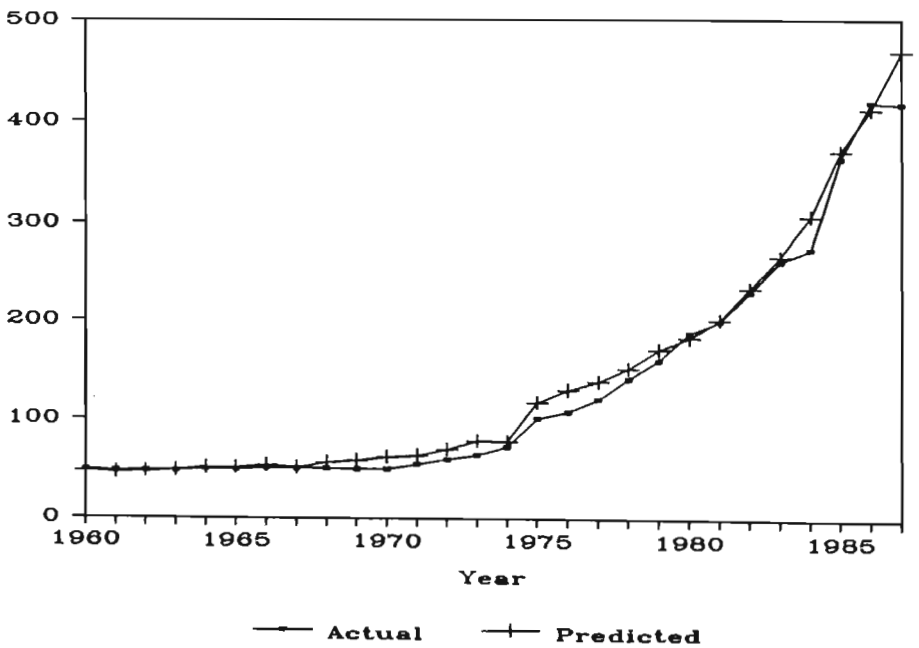

Figure 4.13 Plot of actual versus predicted values of the fertiliser price index (1975=100)

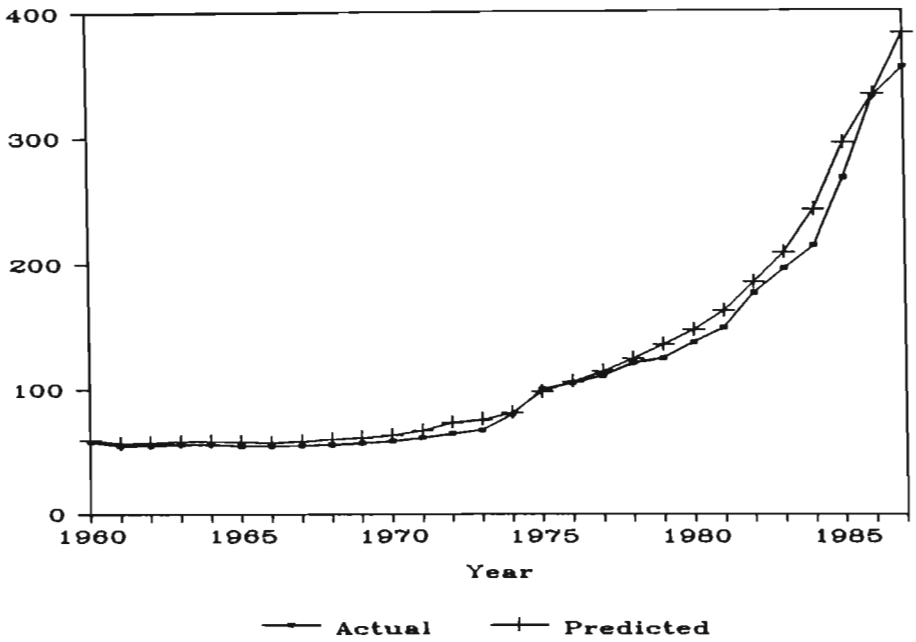

Figure 4.14 Plot of actual versus predicted values of the dips and sprays price index (1975=100)

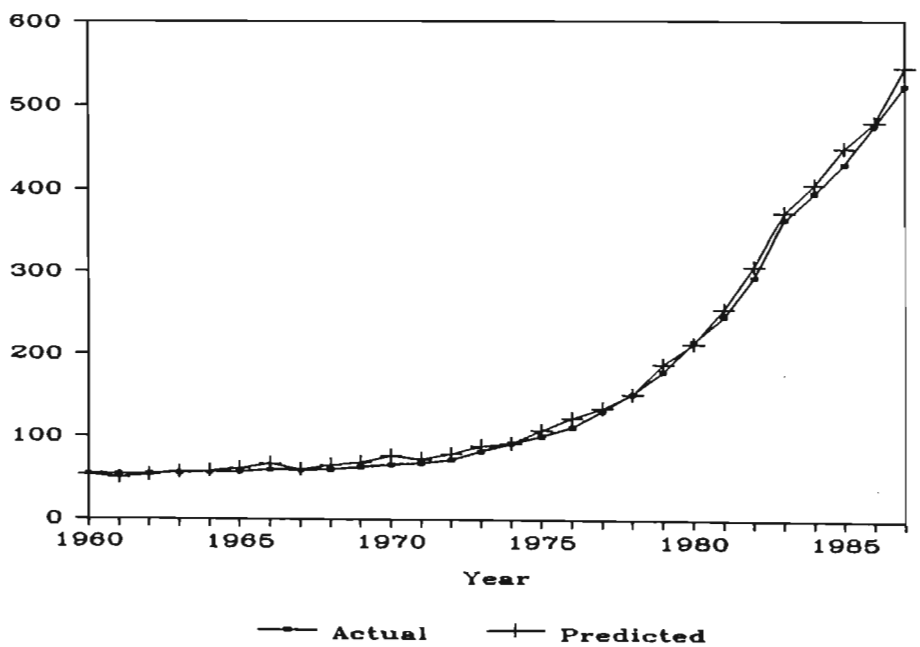

Figure 4.15 Plot of actual versus predicted values of the stock and poultry feed price index (1975=100)

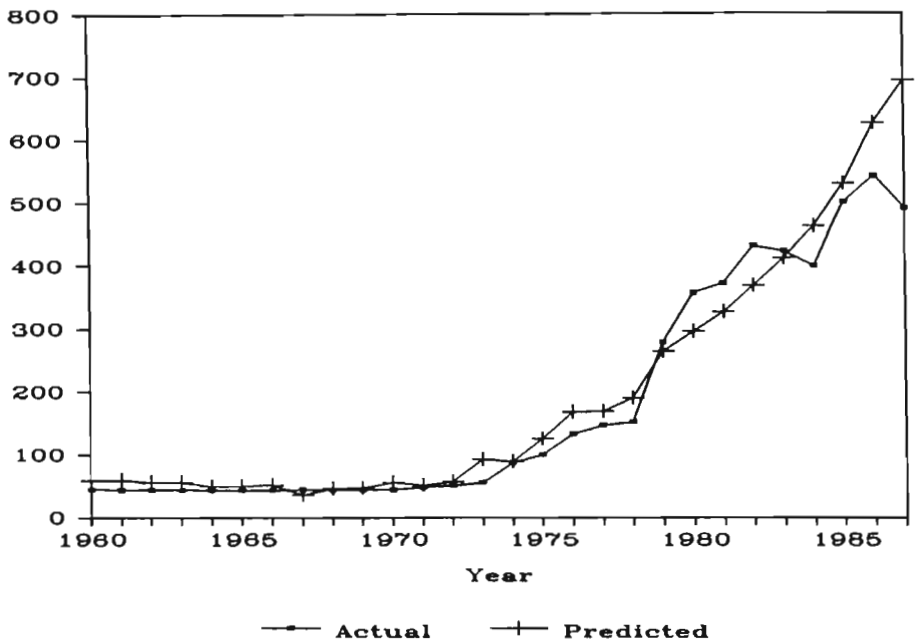

Figure 4.16 Plot of actual versus predicted values of the fuel price index (1975=100)

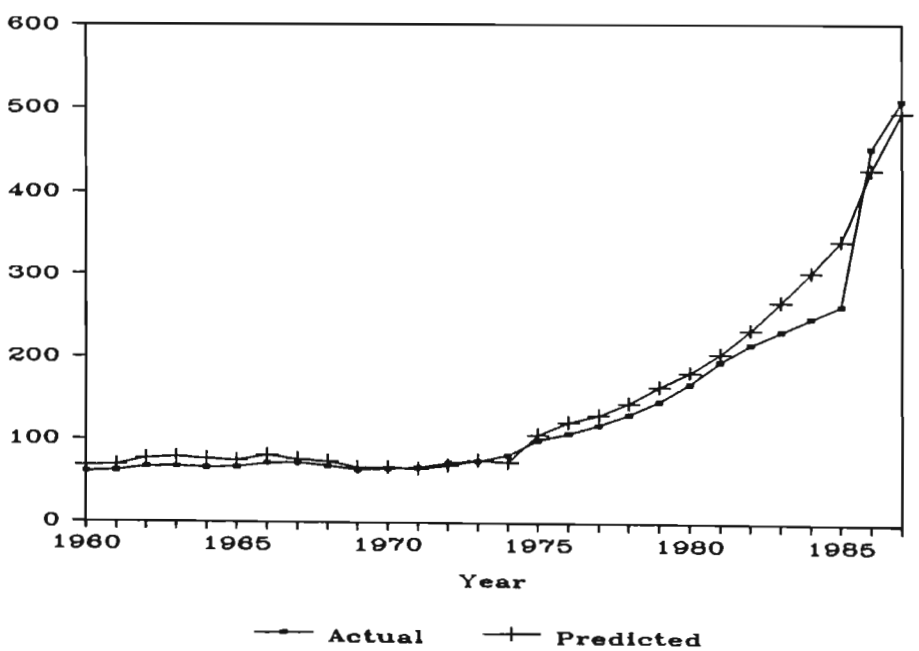

Figure 4.17 Plot of actual versus predicted values of the packing materials price index (1975=100)

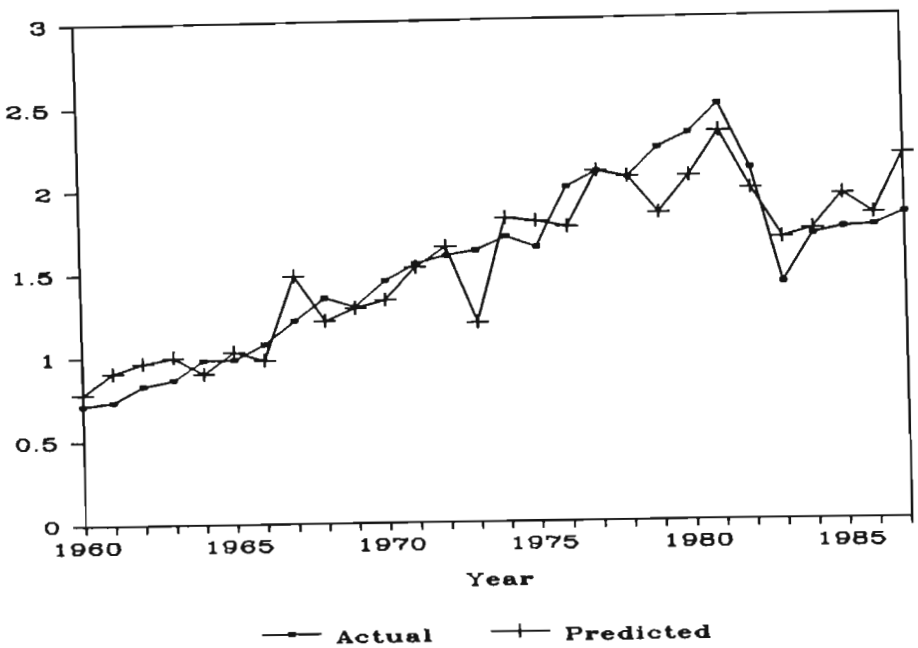

Figure 4.18 Plot of actual versus predicted values of real fertiliser demand (R 100 million, base year = 1975)

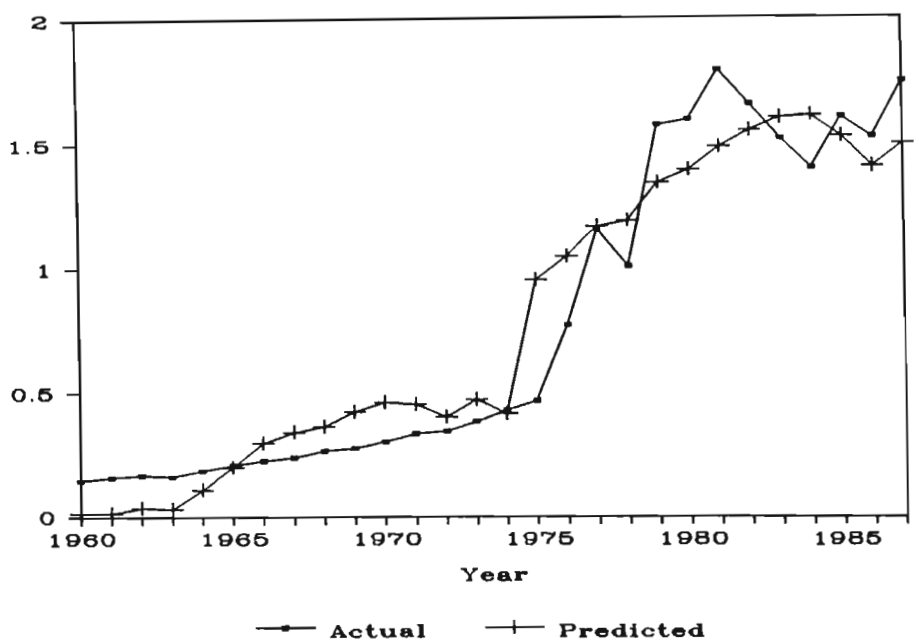

Figure 4.19 Plot of actual versus predicted values of real dips and sprays demand (R 100 million, base year = 1975)

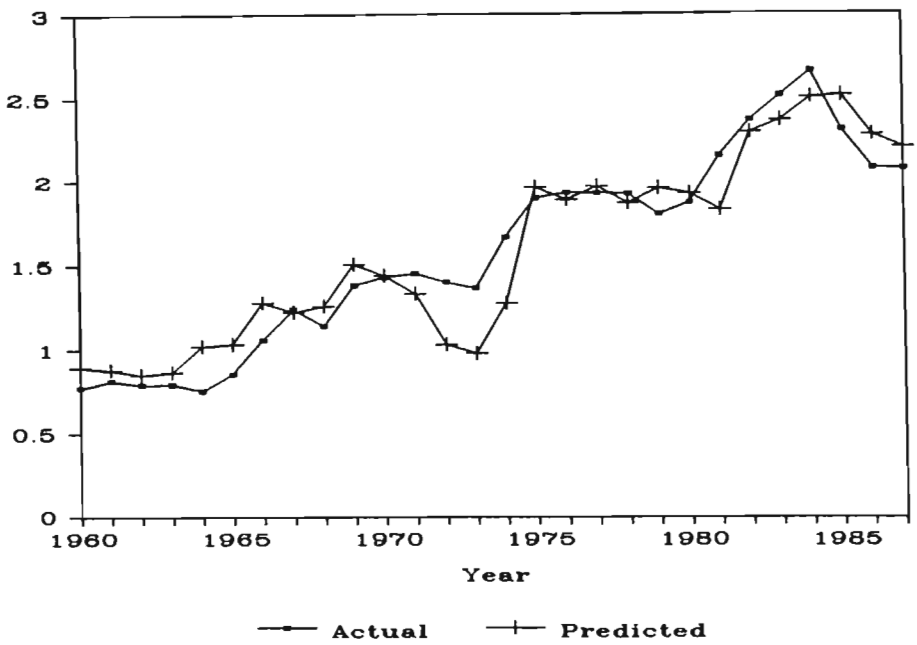

Figure 4.20 Plot of actual versus predicted values of real stock and poultry feed demand (R 100 million, base year=1975)

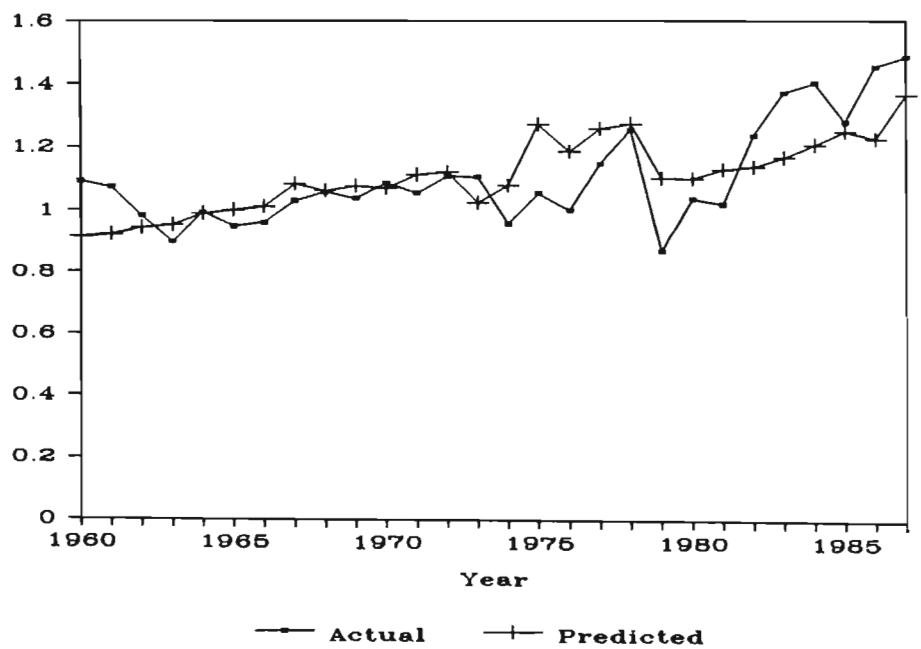

Figure 4.21 Plot of actual versus predicted values of real fuel demand (R 100 million, base year=1975)

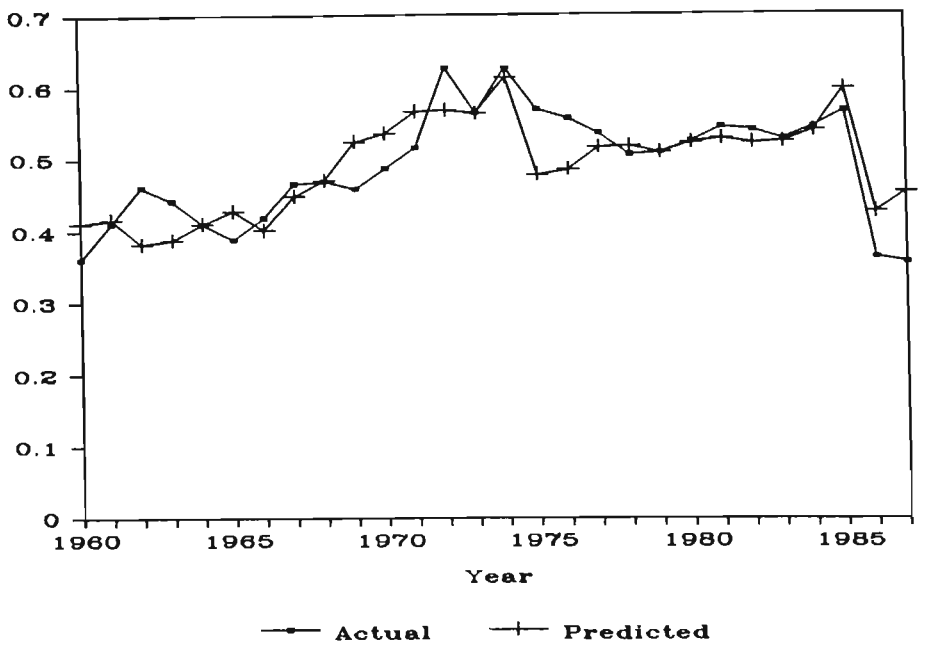

Figure 4.22 Plot of actual versus predicted values of real packing materials demand (R 100 million, base year=1975)

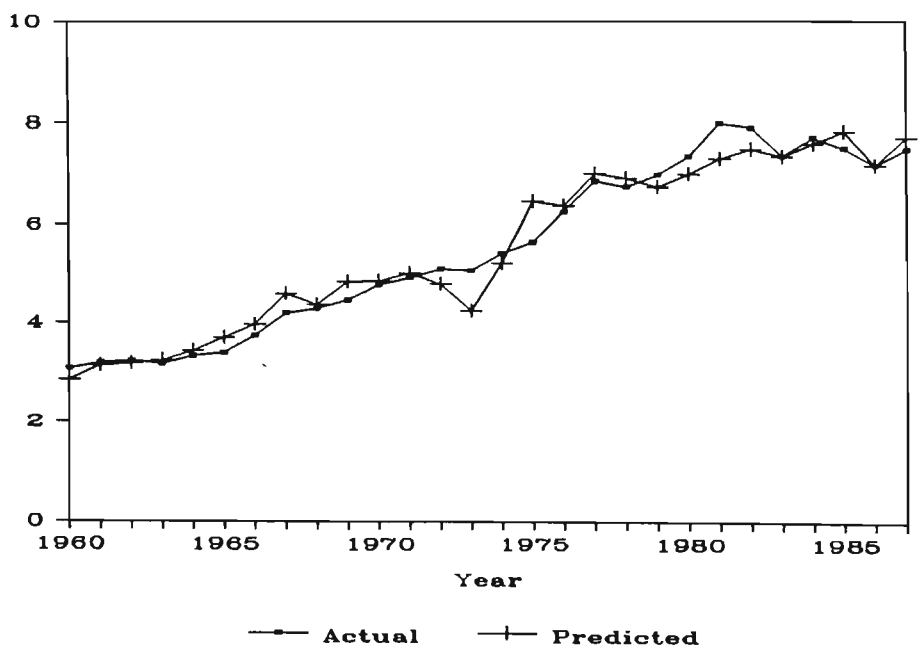

Figure 4.23 Plot of actual versus predicted values of total real input demand (R 100 million, base year=1975)

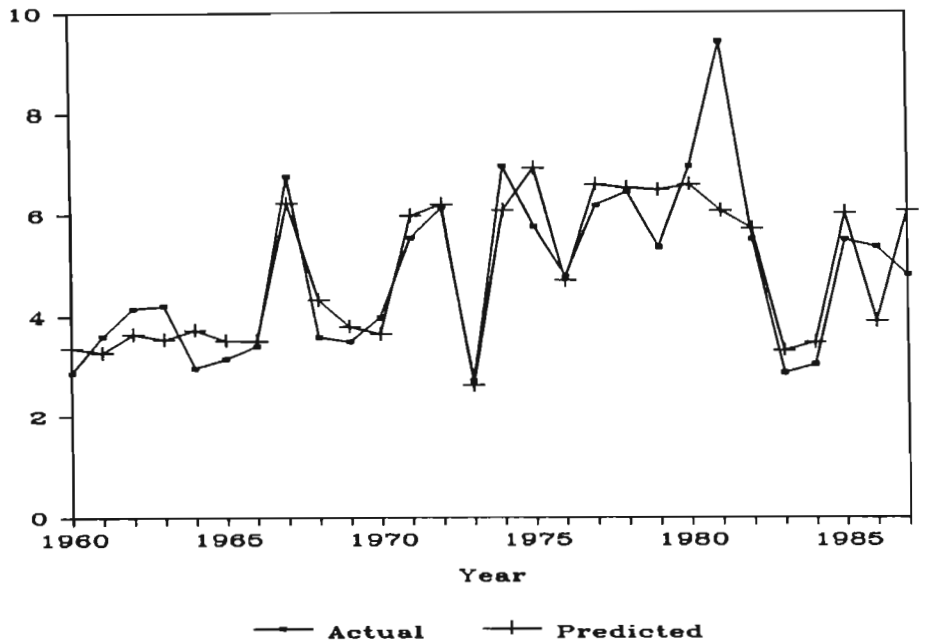

Figure 4.24 Plot of actual versus predicted values of real maize supply (R 100 million, base year=1975)

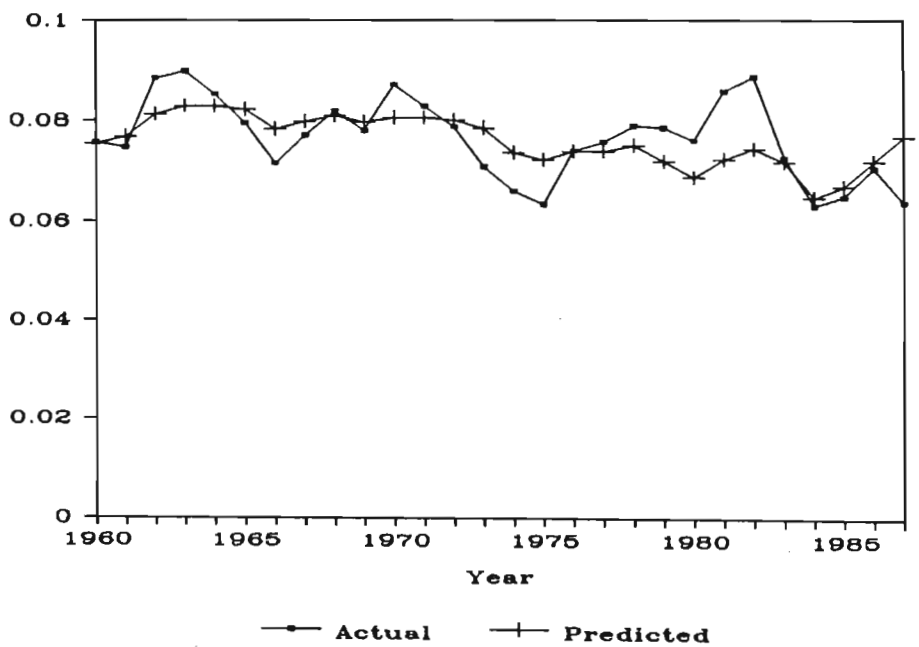

Figure 4.25 Plot of actual versus predicted values of real per capita human maize demand (R 100, base year=1975)

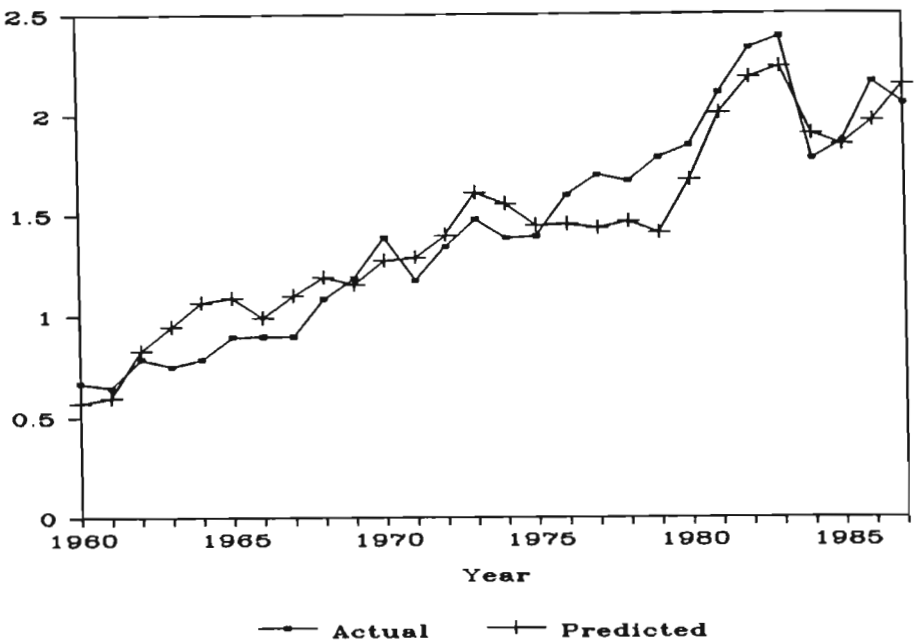

Figure 4.26 Plot of actual versus predicted values of real animal maize demand (R 100 million, base year = 1975)

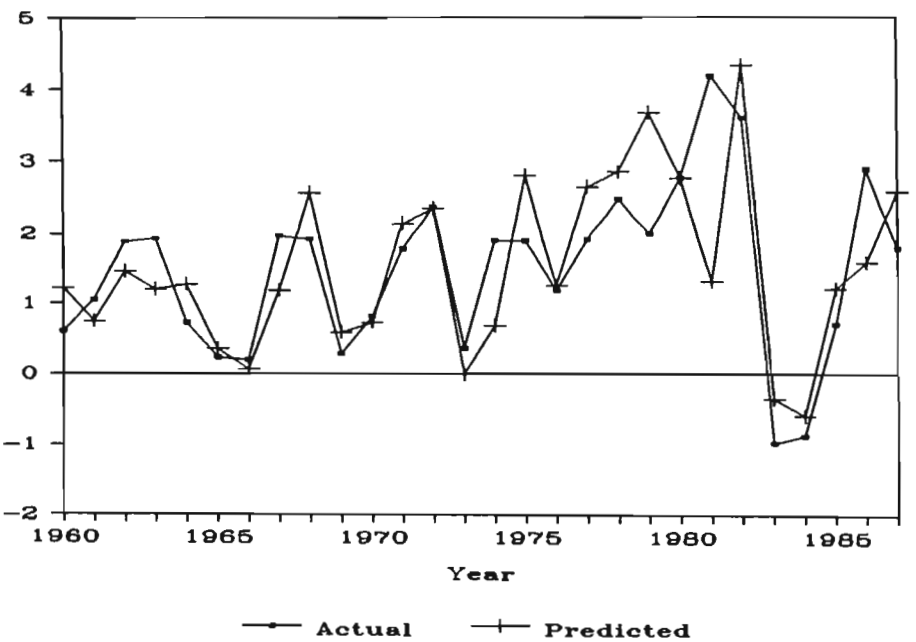

Figure 4.27 Plot of actual versus predicted values of real maize exports (R 100 million, base year = 1975)

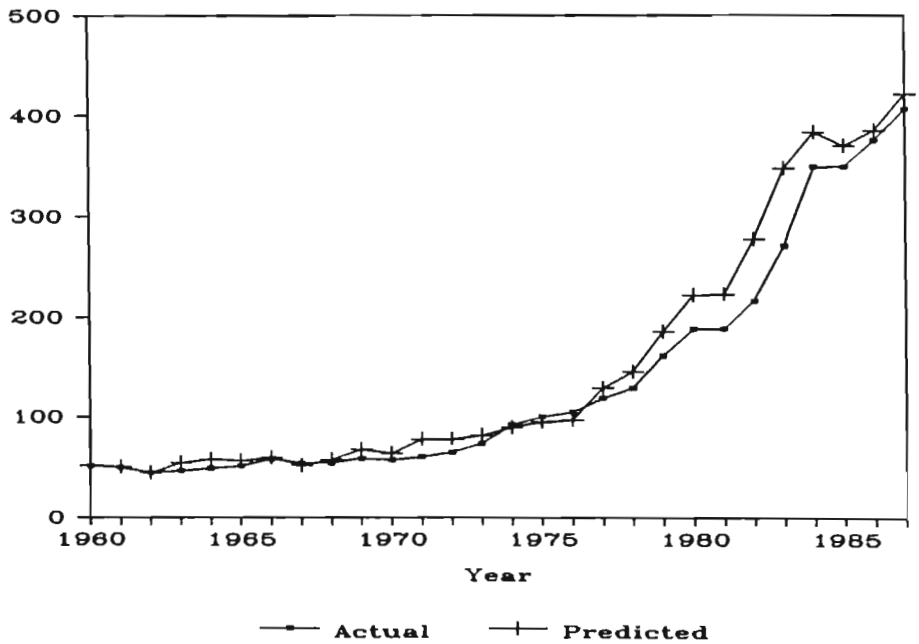

Figure 4.28 Plot of actual versus predicted values of the maize producer price index (1975=100)

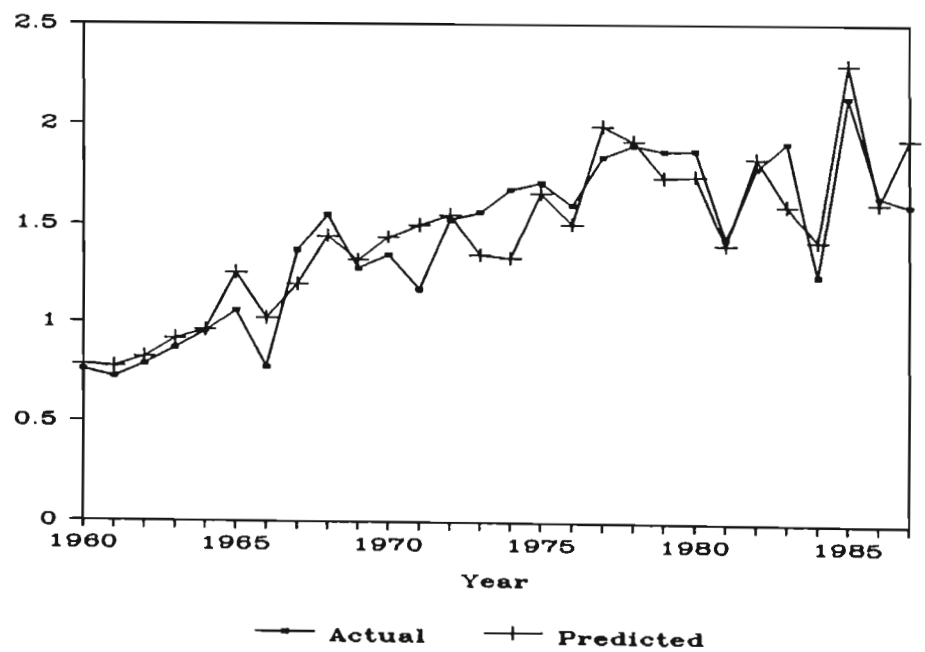

Figure 4.29 Plot of actual versus predicted values of real sugar cane supply (R 100 million, base year=1975)

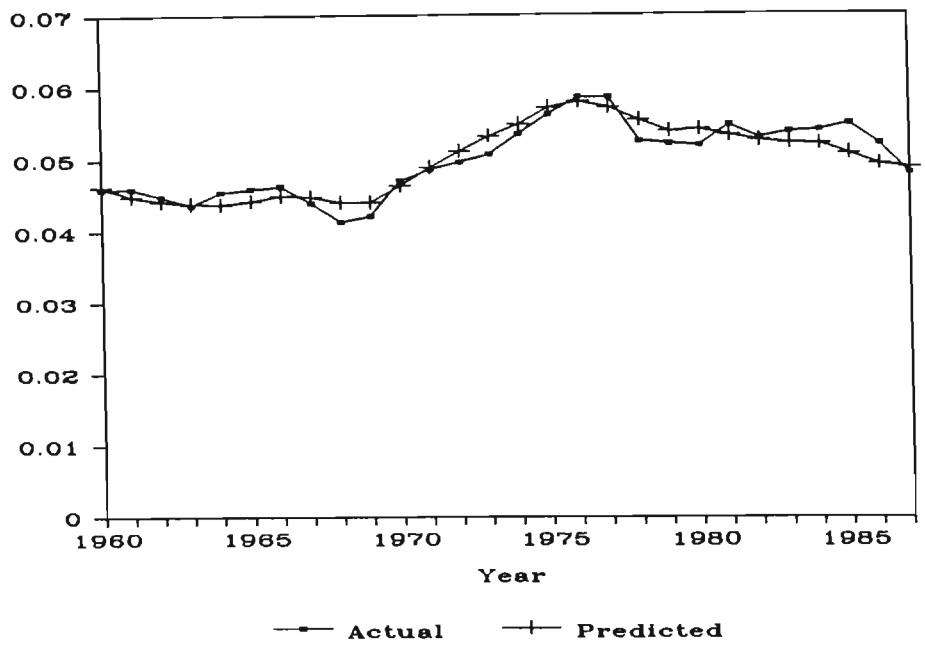

Figure 4.30 Plot of actual versus predicted values of real per capita sugar demand (R 100, base year=1975)

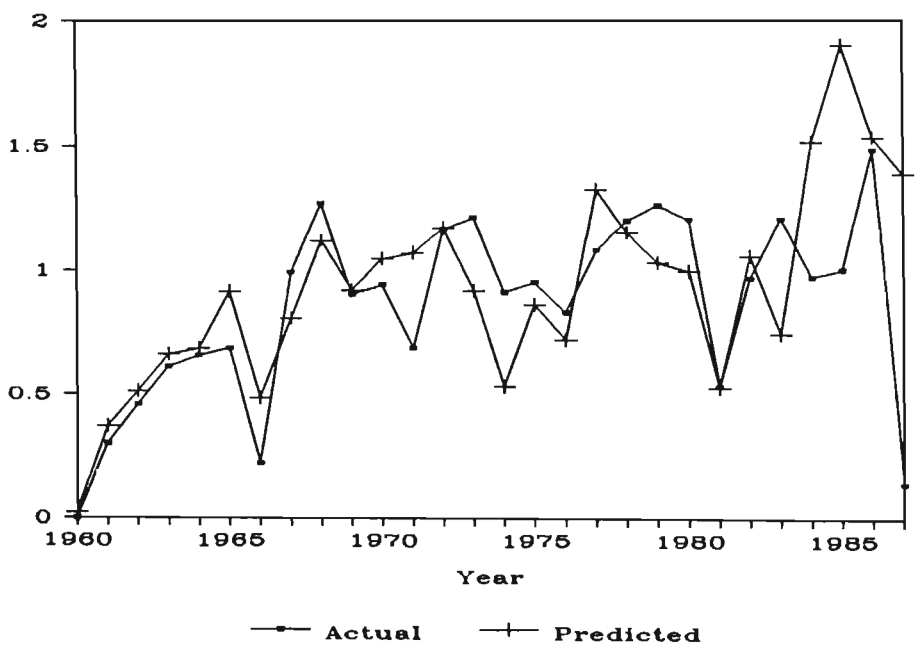

Figure 4.31 Plot of actual versus predicted values of real sugar exports (R 100 million, base year=1975)

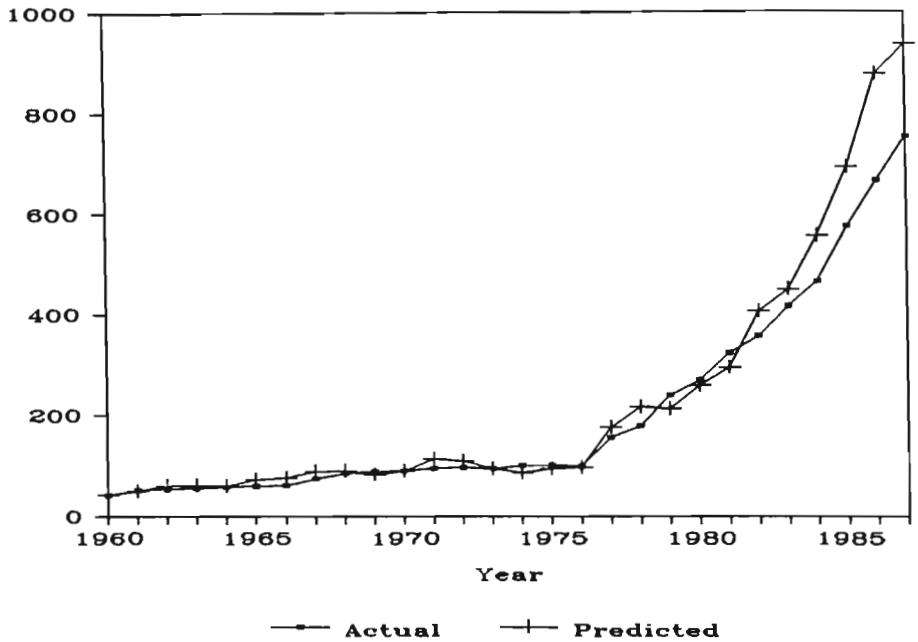

Figure 4.32 Plot of actual versus predicted values of the sucrose price index (1975=100)

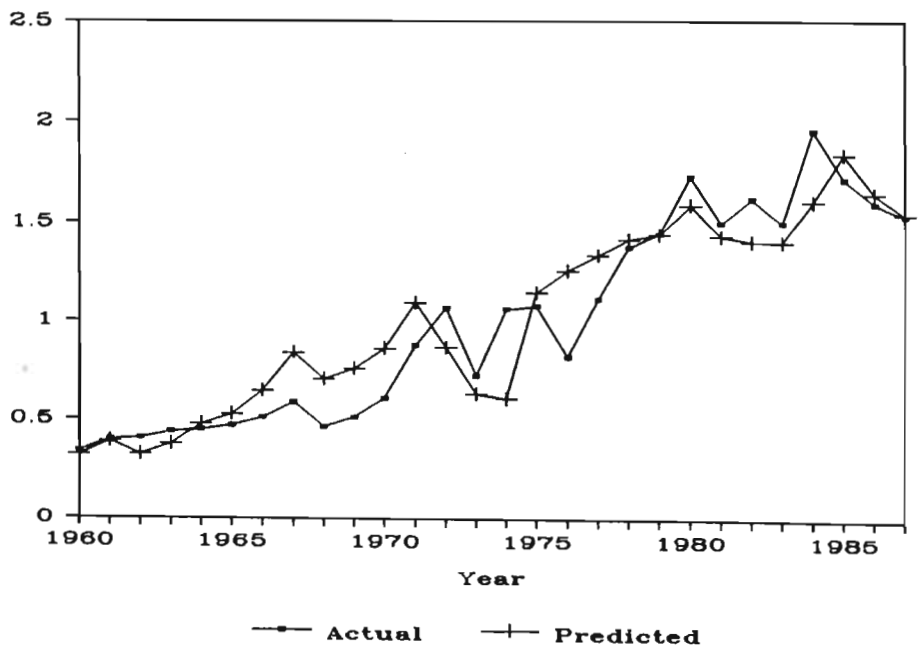

Figure 4.33 Plot of actual versus predicted values of real hay supply (R 100 million, base year =1975)

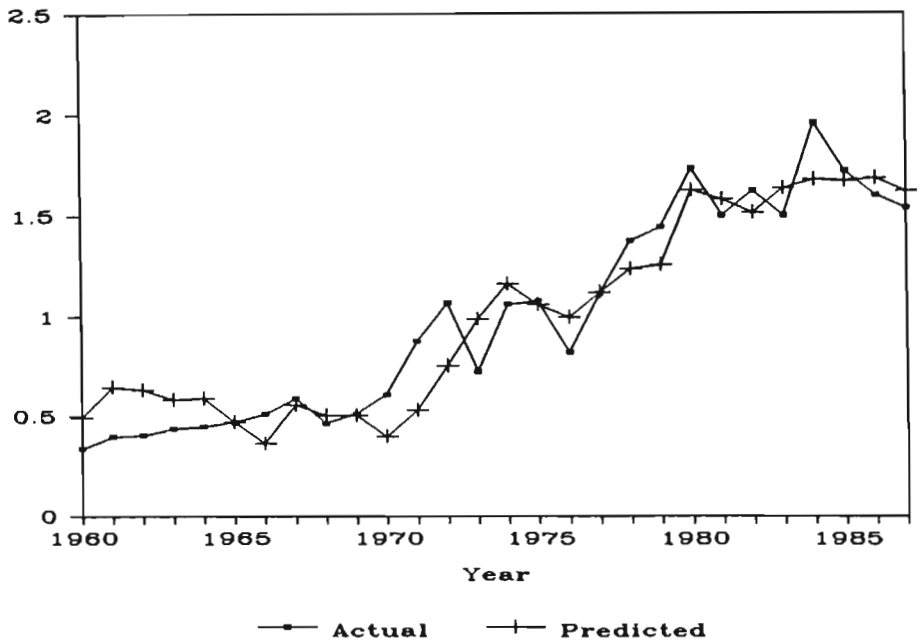

Figure 4.34 Plot of actual versus predicted values of real hay demand (R 100 million, base year = 1975)

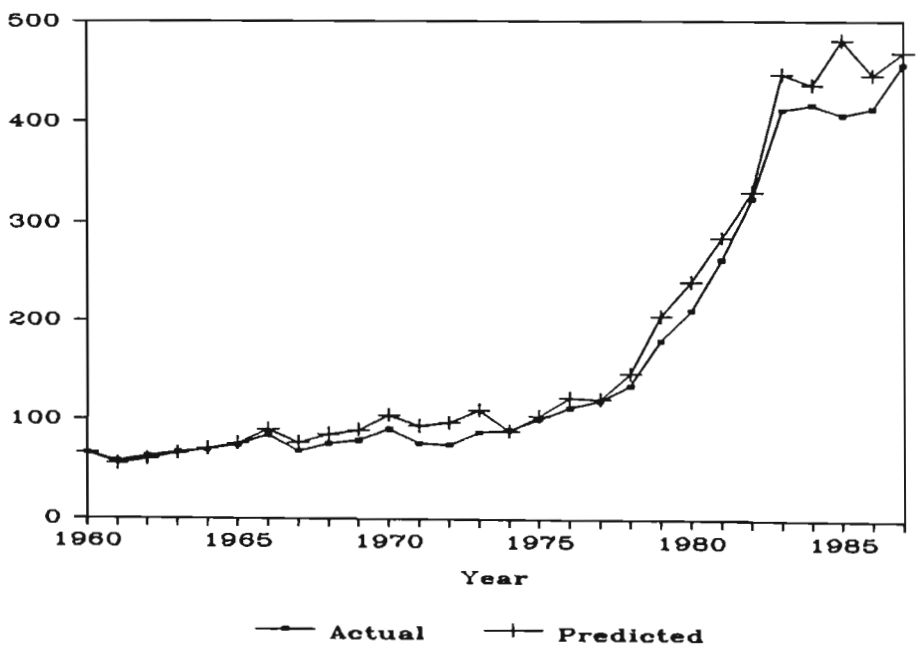

Figure 4.35 Plot of actual versus predicted values of the hay price index (1975 = 100)

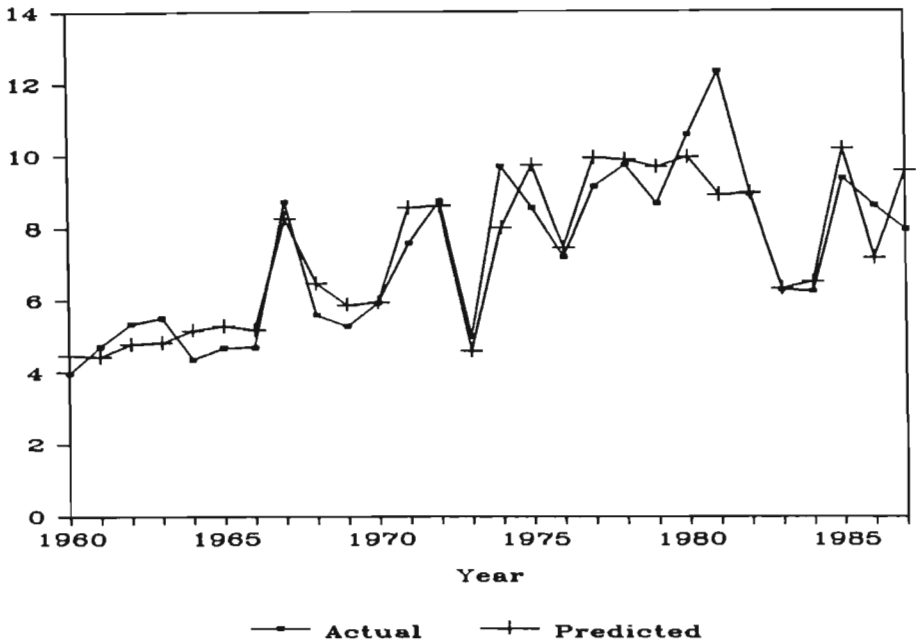

Figure 4.36 Plot of actual versus predicted values of total real gross farm income in the field crop sector (R 100 million, base year=1975)

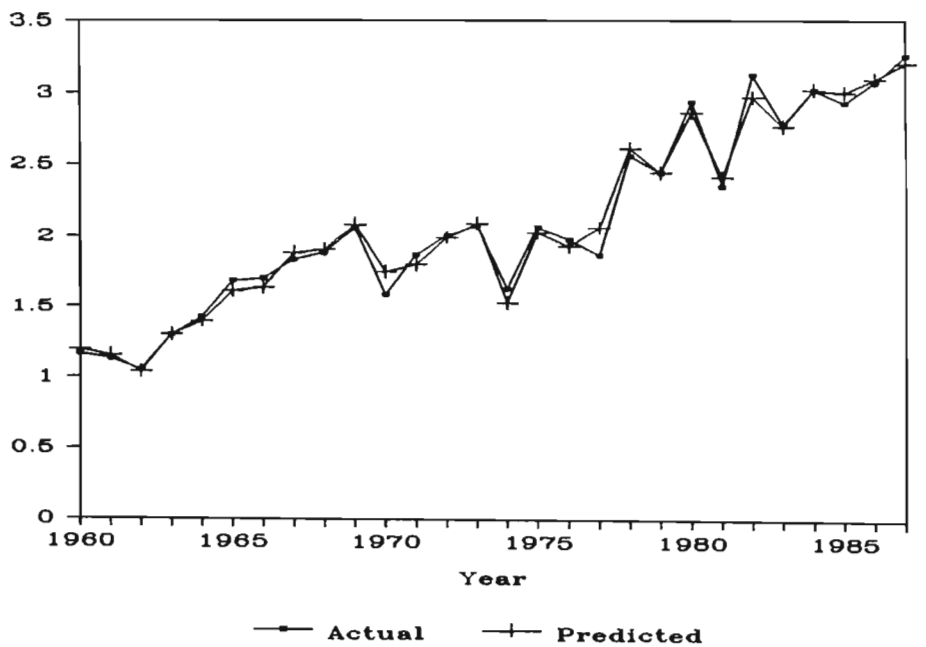

Figure 4.37 Plot of actual versus predicted values of real deciduous fruit supply (R 100 million, base year=1975)

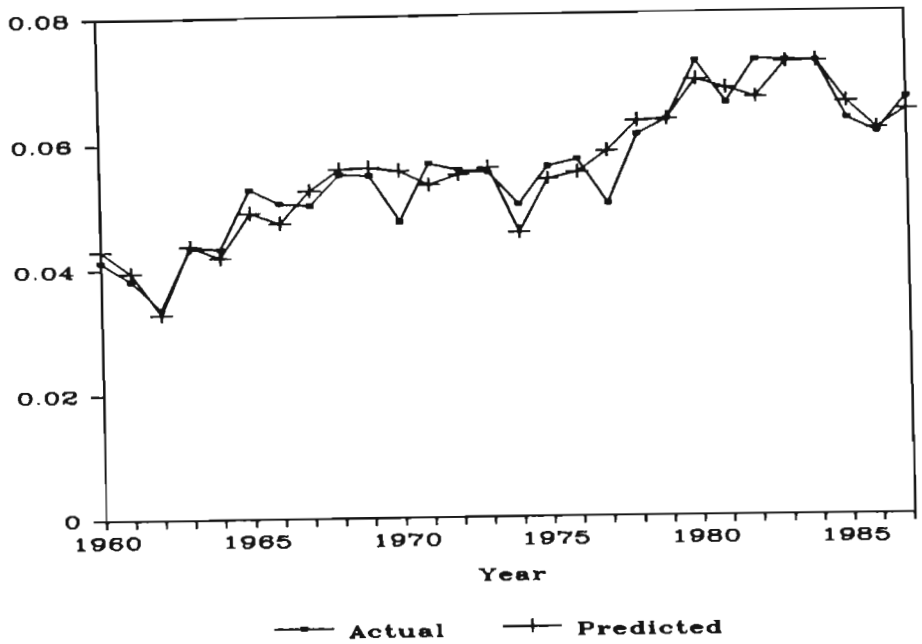

Figure 4.38 Plot of actual versus predicted values of real per capita deciduous fruit demand (R 100, base year = 1975)

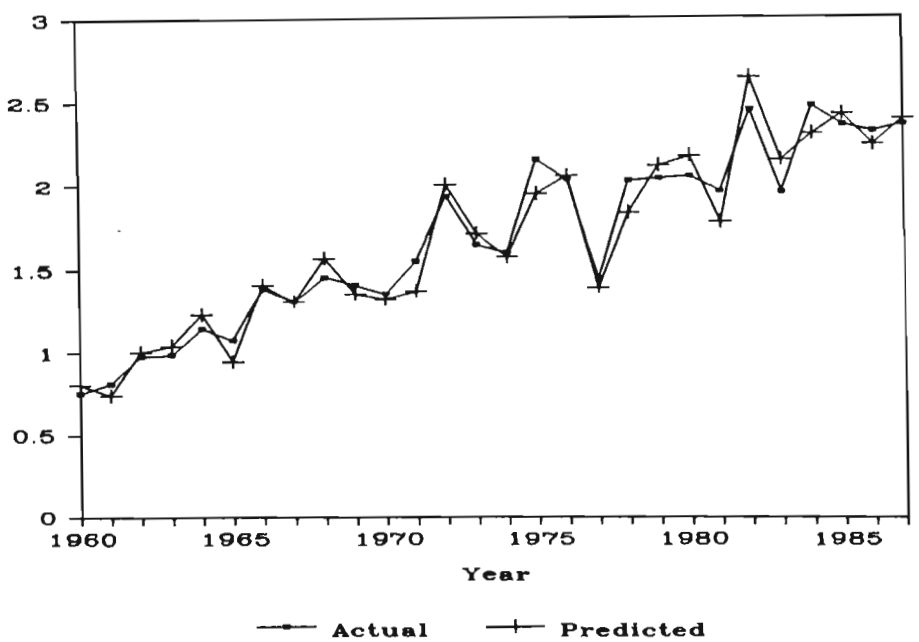

Figure 4.39 Plot of actual versus predicted values of real deciduous fruit exports (R 100 million, base year = 1975)

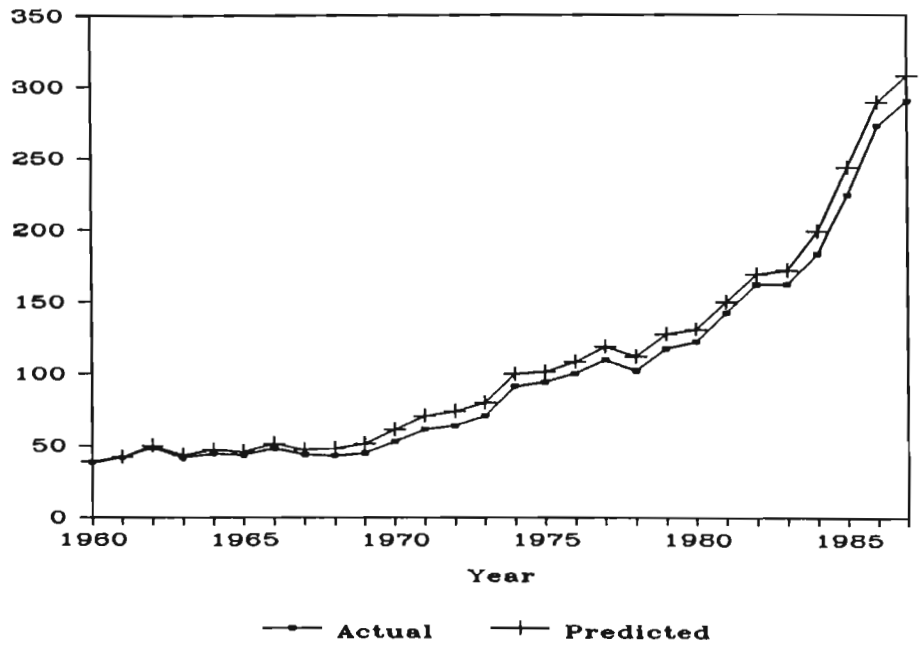

Figure 4.40 Plot of actual versus predicted values of the deciduous fruit market price index (1975=100)

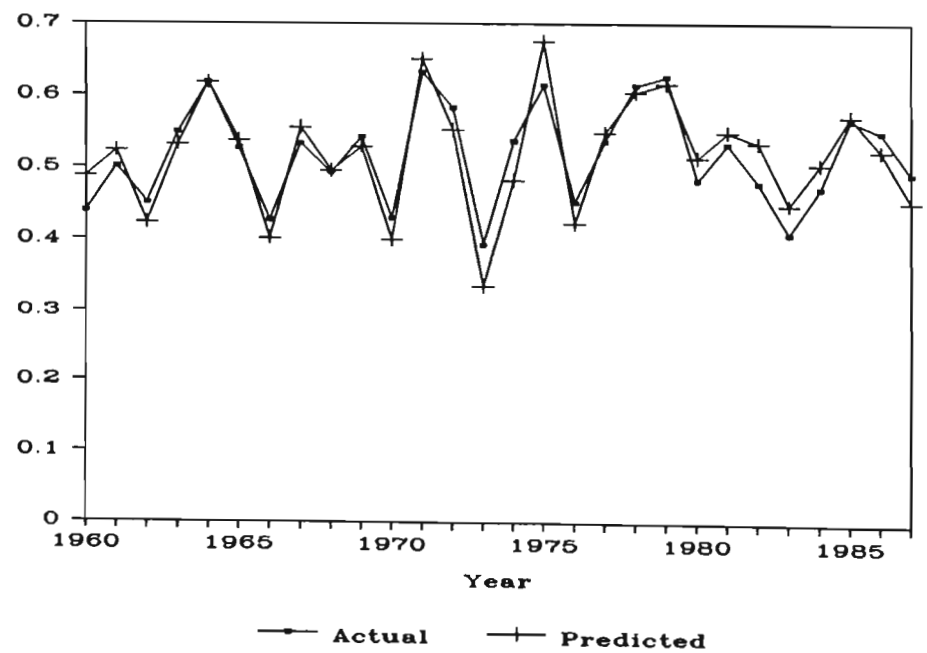

Figure 4.41 Plot of actual versus predicted values of real citrus fruit supply (R 100 million, base year=1975)

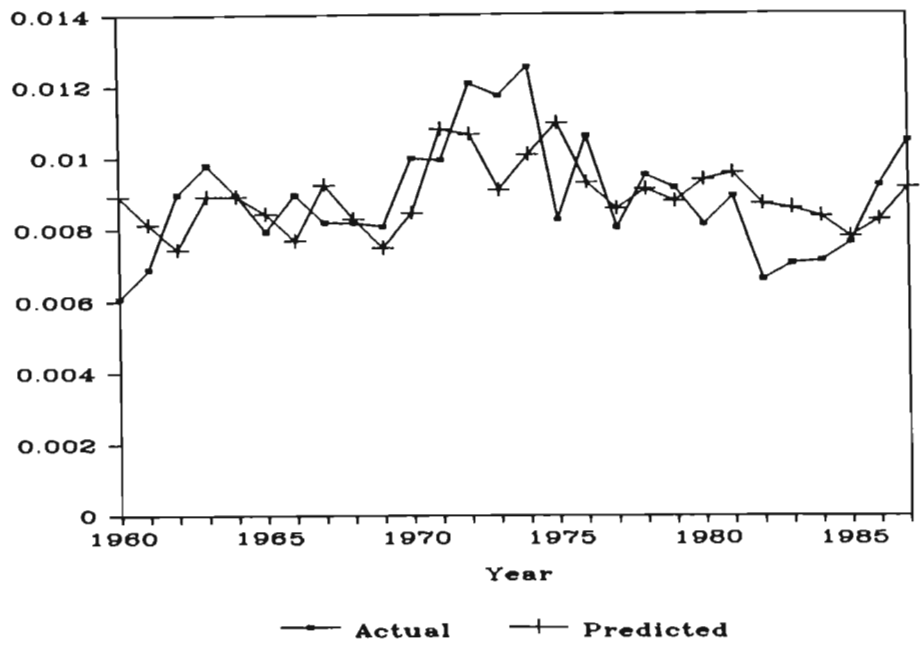

Figure 4.42 Plot of actual versus predicted values of real per capita citrus fruit demand (R 100, base year = 1975)

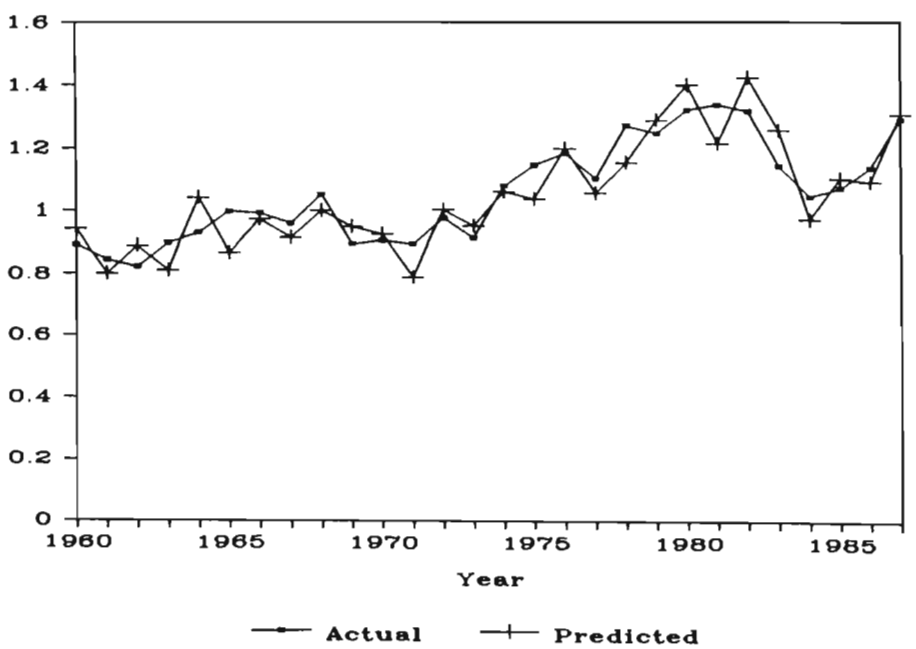

Figure 4.43 Plot of actual versus predicted values of real citrus fruit exports (R 100 million, base year = 1975)

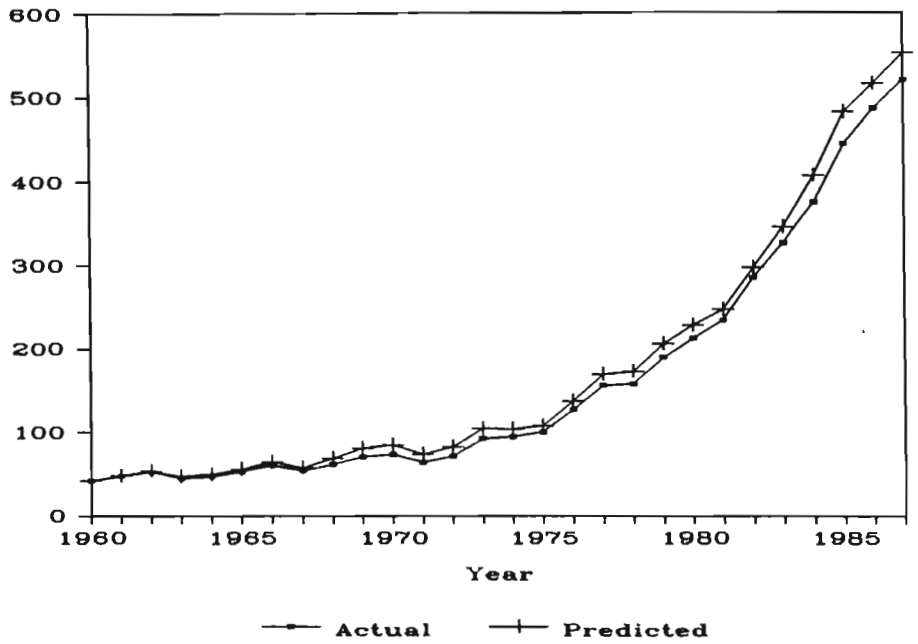

Figure 4.44 Plot of actual versus predicted values of the citrus fruit market price index (1975=100)

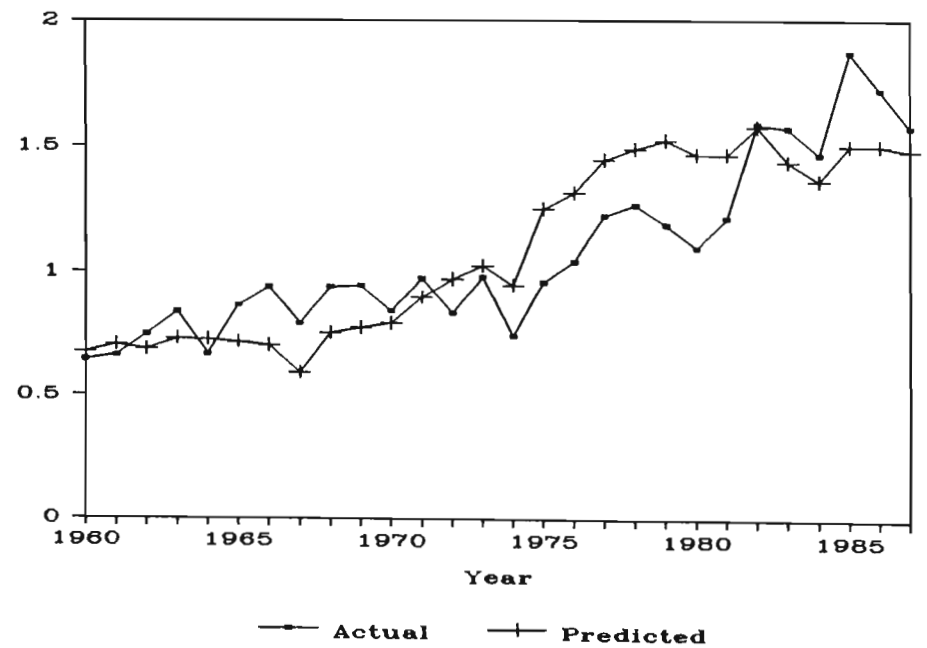

Figure 4.45 Plot of actual versus predicted values of real vegetable supply (R 100 million, base year=1975)

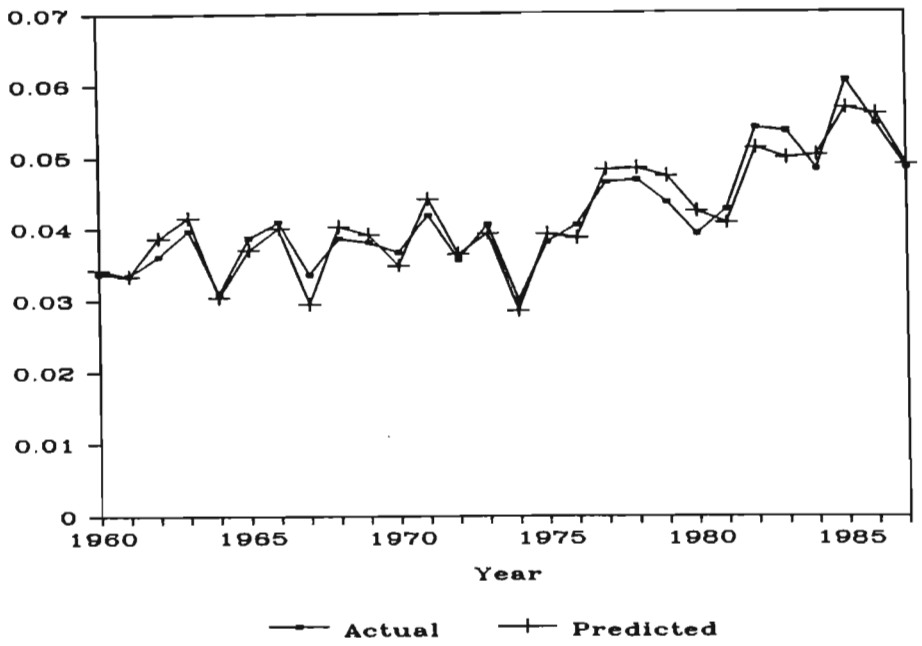

Figure 4.46 Plot of actual versus predicted values of real per capita vegetable demand (R 100, base year=1975)

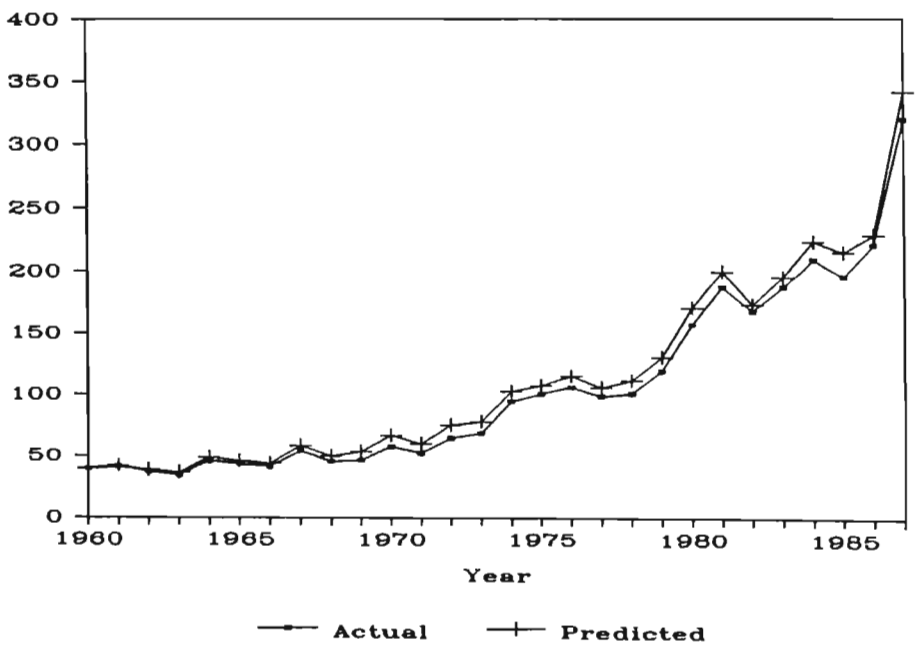

Figure 4.47 Plot of actual versus predicted values of the vegetable market price index (1975=100)

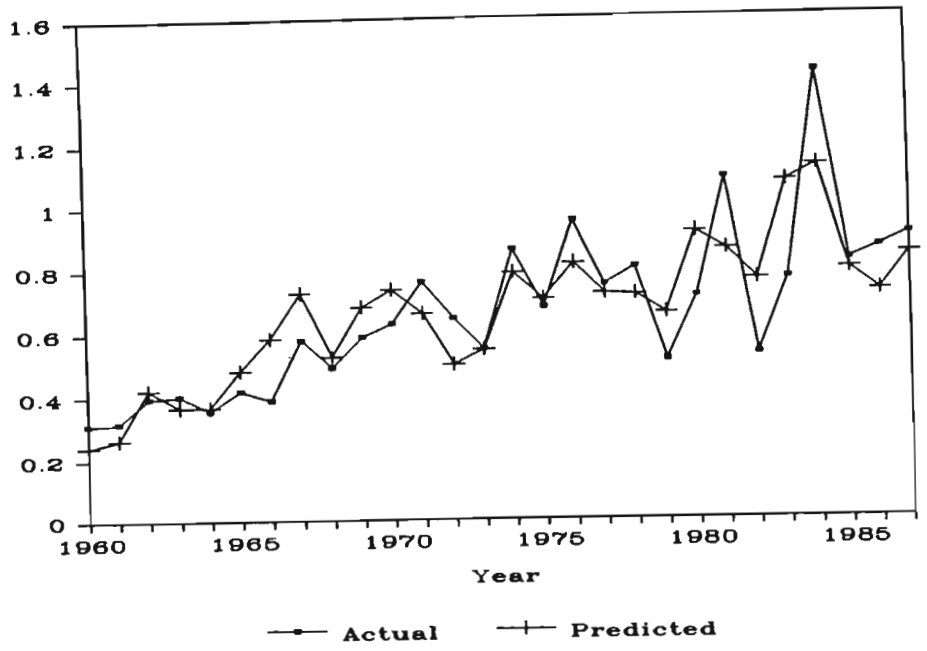

Figure 4.48 Plot of actual versus predicted values of real potato supply (R 100 million, base year = 1975)

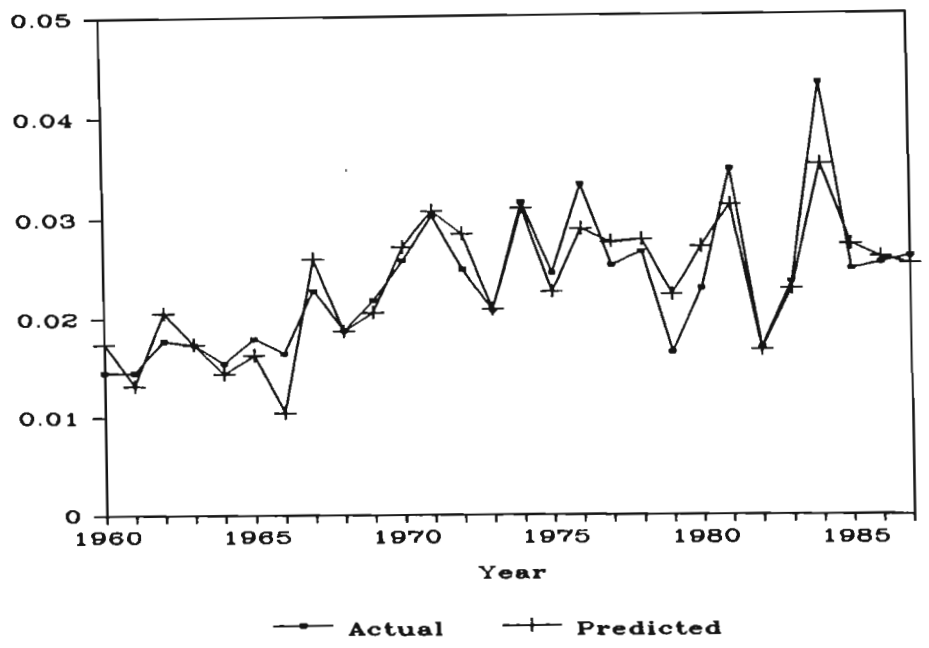

Figure 4.49 Plot of actual versus predicted values of real per capita potato demand (R 100, base year = 1975)

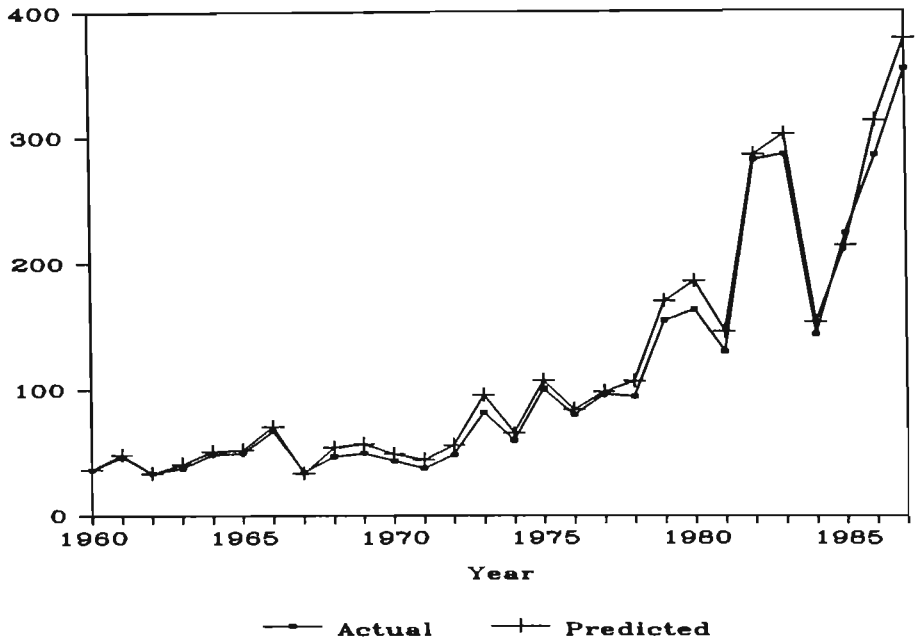

Figure 4.50 Plot of actual versus predicted values of the potato market price index (1975=100)

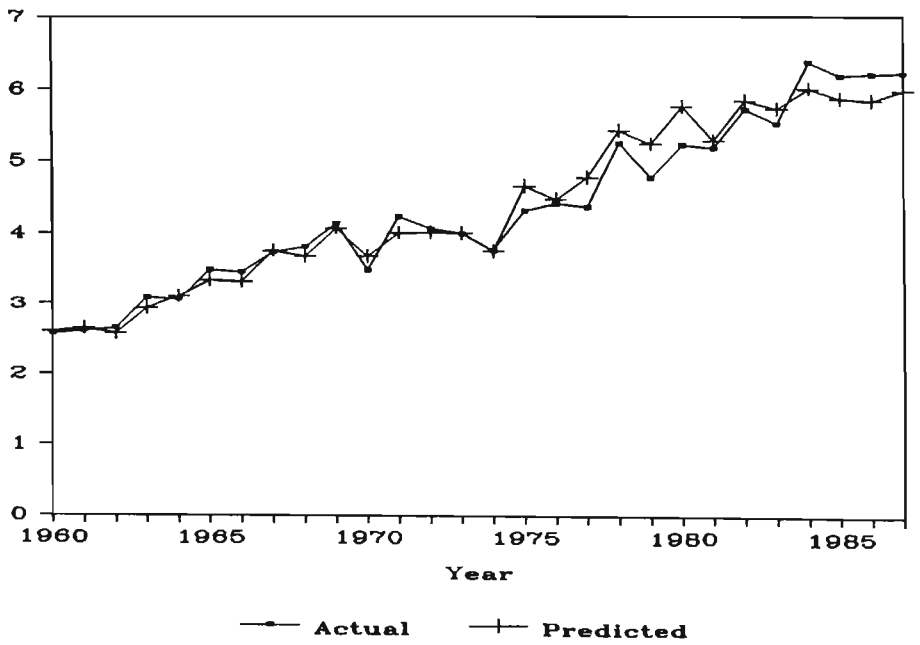

Figure 4.51 Plot of actual versus predicted values of total real gross farm income in the horticultural sector (R 100 million, base year=1975)

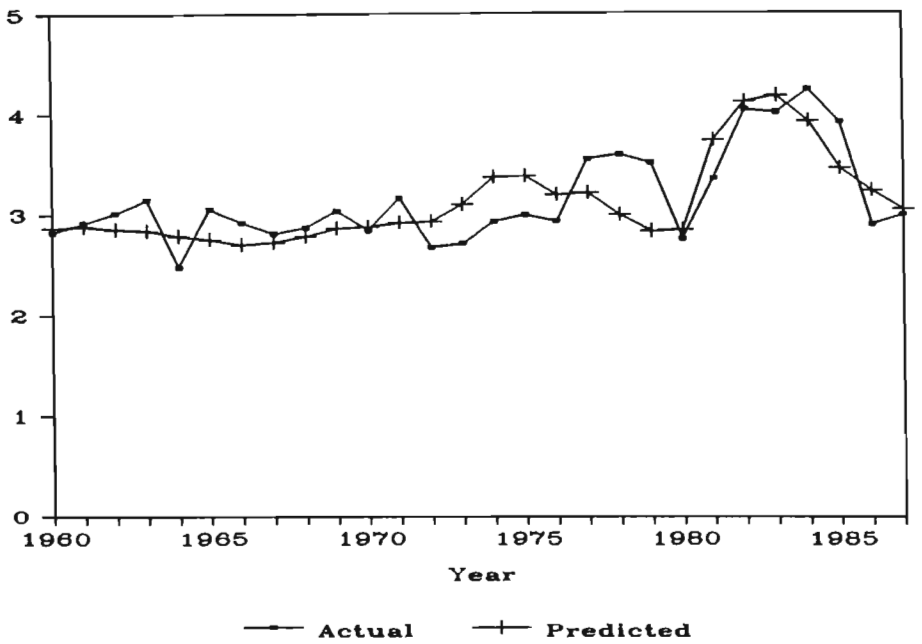

Figure 4.52 Plot of actual versus predicted values of real beef supply (R 100 million, base year=1975)

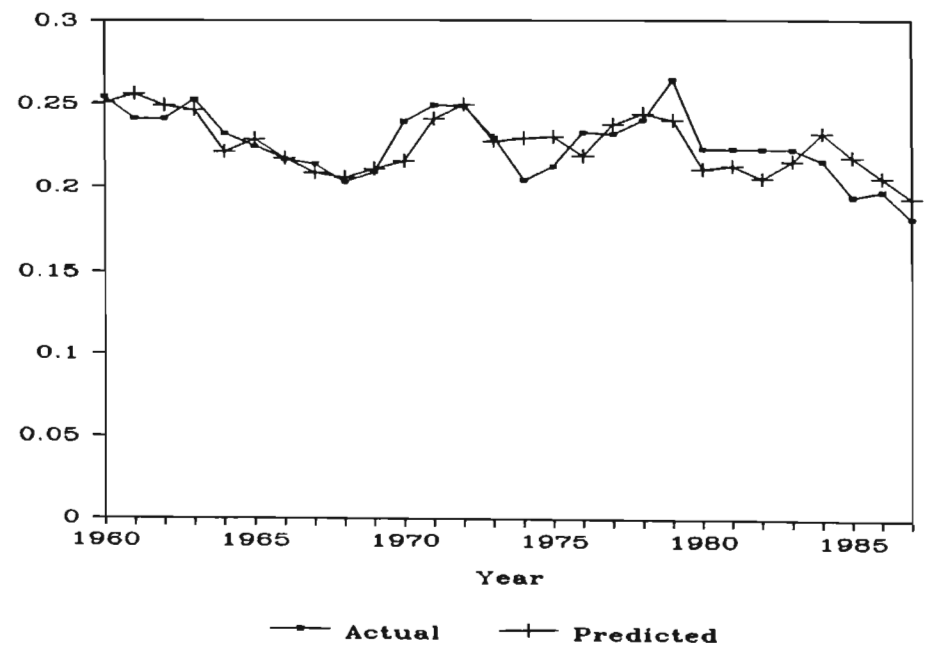

Figure 4.53 Plot of actual versus predicted values of real per capita beef demand (R 100, base year=1975)

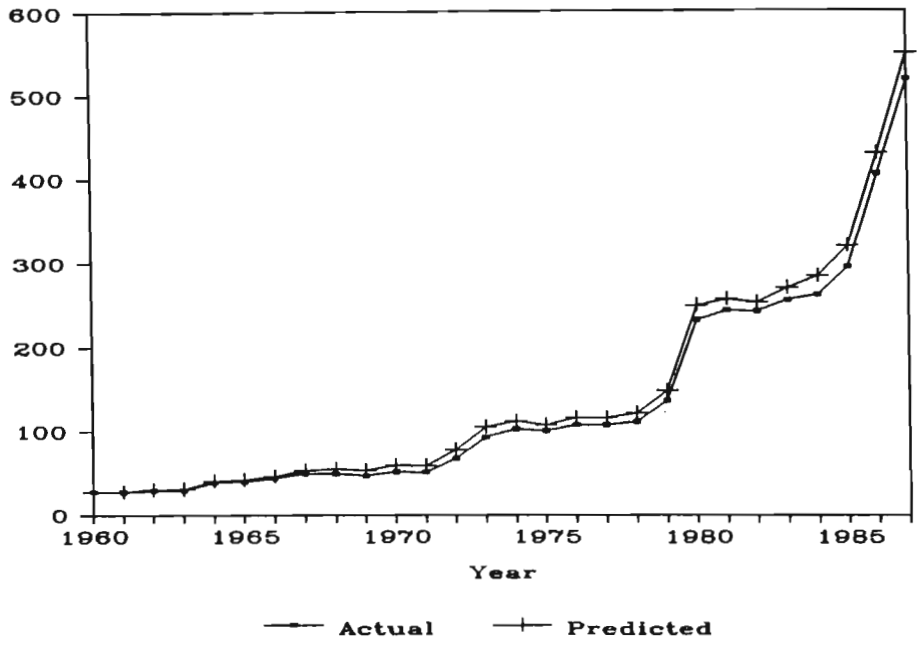

Figure 4.54 Plot of actual versus predicted values of the beef auction price index (1975=100)

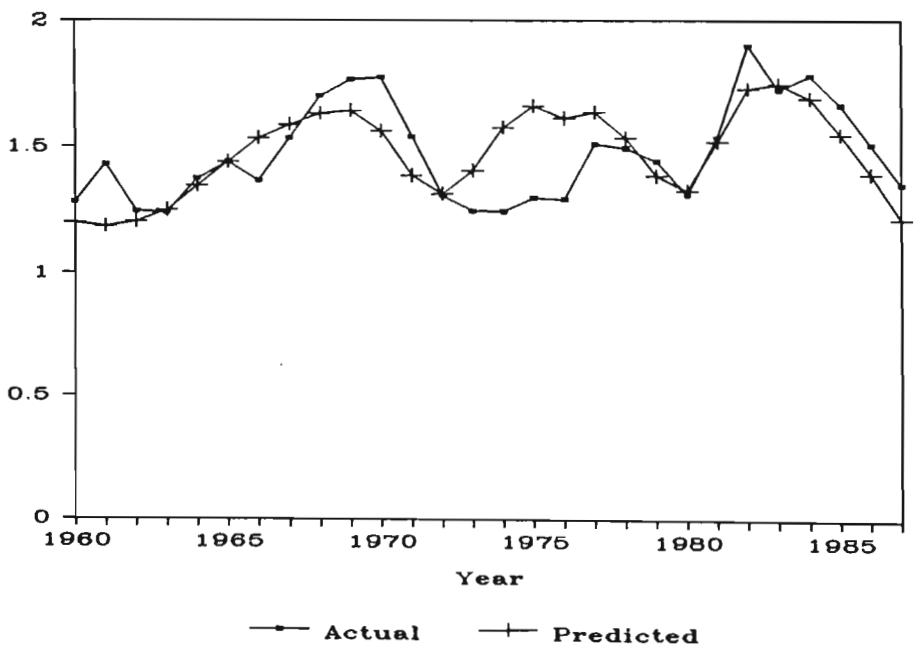

Figure 4.55 Plot of actual versus predicted values of real mutton supply (R 100 million, base year=1975)

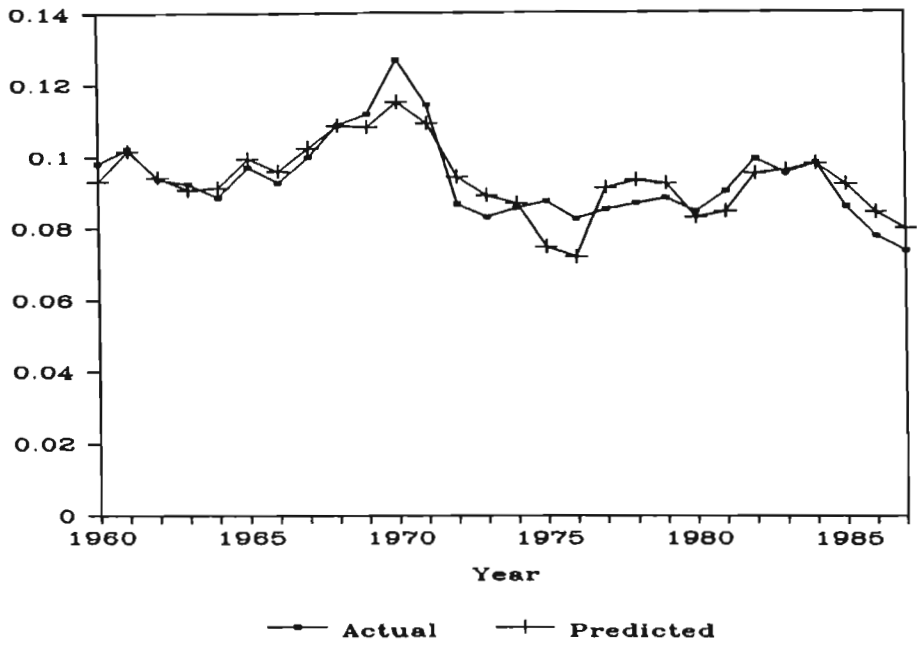

Figure 4.56 Plot of actual versus predicted values of real per capita mutton demand (R 100, base year=1975)

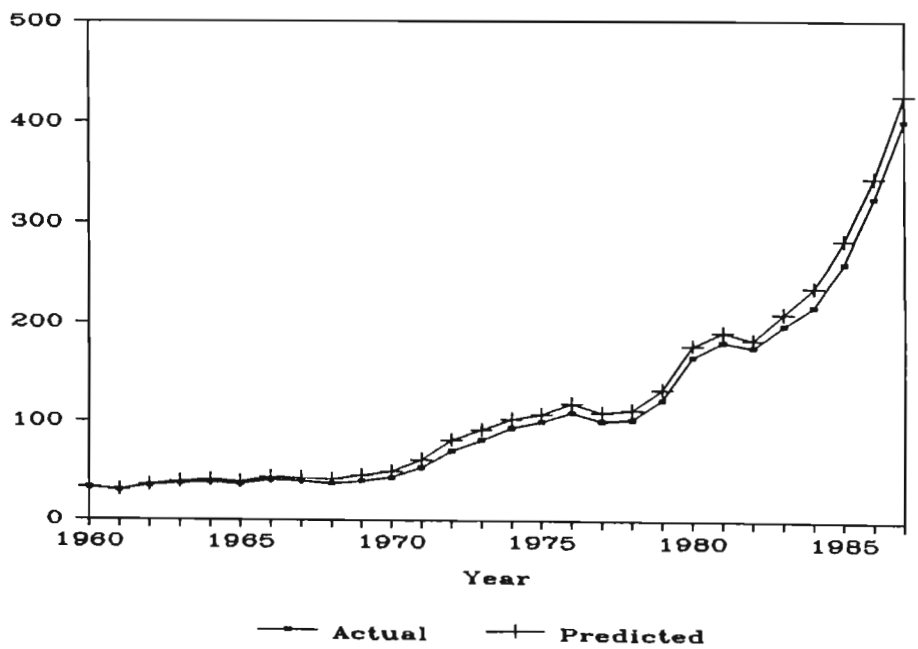

Figure 4.57 Plot of actual versus predicted values of the mutton auction price index (1975=100)

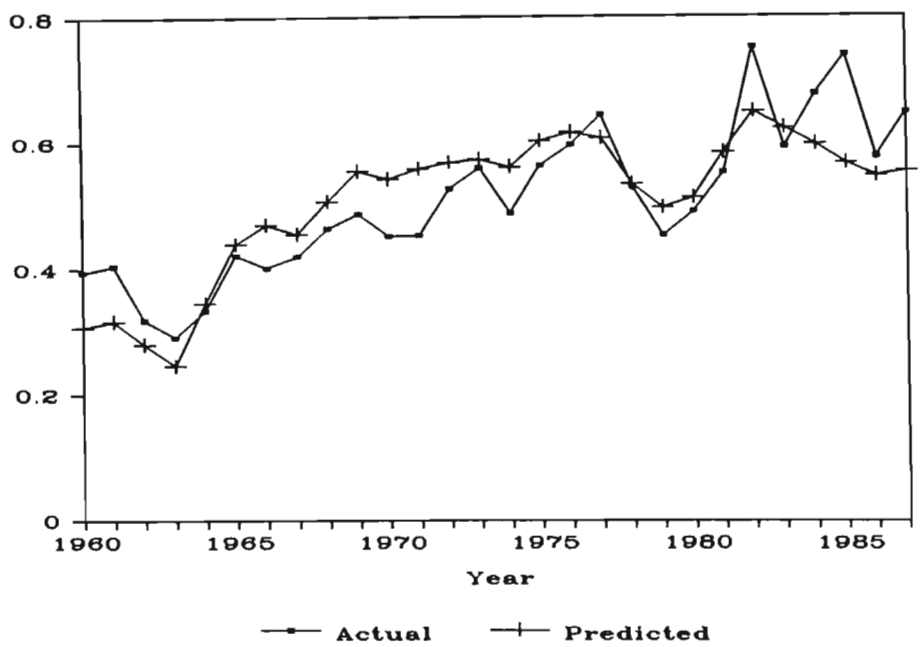

Figure 4.58 Plot of actual versus predicted values of real pork supply (R 100 million, base year=1975)

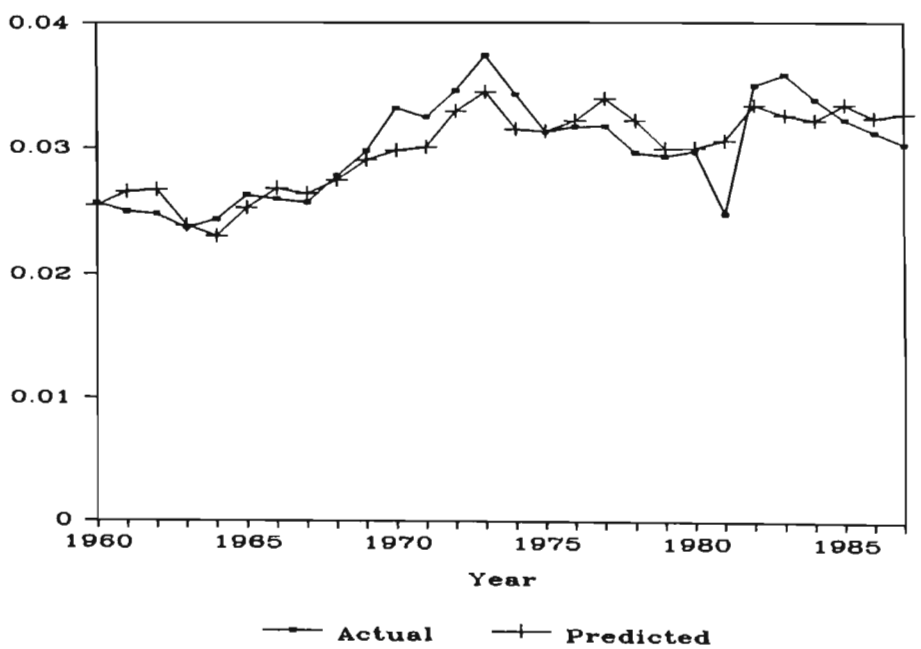

Figure 4.59 Plot of actual versus predicted values of real per capita pork demand (R 100, base year=1975)

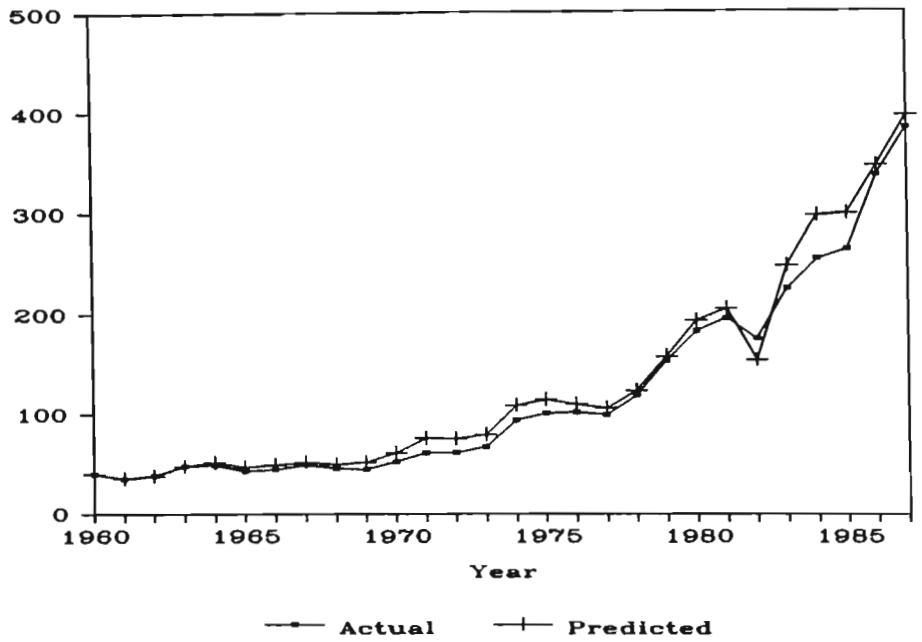

Figure 4.60 Plot of actual versus predicted values of the pork auction price index (1975=100)

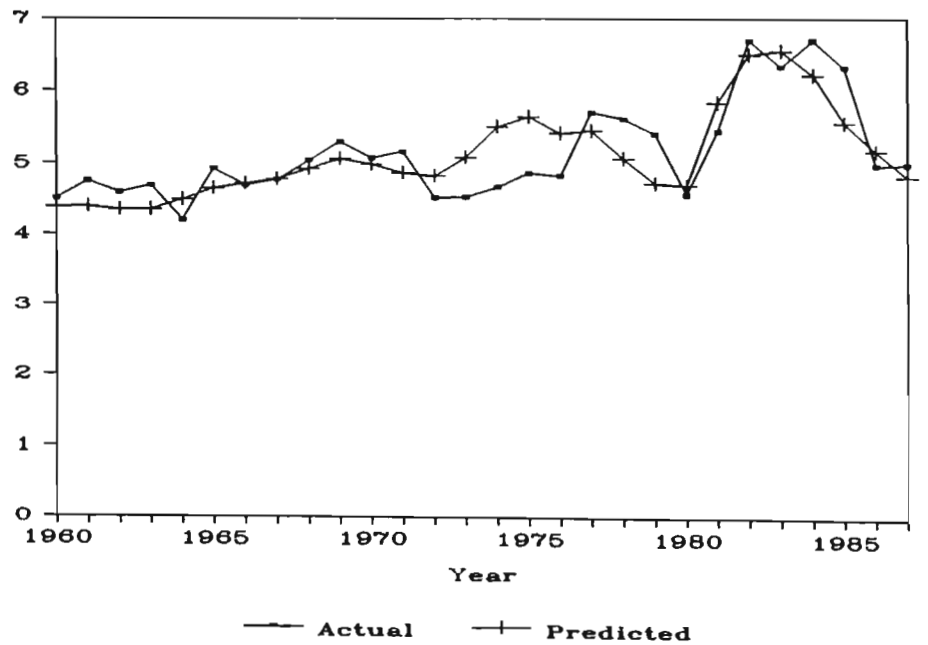

Figure 4.61 Plot of actual versus predicted values of total real gross farm income for red meats (R 100 million, base year=1975)

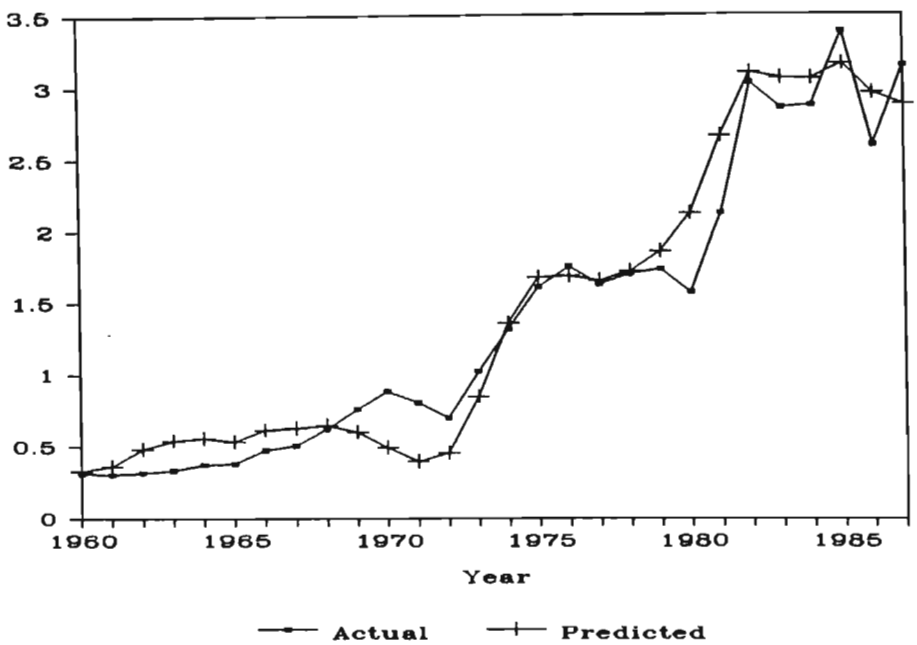

Figure 4.62 Plot of actual versus predicted values of real chicken meat supply (R 100 million, base year=1975)

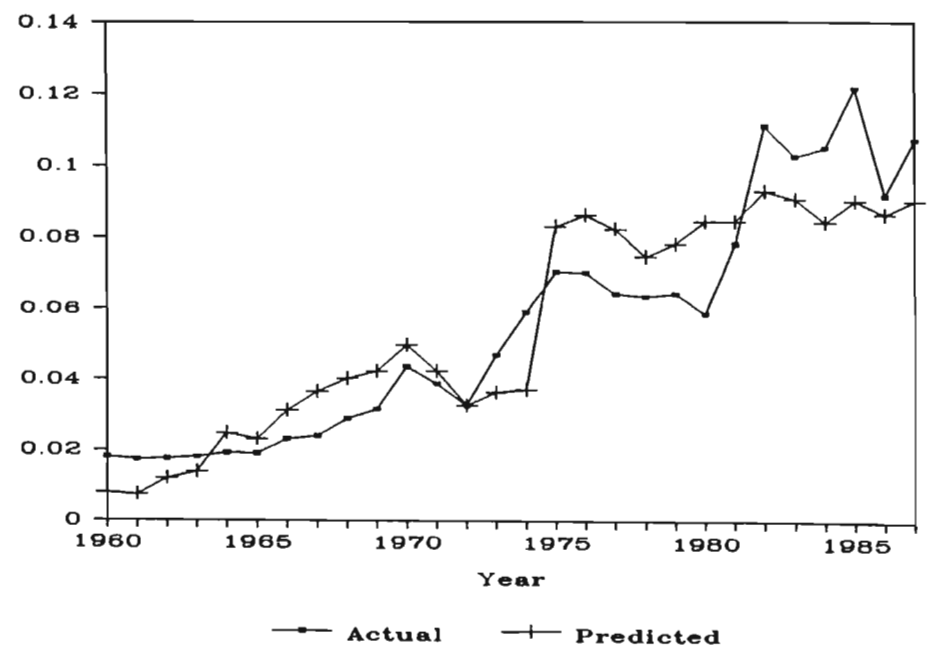

Figure 4.63 Plot of actual versus predicted values of real per capita chicken meat demand (R 100, base year=1975)

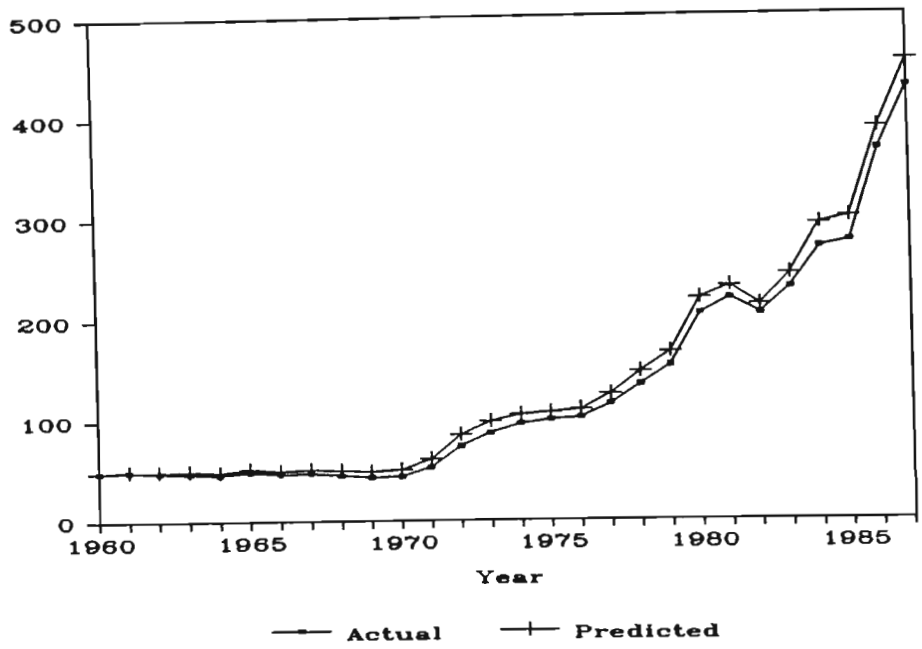

Figure 4.64 Plot of actual versus predicted values of the chicken meat price index (1975=100)

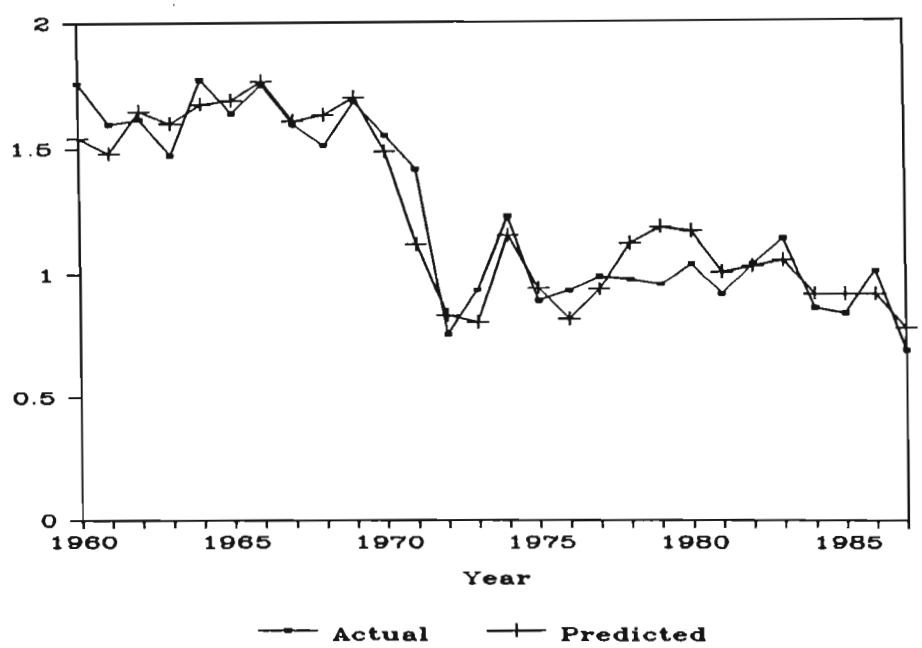

Figure 4.65 Plot of actual versus predicted values of real wool supply (R 100 million, base year=1975)

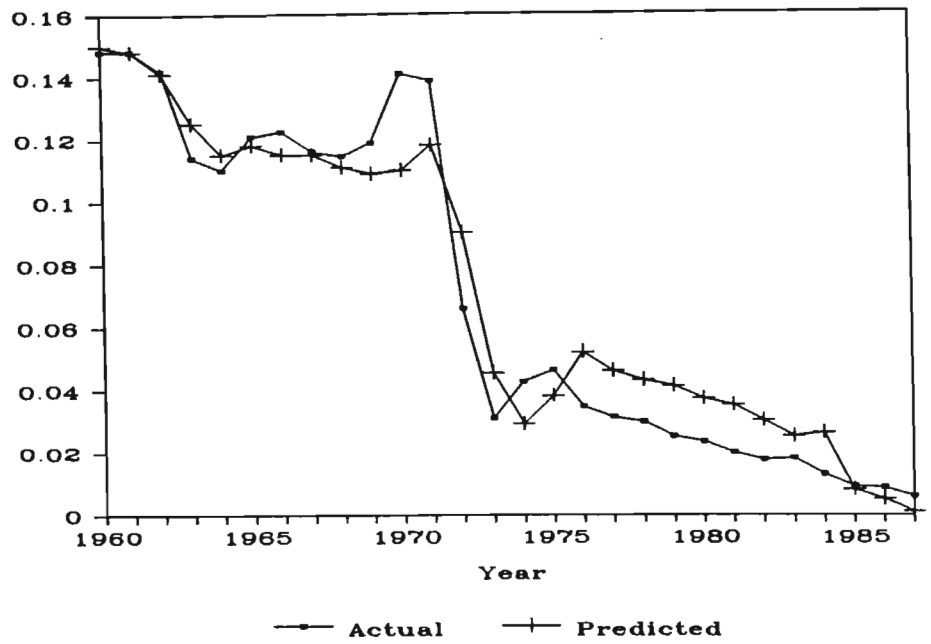

Figure 4.66 Plot of actual versus predicted values of real per capita wool demand (R 100, base year=1975)

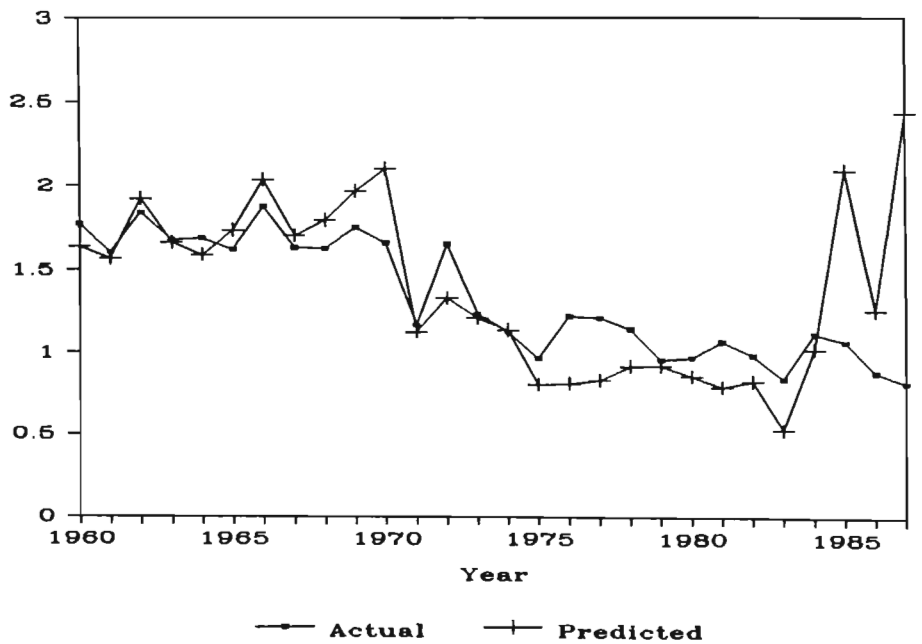

Figure 4.67 Plot of actual versus predicted values of real wool exports (R 100 million, base year=1975)

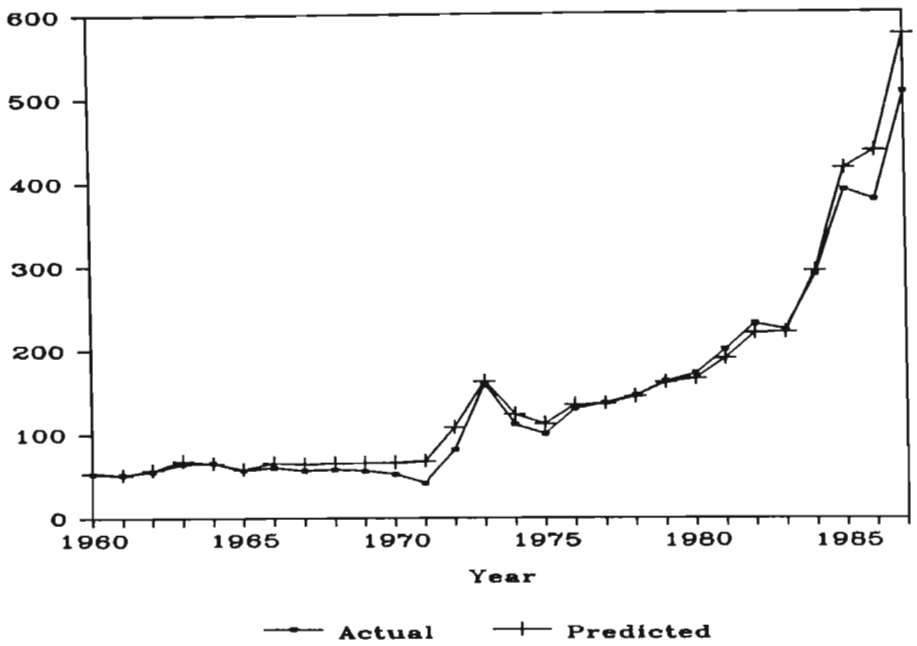

Figure 4.68 Plot of actual versus predicted values of the wool auction price index (1975=100)

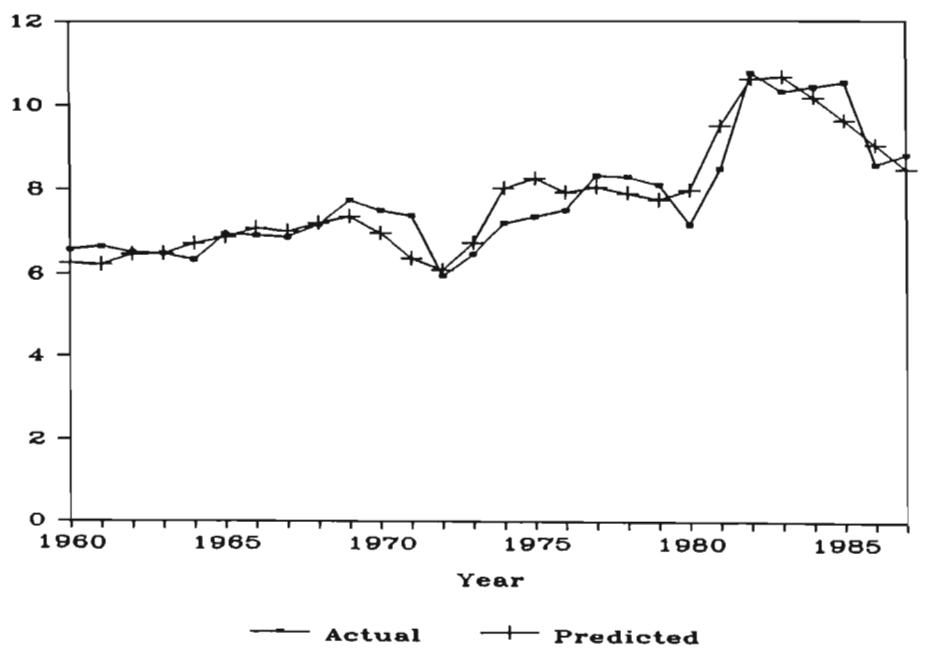

Figure 4.69 Plot of actual versus predicted values of total real gross farm income in the livestock sector (R 100 million, base year=1975)

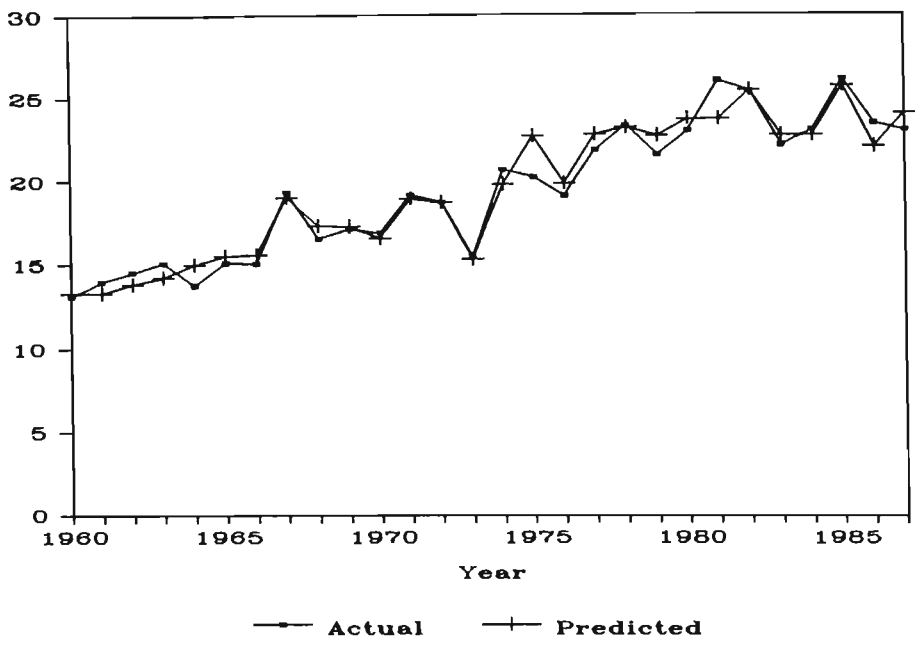

Figure 4.70 Plot of actual versus predicted values of total real gross farm income in the sectors modelled (R 100 million, base year=1975)

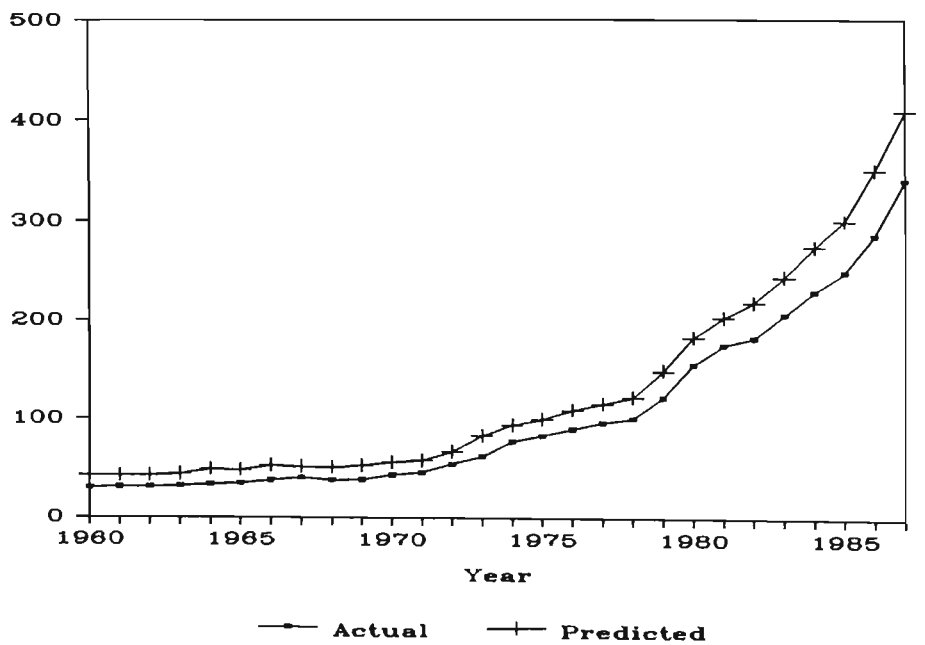

Figure 4.71 Plot of actual versus predicted values of the agricultural price index (1975=100)

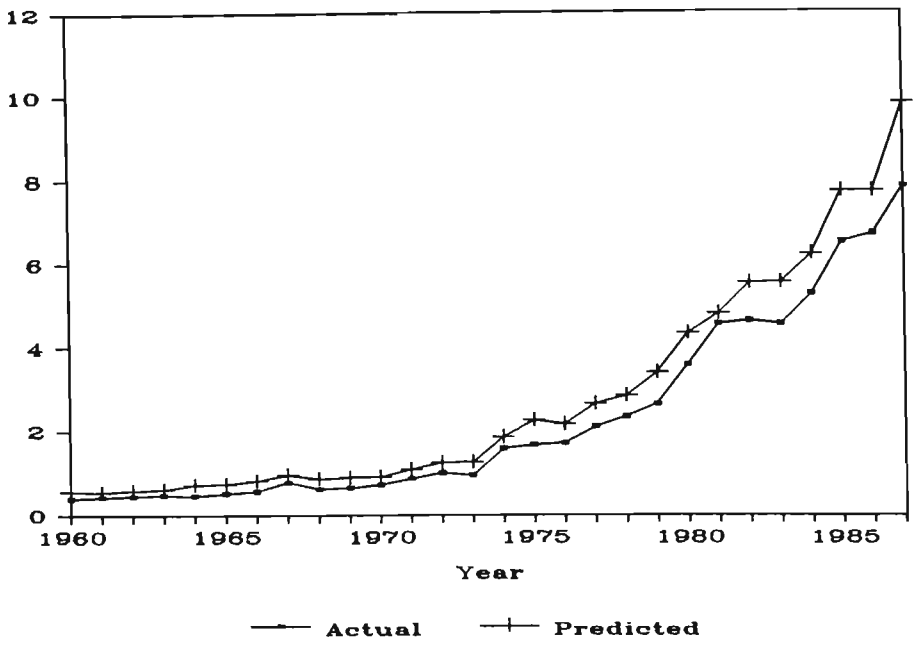

Figure 4.72 Plot of actual versus predicted values of total nominal gross farm income in the sectors modelled (R 100 million, base year=1975)

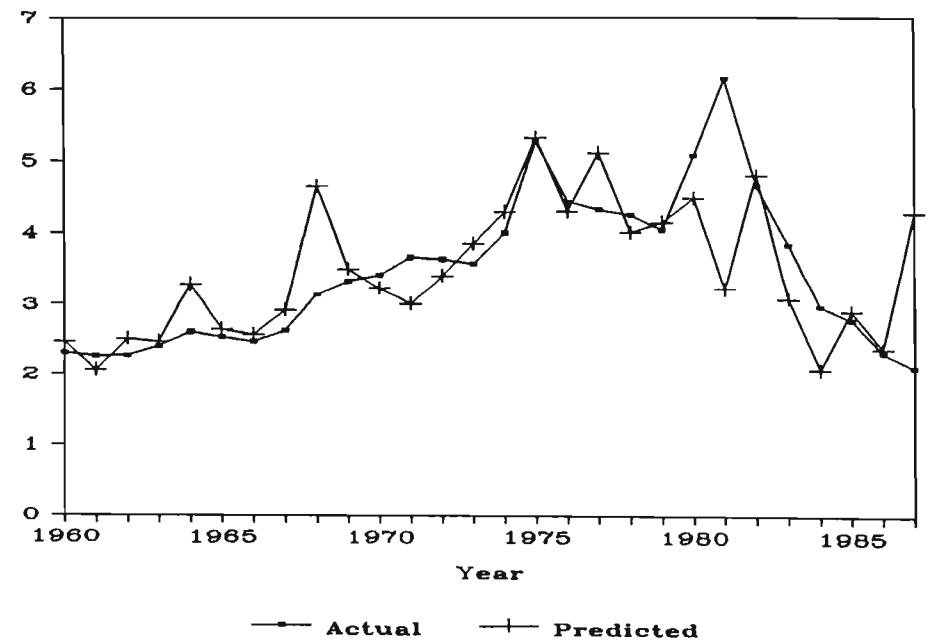

Figure 4.73 Plot of actual versus predicted values of real agricultural investment (R 100 million, base year=1975)

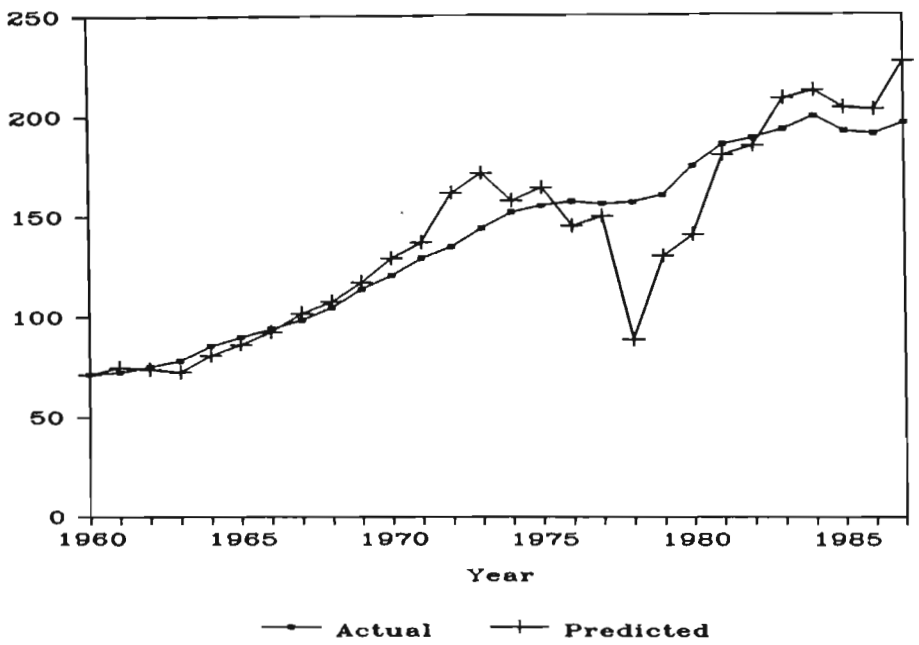

Figure 4.74 Plot of actual versus predicted values of real total personal consumption expenditure (R 100 million, base year=1975)

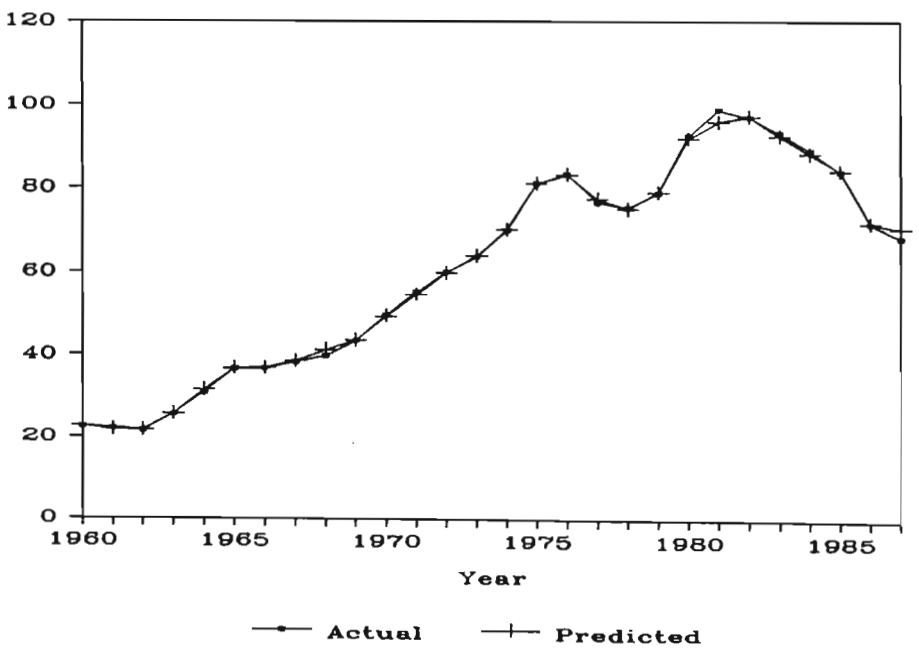

Figure 4.75 Plot of actual versus predicted values of real gross domestic fixed investment (R 100 million, base year=1975)

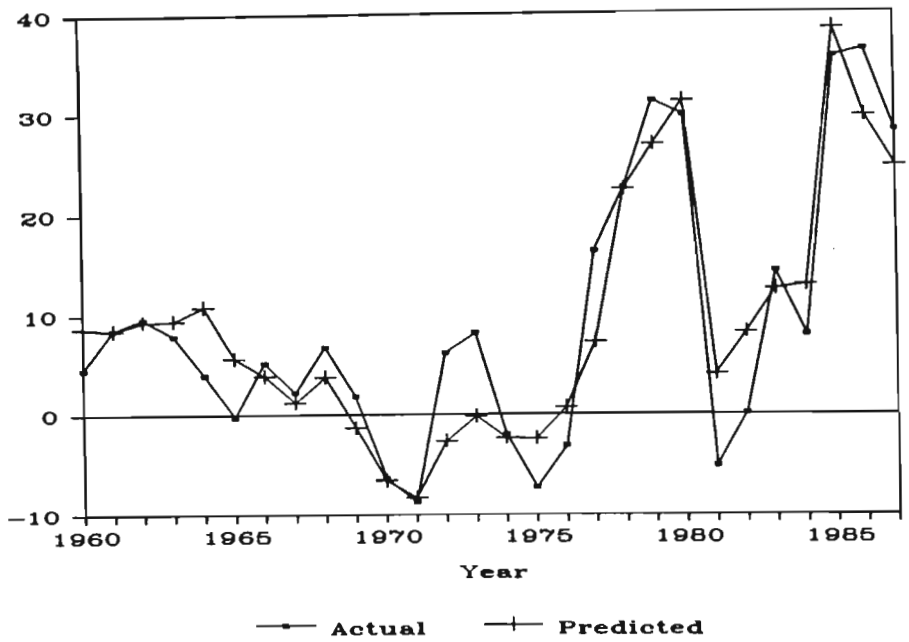

Figure 4.76 Plot of actual versus predicted values of real net exports (R 100 million, base year=1975)

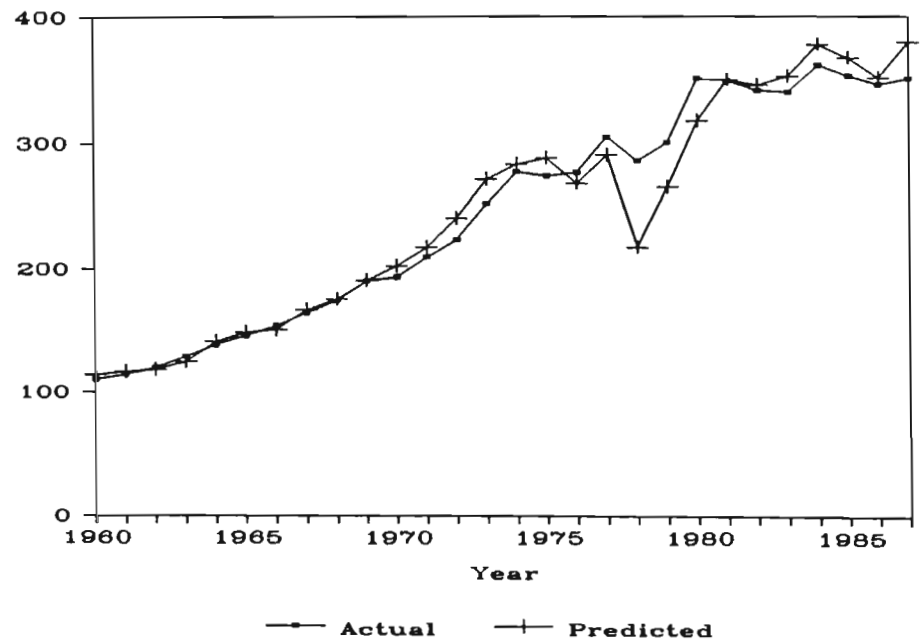

Figure 4.77 Plot of actual versus predicted values of real gross domestic product (R 100 million, base year=1975)

estimated as part of a system of equations. This highlights the importance of validating the model's simulation performance both statistically and graphically.

The model simulates all agricultural input prices (figures 4.13 to 4.17) well, except for the price of fuel (figure 4.16) whose actual values exhibit greater variability. Long-term trends and most short-term fluctuations in real demand for inputs (figures 4.18 to 4.23) have been captured.

Long-term trends in field crop sector variables have been identified reasonably well. The large peaks and troughs in real maize supply (figure 4.24) have been well duplicated, apart from the exceptionally high yield that occurred in 1981. Turning points in declining long-term real per capita human maize consumption have been successfully duplicated with the notable exception of 1987. Although some turning points in real animal maize demand (figure 4.26), mainly occurring between 1976 to 1982, have been missed, the rising long-term trend in consumption is identified. The large short-term fluctuations in real maize exports (figure 4.27) have been replicated reasonably well, except for the periods 1979-1981 and 1986-1987. Turning points in the maize price index (figure 4.28) have been captured, although predictions are upwardly biased resulting in the large U^M value.

Peaks and troughs in real sugar cane supply (figure 4.29) and real per capita sugar demand (figure 4.30) are well simulated, but estimates of the sucrose price index (figure 4.32) are upwardly biased. Large fluctuations in real sugar exports (figure 4.31) are generally captured, except after 1983. Upward trends and most short-term movements in real hay supply (figure 4.33) and demand (figure 4.34) have been captured. The hay price index (figure 4.35) is closely duplicated except for the 1985 peak.

Total real gross farm income in the field crop sector (figure 4.36) is well simulated apart from the 1982 peak. This is due to real maize supply being underestimated in 1982.

The model simulates real supply, real per capita demand, real exports and market price indices of deciduous fruit (figures 4.37 to 4.40), citrus fruit (figures 4.41 to 4.44), vegetables (figures 4.45 to 4.47) and potatoes (figures 4.48 to 4.50) adequately. Predicted peaks and troughs in real vegetable and potato supply are not as large as actual values. The upward trend in total real gross farm income in the horticultural sector (figure 4.51) is clearly identified.

Short term fluctuations in real beef (figure 4.52) and mutton (figure 4.55) supply have been well duplicated, particularly their increases from 1981 to 1984. These increases are probably due to droughts (reduced grazing) in the early 1980's, and high interest rates (stock effects) which peaked in 1984.

Short-term fluctuations in real pork supply (figure 4.58) have been simulated less successfully, although the rising long-term trend is identified.

The long-term downward trend in real per capita beef (figure 4.53) and mutton (figure 4.56) demand is closely simulated, along with most turning points and short-term fluctuations. Real per capita pork demand (figure 4.59) exhibits an upward long-term trend which is identified, while the trough in 1981 is understated.

Rising beef, mutton and pork price indices (figures 4.54, 4.57 and 4.60) have been extremely well replicated. Fluctuating real income for red meats (figure 4.61) is identified, although income between 1972 and 1977 is overstated.

The considerable increase in real supply (figure 4.62) and per capita demand (figure 4.63) of chicken meat has been captured by the model. Short-term fluctuations are well represented, although the magnitude of the peaks and troughs are underestimated. The chicken meat price index (figure 4.64) has been well simulated. Declining real supply and real per capita wool demand (figures 4.65 and 4.66) are adequately modelled, although fluctuations in real wool supply during 1960-1970 and 1976-1978 are understated. The rapid decline in real per capita wool demand from 1971 onwards has been captured, but actual values are overstated during 1976-1984. Real wool exports (figure 4.67) is simulated adequately except for 1985-1987.

Estimated total real gross farm income in the livestock sector (figure 4.69) is a very good fit with long and short-term fluctuations being well duplicated. As this function is the summation of real supply of the three red meat products, chicken meat and wool, it exhibits the same short-term fluctuations as the individual real supply functions. The same is true for total real gross farm income in the sectors modelled (figure 4.70). The upward long-term in the agricultural price index (figure 4.71) and total nominal gross farm income in the sectors modelled (figure 4.72) is simulated but overstated. Real agricultural investment (figure 4.73) is well replicated except for the peak in 1981 which has been represented by a trough.

Turning points in real total personal consumption expenditure (figure 4.74), real gross domestic fixed investment (figure 4.75), real net exports (figure 4.76) and real gross domestic product (figure 4.77) have been successfully replicated. The trough in total personal consumption expenditure in 1978 is replicated by real gross domestic product.

The estimated model represents the best fit in terms of statistical significance and underlying economic theory. Model validation results indicate that actual data series are satisfactorily reproduced by the model. It can now be used to simulate different policy scenarios for policy analysis. Chapter 5 reports the results of the dynamic simulations.

CHAPTER 5

POLICY ANALYSIS

5.1 Introduction

In this chapter, the model is used for *ex post* policy analysis. Firstly, an expansionary monetary policy is dynamically simulated by increasing money supply by 15 percent annually from 1972 to 1987. Dynamic elasticities are computed to analyse the dynamic response of key endogenous variables to the continuous change in money supply over time.

The model is then simulated three times so that the separate effects of changes in the interest rate, general price level and exchange rate on endogenous agricultural sector variables can be analysed. Dynamic elasticities of these endogenous variables with respect to changes in the general price level, exchange rate and interest rate are computed.

5.2 Dynamic simulation of an expansionary monetary policy

The 15 percent annual rate of increase in money supply is selected because it closely approximates the rate of increase in monetary aggregates targeted by the SARB (South African Reserve Bank). The simulations commence in 1972 as this is the first year that the exchange rate is determined by monetary variables. The objective is to analyse the impacts of this expansionary monetary policy on South African agriculture and determine the response of key macro- and agricultural sector endogenous variables to a continuous increase in money supply by computing dynamic elasticities. These elasticities indicate how variables behave over time in response to a change in another variable (Pindyck and Rubinfeld, 1981, p.395).

According to theory, an increase in money supply causes interest rates to fall, the general price level to rise and rand exchange rate to depreciate in the short-run. Lower real interest rates should increase real supply in the field crop and horticultural (excluding vegetables) sectors via lower cost effects. Livestock producers will reduce supply due to lower opportunity costs of off-farm investment, and thus herd investment will increase.

Inflation and exchange rate effects of the expansionary policy will be transmitted via impacts on agricultural input prices. Higher inflation raises input prices, while depreciation of the rand exchange rate raises the cost of the imported component of agricultural inputs. Increased input prices will impact negatively on real supply of all products.

Table 5.1 presents results of the dynamic simulation of an annual 15 percent increase in money supply from 1972 to 1987. Percentage changes were derived by comparing simulated results with the base simulation. The sign and magnitude of the changes are consistent with *a priori* expectations and economic theory.

Initially, the money supply expansion causes both interest rates to decline, the general price level to rise and exchange rate to depreciate. The treasury bill rate and nominal prime overdraft rate decrease by 7,75 percent and 5,92 percent respectively in 1972. In 1987, these interest rates decline by 29,96 percent and 29,15 respectively. The exchange rate depreciates by 3,23 percent in 1972 and continues to depreciate at an increasing rate to 29,54 percent in 1987. The general price level rises by 0,52 percent in 1972 and continues to increase at an increasing rate, rising by 7,90 percent in 1987.

Input price indices all increase in the long-run as expected. Price indices of fertilisers, dips and sprays, and stock and poultry feed increase by 16,61 percent, 12,69 percent and 10,67 percent respectively in 1972. The indices then increase at fluctuating rates until 1987 when they increase by 17,31 percent, 17,61 percent and 10,22 percent respectively. Price indices of fuel and packing materials also both increase at fluctuating rates over the simulation period. Increases in input prices reduce real demand for the respective inputs as expected, except for fuel between 1980-1983 and packing materials during 1974-1975. Total real input demand falls consistently throughout the simulation period by between 22,57 percent (1973) and 4,11 percent (1975).

Real maize supply decreases from 1972-1975, 1979-1983 and in 1986 by small percentages ranging from -0,40 percent (1975) to -13,50 percent (1973). During these periods, negative impacts of the higher fertiliser price outweigh the positive impacts of the lower real interest rate. During the periods when real maize supply rose, the decrease in the real interest rate may have outweighed the negative impacts of the higher fertiliser price. With the exception of four years for sugar cane (1978, 1984, 1985 and 1987) and three years for hay (1984, 1985 and 1987), real supply of both products declines over the study period.

Table 5.1 Percentage changes of key endogenous variables due to an annual 15 percent increase in money supply, 1972-1987.

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Treasury bill rate (TBR_t)	-7,75	-9,90	-8,60	-9,96	-6,63	-3,38	12,19	11,26	8,51	-1,56	-4,06	-6,28	-9,21	-14,83	-18,85	-29,96
Nominal prime overdraft rate (R_t)	-5,92	-7,71	-6,75	-7,83	-5,15	-2,62	9,02	8,26	6,30	-1,55	-4,31	-6,48	-10,13	-16,20	-18,86	-29,15
Real prime overdraft rate (RR_t)	-37,57	-45,21	-48,50	-179,1	-74,15	-61,21	7,87	5,88	2,49	-25,91	-24,00	-24,98	-47,42	-88,38	-79,04	-84,96
Rand exchange rate (XR_t)	3,23	5,67	5,52	5,41	4,60	4,92	5,47	13,72	20,20	26,30	21,69	25,42	22,50	20,82	26,61	29,54
General price level (CPI_t)	0,52	1,07	1,65	2,22	2,77	3,25	3,73	4,19	4,62	5,08	5,53	5,98	6,44	6,98	7,45	7,90
Fertiliser price index ($FTPI_t$)	16,61	18,76	15,25	8,91	10,10	9,84	9,20	15,73	16,65	13,67	14,79	14,73	12,77	18,30	18,37	17,31
Dips and sprays price index ($DSPI_t$)	12,69	14,91	12,21	6,53	8,67	8,24	7,31	14,92	16,46	13,34	15,03	14,73	11,96	18,00	18,13	17,61
Stock and poultry feed price index ($FDPI_t$)	10,67	9,71	7,02	4,58	7,03	6,65	6,80	8,51	8,41	6,22	6,75	7,43	7,88	10,12	9,05	10,22
Fuel price index ($FLPI_t$)	30,51	25,20	13,95	7,63	8,44	10,29	12,98	10,00	10,48	9,28	9,75	12,46	16,12	16,00	14,51	15,13
Packing materials price index ($PMPI_t$)	21,25	14,54	13,63	9,89	10,52	10,73	11,73	11,46	10,92	9,74	9,04	10,74	13,99	14,84	11,55	11,55
Real fertiliser demand ($QFERT_t/FTPI_t$)	-26,47	-34,59	-19,19	-2,91	-9,99	-8,25	-5,07	-7,56	-2,78	-5,83	-6,35	-6,04	-15,43	-9,43	-7,47	-14,96

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Real dips and sprays demand ($QDIPS_t/DSPI_t$)	-87,65	-71,82	-32,82	-11,76	-2,07	-4,57	-5,08	-15,91	-12,93	-14,10	-11,11	-13,19	-19,26	-21,53	-9,89	-15,78
Real stock and poultry feed demand ($QFEED_t/FDPI_t$)	-14,71	-14,66	-3,75	-6,00	-8,89	-2,95	-1,64	-7,05	-2,43	-7,23	-7,11	-5,78	-5,88	-7,73	-5,68	-8,66
Real fuel demand ($QFUEL_t/FLPI_t$)	-4,53	-5,86	-3,99	-19,43	-15,36	-11,10	-8,78	-5,87	3,77	5,18	5,80	9,97	-2,24	-1,44	-1,53	-9,26
Real packing materials demand ($QPACK_t/PMPI_t$)	19,04	-1,91	10,96	8,11	-0,45	-6,41	-12,00	-12,06	-8,87	-5,17	-8,69	-14,79	-18,80	-21,64	-1,18	-9,37
Total real input demand ($TINPT_t/TINPI_t$)	-18,51	-22,57	-9,78	-4,11	-8,26	-6,52	-5,34	-9,14	-4,12	-6,10	-5,88	-7,02	-11,24	-10,90	-5,98	-11,98
Real maize supply ($MZSS_t/MZPI_t$)	-1,71	-13,50	-6,15	-0,40	2,18	0,85	2,61	-0,88	-2,15	-4,25	-0,62	-4,87	14,36	7,54	-3,93	2,71
Real sugar cane supply ($SCSS_t/SCPI_t$)	-10,83	-22,90	-22,08	-4,49	-1,65	-7,12	2,54	-5,71	-7,92	-12,20	-4,21	-9,59	21,68	7,68	-7,82	4,17
Real hay supply ($HYSS_t/HYPI_t$)	-38,71	-58,00	-62,28	-26,28	-14,45	-10,30	-2,34	-5,93	-9,91	-14,93	-12,00	-15,27	2,11	8,52	-3,60	1,88
Total real gross farm income in the field crop sector ($FCINC_t/FCPI_t$)	-7,09	-22,99	-14,40	-4,43	-1,41	-2,14	1,52	-2,44	-4,37	-7,33	-3,22	-8,46	12,65	7,74	-4,78	2,87
Real vegetable supply ($VGSS_t/VGPI_t$)	-11,45	-12,67	-14,88	-11,43	-11,55	-11,05	-10,31	-8,95	-8,32	-6,77	-5,82	-5,92	-6,08	-6,49	-5,92	-5,28

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Real potato supply ($PTSS_t/PTPI_t$)	-15,78	-19,82	-19,14	-12,43	-10,94	-10,41	-7,97	-7,71	-7,14	-6,51	-4,98	-6,48	-2,21	1,29	-4,60	-1,62
Total real gross farm income in the horticultural sector ($HTINC_t/HTPI_t$)	-3,61	-5,06	-3,95	-5,34	-3,65	-9,27	-4,64	-3,36	-2,52	-4,42	-0,53	-3,28	-2,32	-2,83	-1,92	-0,13
Real beef supply ($BFSS_t/BFPI_t$)	-4,41	4,30	4,76	-3,58	-11,36	-11,54	-13,83	-6,84	-1,92	4,69	-2,61	-0,24	-16,84	-26,05	-9,40	-13,42
Real mutton supply ($MTSS_t/MTPI_t$)	-18,54	-17,79	-16,92	-15,99	-20,40	-22,09	-24,34	-24,79	-23,70	-17,91	-17,37	-15,91	-24,36	-35,83	-38,78	-44,45
Real pork supply ($PKSS_t/PKPI_t$)	-10,40	-5,28	-1,94	-2,87	-10,88	-15,34	-16,92	-12,20	-10,15	-1,88	-4,30	-3,40	-13,66	-21,27	-15,66	-16,35
Total real gross farm income for red meats ($RMINC_t/RMPI_t$)	-8,92	-2,86	-1,85	-6,87	-13,76	-14,93	-17,17	-12,77	-9,33	-2,29	-6,82	-4,74	-18,55	-28,24	-18,69	-22,15
Real chicken meat supply ($CHSS_t/CHPI_t$)	-95,75	-67,15	-52,33	-38,94	-39,58	-40,08	-36,54	-35,06	-32,52	-28,31	-26,86	-27,30	-29,43	-33,55	-36,97	-35,73
Real wool supply ($WLSS_t/WLPI_t$)	-21,14	-27,13	-23,84	-20,30	-22,72	-23,21	-20,69	-22,11	-22,46	-24,36	-21,57	-20,62	-23,24	-33,18	-41,75	-43,29
Total real gross farm income in the live stock sector ($LVINC_t/LVPI_t$)	-17,21	-14,87	-14,80	-15,26	-20,12	-20,91	-21,58	-19,29	-17,32	-12,26	-14,21	-13,06	-22,08	-30,28	-27,13	-28,76
Real maize producer price index ($MZPI_t/CPI_t$)	15,62	57,95	55,56	4,09	-15,35	-7,02	-20,04	6,10	14,06	29,31	3,52	14,79	-38,87	-43,71	18,56	-19,53

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Maize producer price index ($MZPI_t$)	16,23	59,65	58,14	6,41	-13,00	-4,00	-17,05	10,55	19,34	35,88	9,25	21,65	-34,94	-39,77	27,40	-13,17
Real sucrose price index ($SCPI_t/CPI_t$)	62,61	88,40	84,70	90,52	30,04	104,13	-2,97	75,70	98,65	134,92	45,05	93,05	-127,19	-71,08	67,90	-40,97
Sucrose price index ($SCPI_t$)	63,99	83,98	92,72	97,76	33,65	110,76	6,57	83,07	107,85	146,86	53,09	104,60	-128,94	-69,06	80,41	-36,30
Real hay price index ($HYPI_t/CPI_t$)	48,59	56,46	60,30	63,68	52,43	29,54	10,67	30,22	20,97	37,09	36,05	31,15	16,62	17,10	28,61	33,21
Hay price index ($HYPI_t$)	49,37	58,14	62,95	67,32	56,66	33,75	14,81	35,69	26,57	44,06	43,58	39,00	24,13	25,28	38,20	43,75
Real vegetable price index ($VGPI_t/CPI_t$)	10,91	12,90	11,28	11,94	12,90	16,14	16,14	13,42	10,07	7,75	9,19	8,43	8,05	11,17	10,86	7,31
Vegetable market price index ($VGPI_t$)	11,49	14,12	13,12	14,43	16,04	19,92	20,48	18,18	15,17	13,23	15,23	14,91	15,02	18,94	19,13	15,79
Real potato market price index ($PTPI_t/CPI_t$)	25,30	22,33	48,36	17,97	24,72	19,10	14,28	8,98	11,95	14,99	5,71	11,04	8,31	-2,69	7,35	2,82
Potato market price index ($PTPI_t$)	25,96	23,64	50,82	20,60	28,18	22,97	18,55	13,56	17,13	20,83	11,57	17,68	15,29	4,09	15,35	10,95
Real beef auction price index ($BFPI_t/CPI_t$)	4,99	-3,59	-4,22	4,04	13,32	15,03	18,69	7,28	1,27	-4,01	2,94	0,28	22,72	33,23	7,63	9,36
Beef auction price index ($BFPI_t$)	5,54	-2,56	-2,63	6,35	16,47	18,77	23,12	11,78	5,96	0,85	8,64	6,01	30,63	42,53	15,66	18,01

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Real mutton auction price index ($MTPI_t/CPI_t$)	12,03	10,39	9,80	10,75	14,17	19,41	23,12	20,27	15,26	12,78	16,22	14,32	22,53	30,50	26,36	24,12
Mutton auction price index ($MTPI_t$)	12,62	11,58	11,61	13,22	17,34	23,29	27,73	25,32	20,59	18,51	22,66	21,16	30,42	39,62	35,78	33,94
Real pork auction price index ($PKPI_t/CPI_t$)	16,67	7,98	2,131	3,68	17,17	27,77	26,83	15,12	11,13	2,29	8,76	4,464	17,64	31,43	19,68	20,46
Pork auction price index ($PKPI_t$)	17,28	9,14	3,82	5,991	20,42	31,92	31,57	19,95	16,28	7,49	14,78	10,71	25,22	40,61	28,60	29,99
Real chicken meat price index ($CHPI_t/CPI_t$)	87,55	76,61	85,08	14,07	13,44	8,75	8,08	11,15	28,20	22,15	14,23	11,14	3,61	5,95	2,01	12,24
Chicken meat price index ($CHPI_t$)	88,53	78,51	88,14	12,16	11,04	5,79	4,64	7,43	24,88	18,20	9,48	5,83	2,59	13,35	5,28	5,30
Real wool auction price index ($WLPI_t/CPI_t$)	12,34	10,73	18,72	15,70	13,82	17,63	19,34	21,60	23,08	20,83	18,17	19,73	16,20	18,58	25,30	19,20
Wool auction price index ($WLPI_t/CPI_t$)	12,34	10,73	18,72	15,70	13,82	17,63	19,34	21,60	23,08	20,83	18,17	19,73	16,20	18,58	25,30	19,20
Real per capita human maize demand ($MZDH_t/MZPI_t$)	-19,07	-33,18	-37,99	-17,15	3,24	4,78	10,19	-3,82	-13,80	-27,34	-26,24	-34,67	35,46	26,00	6,61	11,80
Real animal maize demand ($MZDA_t/MZPI_t$)	-30,26	-68,83	-94,32	-49,50	13,04	26,04	45,06	27,17	-8,96	-37,48	-36,58	-51,07	12,87	69,92	39,88	49,13

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Real per capita sugar demand ($SGDD_t/SCPI_t$)	-50,98	-70,79	-69,60	-42,67	-24,30	-27,22	-16,19	-15,99	-20,80	-28,56	-25,13	-30,25	5,65	15,76	-11,48	-6,55
Real hay demand ($HYDD_t/HYPI_t$)	-83,16	-83,58	-65,55	-52,29	-31,99	-10,04	9,21	-7,261	-15,11	-24,31	-18,17	-23,16	2,81	11,72	1,89	7,64
Real per capita vegetable demand ($VGDD_t/VGPI_t$)	-13,65	-13,44	-18,49	-13,21	-15,25	-11,27	-11,89	-10,21	-11,05	-8,92	-4,90	-4,49	-3,93	-6,18	-3,26	-5,35
Real per capita potato demand ($PTDD_t/PTPI_t$)	-10,04	-26,17	-19,58	-11,27	-9,87	-5,61	-8,66	-7,83	-12,94	-7,75	-1,23	-11,29	-0,49	7,83	-8,38	-0,46
Real per capita beef demand ($BFDD_t/BFPI_t$)	40,23	46,43	50,83	-9,533	-14,32	-11,18	-11,89	-8,89	-19,38	-10,37	-9,10	-5,38	-13,05	-14,55	-5,90	-13,76
Real per capita mutton demand ($MTDD_t/MTPI_t$)	-11,84	-11,44	-11,43	-13,66	-18,39	-16,48	-17,55	-16,38	-16,31	-12,74	-12,12	-10,65	-16,16	-24,09	-23,85	-24,52
Real per capita pork demand ($PKDD_t/PKPI_t$)	-15,18	-9,07	-6,44	-5,80	-8,07	-11,11	-10,76	-6,10	-5,16	-0,24	6,25	0,73	-9,42	-14,65	-8,88	-6,83
Real per capita chicken demand ($CHDD_t/CHPI_t$)	22,50	18,36	19,25	14,73	16,74	13,75	16,04	13,85	29,90	19,08	11,40	8,14	12,54	8,64	5,10	13,88
Real per capita wool demand ($WLDD_t/WLPI_t$)	10,35	46,16	35,37	24,07	29,17	32,69	36,96	45,13	50,19	64,18	89,28	90,73	18,07	46,21	85,17	48,68
Real maize exports ($MZX_t*XR_t/MZXPI_t$)	26,39	34,46	13,48	41,86	-9,61	-12,58	-26,19	-4,21	29,98	12,70	61,61	28,73	-8,25	-45,91	-13,12	-67,48

Table 5.1 continued

Endogenous variable	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Real sugar exports ($SGX_t*XR_t/SGXPI_t$)	24,65	26,40	54,99	60,55	59,82	22,30	36,50	23,72	30,43	47,33	51,33	56,50	90,37	14,88	18,41	58,24
Real deciuous fruit exports ($DFX_t*XR_t/DFXPI_t$)	3,232	5,677	5,528	5,419	4,601	4,928	5,470	13,72	20,20	26,30	21,69	25,42	22,50	20,82	26,61	29,54
Real citrus fruit exports ($CFX_t*XR_t/CFXPI_t$)	3,232	5,677	5,528	5,419	4,601	4,928	5,470	13,72	20,20	26,30	21,69	25,42	22,50	20,82	26,61	29,54
Real wool exports ($WLX_t*XR_t/WLXPI_t$)	32,91	12,25	2,99	13,93	50,18	46,12	29,56	22,06	44,40	54,83	57,11	11,92	24,62	36,73	14,74	56,05
Real agricultural investment ($AGINV_t/AIPI_t$)	-10,63	-27,90	-22,57	-5,57	-2,50	-4,95	-0,93	-8,36	-10,26	-19,49	-9,98	-20,22	10,73	6,03	-29,44	-7,55
Total real gross farm income in the sectors modelled ($AGINC_t/AGPI_t$)	-9,83	-14,90	-12,42	-6,99	-9,34	-8,98	-7,89	-6,77	-6,25	-8,07	-6,59	-8,29	-9,45	-11,52	-14,26	-9,71
Agricultural price index ($AGPI_t$)	28,29	26,42	30,29	11,84	8,99	12,62	10,22	18,78	18,46	23,66	17,62	21,71	14,88	11,07	23,69	9,20
Total nominal gross farm income in the sectors modelled ($AGINC_t$)	15,67	7,58	14,10	1,22	-1,18	2,49	1,53	10,73	11,06	13,68	9,86	11,61	4,02	-1,72	6,05	-1,39

Real vegetable supply declines consistently at a decreasing rate over the simulation period. This is to be expected as the lack of an interest rate linkage between money supply and real vegetable supply implies that no lower real interest rate cost effects offset increased cost effects of the higher input price. Real potato supply exhibits a similar trend, rising only in 1985.

Cost effects of higher input costs reinforce stock effects of the lower real interest rate, causing real supply of beef (except 1973, 1974 and 1981), mutton and pork to decrease. Annual percentage decreases in real mutton supply are greater than those of real beef and pork supply. Real beef and mutton supply decline by 4,41 percent and 18,54 percent in 1972 and 13,42 and 44,45 percent in 1987, respectively. The fall in real pork supply ranges between 1,88 percent (1981) and 21,27 percent (1985). Total real gross farm income for red meats declines annually throughout the period, by between 1,85 percent (1974) and 28,24 percent (1985).

Due to no interest rate linkage, increased cost effects of higher input prices on real chicken meat and wool supply are not offset by the lower real interest rate, thus reducing chicken meat and wool supply.

The fall in real supply of agricultural products in most years of the simulation period raises the respective product prices. Real and nominal maize prices increase in all years except 1976, 1977, 1978, 1984, 1985 and 1987. Percentage changes in the real and nominal sucrose prices are relatively large compared to those of other products due to the very small estimated price elasticity of real sugar cane supply. Real and nominal prices of hay, vegetables, potatoes, beef (except 1973-1974 and 1981), mutton, pork, chicken meat and wool all increase as expected.

Real per capita quantity demanded of all products decreases (increases) in response to increases (decreases) in respective real product prices. Real per capita sugar demand decreases by 50,98 percent in 1972, but the rate of decrease declines over time. Real per capita demand for red meat products decreases, except for beef during 1972-1974 when cross effects of the higher real chicken meat price raise real per capita beef demand. The decrease in real animal maize demand during 1972-1975 and 1980-1983 indicates that the negative impacts of the higher real maize price outweigh the positive cross effects of higher real beef and feed prices during these years.

Real exports of sugar, deciduous fruit, citrus fruit and wool increase throughout the simulation period. Real maize exports rise during 1972-1975 and 1980-1983. Increased real exports can be attributed to positive impacts of the depreciated rand on gross returns from foreign sales and decreases in domestic real per capita demand which increases product availability for export. The decline of real maize

exports during 1976-1979 and 1984-1987 is due to increased real animal maize demand during these years.

Real agricultural investment declines in all years except for 1984 and 1985. This implies that in most years, the reduction in real gross farm income outweighs positive impacts of the lower real interest rate.

Total real gross farm income in the sectors modelled falls in each year of the simulation period. The largest and smallest decreases are 14,90 percent (1973) and 6,25 percent (1980) respectively. Total nominal gross farm income increases in all years except 1976, 1985 and 1987. This is due to the increase in the nominal agricultural price index. The years in which total nominal gross farm income decrease coincide with the years in which increases in the agricultural price index were the smallest.

It is important to note that the increase in agricultural prices does not maintain or increase real gross farm incomes. The combined higher cost effects of the depreciated rand exchange rate and higher general price level outweigh the lower cost effects of a lower real interest rate in the field crop and horticultural sectors, and reinforce stock effects of the lower real interest rate in the livestock sector.

Table 5.2 reports the dynamic elasticities of key endogenous variables with respect to a one percent increase in money supply during 1972-1987. Dynamic elasticities of an annual one percent increase in money supply are calculated as,

$$E_{Ms} = \frac{\overline{Ms}}{\overline{V}} \frac{\overline{\Delta V}}{\overline{\Delta Ms}} \qquad (5.1)$$

where $\overline{Ms}$ and $\overline{V}$ are the means of money supply and the endogenous variable of interest respectively. $\overline{\Delta Ms}$ and $\overline{\Delta V}$ are the average changes in money supply and the endogenous variable of interest respectively over the simulation period.

Impacts on monetary variables conform with *a priori* expectations, with an elastic response of the real interest rate to a one percent increase in money supply. The positive long-run elasticity of the general price level indicates that a one percent 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.

Table 5.2 Dynamic elasticities of key endogenous variables with respect to an annual one percent increase in money supply, 1972-1987

Key endogenous variable	Dynamic elasticity
Treasury bill rate (TBR_t)	-0,584
Nominal prime overdraft rate (R_t)	-0,417
Real prime overdraft rate (RR_t)	-10,458
Consumer price index (CPI_t)	0,369
Exchange rate (XR_t)	1,208
Fertiliser price index ($FTPI_t$)	1,015
Dips and sprays price index ($DSPI_t$)	1,963
Stock and poultry feed index ($FDPI_t$)	0,553
Fuel price index ($FLPI_t$)	0,868
Packing materials price index ($PMPI_t$)	0,791
Real fertiliser demand ($QFERT_t/FTPI_t$)	-0,627
Real dips and sprays demand ($QDIPS_t/DSPI_t$)	-1,033
Real stock and poultry feed demand($QFEED_t/FDPI_t$)	-0,420
Real fuel demand ($QFUEL_t/FLPI_t$)	-0,334
Real packing materials demand ($QPACK_t/PMPI_t$)	-0,298
Total real input demand ($TINPT_t/TINPI_t$)	-0,581
Real maize supply ($MZSS_t/MZPI_t$)	-0,043
Real sugar cane supply ($SCSS_t/SCPI_t$)	-0,377
Real hay supply ($HYSS_t/HYPI_t$)	-0,884
Total real gross farm income in field crop sector ($FCINC_t/FCPI_t$)	-0,241
Real vegetable supply ($VGSS_t/VGPI_t$)	-0,574
Real potato supply ($PTSS_t/PTPI_t$)	-0,540
Real gross farm income in horticultural sector ($HTINC_t/HTPI_t$)	-0,226
Real beef supply ($BFSS_t/BFPI_t$)	-0,462
Real mutton supply ($MTSS_t/MTPI_t$)	-1,587
Real pork supply ($PKSS_t/PKPI_t$)	-0,714
Total real gross farm income for red meats ($RMINC_t/RMPI_t$)	-0,802
Real chicken meat supply ($CHSS_t/CHPI_t$)	-2,369
Real wool supply ($WLSS_t/WLPI_t$)	-1,711
Total real gross farm income in livestock sector ($LVINC_t/LVPI_t$)	-1,299
Real maize producer price ($MZPI_t/CPI_t$)	0,333
Maize producer price index ($MZPI_t$)	0,385
Real sucrose price index ($SCPI_t/CPI_t$)	3,167
Sucrose price index ($SCPI_t$)	1,719
Real hay price index ($HYPI_t/CPI_t$)	2,331
Hay price index ($HYPI_t$)	2,555

Table 5.2 continued

Key endogenous variable	Dynamic elasticity
Real vegetable market price index ($VGPI_t/CPI_t$)	0,748
Vegetable market price index ($VGPI_t$)	1,073
Real potato market price index ($PTPI_t/CPI_t$)	0,984
Potato market price index ($PTPI_t$)	1,096
Real beef auction price index ($BFPI_t/CPI_t$)	0,457
Beef auction price index ($BFPI_t$)	0,940
Real mutton auction price index ($MTPI_t/CPI_t$)	1,348
Mutton auction price index ($MTPI_t$)	1,149
Real pork auction price index ($PKPI_t/CPI_t$)	0,989
Pork auction price index ($PKPI_t$)	1,424
Real chicken meat price index ($CHPI_t/CPI_t$)	0,529
Chicken meat price index ($CHPI_t$)	0,216
Real wool auction price index ($WLPI_t/CPI_t$)	1,196
Wool auction price index ($WLPI_t$)	1,272
Real per capita human maize demand ($MZDH_t/MZPI_t$)	-0,626
Real per capita sugar demand ($SGDD_t/SCPI_t$)	-1,762
Real hay demand ($HYDD_t/HYPI_t$)	-1,301
Real per capita vegetable demand ($VGDD_t/VGPI_t$)	-0,606
Real per capita potato demand ($PTDD_t/PTPI_t$)	-0,552
Real per capita beef demand ($BFDD_t/BFPI_t$)	-0,046
Real per capita mutton demand ($MTDD_t/MTPI_t$)	-1,077
Real per capita pork demand ($PKDD_t/PKPI_t$)	-0,523
Real per capita chicken meat demand ($CHDD_t/CHPI_t$)	-0,271
Real per capita wool demand ($WLDD_t/WLPI_t$)	-0,481
Real animal maize demand ($MZDA_t/MZPI_t$)	-0,267
Real maize exports ($MZX_t*XR_t/MZXPI_t$)	0,814
Real sugar exports ($SGX_t*XR_t/SGXPI_t$)	2,784
Real deciduous fruit exports ($DFX_t*XR_t/DFXPI_t$)	1,072
Real citrus fruit exports ($CFX_t*XR_t/CFXPI_t$)	1,046
Real wool exports ($WLX_t*XR_t/WLXPI_t$)	0,664
Real agricultural investment ($AGINV_t/AIPI_t$)	-0,718
Total real gross farm income in the sectors modelled ($AGINC_t/AGPI_t$)	-0,672
Agricultural price index ($AGPI_t$)	1,196
Total nominal gross farm income in the sectors modelled ($AGINC_t$)	0,426

The rand/SDR exchange rate depreciates by 1,208 percent per annum. Although the response is elastic, it is smaller than that estimated by Devadoss (1985) for the U.S. dollar. This could be due to a greater degree of SARB management of the rand, and the existence of a dual currency system for much of the simulation period. The estimated elasticity response would probably be higher if the monetary authorities had not required that trade transactions be conducted in commercial rands (as modelled) and capital transactions in financial rands, rather than a single currency unit.

Positive dynamic 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 the fertiliser price (1,015) and price of dips and sprays (1,963) reflect the effects of both linkages. The smaller stock and poultry feed price elasticity (0,553) could be due to farmers feeding more home-produced feed. Total real input demand declines by 0,581 percent.

Real supply of all products decreases in the long-run in response to the money supply increase. The real maize (-0,043), sugar cane (-0,377), vegetable (-0,574) and potato (-0,540) supply responses are all inelastic. Real vegetable supply may decrease the most since cost reducing effects of lower real interest rates are not captured. For maize, sugar, hay and potatoes, increased cost effects of higher input prices offset the reduced cost effects of the lower real interest rate. Real gross income in the field crop and horticultural sectors declines by 0,241 percent and 0,226 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 0,462 percent, mutton supply by 1,587 percent and pork supply by 0,714 percent. Real gross farm income of red meat producers declines by 0,802 percent. Real chicken meat supply and real wool supply decrease by 2,369 percent and 1,711 percent respectively. Real gross farm income in the livestock sector is reduced by 1,299 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 sucrose (3,167), hay (2,331), mutton (1,149) and wool (1,196). Higher real prices of all products cause real per capita demand for all products to decline. Nominal price indices of sucrose (1,719), hay (2,555), vegetables (1,073) potatoes (1,096), mutton (1,348), pork (1,424) and wool (1,272) are elastic with respect to the annual one percent increase in money supply. This implies that the general price level rises faster than prices of all products except sucrose (sugar), hay, mutton and wool.

All elasticities of real per capita demand are less than one, except for sugar (-1,762), hay (-1,301) and mutton (-1,077). This is due to the relatively larger percentage increases in real prices of these products. All changes in real per capita demand are due to real price effects. As a link between money supply and real disposable income is not specified in the model, the simulation assumes that real income effects remain constant, i.e. the increase in the general price level equals the increase in nominal disposable income and real per capita disposable income remains constant. The negative dynamic elasticity of real animal maize demand (-0,267) indicates that the increase in the real maize price outweighs the effects of higher real beef and stock and poultry feed prices.

Real agricultural investment declines by 0,718 percent with respect to a one percent increase in money supply which indicates that the effect of lower real gross farm income has outweighed the positive effects of the lower real interest rate.

The negative elasticity of total real gross farm income in the sectors modelled (-0,672) 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.

5.3 Dynamic simulations of the separate effects of the three key macrovariables

As the direction and magnitude of the impacts of changes in the interest rate, general price level and exchange rate differ for each product, it would be of interest to distinguish between the separate effects of these variables. Three model simulations are therefore conducted in which one macrovariable is exogenously changed, holding the other two constant. The general price level is increased by 15 percent, exchange rate depreciated by 15 percent and the treasury bill rate is lowered by three percentage points in three separate simulations. This should reveal the individual impacts of these three key macrovariables on key endogenous variables in the agricultural sector.

Table 5.3 reports dynamic elasticities of key endogenous variables with respect to one percent changes in the general price level, exchange rate and interest rate.

The dynamic elasticities indicate that all three macrovariables have significant effects on the endogenous variables in the agricultural sector. Signs of the dynamic elasticities indicate the direction of the impacts of the three macrovariables. The absolute magnitude of the elasticities indicates that

Table 5.3 Dynamic elasticities of key endogenous variables with respect to annual one percent changes in the general price level, exchange rate and interest rate, 1972-1987

Key endogenous variable	Dynamic general price level elasticity	Dynamic exchange rate elasticity	Dynamic interest rate elasticity
Real prime overdraft rate (RR_t)	-3,783	-	-
Fertiliser price index ($FTPI_t$)	1,294	0,193	-
Dips and sprays price index ($DSPI_t$)	1,212	0,234	-
Stock and poultry feed price index ($FDPI_t$)	0,758	0,101	-
Fuel price index ($FLPI_t$)	1,530	-	-
Packing materials price index ($PMPI_t$)	1,394	-	-
Real fertiliser demand ($QFERT_t/FTPI_t$)	-1,033	-0,201	-
Real dips and sprays demand ($QDIPS_t/DSPI_t$)	-1,406	-0,231	-
Real stock and poultry feed demand ($QFEED_t/FDPI_t$)	-0,682	-0,072	-
Real fuel demand ($QFUEL_t/FLPI_t$)	-0,527	-	-
Real packing materials demand ($QPACK_t/PMPI_t$)	-0,511	-	-
Total real input demand ($TINPT_t/TINPI_t$)	-0,899	-0,110	-0,005
Real maize supply ($MZSS_t/MZPI_t$)	-0,181	-0,037	-0,125
Real sugar cane supply ($SCSS_t/SCPI_t$)	-0,807	-0,161	-0,246
Real hay supply ($HYSS_t/HYPI_t$)	-1,666	-0,325	-0,409
Total real gross farm income in field crop sector ($FCINC_t/FCPI_t$)	-0,538	-0,107	-0,194
Real vegetable supply ($VGSS_t/VGPI_t$)	-0,802	-0,165	-
Real potato supply ($PTSS_t/PTPI_t$)	-0,900	-0,169	-0,083
Total real gross farm income in horticultural sector ($HTINC_t/HTPI_t$)	-0,341	-0,126	-0,014
Real beef supply ($BFSS_t/BFPI_t$)	-0,418	-0,060	0,328
Real mutton supply ($MTSS_t/MTPI_t$)	-1,592	-0,353	0,519
Real pork supply ($PKSS_t/PKPI_t$)	-0,861	-0,105	0,313
Total real gross farm income for red meats ($RMINC_t/RMPI_t$)	-0,704	-0,146	0,380
Real chicken meat supply ($CHSS_t/CHPI_t$)	-3,199	-0,725	0,042
Real wool supply ($WLSS_t/WLPI_t$)	-1,886	-0,447	0,403
Total real gross farm income in livestock sector ($LVINC_t/LVPI_t$)	-1,568	-0,293	0,260
Real maize producer price ($MZPI_t/CPI_t$)	1,120	0,257	0,858
Maize producer price index ($MZPI_t$)	2,304	0,123	0,801
Real sucrose price index ($SCPI_t/CPI_t$)	9,385	2,028	3,268
Sucrose price index ($SCPI_t$)	9,942	0,884	2,918
Real hay price index ($HYPI_t/CPI_t$)	4,105	0,615	0,694
Hay price index ($HYPI_t$)	5,585	0,448	0,715
Real vegetable market price index ($VGPI_t/CPI_t$)	1,039	0,219	-0,050
Vegetable market price index ($VGPI_t$)	2,130	0,172	-0,025

Table 5.3 continued

Key endogenous variable	Dynamic general price level elasticity	Dynamic exchange rate elasticity	Dynamic interest rate elasticity
Real potato market price index ($PTPI_t/CPI_t$)	1,607	0,326	0,205
Potato market price index ($PTPI_t$)	2,618	0,159	0,261
Real beef auction price index ($BFPI_t/CPI_t$)	0,453	0,039	-0,343
Beef auction price index ($BFPI_t$)	1,349	0,034	-0,314
Real mutton auction price index ($MTPI_t/CPI_t$)	1,567	0,168	-0,384
Mutton auction price index ($MTPI_t$)	2,448	0,165	-0,409
Real pork auction price index ($PKPI_t/CPI_t$)	1,254	0,159	-0,439
Pork auction price index ($PKPI_t$)	2,053	0,106	-0,415
Real chicken meat price index ($CHPI_t/CPI_t$)	1,875	1,711	0,967
Chicken meat price index ($CHPI_t$)	2,089	1,885	1,444
Real wool auction price index ($WLPI_t/CPI_t$)	1,744	0,199	-0,280
Wool auction price index ($WLPI_t$)	1,685	0,187	-0,315
Real per capita human maize demand ($MZDH_t/MZPI_t$)	-1,325	-0,462	-0,629
Real per capita sugar demand ($SGDD_t/SCPI_t$)	-3,022	-0,701	-0,680
Real hay demand ($HYDD_t/HYPI_t$)	-2,414	-0,634	-0,684
Real per capita vegetable demand ($VGDD_t/VGPI_t$)	-0,844	-0,179	0,125
Real per capita potato demand ($PTDD_t/PTPI_t$)	-0,903	-0,182	0,070
Real per capita beef demand ($BFDD_t/BFPI_t$)	-0,702	-0,907	0,697
Real per capita mutton demand ($MTDD_t/MTPI_t$)	-1,088	-0,158	0,355
Real per capita pork demand ($PKDD_t/PKPI_t$)	-0,629	-0,133	0,263
Real per capita chicken meat demand ($CHDD_t/CHPI_t$)	-1,476	-1,676	-0,110
Real per capita wool demand ($WLDD_t/WLPI_t$)	-1,346	-0,415	-0,205
Real animal maize demand ($MZDA_t/MZPI_t$)	-1,333	-1,040	-2,003
Real maize exports ($MZX_t*XR_t/MZXPI_t$)	3,419	1,802	3,685
Real sugar exports ($SGX_t*XR_t/SGXPI_t$)	2,981	0,688	0,855
Real deciduous fruit exports ($DFX_t*XR_t/DFXPI_t$)	-	1,016	-0,007
Real citrus fruit exports ($CFX_t*XR_t/CFXPI_t$)	-	1,020	-0,009
Real wool exports ($WLX_t*XR_t/WLXPI_t$)	0,212	0,113	-0,098
Real agricultural investment ($AGINV_t/AIPI_t$)	-1,372	-0,282	0,297
Total real gross farm income in the sectors modelled ($AGINC_t/AGPI_t$)	-0,944	-0,113	0,029
Agricultural price index ($AGPI_t$)	2,414	0,212	0,209
Total nominal gross farm income in the sectors modelled ($AGINC_t$)	1,121	0,081	0,238

monetary policy exerts most of its influence through the inflation linkage. General price level elasticities exceed interest rate and exchange rate elasticities for all endogenous variables, except real per capita beef and chicken meat demand. The signs of the dynamic elasticities are discussed firstly, followed by a comparison of their absolute magnitudes.

The increase in the general price level and depreciation in the exchange rate raise input prices. Dynamic elasticities of the price indices and real demand for all inputs are positive with respect to the general price level and exchange rate except for fuel and packing materials which are not linked to monetary policy via the exchange rate linkage. No interest linkage is modelled between money supply and input prices and real input demand.

Dynamic elasticities of real supply of all products are negative with respect to the general price level and exchange rate, indicating negative impacts of increased inflation and the exchange rate depreciation. Negative interest rate elasticities of real supply of field crop and horticultural sector products indicate cost effects of the lower real interest rate. Positive interest rate elasticities of real beef (0,328), mutton (0,519) and pork (0,313) supply indicate stock effects of the lower real interest rate which reinforce the negative impacts of higher inflation and depreciated exchange rate.

Total real gross farm income in the field crop, horticultural and livestock sectors is reduced by higher inflation and the depreciated exchange rate. As expected, the lower real interest rate raises total real gross farm income in the field crop and horticultural sectors and reduces total real gross farm income for red meats. All three macrovariables impact negatively on total real gross farm income for the sectors modelled.

Positive general price level and exchange rate elasticities for real and nominal product price indices indicate the positive impact of higher inflation and depreciated exchange rate on agricultural product prices due to reduced real supply. As expected, interest rate elasticities of product prices in the field crop and horticultural sectors are positive and those for red meats are negative.

Positive impacts of higher inflation and the depreciated exchange rate on product prices reduce real per capita demand for all products. The lower real interest rate raises real per capita demand for field crop and horticultural products and reduces real per capita demand for red meats.

Real exports of maize, sugar, deciduous fruit, citrus fruit and wool increase in response to the depreciated exchange rate. Real exports of deciduous and citrus fruits only capture effects of the depreciated

exchange rate as inflation and interest rate linkages could not be modelled between money supply and real fruit supply. Increased real exports of both fruits are due solely to positive impacts of the depreciated rand on gross returns from exports. Real exports of maize, sugar and wool are increased by the higher general price level and real maize and sugar exports are reduced by the lower interest rate. These movements are due to changes in real product prices which affect real per capita demand and real animal maize demand and therefore quantities available for export.

The size of the dynamic elasticities of all input price indices, except for stock and poultry feed (0,758), are elastic with respect to the general price level, while the response of fertiliser (0,193), dips and sprays (0,234), and stock and poultry feed (0,101) price indices to changes in the exchange rate is inelastic.

The absolute magnitude of the elasticities indicates that changes in the general price level generally exert the largest influence on real agricultural supply. Real hay, potato, mutton, chicken and wool supply are all highly elastic with respect to inflation. No exchange rate or real interest rate elasticities of real supply exceed unity. Real interest rate elasticities of real maize supply and real supply of the three red meat products exceed the exchange rate elasticities.

The response of real gross farm income in the field crop, horticultural and red meat sectors to changes in all three macrovariables is inelastic. Real gross farm income in the livestock sector is inelastic with respect to the exchange rate and real interest rate, but elastic with respect to the general price level.

All product price indices are highly elastic with respect the general price level. This is to be expected as the increased general price level has the greatest impact on real supply. The real sucrose price is the only product price that is elastic with respect to the exchange rate and interest rate. All product price indices, except for vegetables and chicken meat, respond more to interest rate than exchange rate changes.

Real per capita demand of all products is most responsive to the increased general price level (except for beef and chicken meat). Real per capita demand for all products is inelastic with respect to exchange and interest rate changes, except for real per capita chicken meat demand whose response to exchange rate changes is elastic.

Real maize and sugar exports are elastic and real wool exports are inelastic with respect to the general price level. Real maize exports are elastic with respect to the interest rate, again due to increases in human and animal maize demand which reduce quantities available for exports.

Total real gross farm income in the sectors modelled is inelastic with respect to all three macro-variables, but again, is most responsive to the increased general price level. The very small interest rate elasticity is expected given that cost effects of interest rate changes on real crop supply differ from stock effects of these changes on real supply of red meats.

5.4 Summary

Simulation results show that monetary policy has significant effects on South African agriculture through the interest rate, inflation and exchange rate linkages. Simulation results indicate that an expansionary monetary policy impacts negatively on real supply of agricultural products. Real farm income declines due to the impact of higher input prices. Positive impacts of lower real interest rates do not offset effects of higher input prices in the field crop and horticultural sectors. Lower real interest rates reduce real supply of red meat products by increasing opportunity costs of off-farm investment. The depreciated exchange rate increases real exports of maize, wool, deciduous fruit, citrus fruit and wool. The net effect of an expansionary monetary policy is a decline in total real gross farm income in the sectors modelled.

Simulations of the individual effects of the three macrovariables on endogenous agricultural variables indicate that inflation is the most important linkage between monetary policy and South African agriculture. The absolute magnitude of the general price level dynamic elasticities exceeded those of the exchange rate and real interest rate for almost all variables. Response of the endogenous variables to an increase in the general price level was generally elastic. Responses to the depreciated exchange rate and lower interest rate were generally inelastic. Policy implications of model simulation results are discussed in the conclusion.

DISCUSSION AND CONCLUSIONS

The structural model successfully simulates linkages between monetary policy and South African agriculture via the interest rate, general price level and exchange rate. Estimated coefficients for these variables have signs that are consistent with *a priori* expectations based on economic theory, and are statistically significant. This evidence supports the hypothesis that macroeconomic variables affect agriculture.

The interest rate linkage was simulated using two interest rates - the treasury bill rate as a proxy for market interest rates, and the prime overdraft rate as the cost of short-term production loans. All coefficients of the explanatory variables were significant and had the right signs.

Estimation of the general price level was based on the monetarist view of the quantity equation in which money supply is assigned an active role in price level determination. The consumer price index was used to represent the general price level and was positively related to the ratio of money supply to real gross domestic product.

The exchange rate was also specified according to the monetarist approach. The estimated equation successfully captures the effects of domestic relative to foreign money supplies, nominal interest rates, and real incomes on the rand exchange rate. A grafted polynomial variable was used to estimate the exchange rate during the period of fixed exchange rates (1960-1971) and floating (albeit managed) exchange rates (1972-1987).

Inflation and exchange rate linkages were simulated by specifying the general price level and exchange rate in the five input price determination equations. Positive coefficients of general price level and exchange rate variables in the input price equations agree with *a priori* expectations.

As South Africa is a price taker on world agricultural commodity markets, foreign demand for South African agricultural exports is independent of the rand exchange rate. Important agricultural export commodities (maize, sugar, deciduous fruit, citrus fruit and wool) were included in the model, but no relationship between the exchange rate and foreign export demand could be established. This contrasts with studies in the United States which have found a strong link between the dollar exchange rate and foreign demand for U.S. agricultural exports. Changes in the rand exchange rate do however affect

rand prices received from agricultural export sales and prices of the imported component of agricultural inputs. Real exports of these commodities were estimated by the market equilibrium identities.

Macrolinkages were completed by specifying the macrovariables in the relevant agricultural sector equations. Negative real interest rate coefficient signs in the real maize, sugar cane, hay and potato supply equations represent the cost effect of interest rate changes on crop production. Positive real interest rate coefficients in the real beef, mutton and pork supply equations reflect stock effects (opportunity costs) of interest rate changes on livestock production. All real interest rate elasticities of real product supply are small, indicating inelastic response to interest rate changes in the short-run. Real agricultural investment is also inelastic with respect to real interest rate changes in the short run.

Inclusion of input prices in the real supply equations completes the inflation and exchange rate linkages. Use of input prices as product price deflators reduced multicollinearity and yielded more significant coefficients with the correct signs. Most price elasticities of real product supply are small suggesting that supply is unresponsive to price changes in the short-run, either due to lack of viable alternatives (e.g. in the case of maize), or long adjustment periods exist in production (e.g. beef herd expansion). The price elasticity of real sugar cane supply is extremely small which is consistent with a crop grown under quota restrictions.

The negative income elasticity of real per capita human maize demand equation supports past findings that maize is an inferior good in South Africa. The importance of maize as a staple food in South Africa will therefore decline under conditions of economic growth ahead of population growth. All other products are normal goods as indicated by positive income elasticities. Significant real beef price and real feed price coefficients in the real animal maize demand equation reflect the derived demand for maize as an animal feed and that animal maize demand is affected by substitute feed prices. The significant chicken meat and beef price coefficients in the real per capita beef and chicken meat demand equations respectively supports the view that beef and poultry are major substitutes in consumption. The estimated real per capita pork demand equation showed that mutton is an important substitute in consumption.

The model simulates historical data well and predicts most turning points in the endogenous variables accurately. This increased confidence in the ability of the model to simulate the dynamic impacts of monetary policy changes on agriculture. Dynamic simulation of an expansionary monetary policy showed that in the short run an increase in money supply causes the treasury bill rate, nominal prime overdraft rate and real prime overdraft rate to fall, general level of prices to rise and rand exchange

rate to depreciate. The positive dynamic elasticity of the general price level with respect to money supply supports an active role for monetary policy in general price level determination. The elastic response of the exchange rate also supports an active role for monetary policy in exchange rate determination.

The increased general price level and depreciated exchange rate raise input prices due to the increased cost of domestic and imported components of agricultural inputs. Responses of the prices of fertilisers and dips and sprays to these macro changes are more elastic than those of the prices of stock and poultry feed, fuel and packing materials. The inelastic response of stock and poultry feed may be due to more feed being produced on farm in response to higher input prices from off-farm sources.

Real supply of all agricultural products declines, as does total real gross farm income in all three sectors modelled. Total real gross farm income in the livestock sector falls relatively more than total real gross farm income in the field crop and horticultural sectors. This is because stock effects of lower interest rate reinforce the negative impacts of higher input prices on real beef, mutton and pork supply, while decreased cost effects of the lower real interest rate offset the negative impacts of higher input prices in the field crop and horticultural sectors. Lower real interest rates reduce cattle, sheep and pig slaughterings as the opportunity costs of off-farm investment rise as returns on interest bearing assets fall. Real exports of maize, sugar, deciduous fruit, citrus fruit and wool increase due to positive impacts of the depreciated rand on gross proceeds and increased quantities available for export due to higher real product prices which reduce domestic demand.

The net effect of the increase in money supply is a decline in total real gross farm income in the sectors modelled. This suggests that monetary policy has major effects on real agricultural incomes which cannot be ignored. The increase in production costs due to higher inflation and depreciated exchange rate impact negatively on real farm incomes. Lower real interest rates reinforce this income decline in the livestock sector and only partly offset it in the field crop and horticultural sectors.

Simulations of the separate effects of the interest rate, inflation and exchange rate on product supply, demand and prices support these results. Impacts of increased inflation exceed the impacts of the depreciated exchange rate and lower interest rate. Signs of the dynamic elasticities confirm macro-variable effects identified by the dynamic simulation of the expansionary monetary policy. The absolute sizes of the dynamic elasticities show that inflation is a relatively more important linkage through which monetary policy impacts on agricultural variables than the exchange rate and interest rate.

Results indicate that South African agriculture is affected by macroeconomic variables and suggest a major role for monetary policy in gross farm income determination. Policy makers must consider the impacts of these variables and monetary policy changes when evaluating and selecting agricultural policies, as they are additional sources of instability for the farm sector.

While this study has empirically identified macrolinkages between monetary policy and agriculture, considerable scope for future research exists. The model could possibly be improved by incorporating impacts of subsidised interest rates and fiscal policy tax concessions. Current concern over the level of farm debt in this country makes it desirable to ascertain the effects of interest rate policy on agricultural debt.

Agriculture is a major employer of unskilled labour in South Africa and wages form an important component of costs of production. Inclusion of the labour market in which the wage rate and employment levels are endogenously determined would add to the model's usefulness for additional policy analysis.

The addition of other sectors to the model would enable analysis of macro policy impacts on more farm products. The wheat, egg, dairy and wine sectors were considered, but attempts made to estimate supply and demand equations for these sectors were hampered by lack of data.

SUMMARY

Since the early 1970's, South African farmers have been exposed to double-digit inflation and fluctuating exchange rates. More recently, the rand exchange rate has declined against major currencies and real per capita incomes have fallen.

The objective of this study was to examine the nature and strength of macroeconomic linkages between monetary policy and South African agriculture via the interest rate, exchange rate, inflation, and real income. The interest rate impacts on real agricultural product supply via the cost of short-term production loans. Stock effects of interest rate changes impact on the livestock sector by altering the opportunity cost of herd investment (off-farm investment in interest bearing assets). Inflation raises production costs which impact negatively on real agricultural supply. Fluctuations in the exchange rate affect prices of imported production inputs and export revenues. Real income is a major determinant of aggregate demand for agricultural commodities.

The impacts of monetary policy on South African agriculture were analysed using a general-equilibrium simultaneous equations model. Annual data from 1960 to 1987 were used to construct 41 behavioural equations and 27 identities representing the field crop (maize, sugar cane and hay), horticultural (deciduous fruit, citrus fruit, vegetables and potatoes) and livestock (beef, mutton, pork, chicken meat and wool) and manufacturing sectors, and money and foreign exchange markets.

The interest rate, general price level and exchange rate were determined endogenously according to the monetarist approach to capture the impact of changes in monetary policy on these variables. The interest rate linkage was simulated using the treasury bill rate (market interest rate) and prime overdraft rate (short-term lending rate). Changes in the general price level impact on agriculture via the agricultural input market. Input price and demand equations were estimated to capture the effects of inflation on input prices and demand. Being a price taker on world agricultural commodity markets, foreign demand for South African agricultural exports is independent of the rand exchange rate. Effects of exchange fluctuations on gross proceeds of maize, sugar, deciduous fruit, citrus fruit and wool exports were modelled. The exchange rate linkage was also specified via the demand for inputs where exchange rate changes affect the price of the imported component of agricultural inputs. Linkages associated with these macrovariables were simulated by specifying real input prices and the real interest rate in real product supply equations.

Specification of the agricultural and manufacturing sector equations was based on the structuralist approach. The agricultural sector is treated as being competitive, producing homogenous goods whose prices are more flexible than those in the macrosector. The manufacturing sector produces goods whose prices are determined on cost-plus basis and are inflexible downwards.

The complete system of equations was estimated by two-stage principal components due to insufficient degrees of freedom. Estimated equations represent the best fit in terms of statistical significance and coefficient signs agree with *a priori* expectations and economic theory. Estimated coefficient signs of the four variables which simulate macrolinkages are all correct. The model generally simulated endogenous variable trends and turning points well.

Dynamic impacts of an expansionary monetary policy on the endogenous variables in the agricultural sector were simulated by increasing money supply by 15 percent annually from 1972 to 1987.

The money supply increase causes the real interest rate to fall, general price level to rise and rand exchange rate to depreciate. Decreased cost effects of lower real interest rates impact positively on real field crop and horticultural supply. Increased stock effects of lower real interest rates cause real supply of beef, mutton and pork to decline as herd investment increases due to increased opportunity costs of off-farm investment in interest bearing assets. Higher inflation and the depreciated exchange rate raise input prices which impact negatively on real supply of all products. Reductions in supply cause product prices to rise which cause real per capita quantity demanded to fall. Real exports increase due to greater quantities available for export and the effect of the depreciated exchange rate on gross proceeds. Real agricultural investment declines due to reduced real farm incomes in the three sectors. The net effect of the expansionary monetary policy is a reduction in total real gross farm income in the sectors modelled.

General price level (inflation) effects appear to be larger than both real interest rate and exchange rate effects. Dynamic elasticities of real gross farm income with respect to all three macrovariables indicate that the net effects of an expansionary monetary policy are a decline in total real gross farm income in the sectors modelled.

Specification of the agricultural and manufacturing sector equations was based on the structuralist approach. The agricultural sector is treated as being competitive, producing homogenous goods whose prices are more flexible than those in the macrosector. The manufacturing sector produces goods whose prices are determined on cost-plus basis and are inflexible downwards.

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Dynamic impacts of an expansionary monetary policy on the endogenous variables in the agricultural sector were simulated by increasing money supply by 15 percent annually from 1972 to 1987.

The money supply increase causes the real interest rate to fall, general price level to rise and rand exchange rate to depreciate. Decreased cost effects of lower real interest rates impact positively on real field crop and horticultural supply. Increased stock effects of lower real interest rates cause real supply of beef, mutton and pork to decline as herd investment increases due to increased opportunity costs of off-farm investment in interest bearing assets. Higher inflation and the depreciated exchange rate raise input prices which impact negatively on real supply of all products. Reductions in supply cause product prices to rise which cause real per capita quantity demanded to fall. Real exports increase due to greater quantities available for export and the effect of the depreciated exchange rate on gross proceeds. Real agricultural investment declines due to reduced real farm incomes in the three sectors. The net effect of the expansionary monetary policy is a reduction in total real gross farm income in the sectors modelled.

General price level (inflation) effects appear to be larger than both real interest rate and exchange rate effects. Dynamic elasticities of real gross farm income with respect to all three macrovariables indicate that the net effects of an expansionary monetary policy are a decline in total real gross farm income in the sectors modelled.

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