Econometric Analysis of the structure of the Regional Maize Sector in Southern Africa

by

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ABSTRACT

The agricultural sector plays a vital role in the economy of the Southern African countries, not only as producer of food, but also as the largest employer of its population. Maize occupies a prominent position in Southern Africa's agriculture being the main food staple grown and consumed by the vast majority of the population. Understanding how the wellbeing of the people of Southern Africa is affected by the supply of and demand for such an important commodity is therefore critical for the design and formulation of agricultural development and trade policies. This is politically important because most of the food demand for maize is satisfied from regional production. In addition, regional maize production contributes substantial direct and indirect economic benefits to the South African economy including export earnings and the supply of an important input for the animal feed and other industrial processes.

Some of the countries in Southern Africa have the biophysical potential and technology to support high production levels of maize. Other countries in the region are major consumers but need to achieve food security through coordinated trade regimes to ensure access to a stable supply and price of such a basic food staple. Major producers of the regional maize supply also face fluctuating climatic conditions, availability of key inputs such as labor and water as well as technological

challenges. Currently however, each country in the region strives to achieve the same collective goal of food security by adopting trade and general economic policies that often indirectly work against attaining these objectives.

It is therefore crucial to understand the various forces that shape and influence patterns of regional maize production and consumption for developing national policies that are consistent with regional goals of economic integration and collaboration. This can only be achieved through the use of models that integrate climate, policy, technology, and institutional determinants of the availability and distribution of such a strategic commodity across the countries of the region.

Structural commodity models provide one tool for providing the necessary information needed for an optimal control of the state of supply and demand of commodities. This study made an attempt to develop and use a regional maize model to understand how the maize sector functions in Southern Africa. The model generated useful information for improving agricultural and general economic policy design towards achieving food security in the region.

The model was used to generate a baseline projection for the period 2002-2007. The baseline projection can be used as a point of comparison with various policy scenarios. Various forecasted values were taken from FAPRI's 2002 outlook, while others macroeconomic variables were assumed to have a forecasted average growth of the previous five years.

The policy simulation results indicated that a large decrease in the Zimbabwean area planted would have a negative effect on the regional net maize trade position and increase prices. The second policy simulation results indicates that if South Africa's yield levels were to experience a severe decline for two consecutive years, the region would be a net maize importer for that period and area harvested and prices would continue to increase well into 2007.

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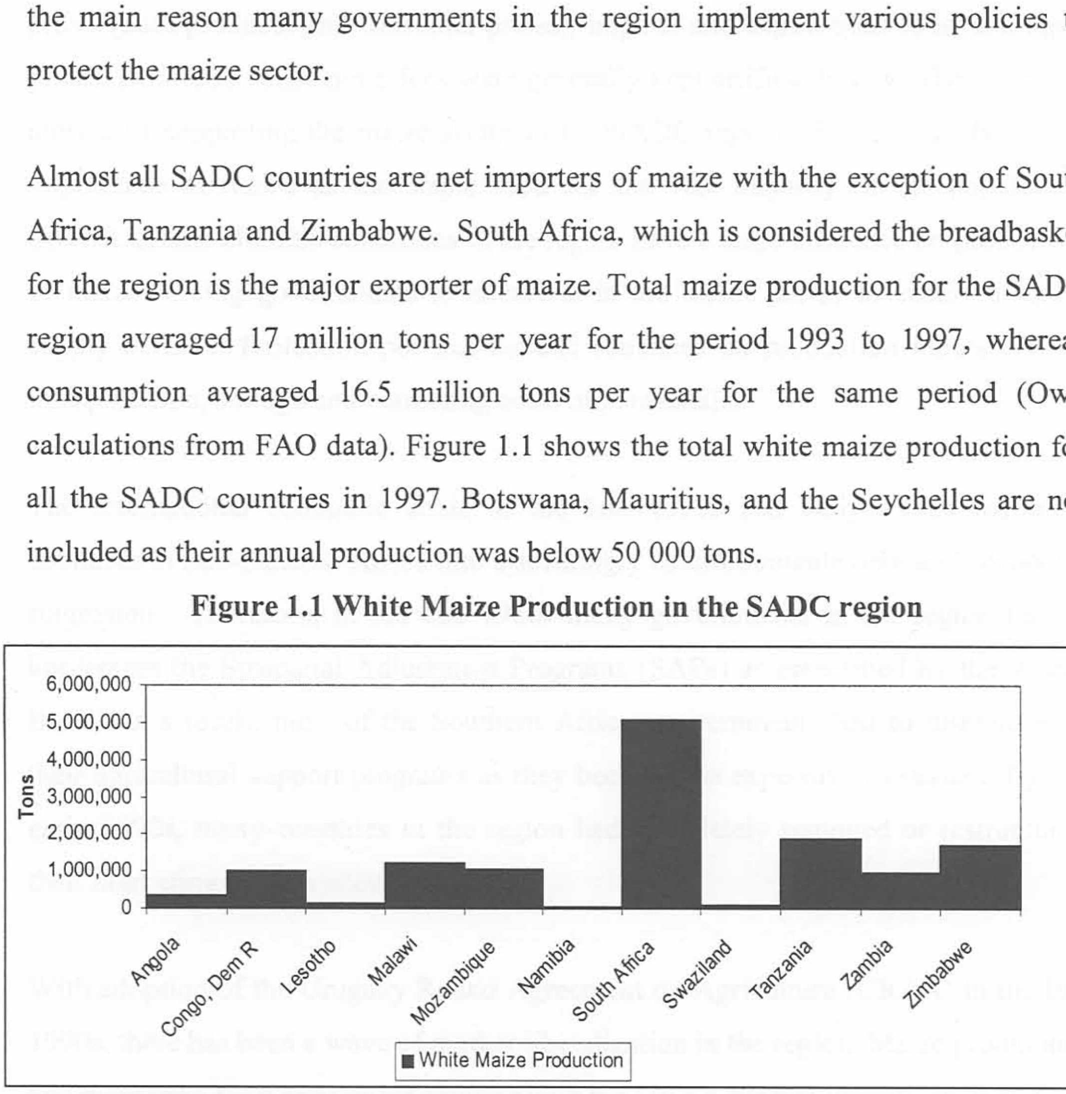
CHAPTER ONE: Introduction

1.1 Background and Motivation

In almost all of the Southern Africa Development Community (SADC) countries maize is cropped on a commercial basis except in Mauritius and Seychelles. Maize meal is the most important food staple in Southern and Eastern Africa. This is one of the main reason many governments in the region implement various policies to protect the maize sector.

Almost all SADC countries are net importers of maize with the exception of South Africa, Tanzania and Zimbabwe. South Africa, which is considered the breadbasket for the region is the major exporter of maize. Total maize production for the SADC region averaged 17 million tons per year for the period 1993 to 1997, whereas consumption averaged 16.5 million tons per year for the same period (Own calculations from FAO data). Figure 1.1 shows the total white maize production for all the SADC countries in 1997. Botswana, Mauritius, and the Seychelles are not included as their annual production was below 50 000 tons.

Figure 1.1 White Maize Production in the SADC region



Source: FAO 2002 data base

Both yellow and white maize are produced in the SADC region. The percentage of white maize production to total maize production varies from country to country. However, on average more than 85 % of total production is white maize except in

South Africa and Zimbabwe. South Africa and Zimbabwe's white maize production comprises 53 % and 77 %, respectively, of total production (Heisey and Edmeades 1999).

As stated earlier, the maize sector in the SADC region used to be highly protected. Governments in Southern Africa, through their grain parastatals, controlled maize prices (both producer and consumer prices), imports and export quantities; and input prices. Domestic consumer prices were generally kept artificially low. Many reasons motivated supporting the maize sector in the SADC region. First, is the historical importance of maize as the staple food for the vast majority of the population. Second, erratic climatic conditions in the region have a large influence on production of maize forcing governments to intervene in the maize sector to ensure a stable supply of food. Protection policies include subsidies on production inputs and on transportation, storage and marketing costs of parastatals.

The international economic crisis of the late 1970s and early 1980s led most countries in Sub-Saharan Africa into a seemingly insurmountable debt and economic stagnation. Therefore, in the late 1980s many governments in the region had to implement the Structural Adjustment Programs (SAPs) as prescribed by the World Bank. As a result, most of the Southern African governments had to dismantle all their agricultural support programs as they became too expensive to sustain. By the early 1990s, many countries in the region had completely removed or restructured their marketing board systems.

With adoption of the Uruguay Round Agreement on Agriculture (URAA) in the late 1990s, there has been a wave of market liberalization in the region. Maize production and marketing have seen major reforms with the URAA market liberalization and the SAPs. Private sector participation in supply of maize inputs (improved seed and fertilizer) and grain marketing has steadily increased during the said period (Hassan et al., 2001). The pace of change differed from country to country, as did the impact of the various reforms. What happens in one country, more often than not, has an effect on another country, as seldom is a country completely isolated. This is of particular interest when it involves food security. With white maize being the primary food staple within SADC, an understanding of the effects that changes in country level policies have on each other and on the regional maize market in terms of prices, production, exports, imports and consumption are crucial for designing policies that would promote food security.

1.2 Problem Statement

Given the importance of the agricultural sector for the SADC region, research on commodity modeling is considered to be lacking in many areas. In light of Southern Africa's desire for greater regional integration, improved prospects for economic growth, equitable development and food security, commodity models are expected to provide critical guidance to policy design for achieving those goals.

To feed it its burgeoning population, Southern Africa has to increase or at least maintain a per capita food supply from a fixed land base and hence the need to increase agricultural production. Commodity market models provide the barometer and analytical tool for measuring the consequences of changes in market conditions for the supply and distribution of agricultural commodities. The SADC maize industry used to be characterized by a large number of disaggregated decision-makers and extensive uncoordinated government intervention. However, recent policy changes and reforms such as market liberalization, structural adjustment program and the SADC economic integration drive, to mention a few, have significantly influenced the performance of the maize sector.

The identification of both economic and non-economic variables that influence maize production and consumption is crucial for appropriate decision-making. It is also of high interest to policy makers to evaluate the implications of the continuing wave of market liberalization and market deregulation in most SADC countries on the supply and availability of maize, the main food staple in the region. This study represents an attempt to develop a structural maize commodity model for the SADC region and use the model to conduct policy analysis and evaluation of plausible scenarios for improved food security through regional integration of maize production and trade.

1.3 Objectives of the Study

The primary objective of econometric modeling of agricultural commodity markets is to specify and measure the relationships among the supply and demand components in order to analyze the structure and economic behavior of markets (Hallam, 1990). Market structure analysis models provide a sound base for econometric forecasts and policy analysis. The growing inter-linkage and complexities of SADC maize markets requires the use of econometric models for a clearer understanding of the structure and functioning of these markets.

Accordingly, the main purpose of this study is to develop a structural econometric model for maize trade in the SADC region, which can be updated easily. An attempt is made to understand the economics and politics of this sector in the region, both from a historical and current perspective, through a formal quantitative analytical approach. More specifically, this study represents a pilot commodity markets modeling exercise with the following objectives:

1). Develop and use a structural econometric model for an in-depth analysis of the overall maize sector of SADC.

2). Use the developed regional SADC maize model to solve for equilibrium supply and demand quantities, prices, and net trade in maize.

3). Use the model to perform policy simulations evaluating the impacts of possible future policy changes on maize supply and use within the region.

4). Generate conditional forecasts and market information that will help policy makers predict changes in food availability.

5). Evaluate the impacts of exogenous shocks such as the impacts of climate fluctuations, political instability (e.g. the current situation in Zimbabwe), changes in macroeconomic conditions such as income growth, inflation, exchange rates, tariffs and subsidies on regional maize markets.

1.4 Research Methodology

Structural commodity models use sets of equations designed to explain market structure and inter-linkages. The development of structural commodity models involves several steps of model building. First, the different components (equations) of the analytical model are specified based on economic theory. Then data needed for the empirical implementation of the model are collected. This study will use secondary data mostly from reliable sources such as government statistical agencies and the United Nation's Food and Agricultural Organization (FAO). Where necessary variables of interest will be created from the data set and at the same time categorized into exogenous and endogenous variables. Some of the structural relationships will be explained by identities while others by behavioral equations. However, the fact that data limitations are a major constraint in the modeling process implies that abstraction from theory is inevitable. In working through the data step, care should be taken to make sure that measures of total demand are equal to total supply quantities.

Once the data stage is completed some basic statistics are calculated and behavioral equations are estimated and evaluated using appropriate econometric methods. Once the estimations have been finalized, plots and error statistics are generated and analyzed with a variety of misspecification tests being performed. After specification tests are performed identities are grouped to form the model, which is solved using the two staged least squares (2SLS) econometric method. The estimated model is then subjected to a battery of statistical tests for validation. This is a crucial step in empirical modeling processes. One of the robust tests available for models validation is the impact multiplier analysis. This test evaluates how well the estimated model tracks the historical data and how well it responds to changes in exogenous variables. A baseline is generated which is followed by the experimental simulation step, where different policy scenarios are evaluated based on the empirically specified and validated model.

An initial conceptual model will be developed based on economic theory and the conceptual knowledge of the special characteristics of the maize sector in the SADC region. Where required the equations in the model may be modified as per availability of the data and problems encountered in empirical estimation such as multicollinearity. Thus all major equations and variables in the system, which satisfactorily explained the structure and market behavior of the sector, and made sense in terms of an economic model, will be retained.

1.5 Data Sources and Limitation

For almost all countries in the Southern Africa region agricultural data are very imprecise due to disruptions in data collection (caused by war in the case of Mozambique and sanctions-induced secrecy in South Africa, for instance) or weak statistical institutions. Another problem with the data in the region is that due to the dualistic characteristic of agriculture in the region in terms of commercial and subsistence farming, much of the data does not account for the subsistence segment. It is clear that not including subsistence farming poses great limitations to the usefulness and accuracy of the model. Due to the lack of data, this study relied mostly on time series data supplied by the FAO. Area harvested, maize production and utilization, and crop prices for most of the countries were obtained from the FAO statistical database. In the case of South Africa, which is the major maize producing country, data were obtained from the National Department of Agriculture. Using data originating from one source ensures a certain degree of consistency. Although data for South Africa was obtained from the National Department of Agriculture, it was cross-checked against data from the FAO statistical database.

Data on macroeconomic variables such as exchange rates, gross domestic product (GDP), consumer price indices (CPI), gross domestic product deflators (GDPD), wage rate indices, population statistics and other required macroeconomic data were compiled from the *International Financial Statistics* (IFS) of the International Monetary Fund. All variables were in real terms, deflated by the relevant deflators.

1.6 Structure and Organization of the Study

This study is organized in seven chapters. The next Chapter provides a brief background of SADC as well as an overview of the maize sector in SADC countries. Chapter three reviews the commodity modelling literature. Chapter four describes the modeling approach and the model structure. The empirical results are reported in Chapter five, whereas in Chapter six the model is used to perform policy simulations. The last chapter provides a summary and concludes the study.

Agriculture is also the largest employer in most countries except in the case of South Africa and Botswana. In Tanzania, for example 55 % of the labor force is employed in agriculture, while Botswana and South Africa each had 3 % of the labor force in agriculture.

2.2 Maize in SADC

Maize, in particular white maize, is the dominant food staple throughout southern Africa, with its importance equaling that of rice and wheat in Asia. Although rice and wheat are also consumed, increases in supply are usually from imports while maize is generally a homegrown crop. Most maize is produced on medium to high potential agricultural land and more densely populated areas and areas with better infrastructure. A distinction should, however, be made that maize for human consumption is generally white maize while maize for animal feed is generally of the yellow variety. Currently about 5% of the maize produced is used for animal consumption, with the exception of South Africa where half of all maize is fed to animals.

This study examines 10 of the 14 SADC member countries. Four countries had to be excluded due to the lack of production, consumption, and general economic data. The remaining 10 countries can be grouped as follows: South Africa, Tanzania, and Zimbabwe are net exporters, Botswana, Lesotho, Malawi, Mauritius, Mozambique, Swaziland and Zambia are net maize importers. For modeling purposes, Botswana, Lesotho, Mauritius, and Swaziland are grouped together to form "the rest of SADC" because of their low production and consumption of maize.

South Africa is the regions' largest producer of maize, producing 43 % of the total maize produced in the SADC region in 1999 (Table 2.2). This is not only due to the fact that it plants the largest area to maize, but also because South Africa's average yield is consistently higher than that of the other countries.

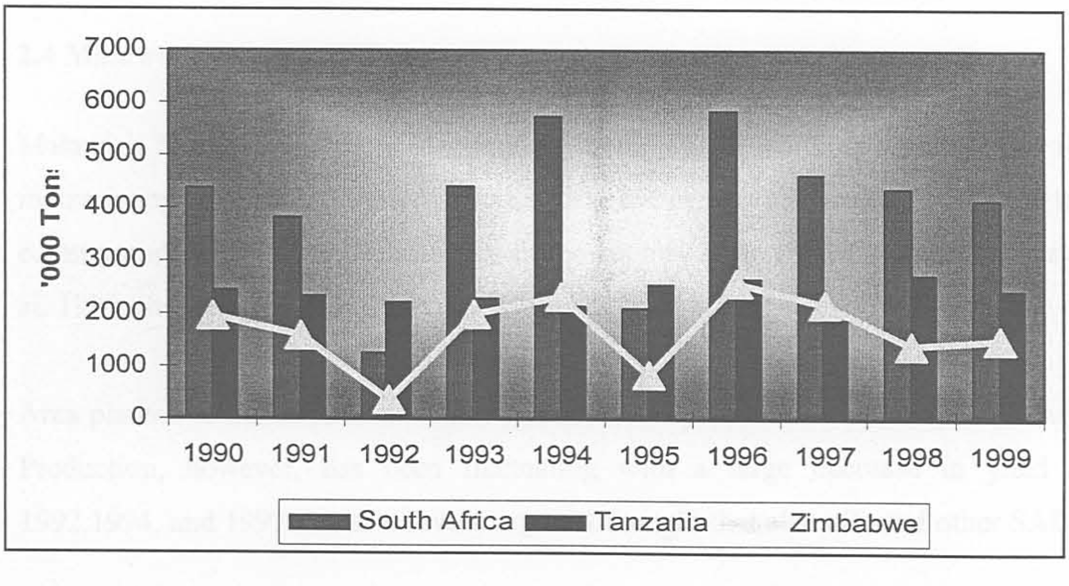
Table 2.2: Area, Yield, Production and Consumption of Maize in SADC: 1999

	Area	Yield	Production	Consumption
	(000 Hectare)	(Ton/Hectare)	(000 T)	(000 T)
Malawi	1400	1.77	2478	2057
Mozambique	1152	1.08	1244	1356
South Africa	3230	2.08	6718	7658
Tanzania	1764	1.39	2452	2643
Zambia	598	1.43	855	1460
Zimbabwe	1446	1.05	1518	2018
Rest of SADC	214	1.14	244	824
SADC	9804	1.42	13922	18016

2.3 Maize Supply

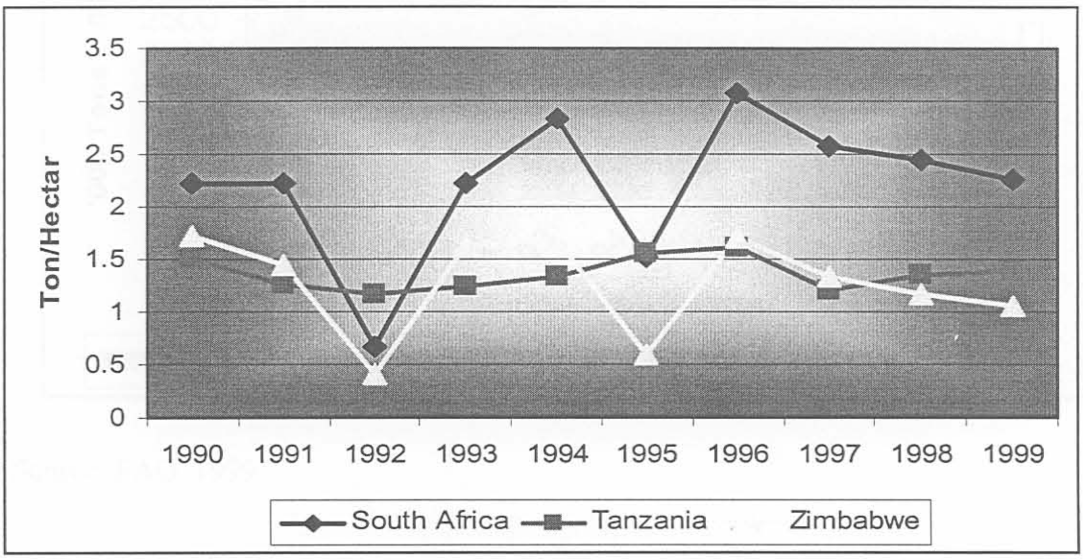
South Africa, Tanzania and Zimbabwe are the main maize producers in the SADC region producing approximately 70 % of the total maize output. Figure 2.1 clearly indicates that of the main white maize producers, South Africa is consistently the largest.

Figure 2.1 White Maize Production In South Africa, Tanzania, And Zimbabwe



On average, between 1990 and 1999 South Africa produces 4 million tons of white maize while Tanzania and Zimbabwe produce 2.3 million tons and 1.6 million tons respectively. The figure also clearly shows that South Africa and Zimbabwe's maize production are affected by similar weather patterns. In fact, they both experienced a sever drought in 1992 and again in 1995. However Tanzania does not seem to have the same weather patterns. This is even more noticeable in figure 2.2, which gives an indication of the changes in maize yields over ten years.

Figure 2.2 White Maize Yields in South Africa, Tanzania, and Zimbabwe



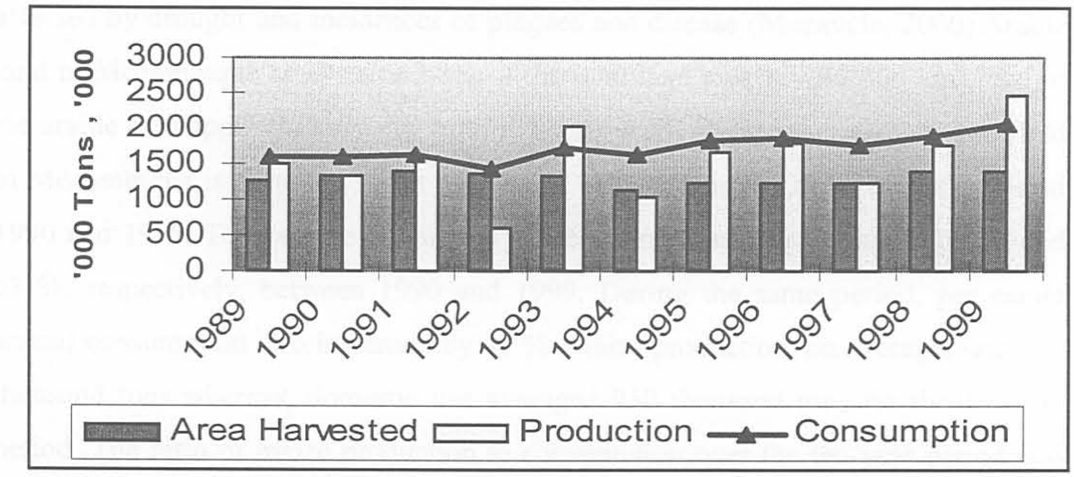
Source: FAO 1999.

2.4 Malawi

Malawi is blessed with an agro-ecological environment, which is highly suited for maize cropping. Maize is mainly produced in the central and southern parts of the country and about 90% of households in the country cultivate maize (Nakhumwa et al. 1999; Smale and Heisey, 1997).

Area planted to maize in Malawi has remained fairly constant over the past decade. Production, however, has been fluctuating with a large decrease in yield in 1992,1994, and 1997 due to a severe regional drought that also affected other SADC countries. Total maize consumption had increased by approximately 22 % in the past decade but per capita consumption has decreased by 26 % over the same period. A crude measure, the ratio of production to consumption, averaged 0.88 indicating that over the last ten-year period Malawi was not self-sufficient in maize except in 1993 and 1999 (Figure 2.3).

Figure 2.3: Malawi Maize Area Harvested, Production And Consumption: 1989-1999



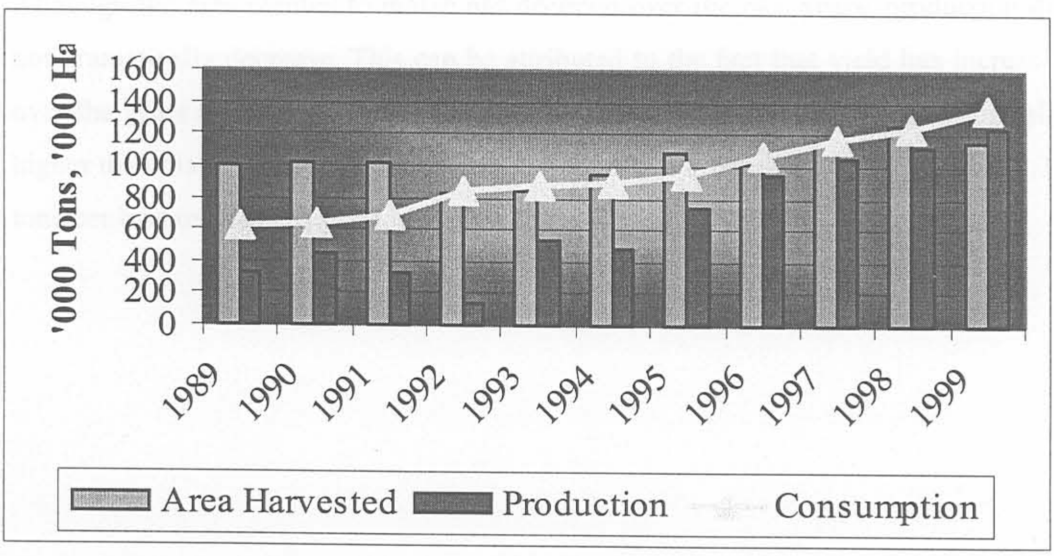
Source: FAO, 1999.

As in other parts of the SADC region, maize is the main food staple in Malawi, supplying about two thirds of the daily food calories' intake. Maize production in Malawi averaged, between 1990 and 1999, 1.3 million tons per annum from 1.2 million hectares of land, whereas domestic consumption averaged 1.4 million tons per annum (Figure 2.3). Malawi was accordingly a net importer of maize. Unimproved local flint varieties are the most commonly used. In 1990, however, higher yielding semi-flint varieties were introduced and widely adopted by small farmers, greatly increasing production. (Smale and Heisey, 1997). It should be noted however that the large decrease in production in 1992 was due to a drought that affected the whole southern African region.

2.5 Mozambique

Mozambique can be divided into three main agro-ecological zones, The Northern, Central, and Southern agro-ecological zones. Although these three zones differ in terms of rainfall and production risk, maize is produced in all of them, with the largest share being produced in the Northern agro-ecological zone. Mozambique's agricultural production for the past two decades has been severely affected by the civil war, and the uncertainty it has created. In addition agriculture was severely affected by drought and incidences of plagues and disease (Mucavele, 2000).Arable land in Mozambique constitutes 3.8% of the total land area of 784 000 km^2, and of the arable area approximately one million hectares are planted to maize. Maize yield in Mozambique is quite low, with an average of 0.62 tons per hectare for the period 1990 and 1999. Total maize production and consumption have increased by 54 and 53 %, respectively, between 1990 and 1999. During the same period, per capita annual consumption also increased by 43 %. Maize production, on average, was 670 thousand tons whereas, domestic use averaged 930 thousand tons for the 1990/99 period. The ratio of maize production to consumption over the ten-year period was consistently below 1 indicating a constant shortage of maize (Figure 2.4).

Figure 2.4: Mozambique Maize Area Harvested, Production And Consumption: 1989-1999



Source: FAO, 1999.

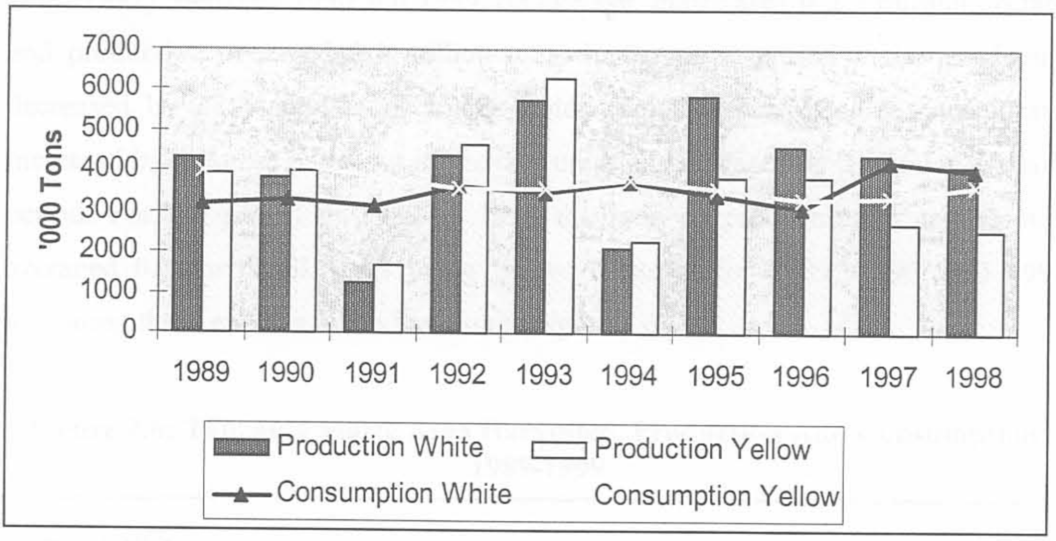
2.6 South Africa

Maize is the most important crop in South Africa, being both the major feed grain and the staple food for the majority of the South African population. Maize is grown in almost all provinces with varying degrees of intensity due to climatic conditions. The Free State is the major maize-producing region, whereas the North West, Gauteng, Mpumalanga and Kuala Zulu Natal are other important growing regions. Maize accounts for approximately 40% of the cultivated area and generates 15% of the gross value of all agricultural products (World Bank, 1994).

On average, between 1993 and 2000, the Free State produced 34% of total maize production, the North-West province 30%, whereas Mpumalanga and Guateng supplied 21% and 5%, respectively. The remaining 10% of production scattered in the remaining five provinces. The area planted to maize varied between 5 million to 3.5 million hectares. The annual average maize production for the past decade has been approximately 8 million tons. South Africa has been plagued by a series of droughts, namely in 1982, 1984, 1988, and again in 1992, which seriously affected maize production.

Although the area planted to maize has declined over the past years, production did not dramatically decrease. This can be attributed to the fact that yield has increased over the years as production technologies improved. Yellow maize yield is normally higher than that of white maize in South Africa. Yellow maize's highest yield of 3.35 tons per hectare was achieved in 1993/1994.

Figure 2. 5: South Africa Maize Production And Consumption: 1989-1998



Source: Nation Department of Agriculture, 2000.

Domestic consumption of maize averaged, between 1990 and 1999, 7.5 million tons, 4.4 million tons white and 3.1 million tons of yellow maize. South Africa has been the breadbasket for SADC, exporting maize and maize products to almost all SADC, as well as to non-SADC countries. Over the past five years there has been a marginal increase in the domestic use of maize in South Africa (Figure 2.5).

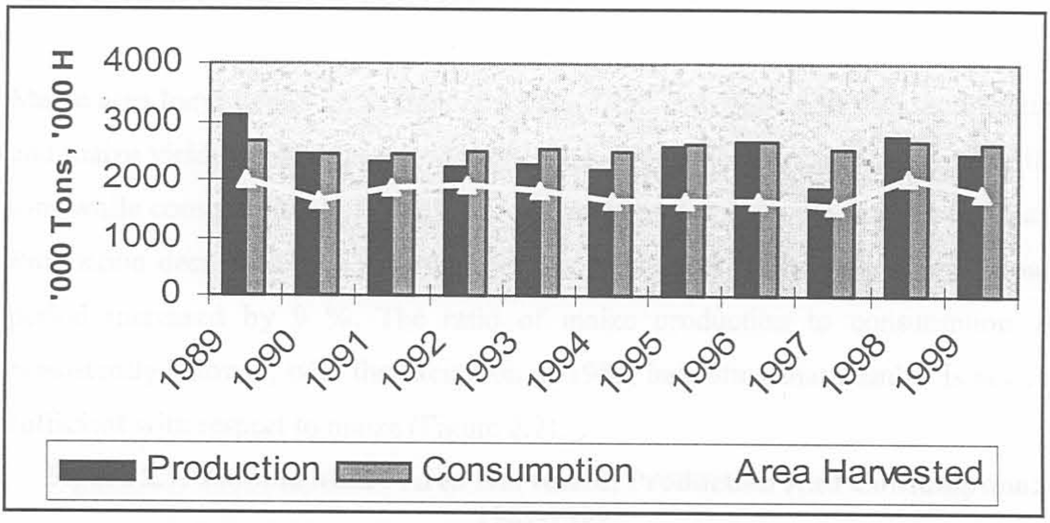
2.7 Tanzania

Agriculture is the backbone of the Tanzanian economy, with more than 80% of the active population is involved in some facet of food production. Agriculture is therefore the country's main source of income, providing 50% of its annual GDP, and 90% of its export earnings. (Lyamachai, *et al,* 1997)

Tanzania has a wide range of agro-ecological climates, and droughts rarely affect the whole country. Maize is cultivated in the western plateau and southwest highlands, mainly in the Iringa, Mbeya, Rukwa and Ruvuma regions. Maize is the most important food staple in Tanzania. Per caput maize consumption is approximately

144 kg and provides 61% of the calorie intake of the average Tanzanian (Lyamachai, *et al,* 1997). Between 1990 and 1999, on average, maize area is 1.7 million hectares and production averaged 2.4 million tons. In the same period maize production decreased by 27 % due to declining yields. Total domestic maize consumption increased by 5 %, but per caput maize consumption decreased by 2.6 % for the same period. For the period of 1989 to 1999 the ratio of production to consumption averaged 0.95 with all years being below 1 except for 1989, 1990, and 1998, indicating that Tanzania is food insecure (Figure 2.6).

Figure 2.6: Tanzania Maize Area Harvested, Production And Consumption: 1989-1999



Source: FAO, 1999.

2.8 Zambia

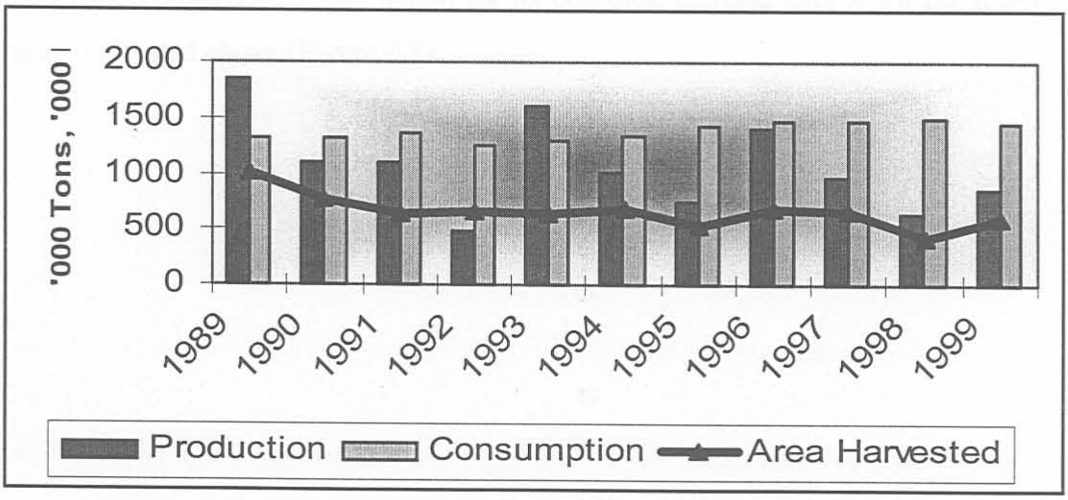
The maize sector used to be highly subsidized in Zambia. The subsidies provided by the government were however, not sustainable as they consituted 17% of the governments annual budget (Howard and Mungoma, 1997). Zambia experienced a "stop-and-go" structural adjustment program (SAP) between 1983 and 1987, as structural adjustment programs were adopted and subsequently the Zambian government abandoned in mid 1987. In 1990/91 the government reintroduced market liberalization under pressure from the international donor community (Howard and

Mungoma, 1997).

Zambia's diverse agro-climates and abundance of natural resources make most of the country suitable for agricultural production. Zambia can be divided into three main agro-ecological zones. Zone I includes the Luangwa and Gwembe valleys in eastern and southern Zambia, respectively, and parts of the Western and Southern provinces. This zone receives less than 800mm of rain. Zone II includes the Central, Eastern, Lusaka, and Southern provinces, and parts of the Western province. Zone III comprises the northern part of the country, which includes, Luapula, Copperbelt, and Northwestern Provinces. Most of the land suitable for agricultural production is found in Zone III (Saasa et al., 1999).

Maize area harvested is on average, between 1990 and 1999, 650 thousand hectares and maize yield is on average 1.6 tons/hectare. Production on average is one million tons while consumption is 1.3 million tons, making Zambia a net importer of maize. Production decreased by 53% from 1989 to 1999. Total consumption for the same period increased by 9 %. The ratio of maize production to consumption was consistently below 1, with the exception of 1989, indicating that Zambia is not self-sufficient with respect to maize (Figure 2.7).

Figure 2.7: Zambia Maize Area Harvested, Production And Consumption: 1989-1999



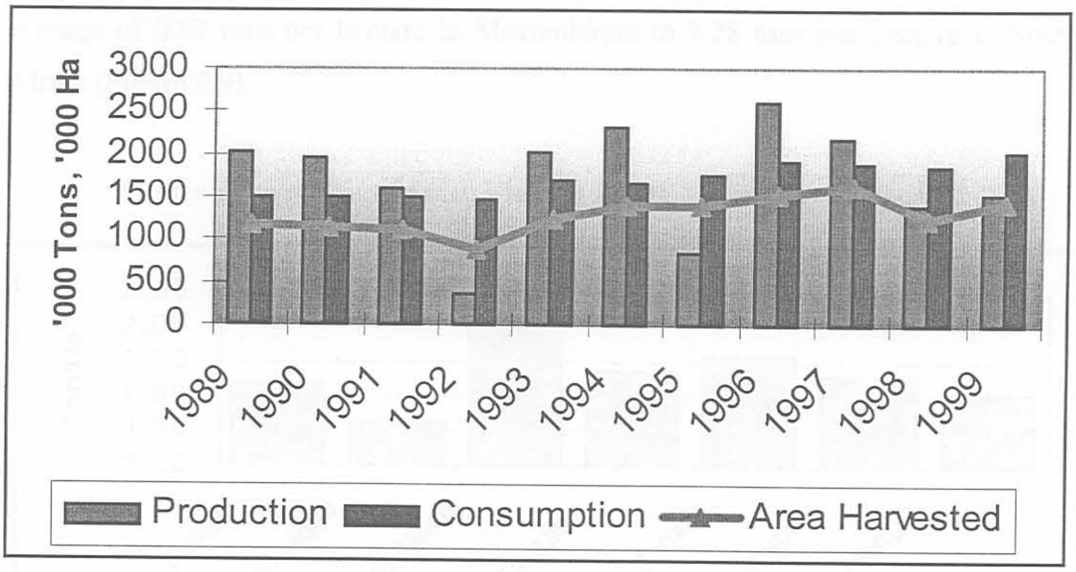
Source: FAO, 1999

2.9 Zimbabwe

Zimbabwe has a dualistic agricultural sector comprising of few commercial farmers, which occupy most of the high potential agricultural regions, and a large smallholder sector, occupying low potential agricultural land where ownership is predominantly communal. Smallholder farmers produce approximately 55% of the total maize (Sukume, 2000). Zimbabwe experienced a first green revolution in the early 1960's when the high yielding maize variety SR52 was released (Eicher and Kupfuma, 1997). Historically maize production was a small-scale farmers' activity. Maize is mainly produced in the southern parts of Mashonaland West, Mashonaland Central, Mashonaland East, and in northern Manicaland.

Between 1989 and 1999, maize area has steadily increased. Maize production however, has not followed the same trend and decreased by 32 % during the same period. For the 1990-99 period, maize production, on average was 1.71 million tons and consumption was, on an average 1.70 million tons. Zimbabwe was a net exporter of maize except for 1992, 1995, 1998 and 1999 due to severe droughts in the region, and again in 1998, and 1999. However, the current political crisis has changed the overall outlook of the country. It is expected that maize production will be the lowest in the history of Zimbabwe in current years. The ratio of production to consumption in Zimbabwe averaged 1.006 between 1989 and 1999, indicating that Zimbabwe produces enough maize for its domestic demand except for the drought years indicated above (Figure 2.8).

Figure 2. 8: Zimbabwe Maize Yield, Production And Consumption: 1989-1999



Source: FAO, 1999

2.10 The Rest Of SADC

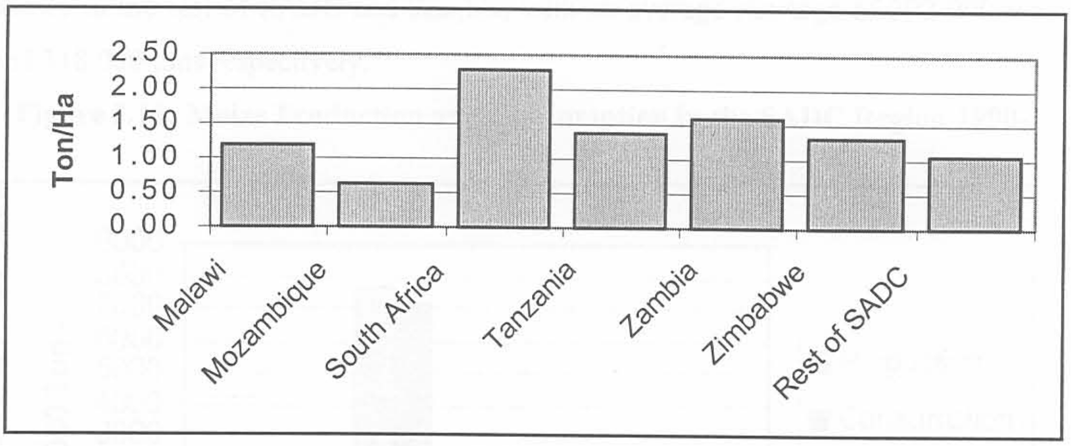
For the purposes of this study the following countries were grouped as the rest of SADC: Botswana, Lesotho, Mauritius and Swaziland. Angola, the Democratic Republic of Congo, Namibia, and the Seychelles were not included due to lack of data for these countries. Over the above ten-year period, the rest of SADC produced on average 234 thousand tons of maize and consumed an average of 666 thousand tons indicating that this group is largely a net importer of maize. The ratio of maize production to consumption was consistently below 1, with an average for the ten-year period of 0.35. This can be explained by the fact that Botswana and Mauritius are not maize producers due to their agro-climatic conditions.

2.11 Summary

From this chapter it is clear that that the countries within the SADC region differ greatly in many aspects, ranging from GDP to their individual food security in terms of maize. Zimbabwe and South Africa are the only countries in the region that consistently have a positive net maize trade. The SADC region as a whole is food secure in terms of maize predominantly due to the surpluses produced in South

Africa and Zimbabwe. Amongst the SADC countries maize yield varies from an average of 0.62 tons per hectare in Mozambique to 2.28 tons per hectare in South Africa (Figure 2.9).

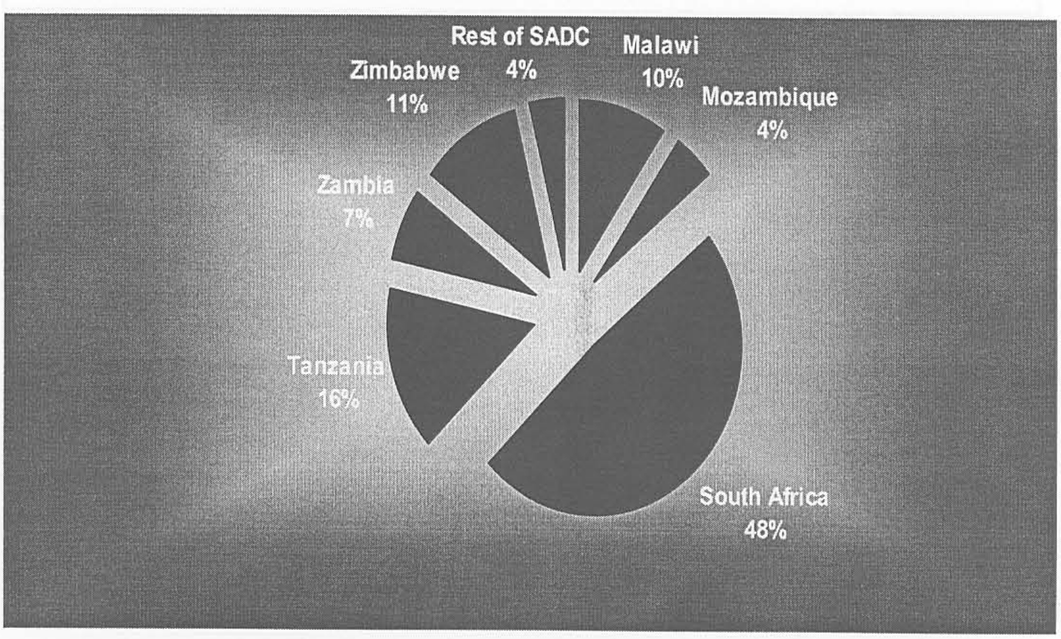
Figure 2.9: Average Maize Yield in SADC Countries 1990-1999



Source: FAO, 1999

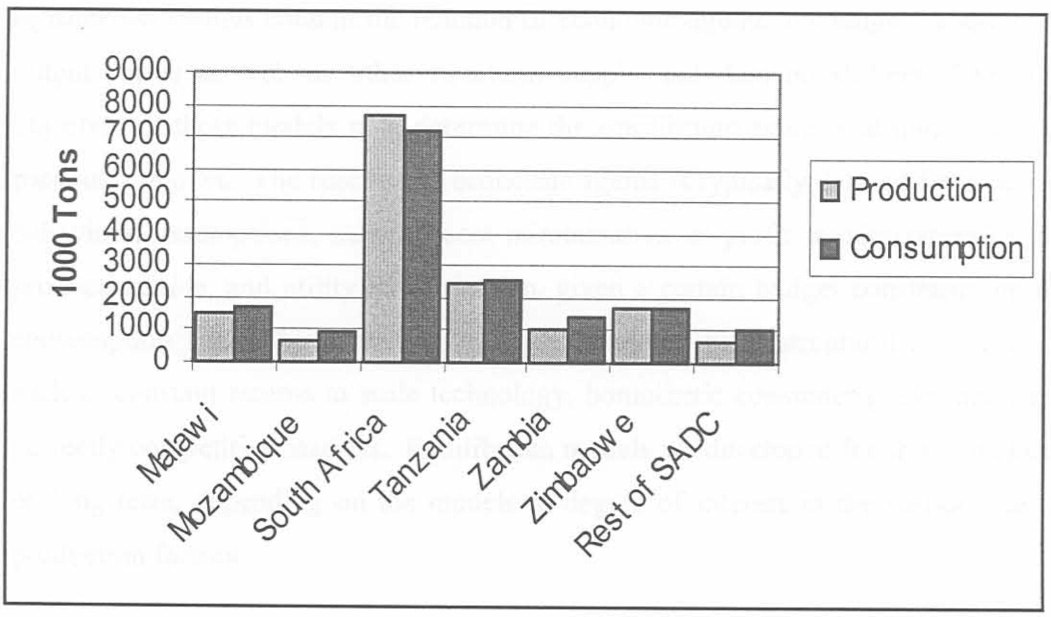
South Africa is the largest producer of maize in the region, producing on average 48 % of the total maize produced in the region, while the rest of SADC and Mozambique produce only 4 % respectively (Figure 2.10).

Figure 2.10: Percentage of Maize Production for the SADC countries 1990-1999



Although the SADC countries produce varying percentages of total production, what is important is how much of that production is consumed. Figure 2.3 represents the average production and consumption of each SADC country between 1989 and 1999. From Figure 2.11 it is clear that, on average, only South Africa and Zimbabwe are food secure in terms of maize. The largest maize deficit on average usually occurs in the rest of SADC and Zambia, with an average shortage of 392 000 tons and 318 000 tons respectively.

Figure 2.11: Maize Production and Consumption in the SADC Region 1990-1999.



One of SADC's main objectives is to promote food security within the region, this however can only be done if policy makers are in a position to make informed decisions. The following chapter discusses the use of commodity modeling as an aid to policy making.

CHAPTER THREE: Approaches to Modeling Commodity Markets

3.1 Introduction

Two main types of models are used in quantitative policy analysis: *time series projection models* and *market equilibrium models*. *Time series projection models* attempt to forecast the future through the extrapolation of historical data. These models put more emphasis on the statistical behavior of historical data rather than on the economic theory behind behavioral equations. On the other hand *Market equilibrium models* contain the reaction of economic agents to changes in input and output prices as well as other structural supply and demand shifters. The main objective of these models is to determine the equilibrium prices and quantities in a particular market. The reaction of economic agents is typically derived from certain behavioral assumptions, namely: cost minimization or profit maximization on the production side, and utility maximization, given a certain budget constraint, on the consumption side. This modeling method also uses many structural assumptions, such as constant returns to scale technology, homothetic consumer preferences, and perfectly competitive markets. Equilibrium models are developed for short, medium, or long term, depending on the modeler's degree of interest in the reallocation of production factors.

This chapter reviews relevant literature on modeling approaches to the analysis and control of economic systems and structure of commodity markets.

3.2 Partial Equilibrium and Economy-Wide Approaches

In quantitative policy analysis models, national economies can be represented as *single market models*, a selected set of multi-markets or multi-sector systems, or as *economy equilibrium wide models*, for a more complete representation of national economies. Partial equilibrium models consider a particular market or sector, for example agriculture, as closed and without linkages to the rest of the economy, meaning that the agricultural sector is affected by the rest of the economy but it has no direct effect on the said economy. The effects of the rest of the world and the local economy on the sector are treated as exogenous. These models can be single or multi-commodity market systems, with the second capturing the interrelationships among the various commodity markets included. Partial equilibrium models develop behavioral equations, which represent the responses of economic agents making supply and demand decisions. These models are mainly applied to detailed policy analysis of specific products. *Economy-wide models* on the other hand, give a complete representation of a national economy, together with trade relations with other economies capturing the effects of international trade on the economy in question. These models are typically specified as: macro-econometric, multi-sector or applied general equilibrium models. (Dervis 1984, Sadoulet and de Janvry 1995)

3.3 Dynamic Versus Comparative Static Analysis Approaches

Quantitative policy analysis models are constructed to deal with changes over time in two ways, as dynamic or comparative static models. Dynamic models provide for an adjustment process over time, through the inclusion of inter-temporal transmission variables as part of the model structure. On the other hand comparative static models compare different but not necessarily related equilibrium points, given different assumptions on the state of exogenous data and policy variables at that point with no reference to the time path between equilibrium points.

Dynamic adjustments over time can be included in equilibrium models in several ways, but usually in a recursive sequential manner such that equilibrium is attained at each time period as adjustment moves over time. In such recursive models policy changes can have lasting effects, on for example production, growth, or consumption.

Comparative static models are used to generate projections in some future time by constructing an artificial future dataset given certain assumptions. This dataset is constructed based on assumptions about changes in the exogenous variables and parameters determining how the state of the world will look like in the future. These models are then solved for equilibrium, which is referred to as the baseline solution to which the outcome of various policy experiments are then compared.

In most commodity market models certain assumptions regarding the commodity traded are made. One such assumption is that all goods are perfect substitutes for each other both domestically and internationally, and are thus homogeneous. Another assumption is that the number of suppliers and buyers is large enough for the market to be considered nearly perfectly competitive. These assumptions greatly simplify trade modeling making it "non-spatial", however they impose the limitation that only trade among industries is possible and not within the same industry.

Trade and domestic economic policies are important elements in formulating quantitative policy analysis models as they distort both domestic and international prices. There are two ways of including policy instruments in a model. The first is to include the price mechanism directly in the model and the second is to use a price transmission relationship capturing the policy intervention. Tariffs and quantitative restrictions on trade are the two policy instruments most commonly modeled.

3.4 Partial Equilibrium Trade Models

Over the past decade, several partial equilibrium trade models have been developed. To name a few: AGLINK, European Simulation Model (ESIM), FAO World Model, Food and Agricultural Policy Research Institute (FAPRI), General Agricultural Policy Simulation (GAPsi), MISS, Static World Policy Simulation (SWOPSIM), and World Agricultural Trade Simulation Modeling System (WATSIM). These models not only differ from each other in model design but also in the commodities modeled and the number of countries included in the model. These models also differ with respect to regional emphasis, for example FAPRI focuses on the US, including, however, linkages to other countries, the ESIM model on Eastern Europe, MISS on the US-EU interactions and GAPsi focuses on the EU. The AGLINK, FAO World Model, FAPRI, and GAPsi are all dynamic recursive models. The AGLINK, FAO World Model, and WATSIM all endogenously model land allocation as, while

AGLINK, ESIM, GAPsi, MISS, and WATSIM explicitly model quantitative policies; the SWOPSIM model however includes bilateral trade using the Armington assumptions. The number of countries and regions included in these models ranges from 147 countries and 1 region in the FAO World Model to 1 country and 3 regions in the MISS model. The number of sectors, or products, varies from 13 in the FAO World Model and GAPsi to 29 in the WATSIM model. (Van Tongeren *et al* 2001)

The models listed above cover only farm products or agriculturally related processed goods. The results that are therefore obtained from a general equilibrium model will differ significantly from the partial equilibrium results if agricultural trade policies cause significant price shifts in other sectors. This is the case in developing countries, and countries in transition, as the share of agriculture in the general economic activity is quite high (Van Tongeren *et al* 2001).

From the previous section it is evident that many partial equilibrium trade models have been estimated at the global level. The few case studies found in the African literature are reviewed below.

Townsend and Thirtle (1997) studied the supply response of small-scale producers in Zimbabwe. The sample period used was 1975-1990, a period in which the government set the maize producer price, and announced it after planting. The variables included to explain maize production were the number of marketing depots in the communal sector, the volume of loans to communal farmers, the increased land through resettlement programs, the population of the communal areas, research and extension expenditures and the amount of rainfall. An error correction model for communal maize production was estimated and the relative price of maize and the number of loans was found to be significant. Townsend and Thirtle reported and own price elasticities of 0.78 and 1.01 in the short and long run respectively.

Foster and Mwanaumo (1995) estimated the dynamic supply response of maize in Zambia using a second-order rational distributed lag model. The sample period was

1971 to 1990. The short run own price and fertilizer price elasticities are reported as 0.54 and –0.48 respectively. The corresponding long run elasticities are 1.57 and –1.44.

Van Zyl (1990) analyzed various economic aspects of the South African maize market. In this study, both supply and demand for maize was studied for the period 1960-1988 using stepwise regression. Van Zyl estimated, at the mean, a price elasticity of supply of 0.136, while own price elasticities of demand for maize by the animal sector was between –1.84 and –2.20 while the human consumption elasticity was estimated as –0.15.

Poonyth , Hassan , and BenBelhassen (2001) studied the acreage response to risk of the maize and wheat sectors in South Africa. Using Generalized Least Squares (GLS) and time series data from 1970 to 1998, they determined that maize and wheat producers in South Africa are risk averse with price risks being an important factor influencing a farmers decision in allocating area to maize.

This study focuses on modeling one commodity, namely maize, in a region and therefore models regional trade in a single commodity. The modeling system and the approach used will be discussed in the following chapter.

CHAPTER FOUR: Modeling Approach of the Study and Structure of the regional SADC maize Model

4.1 Introduction

In this chapter, the modeling approach followed and the structure of the SADC maize model are discussed. The theoretical foundations of the modeling approach are reviewed and the SADC regional maize model is specified and presented together with a discussion of estimation procedures used.

The first sub-section of this chapter reviews the basic elements of the economic theory of the firm and consumer behavior employed in this analysis. The aim of this section is to provide the theoretical foundations for the specification and empirical estimation of the supply and demand segments of the model presented later in this study. Good understanding of the underlying assumptions behind the specified supply and demand systems is important for explaining market behavior in the maize sub-sector (how maize producers and consumers make their production decisions and consumption choices). It also provides the basis for predicting demand and supply responses to changes in policies in SADC countries.

4.2 Supply System

Farm supply is the schedule of amounts farmers would be willing to produce at different *expected* price levels, with all other factors remaining constant (Ferris, 1998)

The analysis of agricultural producers' behavior presented here is based on the neo-classical theory of the firm. The theory assumes that producers maximize profit or net returns subject to some technical and institutional constraints. The technical constraints refer to the firm's production function, which define the physical relationship between factor inputs and the maximum output level for the given technology per unit of time (Varian, 1984). Institutional constraints relate to market structure, which determine the economic environment in which firms operate.

Consider a farm that uses land -A; labor -L, and other inputs (chemicals and capital) -K, in the production of maize. The expected output or the production function, which is simply a conceptualization of the technical relationship between inputs being used and output, can be written as $Q = F(A, L, K)$, where $\frac{\partial F}{\partial A} \geq 0, \frac{\partial F}{\partial L} \geq 0, \frac{\partial F}{\partial K} \geq 0$. (Factor inputs have non-negative marginal contribution to output, i.e. quasi-rents are not negative). Admissible production technology structures also require that the second derivatives be greater than zero. This imposes the law of diminishing marginal return, which also ensures that the production function is concave to the origin. Let p denote the expected output price, *r* the rental cost for land A, *w* the cost of labor L, and *k* the cost of other inputs K. Theory also assumes that output level and output prices are independently distributed random variables and that the farmer is risk neutral. The farmer's decision problem is to maximize expected profit: $Max\Pi(p,r,k,w,TFC) = Max\{pQ - rA - kK - wL - TFC\}$, where pQ is the expected revenue, *r*A is the cost of land, kK is the cost of capital and other inputs, *w*L is the cost of labor and TFC is total fixed cost. The first order conditions of profit maximization imply that, $p\frac{\partial Q}{\partial A} - r = 0, p\frac{\partial Q}{\partial K} - k = 0, p\frac{\partial Q}{\partial L} - w = 0.$

These three equalities state that the farmer will maximize profit by producing output levels where the expected value of the marginal product of each input is equal to the input's cost. The second order conditions require concavity of the production function, which ensures convexity of the profit function to input and output prices. Assuming that the production function is invertible then optimum input demand can be expressed as a function of input and output prices, $K^{\alpha}(p, r, k, w), A^{\alpha}(p.r, k, w)$, and $L^{\alpha}(p, r, k, w)$ which are obtained from solving the first order condition equations. The input demand functions are homogenous of degree zero in input and output prices. Substituting input demand into the production function yields the output supply function, $Q^{\alpha} = f(K^{\alpha}, A^{\alpha}, L^{\alpha})$, which is also homogenous of degree zero in output and input prices.

From the convexity property of the profit function it follows that the expected supply function is upward sloping and that the input demand functions are downward sloping. It follows that the marginal effects of an increase in output price p on input demands are equal in absolute magnitude, but are of opposite sign, to the marginal effect of an increase in the corresponding input price on output supply.

Alternatively, the above derivation can be achieved by using the cost minimization paradigm, which give the same results. Another, commonly used method is the duality theory to solve for the input demand. The advantages of duality, as described by Lopez (1982), are that the simultaneous equation bias is avoided since profit and input demand functions are expressed as functions of exogenous variables and that the duality method can be used to compute the *mutatis mutandis* elasticities associated with supply and demand. The foundations of duality theory are the indirect profit and cost functions, which are obtained from the profit maximization and cost minimization specifications of the firms' supply decision. Following the same procedure as in profit maximization, input factor demand functions are obtained. The input factor demands can be written as a function of output and input prices $K^{\alpha}(p,r,k,w), A^{\alpha}(p,r,k,w)$ and $L^{\alpha}(p,r,k,w)$. Substituting the factor inputs into production function yields the profit maximizing output level $Q^{\alpha} = f(K^{\alpha}, A^{\alpha}, L^{\alpha})$. The indirect profit function is then $\Pi(p,r,k,w) = pf(A^{\alpha}, K^{\alpha}, L^{\alpha}) - rA - kK - wL$, which is a function of output and input prices. Using the Envelope Theorem, taking partial derivatives of the indirect profit functions with respect to output and input prices, yields the output supply $\frac{\partial \Pi}{\partial P} = f(A^{\alpha}, K^{\alpha}, L^{\alpha})$, $\frac{\partial \Pi}{\partial A} = -A^{\alpha}(p,r,k,w)$, and input demand functions $\frac{\partial \Pi}{\partial K} = -K^{\alpha}(p,r,k,w)$ and $\frac{\partial \Pi}{\partial L} = -L^{\alpha}(p,r,k,w)$.

4.2.1 Elasticities of Supply and Input Demand

Economists have devised a convenient way of expressing relationships within the supply system using elasticities. Elasticity measures the degree of responsiveness of the independent variable to a percentage change in the dependant variables. Generally, four types of elasticities are important in econometric studies, namely: own price elasticity, cross price elasticity, input price elasticity, and income elasticities. For simplicity, suppose the agricultural producer can produce only two commodities, wheat (w) and maize (m). The own price elasticity of supply measures the percentage change in output in response to a 1 % change in output price p_m of maize, *ceteris paribus*.

Mathematically, it is defined as $\varepsilon_{mm} = \frac{\frac{\Delta Q_m}{Q_m}}{\frac{\Delta P_m}{P_m}} = \frac{\Delta Q_m}{\Delta P_m} * \frac{P_m}{Q_m} \succ 0$. The cross price supply elasticity measures the percentage change in output caused by a 1 % change in the price of another output, in this case the wheat price p_w, and the elasticity is defined as $\varepsilon_{mw} = \frac{\partial Q_m}{\partial P_w} * \frac{P_w}{Q_m} \prec 0$. Similarly, the input price elasticities for other inputs -K, labour-L and land-A measure the percentage change in output given a 1 % change in one of these input prices. Input price elasticity are expressed as: $\varepsilon_{mk} = \frac{\partial Q_m}{\partial k} * \frac{k}{Q_m} \prec 0$, $\varepsilon_{ml} = \frac{\partial Q_m}{\partial w} * \frac{w}{Q_m} \prec 0$, and $\varepsilon_{sA} = \frac{\partial Q_m}{\partial r} * \frac{r}{Q_m} \prec 0$.

There are many relationships among elasticities the most important, however is that of "no money illusion". This means that if all prices increase by the same percentage output quantity should not be affected, as the negative effects of input price increases will be offset by the positive effects of own price increases. This implies that a marginal change in the level of output Q_m, due to change in the price of an input is equal to negative value of the marginal change in input use following a marginal change in output price p. This can be mathematically represented as: $\frac{\partial Q_s}{\partial k} = -\frac{\partial K}{\partial P_s}$, $\frac{\partial Q_s}{\partial w} = -\frac{\partial L}{\partial P_s}$, $\frac{\partial Q_s}{\partial r} = -\frac{\partial A}{\partial P_s}$. The symmetry relationship can therefore be established as $\frac{\partial k}{\partial r} = \frac{\partial A}{\partial K}$, and similarly for all other inputs.

4.2.2 The Dynamics of Supply and Expectations Models

Heady et al (1961) postulated that farmers operate in a dynamic world where prices and input-output relationships are not known with certainty, and are subject to change through time. Producers are not in a position to fully adjust their input use or output in one period of time. It is for this reason that a dynamic approach may be more appropriate when modeling agricultural production. Since agricultural production occurs under less than perfect certainty, due to its biological nature, and because input use decisions for are sequential, time plays a crucial role. In the short-run, some inputs are fixed and in long run all inputs vary, which suggest that input use is a function of time. Thus, when taking time in consideration, there are various possible ways that the firm can adjust its input use and hence the movement from one equilibrium point to another. This adjustment is not instantaneous due to price uncertainty, fixity, and non-divisibility of factor inputs.

Various methods have been used to represent dynamic output supply response. The most commonly used method is the Koyck's distributed lag model (Koyck, 1954) and Nerlove's partial adjustment model (Nerlove, 1958) with various functional forms to represent producers' expectations. Since farmers do not know what will be the price level at harvest time or at what price they will sell their output, their cropping decisions are based on certain expectations. The most cited types of expectations in the literature are naive, extrapolative, adaptive, rational and quasi-rational. The most widely used is the adaptive expectations assumption. According to Nerlove's (1958) seminal paper, the partial adjustment model assumes that the change in price expectations in the current period is some proportion, ∂, of the error made in formulating expectations in the previous period. Producers adjust toward the optimum level of output Q_t according to the following equation $P_t^e - P_{t-1}^e = \partial(P_{t-1} - P_{t-1}^e)$ where P_t is the normalized price of output; "e" is the expectations operator in respective periods, and ∂ is the coefficient of expectation with $0 < \partial < 1$. Rewriting the above equation one gets $P_t^e = \partial P_{t-1} + (1-\partial)P^e{}_{t-1}$. This equation means that the expected price at time t is the sum of last period's expected price plus some adjustment factor and last period's actual price. In support of his argument Nerlove (1956) stated the following hypothesis "...each period people revise their notion of 'normal' price in the proportion to the difference between the current price and the previous ideal 'normal' price." The above equation can be express as a first-order difference equation $P_t^e = \sum_{i=0}^{\infty} \partial(1-\partial)^i P_{t-1-i}$, which can be solved for P_t^e and is a weighted moving average of past actual prices where the weights decline with time. In this case, a highly simplified version of output supply function is used where output is a function of the expected price (normalized) and Z is an exogenous variable, $Q_t = \beta_0 + \beta_1 P_t^e + \beta_2 Z_t + \upsilon_t$ where β_1 is the long-term response, and ν_t is an error term. An algebraic manipulation of the price and output function yields the following output supply function,

$$Q_t = \beta_0 \partial + \beta_1 \partial P_{t-1} + (1-\partial)Q_{t-1} + \beta_2[Z_t - (1-\partial)Z_{t-1}] + \upsilon_t - (1-\partial)\upsilon_{t-1}$$

Rewriting the above $Q_t = \Pi_0 + \Pi_1 P_{t-1} + \Pi_2 Q_{t-1} + \Pi_3 Q + \varepsilon_t$, where

$$\Pi_0 = \beta_0 \partial,\ \Pi_1 = \beta_1 \partial, \Pi_2 = 1-\partial,\ \Pi_3 = \beta_2,\ Q = Z_t - (1-\partial)Z_{t-1}, \varepsilon_t = \upsilon_t - (1-\partial)\upsilon_{t-1}.$$

The above is a output supply function of known variables only, i.e., lagged price, lagged output, and some exogenous variables. OLS estimation of the above equation will not yield reliable estimates because of the presence of serial correlation created by the lagged values of dependent variables. However, Maximum likelihood (MLE) or instrumental variable estimation methods will yield estimates with the desired properties.

Once the supply equation has been estimated, the short and long run multipliers can be computed. The short-run is a period of time during which some input factors of production are fixed and some inputs may vary in response to price, whereas in the long run all input factors can vary. The short and long run multipliers are obtained as follows:

$$\frac{\partial Q_{t+1}}{\partial P_{t+1}} = \Pi_1(1 + \Pi_1 + \Pi_2 + \Pi_1^2 + ...) = \frac{\Pi_1}{1-\Pi_2}$$

The short-run multiplier is the estimated value of the coefficient $\beta_1\partial$ and the long - run multiplier or long run response ∂ is the short- run multiplier divided by one minus the coefficient of lagged output. In terms of elasticities, the short-run elasticity is $E^s = \frac{\partial Q_t}{\partial P_{t-1}} * \frac{P_{t-1}}{Q_t} = \Pi_1 * \frac{\overline{P}}{\overline{Q}}$. And the long run elasticity is $E^L = \frac{\Pi_1}{1-\Pi_2} * \frac{\overline{P}}{\overline{Q}}$, where $\overline{P}, \overline{Q}$ are mean values of price and output. So far, the value of β has been assumed to be between zero and one. But when the value of β is one, it gives rise to the "cobweb" model, which shows how a higher price leads to a higher level of output in next period and given a downward sloping demand curve causes a lower price in the next period, which in turn leads to a low level of output and a high price in the next period, and so on. The other two commonly used expectation methods are the naive price expectation and rational expectations. For rational expectations it is presumed that producers do not make systematic errors. For the purpose of this study the adaptive expectation is adopted for the empirical estimation models used.

4.3 The Demand System

Aggregate demand for almost all agricultural crops can be divided into demand for direct use, i.e. primary demand, demand for intermediate use (a derived demand), and inventory demand. Consumer demand, or the retail demand, is defined as a schedule of quantities of a particular commodity that an individual consumer is willing and able to buy as the price of that commodity varies, all other factors held constant per unit of time. Derived demand is the demand for intermediate goods. For example, demand for maize for maize manufacturing and demand for maize by the beverage industry and other food manufacturing industries represent derived demand. The demand for stock, i.e. inventory demand, is due to the price expectations for precautionary reasons.

4.3.1 Consumer Demand

Retail demand for a commodity is the demand for a commodity in its final form. In our case, this is maize meal. The consumer demand relationship can be defined as quantity of maize meal demanded as a function of prices and income. The law of demand states that there is an inverse relationship between quantity demanded and its own price. In other words, the demand curve is downward sloping.

The theoretical specification for food use is based upon consumer theory of utility maximization subject to budget constraints, i.e., consumer maximizes his or her utility function subject to a given level of income. Mathematically, the optimization problem is Max U($\underline{X}$) subject to $I = \sum_{1}^{N} P_i X_i$, where U($\underline{X}$) is the consumer's utility function, which is assumed to satisfy some regularity conditions, $\underline{X}$ is a vector representing the bundle of n goods and p_i is the price of good i. The utility function is a strictly quasi-concave and twice differentiable function. Consumer preferences are assumed to satisfy certain properties (reflexive, transitive, completeness, continuous and weakly monotonic). The optimization problem is solved using the Lagrange multiplier. Assuming that the second order conditions are satisfied for a global maximum, i.e., all income is spent. Solving the (n+1) first order equations, the demand functions of Xi's are obtained, which are implicit functions of prices and income. These implicit functions are homogenous of degree zero in prices and income. The indirect utility function is then obtained by substituting the solved values of Xi's into the direct utility function, i.e., $U^*(P_1,...P_N, I) = U^*[X_1^*(P_1,...P_N, I)...X_N^*(P_1,...P_N, I)$ The indirect utility function approach allows us to derive the uncompensated (Marshallian) demand function by differentiating the indirect utility function with respect to prices and income. The Marshallian demand function is obtained as follows

$$\frac{\dfrac{\partial U^*(P_1,...P_N, I)}{\partial P_i}}{\dfrac{\partial U^*(P_1,...P_N, I}{\partial I}} = X_i^*(P_1,...P_N, I)$$

By applying the Hotelling-Wold identity to the indirect utility function the inverse uncompensated demand function is obtained (Johnson *et al*, 1984).

Alternatively, the problem can be approached as an expenditure minimization problem. Inverting the indirect utility function and solving for I in terms of U and p gives the expenditure function. The problem can be stated as the minimum cost of attaining a given U^0 at a given price vector $\underline{P}$.

From the above derivation, the consumer demand for a commodity can be expressed as a function of prices and income (I) in its simplest form $Q^D = F(P_m, P_s, I)$ where Pm is the price of the commodity in question, and Ps is prices of competing and complementary goods. Summing the individual consumer demand yields the total consumer demand.

As in the case of supply it is useful to have measures of the responsiveness of quantity demanded due to changes in price and income (demand elasticities). The own price elasticity of demand is defined as the proportionate change in quantity demanded of X_i (maize in our case) due to a proportionate change in the price of X_i, ceteris *paribus*. Mathematically, the own price elasticity of demand is expressed as $e_{ii} = \frac{\partial X_i}{\partial P_i}\frac{\overline{P_i}}{\overline{X_i}} < 0$. The cross price elasticities of demand measure the proportionate change in the quantity demanded of good X_i relative to the proportionate change in the price of good j, *ceteris paribus*. Mathematically, if $e_{ij} = \frac{\partial X_i}{\partial P_j}\frac{\overline{P_j}}{\overline{X_i}} > 0$, then the good "i" is a substitute for good j and $e_{ij} < 0$ if good i is complementary. Finally the income elasticity is defined as $\eta_j = \frac{\partial X_i}{\partial I}\frac{\overline{I}}{\overline{X_i}}$. This measures the proportionate change in the demand quantity of good "i" due to a proportionate change in income I.

As in the case of supply elasticities, certain interrelationships among the elasticity's can be established. Demand functions have four fundamental properties: homogeneity of degree zero, Engel aggregation, Cournot aggregation, and the Slutsky condition. For simplicity, a trend term (t) may be included in demand equations i.e., $Q^D = F(T, P_m, P_s, I)$ to capture the process of habit formation.

4.3.2 Inventory Demand

Many agricultural products are produced at one point of time during a crop year whereas consumption occurs through out the whole period. According to Bressler and King (1970), demand for stocks can be decomposed into a transaction demand, precautionary demand and speculative demand. Hence changes in stocks in the short-run can exert a considerable influence on supply.

For the purpose of this study the stock behavior specification is expressed as follows:

$SC_t = S_t(SC_{t-1}, P_t, Q_t, Q_{t-1})$

where SC is the change in stocks, P is the price, and Q is the quantity produced.

The above theoretical concepts contribute significantly to the understanding of supply and demand of agricultural commodities. Furthermore, the economic theory developed will help in portraying the reality of the SADC maize industry later in the empirical chapter.

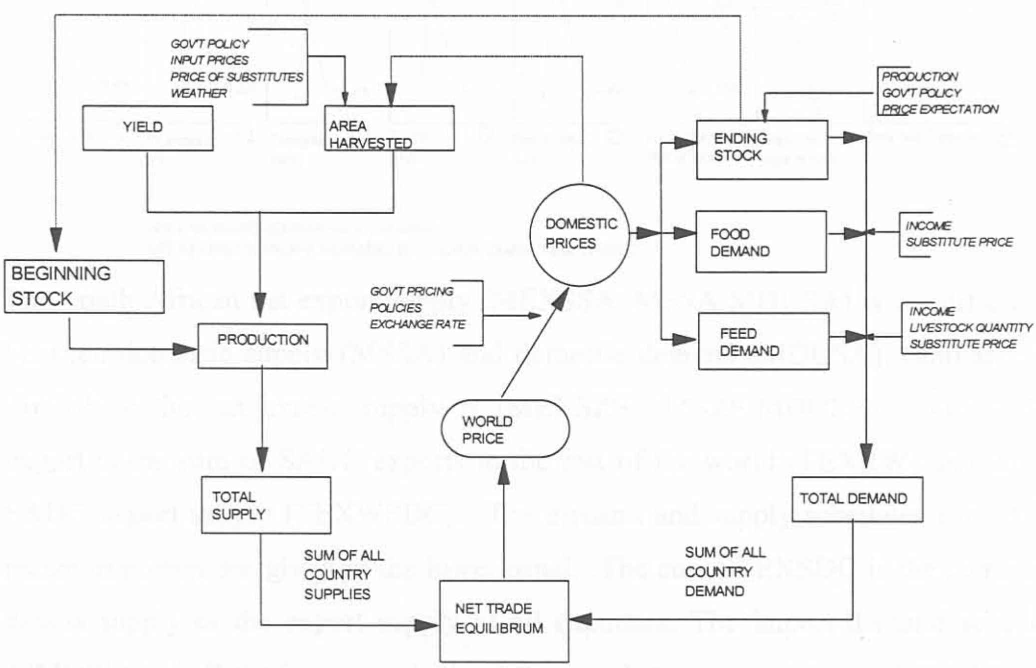
4.4 Model Structure and Model Specification

In this sub section, the structure of the SADC maize industry is described using flow charts and price-quantity (P-Q) space. The model is a nonspatial partial equilibrium model—nonspatial because it does not identify trade flows between specific regions and partial equilibrium because only one commodity is modeled.

The flow chart is a causal ordering of the supply-utilization-price structure. It facilitates the understanding of the nature of the economic and statistical relationships among variables that influence production and consumption. It also explains how policy and other relevant variables influence production and the consumption of the commodity under consideration.

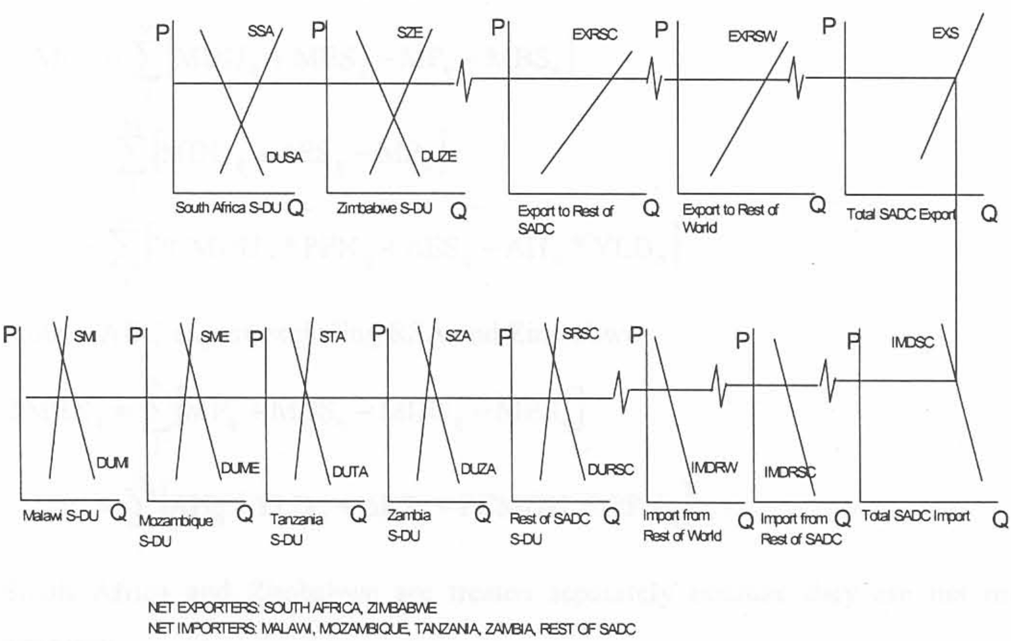
It has been common in crop modeling to start with area planted but unavailability of data on areas planted to maize in the SADC countries made it impossible to start modeling the structure of the SADC maize sector from the initial stage of area planted. Area harvested is a good proxy for the area planted and is a reliable indicator of planned production. To capture the regional diversity in maize production, the SADC maize production block has been disaggregated to the country level so as to reflect the production characteristics in each member state. For an individual country, area harvested times yield per hectare gives the maize production. Total maize supply for an individual country is an identity and includes total production plus beginning stocks. Similarly total demand for maize for an individual country is also an identity and is equal to the sum of ending stocks, food demand and feed demand. Figure 4.1 depicts the structural components of the SADC maize model. The left hand side of figure 4.1 is the supply side and the right hand side represents the demand side. Summing across the individual countries the total SADC maize supply and total demand is computed. Equilibrium quantities and net trade are determined by equating excess demands and supplies across the region and explicitly linking price in each region to a world price. The price-linkage equation defines the degree of price transmission of external market conditions into the internal system. Trade in maize in SADC countries occurred whether or not price transmission is allowed.

Figure 4.1: Structure of the SADC Maize Model



The above flow chart elaborates on the structure of the SADC maize sector discussed above and provide guidance towards the empirical estimation of the SADC maize model. The basic elements of a nonspatial equilibrium supply and demand model are illustrated in figure 4.2. The P - Q space depicts the market at a specific point of time holding non-price factors constant. The P - Q space depicts the economic relationships, from the initial point of production to the final use of the product. The P - Q space is a convenient way of relating supply and utilization by means of price. Hence the flow chart and the P- Q space are closely linked.

Figure 4.2: Determination of Equilibrium Price and Quantities in the SADC Maize Model



The South African net export supply (MEXSSA=MSSA-MDUSA) is the difference between domestic supply (MSSA) and domestic demand (MDUSA). Similarly for Zimbabwe the net excess supply is (MEXSZE =MSZE-MDUZE). Total SADC export is the sum of SADC exports to the rest of the world (TEXRW) and within SADC export supply (TEXWSDC). The demand and supply schedules for SADC maize importers are given in the lower panel. The curve TEXSDC is the combined excess supply or the export supply of all exporters. The import demand schedule TIMDSDC of all the importers is the difference between total demand (TDSC) and

total supply (TSSC), which includes import from the rest of the world, (IMPDW) and imports from other SADC countries (IMPDSC). The export demand schedule facing South Africa and Zimbabwe is the difference between import demand of all importers and export supply of all competitors in the region. The kinked price equilibrium is due to certain countries restrictive trade policies and pricing mechanisms, which are transmitted to domestic price from the world price variability. Trade equilibrium is achieved by the clearing of excess demands and supplies generated within each country and imports from the rest of the world and export to the rest of the world. The necessary components of
the model are given by the following equation:

Total SADC import including imports from the rest of the world

$$\begin{aligned} TIMD_t &= \sum_j^M \left[MDU_{tj} + MES_{tj} - MP_{tj} - MBS_{tj}\right] \\ &= \sum_j^M \left[MDU_{tj} + \Delta ES_{tj} - MP_{jt}\right] \\ &= \sum_j^M \left[PCMDU_{tj} * PPN_{tj} + \Delta ES_{tj} - AH_{jt} * YLD_{tj}\right] \end{aligned}$$

Total SADC export excluding RSA and Zimbabwe

$$\begin{aligned} TMEX_t &= \sum_j^N \left[MP_{tj} + MBS_{tj} - MDU_{tj} - MES_{tj}\right] \\ &= \sum_j^N \left[AH_{tj} * YLD_{tj} + \Delta ES_{tj} - PCMDU_{tj} * PPN_{tj}\right] \end{aligned}$$

South Africa and Zimbabwe are treated separately because they are net maize exporters.

South Africa excess supply

$$\begin{aligned} MEXSSA_t &= MSSA_t - DUSA_t \\ &= MAHSA_t * MYLDSA_t + \Delta ESSA_t - PCMDUSA_t * PPNSA_t \end{aligned}$$

Zimbabwe excess supply

$$\begin{aligned} MEXZE &= MSZE - DUZE \\ &= MAHZE_t * MYLDZE_t + \Delta ESZE_t - PCMDUZE_t * PPNZE_t \end{aligned}$$

Total SADC export

$$TEXSDC_t = MEXSSA_t + MEXZE_t + TMEX_t$$

Total SADC imports (SADC demand minus domestic supply)

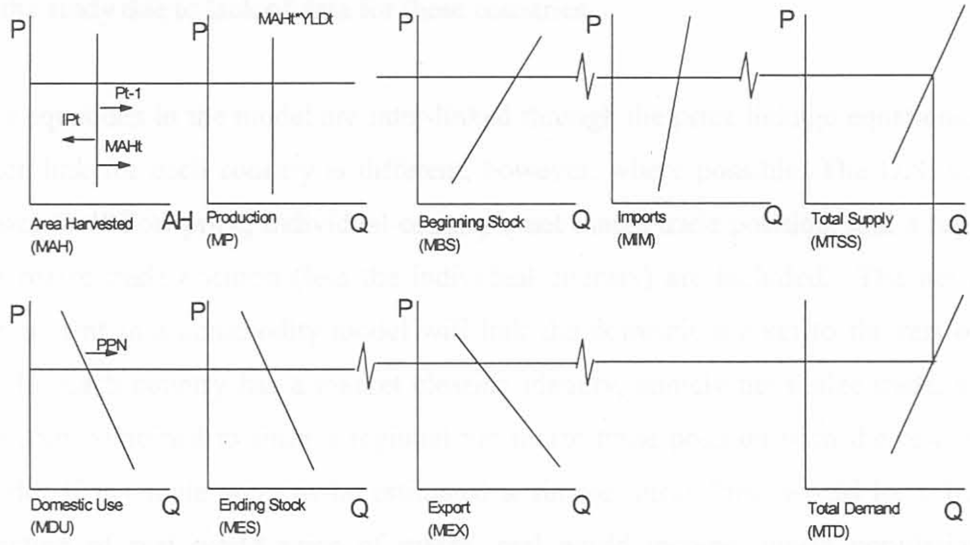
$$TIMDSDC_t = TDSC_t - TSSC_t$$

SADC maize market equilibrium

$$NTMSDC_t = TEXSDC_t - TIMDSDC_t$$

Figure 4.3 is the P - Q space for a specific SADC maize producing country. The first block represents the farm level. The arrows indicate the directional influence of the variables, i.e. the expected sign of the parameter associated with the variable in the Total supply is equal to beginning stocks plus imports and total maize production. The supply decision responds to the expected price of maize, a viable substitute crop, an index of input prices, and competing crop prices. The area harvested is influenced by the producer price of maize, the price of production inputs, the price of competing crops and some other exogenous variables, $AHt = F(AH_{t-1}, RPM_t, RCP_{t-1}, X_t,)$. Competing crops may differ from one country to another. Area harvested responds directly to the lagged price of maize, and consequently in the very short- run is perfectly inelastic, as represented by a vertical line. Competing crop prices, such as wheat prices, influence resource allocation, and are known as shifters. Area harvested times yield (AH_t*YLD_t), gives maize production. For most countries, the production block consists of the following: one behavioral equation, area harvested and one production identity, (maize area harvested times maize yield per hectare). The supply block consists of total domestic production, imports and beginning stocks.

Figure 4.3: P-Q Space for the Individual Country



The demand block consists of the total domestic use, exports and ending stocks. The consumption demand for maize responds to the current domestic retail price of maize, with population and income as demand shifters. In general, human consumption demand for maize (in maize meal form) is influenced by the domestic price of maize and income and has a downward sloping curve. Total human consumption of maize is specified as demand per capita multiplied by total population. Net exports are used as the market clearing identity, which is implicitly influenced by the world price and vice versa. The domestic total supply block of the i^{th} country (exporting or importing) is the cumulative sum of maize production, maize imports and beginning stocks. Assuming maize in any form is consumed by humans, maize utilization is expressed as per capita consumption, and is a function of consumer price of maize deflated by the consumer price index, and per capita GDP deflated by the GDP deflator and a time trend to account for habit formation. Ending stocks in period t are the beginning stocks for period t+1. However due to unavailability of data for ending stock, change in stocks is modeled for the each country.

The model contains seven country sub-models. The countries included in the study are Malawi, Mozambique, South Africa, Tanzania, Zambia, Zimbabwe, and the rest of the SADC, which includes Botswana, Lesotho, Mauritius, and Swaziland. Angola, the Democratic Republic of Congo, Namibia, and the Seychelles were not included in the study due to lack of data for these countries.

The equations in the model are inter-linked through the price linkage equations. The price link for each country is different, however, where possible. The U.S. yellow maize Gulf Port price, individual country's net maize trade position, and a regional net maize trade position (less the individual country) are included. The net trade component in a commodity model will link the domestic market to the rest of the world. Each country has a market clearing identity, namely net maize trade, which are then combined to form a regional net maize trade position with the rest of the world. If net trade were to be estimated a simple linear form would have been a function of real world price of maize, real world income, world population. A reduced from of the world price equation is derived from FAPRI's world grain model. This world price equation can be thought of as an inverted total net trade demand equation, i.e., SADC net exports and world price are negatively related.

4.5 Estimation and Model Solution Procedures

In the following subsections, the modeling approach, the estimation procedures and method for evaluating econometric models are discussed. The main issues involved in constructing a structural econometric commodity model are briefly discussed. An econometric model can be a single equation or set of equations that establish certain relationships among the institutional, definitional and behavioral variables. Broadly speaking, a forecasting model can be classified as a structural model. Econometric commodity models provide a powerful analytical tool for examining the complexities associated with agricultural commodity markets. The recent developments in statistical and economic theory and computational technologies have improved formulation and estimation methods. Statistical estimation techniques are used to estimate the equations to ascertain the relationship between the endogenous and the exogenous variables. For example, in the supply function, a positive sign is expected for output price and a negative sign for input price. At same time, the sum of the output price elasticities is expected to be equal to the sum of the input price elasticities in absolute terms due to the fact that production functions are homogeneous of degree zero in prices.

The modeling exercise in this study starts with model specification, consisting of a set of estimable equations, which are linear in variables. The rational for this simple specification is that there is no *a priori* information as to the functional form. Second, the statistical estimation procedures are best developed for linear models, which help in computing the desirable analytical characteristics of the equations. For example the reduced form of linear models are easily estimable, and dynamic properties of the model can be evaluated readily. Reliability statistics and other test statistics are easily available to test the forecasts in the case of a linear reduced form. With these functions, the problems of structural change and updating the model can be handled easily.

The equations in the structural econometric model can be classified as either behavioral equations or as identities. Behavioral equations are based on economic theory and are estimated from historical data using statistical estimation tools. Identities are equations that hold true by definition. The relationships among different variables and the causal effects of these variables are explained by these equations. The sign of estimated parameters associated with the variables in the behavioral equations indicate the directional influence of the variables. For example, a negative sign is associated with the estimated parameters for the competing crops prices variable in an area-harvested equation.

The behavioral equations contain both endogenous and exogenous variables. Endogenous variables are explained by behavioral equations and/or identities. For example, in our case area harvested and maize production are all endogenous variables. Exogenous variables are variables that are not explained within the model and are considered to be known. For example, in this case, yield, GDP, the exchange rate and policy variables are considered as exogenous variables.

As stated earlier the structural econometric model of SADC maize sector consists of the maize production block, a demand block, a market clearing identity- net trade and the price linkage. All in all, there are 64 equations in the model. Out of these, 27 are behavioral equations. The behavioral equations consist of seven area harvested equations, seven change in stock equations, a per capita consumption equation for each of the seven countries, and a price linkage equation for all the countries except the rest of SADC which is directly linked to the U.S. Gulf port price. The remaining 37 equations are identities. The identities include production, yield, total domestic consumption, local net trade, regional net trade for each country, and a market clearing identity with the rest of the world. The total SADC supply is the sum of total SADC maize production, imports, and stock change.

All equations are estimated using the classical ordinary least squares (OLS) method. This step is based on *a priori* knowledge and economic theory, which helps in the identification of variables to be used in the behavioral equation. The OLS estimation technique chooses the line that minimizes the sum of squared deviation of the observation from the line. Let $Y = X\beta + \xi$ be linear model where Y is (nx1) column vector of n endogenous variable, X is a (n x m) matrix of exogenous variables, β is (mx1) vector of parameters to be estimated and ξ is (nx1) vector of normally, identically distributed error ($\xi \cup N(0,\sigma^2 I)$ where I is a (nxn) identity matrix. The OLS estimation technique is to minimize $\xi'\xi = Y'Y - 2\beta'X'Y + \beta'X'X\beta$. Solving for $\hat{\beta}' = (X'X)^{-1}X'Y$, which is unbiased estimator of the vector of unknown parameters β. In summary, under the above assumptions the parameters estimates of β are the best linear unbiased estimators (Greene, 2000). Once the coefficients of the equations are estimated individually, the equations and variables, which will forms part of the system and which satisfactorily explain inter-linkages among sectors are retained.

The econometric model of the SADC maize sector expresses interdependence of variables that influence the supply and utilization of maize in the SADC through a system of simultaneous equations. Each equation in such a system describes a different relationship among a different set of the variables in the system. However all of these relationships are assumed to hold simultaneously. The OLS method of estimation is inadequate. The use of OLS may yield biased and inconsistent estimates unless the model is exactly identified. Various estimation procedures such as the two least square (2SLS), three stage least square (3SLS), instrumental variable methods (IV), full information maximum likelihood (FIML), and indirect least square method (ILS) are used to eliminate the simultaneous bias. Among these, the most common estimation technique for a simultaneous model is the 2SLS method. The 2SLS estimates is a useful estimation procedure for an over identified model. This estimation procedure uses information available from the specification of each equation to obtain unique estimates of each of the parameters in the system. The 2SLS estimates are both consistent and efficient. For the purpose of this study, the 2SLS estimation procedure is used. The results of the 2SLS estimation are reported and discussed in Chapter five.

The next step is to solve or simulate the model. The Gauss-Seidel solution algorithm is used to solve the model's simultaneous system of equations. For an in depth discussion of this algorithm, the reader is directed to Fair (1984). The underlying assumption for the Gauss-Seidel Algorithm is that the error term in each behavioral equation is zero. Since the model in this study is linear, the expected value of the error term is zero by the classical assumption. Hence, solving the model results in the predicted values of endogenous variable being equal to their expected values. The Gauss-Seidel technique requires that the equations in the model be rewritten with each endogenous variable on the left hand side of the equations.

4.6 Validation Tests

Once the model is solved, then the model performance is tested. The model is validated to verify its ability to replicate historical characteristics. Two simulation methods have been proposed for the validation of simultaneous equation systems. They are static and dynamic simulations over the historical period. A static simulation is one where the historical values of the lagged endogenous variables are used each year the model is solved. In contrast, in the dynamic simulation, the lagged endogenous variables are assigned their estimated values in the initial period for which the model is solved. In successive periods, the previous-period solution values are used for the lagged endogenous variables. Thus, the model feeds off itself in generating estimates over the validation period. For the static solution (or simulation), the actual values of the predetermined variables are substituted in the equation. For dynamic solution the solved value from the previous period is used for the lagged endogenous variable (Greene 2000).

A naive method of evaluation is the visual inspection of a graphical plot of the actual values and the simulation replicates the actual values. This will give an indication of whether the historical simulation replicated the actual values. This is performed, by checking how well the simulation captures the turning points. Appendix A gives a graphical representation of the historical simulation.

Various statistical measures have been used to test the model. The most commonly used is the root-mean-square (RMSE) simulation error. The RMSE of the simulation for an endogenous variable for example MAH_t (Area Harvested) is defined as $RMSE = \sqrt{\frac{1}{N}\sum_{1}^{N}\left[MAH_t^s - MAH_t^A\right]^2}$ where MAH_t^S is the simulated value of maize area harvested (MAH) in period t and MAH_t^A is the actual value of MAH and N is the number of observations. The RMSE measures the deviation of the simulated endogenous variable from the actual values. When the RMSE is compared with the average size of the variable BAH, the RMSE percentage error (RMSE%) is used where $RMSE\% = \sqrt{\frac{1}{N}\sum_{1}^{N}\left[\frac{MAH_t^s - MAH_t^A}{MAH_t^A}\right]^2}$. Two other measures used are the mean simulation error (MSE), defined as $MSE = \frac{1}{N}\sum_{1}^{N}\left[MAH_t^s - MAH_t^A\right]^2$ and the associated means simulation percentage error (MSE%) MSE%

$\text{MSE\%} = \frac{1}{N}\sum_{1}^{N}\left[\frac{\text{MAH}_t^s - \text{MAH}_t^A}{\text{MAH}_t^A}\right]^2$. Another statistic useful in evaluating the performance of the historical simulations or ex post forecasts is the mean absolute error (MARE), which is defined as follows, $\text{MARE} = \frac{1}{N}\sum_{i}^{N}\left|\frac{\text{MAH}_t^s - \text{MAH}_t^A}{\text{MAH}_t^A}\right|$. This statistic is an increasing function of the absolute value of the model's prediction error and is independent of the units of measurements. If MARE equals 0, the model fits the historical data perfectly. Thus, MARE is bounded from zero but not from the above and increases as the absolute value of the estimation error increases. Theil (1971) proposed the widely used Theil's inequality coefficient,

$$U = \frac{\sqrt{\frac{1}{N}\sum_{1}^{N}\left[\text{MAH}_t^s - \text{MAH}_t^A\right]^2}}{\sqrt{\frac{1}{N}\sum_{1}^{N}\left(\text{MAH}_t^A\right)^2}\sqrt{\frac{1}{N}\left(\text{MAH}_t^s\right)^2}}$$

where U lies between zero and 1. If U=0, then there is a perfect fit. Whereas if U =1, the model has a bad fit. Furthermore, Thiel's U statistics can be decomposed into three components: the bias proportion U^M, the variance proportion U^S and the covariance proportion U^C. It can be shown that $U^M + U^S + U^C = 1$. U^M measures the extent to which the average values of simulated and actual values of the variable differ. A value of U^M close to zero is desirable, and if U^M is not close to zero, this indicates the presence of a systematic error. U^S indicates the model's capability to replicate the degree of variability in the variable. A large U^S implies that the actual series has fluctuated considerably whereas the simulated variable has not or vice versa. U^C measures the unsystematic error. A values of $U^M = U^S = 0$ and $U^C = 1$ is ideal. (Pindyck and Rubinfeld, 1998)

Apart from the above statistical measures, a method commonly used to evaluate the properties of a model is the computation of impact multipliers from a deterministic simulation. Multiplier analysis is concerned with the evaluation of changes in endogenous variables caused by changes in an exogenous variable. Both static and dynamic multipliers are considered here. Short-run multipliers explain changes in endogenous variable over a single or specific period of time and dynamic multipliers explain changes that have a cumulative effect over a period of time. The results of this test are discussed in Chapter five. In this study, a further step is involved which is to formulate a baseline. A baseline is a prediction of the endogenous variables based on the expected changes in exogenous variables in the future. Finally, the model is used to evaluate the consequences of policy changes on the SADC maize sector.

CHAPTER FIVE: Results of the Empirical Analysis

This chapter reports the estimated results of the model obtained from the 2SLS estimation procedures of the system as a whole. Two main blocks were estimated using OLS, a production or supply block and a consumption or demand block. The supply and demand blocks are estimated for seven main maize producing or consuming countries, with the rest of SADC treated as one group. For each of these six countries and the rest of SADC single equations for demand, supply and stock change was estimated using single equations. Net trade was used to close the model, and was determined by equating excess demand and excess supply across the whole region. All the regional prices are furthermore explicitly linked to a world reference price. All equations were estimated for the period 1977 to 1997.

Maize can be divided into both white and yellow maize, however due to the lack of data in this respect maize was modeled as a homogeneous product. The supply equations are conventional Nerlove partial adjustment models with all prices and incomes deflated into real terms using a GDP deflator and consumer price index. A further assumption made was that both demand and supply responses were homogeneous of degree zero with respect to price and expenditures. Both the demand and supply equations fit the data well and all the signs are correct. Although a yield equation was not estimated due to its relationship with area harvested and production, a trend equation was estimated for forecasting purposes.

The following sections contain the empirical results of the model. The t-statistics are presented in parentheses while short run elasticities and long elasicities are presented in the brackets and square brackets respectively. The mnemonic of the variables is given in appendix C.

5.1 Malawi Sub-model

The production block of Malawi is presented in equations 5.1 to 5.3. Maize area harvested in Malawi ($MAMAH_t$) was estimated as a linear function of lagged area harvested, a time trend to represent technological change, lagged maize producer price divided by the U.S. potash price, and a dummy variable for the year 1994. Although the variables were not all found to be statistically significant at the 5 % level, they are maintained in the model for its overall significance. The estimated short run own price elasticity is 0.092 whereas the long run is 0.1331. The own price elasticity indicates that a 1% increase in the producer price of maize divided by the U.S. potash price in Malawi Quachas will cause a 0.0924 % increase in area planted, indicating that area planted is relatively inelastic to own price. Various alternative specifications were estimated however based on economic and statistical theory and equation 5.1 was kept. Malawi maize production ($MAMPR_t$) is an identity and equal to area planted times yield.

Malawi's maize domestic consumption consists mainly of food use. Maize per capita consumption is a function of own price, price of substitutes and disposable income. Maize per capita consumption (MAMFOPC) was estimated as a function of real maize price, per capita real income as a proxy for disposable income, and a time trend to indicate changes in preferences. A shift is also included due to a change in the price trend in that year whereas DUM82 for the shock due to SAPS. Total domestic consumption is per capita consumption times total population.

Malawi's change in maize stock ($MAMSC_t$) was modeled as a function of lagged maize production and real maize domestic price. A dummy variable for 1993 was also included to capture the effects of the severe drought of 1992. Although the price variable has a low t-value, it was maintained in the model due to its economic significance. Drawing on economic theory, the estimated coefficients appearing in the equations have the correct sign and are statistically significant. The own price elasticity of demand is -0.061 and income elasticity of demand is 0.076.

Malawi's net trade position is an identity composed of total production (MAMPR), change in stock (MAMSC), maize used for human consumption (MAMFO), and other uses (MAMOU) such as industrial and animal consumption.

Malawi's real maize producer price was estimated as a function of the regional maize net trade position (RENTMA), a time trend, and a dummy for the years 1982 and 1995. All the variables are significant at the 5 % level except the dummy variable for 1995.

Equation 5.1: Malawi Maize Area harvested

$$
\begin{array}{lll}
MAMAH_t & = & +560154.78 \\
 & & +0.305*MAMAH_{t-1} + 146086.58*RMAMPP_{t-1} - \\
 & & (1.57) \qquad\qquad\qquad (1.85) \\
 & & \qquad\qquad\qquad\qquad\quad <0.092> \\
 & & \qquad\qquad\qquad\qquad\quad [0.1331] \\
 & & -186999.01*DUM94 \; +14009.11*TT \\
 & & (-2.79) \qquad\qquad\qquad (2.99) \\
R^2 = 0.722 & & D.W. = 2.033 \qquad\qquad D.F.= 5
\end{array}
$$

Equation 5.2: Malawi Maize Production

$$MAMPR_t \quad = \quad MAMAH_t * MAYLD_t$$

Equation 5.3: Malawi Yield

$$MAYLD_t \quad = \quad MAMPR_t \,/\, MAMAH_t$$

Equation 5.4: Malawi Maize Per Capita Domestic Consumption

$$
\begin{array}{lll}
MAMFOPC_t & = & +171.95 \\
 & & -\ 0.0138*RMAMCPD_t + 0.0075*RMAGNID_t \\
 & & (-0.60) \qquad\qquad\qquad (0.48) \\
 & & <-0.061> \qquad\qquad\quad <0.076> \\
 & & -\ 13.83*SHIFT82 \; -0.061*TT2 \; +10.89*DUM82 \\
 & & (-0.98) \qquad\qquad\quad (-1.88) \qquad\quad (0.59) \\
R^2 = 0.92 & & D.W. = 1.322 \qquad\qquad D.F= 5
\end{array}
$$

Equation 5.5: Malawi Maize Total Domestic Consumption

$$MATOFOU_t = MAMFOPC_t * MAPOP_t$$

Equation 5.6: Malawi Change in Maize Stock

$$MAMSCt = -456633 + 0.368*MAMPR_{t-1} - 348.95*RMAMPPD_t$$
(2.36) (-0.27)
$$-534962*DUM93$$
(-2.83)

$R^2 = 0.67$ D.W. = 1.92 D.F.= 4

Equation 5.7: Malawi Maize Net Trade

$$MAMNT = MAMPR + MAMSC - MAMFO - MAMOU$$

Equation 5.8: Malawi Maize Price

$$RMAMPPDt = 111.57 - 0.000032*RENTMA_t - 0.09322*TT2$$
(-7.67) (-14.81)
$$+ 57.97*DUM82 + 4.068*DUM95$$
(14.82) (0.99)

$R^2 = 0.95$ D.W. = 0.72 D.F.= 5

5.2 Mozambique Sub-model

Equations 5.9 to 5.11 are the Mozambique production block. Maize area harvested in Mozambique ($MOMAH_t$) was estimated as a linear function of lagged area harvested, a time trend to represent technological change, and Mozambique's maize producer price divided by the U.S. potash price in Mozambique's local currency, and a dummy variable for 1992-94. Not all the variables are statistically significant at the 5 % level, they are however maintained in the model for it's over all significance. The estimated short run own price elasticity is 0.0439 whereas the long run is 0.0667. The linear time trend is a surrogate for technological change and other forces that are shifting the supply curve outwards over time. The estimated coefficient of the lagged dependent variable suggests that adjustment does not occur fully in one period. Various other specifications for area harvested were estimated but equation 5.9 is retained based on economic and statistical theory. Mozambique maize production ($MOMPR_t$) is an identity and equal to area harvested times yield.

Equation 5.9: Mozambique Maize Area harvested

$MOMAH_t$ = + 303799

+ $0.340*MOMAH_t$ + $34398.11*MOMPP_{t-1}$

(1.96) (1.79)

$< 0.044>$

[0.0667]

-134316.64*DUM9294 +20342.59*TT

(-2.94) (3.56)

$R^2 = 0.75$ D.W. = 1.73 D.F.= 6

Equation 5.10: Mozambique Maize Production

$MOMPR_t$ = $MOMAH_t$ * MOYLDt

Equation 5.11: Mozambique Maize Yield

$MOYLD_t$ = $MOMPR_t$ / $MOMAH_t$

Equation 5.12: Mozambique Maize Per Capita Domestic Consumption

$MOMFOPC_t$ = + 18.21

$- 0.0012*RMOMCPD_t$ $+ 0.0017*RMOGDPD_t$

(-4.79) (6.05)

$<-0.1663>$ $<0.331>$

+ 11.144*DUM78 + 0.089*DUM81 + 20.93*LTT

(3.20) (8.61) (5.48)

$R^2 = 0.93$ D.W. = 2.00 D.F.= 6

Equation 5.13: Mozambique Maize Total Domestic Consumption

$MOTOFOU_t$ = $MOMFOPC_t$ * $MOPOP_t$

Equation 5.14:Mozambique Change in Maize Stock

$MOMSC_t$ = -20710

+ $0.075*MOMPR_{t-1}$ + 136146*DUM94 – 1291.4*TT

(2.40) (7.95) (-2.04)

$R^2 = 0.82$ D.W. = 2.58 D.F.= 4

Equation 5.15:Mozambique Maize Net Trade

MOMNT = MOMPR + MOMSC – MOMFO - MOMOU

Equation 5.16:Mozambique Maize Price

$$
\begin{array}{lll}
RMOMPP_t & = & +127943 \\
 & & +\ 0.0077*RMOGDP_t - 0.00111*RENTMO \\
 & & \quad (2.96) \qquad\qquad\qquad (-2.88) \\
 & & \quad <0.00008> \qquad\qquad <-0.0033> \\
 & & -\ 117804*SHIFT85 - 98917*DUM8687 \\
 & & \quad (-42.31) \qquad\qquad\qquad (-24.33) \\
R^2 = 0.99 & & D.W. = 2.04 \qquad\qquad D.F.= 5
\end{array}
$$

Mozambique's per capita food consumption (MOMFOPC) is model as a function of real own price, per capita gross national income as a proxy for disposable income, and a time trend to indicate changes in preferences. Two dummy variables were included in the model for the years 1985 and 1988; these dummies are included due to a spike in the maize price and a 55 % devaluation of the currency in 1985 and 1988 respectively. All the variables have the correct signs and are significant at the 5 % level. For the consumption block, the time trend is a surrogate for taste and habit formation that may shift the demand curve outward. Total maize consumption is maize per capita consumption time population.

Mozambique's change in maize stock ($MOMSC_t$) was modeled as a function of lagged maize production a time trend and a dummy for 1994 to capture a spike in that year. All the variables are significant at the 5 % level.

Mozambique's real maize producer price was modeled as a function of real GDP, regional net trade (RENTMO), a shift for 1995 and a dummy for the years 1986-1987. All the variables have the correct sign and are significant at the 5 % level.

5.3 South Africa Sub-model

The South Africa production block consists of equation 5.17 to 5.19. Maize area harvested (SAMAH) was estimated as a linear function of lagged area planted, real maize producer price, October rainfall in the main maize producing regions, and a dummy variable for 1996. The dummy variable was included to capture the increased uncertainty faced by farmers due to the dismantling of the maize marketing board in the following marketing season. All the variables except October rainfall are significant at the 5 % level. This variable is however maintained in the model for it's over all significance and for the calculation of long run elasticities. Various alternative specifications were estimated which included wheat, sorghum, and oilseeds as competing crops, but the associated coefficients were low and insignificant, thus based on statistical and economic theory the above equation is kept. The estimated short run and long supply elasticity 0.0631 and 0.1339 respectively. South Africa maize production (SAMPR) is an identity and equal to area planted times yield.

Equation 5.17: South Africa Maize Area Harvested

$$SAMAH_t = +1422823 + 0.528{*}SAMAH_{t-1} + 618.601{*}SAMPPD_{t-1} + 2128.23{*}SAOCTR_t - 836126{*}DUM96$$

0.528*SAMAH(t-1): (2.46)	618.601*SAMPPD(t-1): (2.46) <0.0631> [0.1339]	
2128.23*SAOCTR(t): (1.37)	836126*DUM96: (-4.04)	

$R^2 = 0.82$ D.W. = 1.67 D.F.= 6

Equation 5.18:South Africa Maize Production

$$SAMPR_t = SAMAH_t * SAYLDt$$

Equation 5.19: South Africa Yield

$$SAYLD_t = SAMPR_t / SAMAH_t$$

Maize in South Africa is mainly consumed in two sectors; animal feed (SAMFEED) and human consumption (SAMFOPC). South African maize consumption is therefore modeled in two components. Per Capita human consumption is modeled as a function of real maize meal price, real bread price, real per capita GDP as a proxy for disposable income, and a dummy variable for the years 1987-1989. South African animal feed use is modeled as a function of real maize price, real weighted average meat prices, real sunflower producer price, and a time trend to capture technological advances in feed formulations and animal genetic improvements. Sunflower is a compliment to maize in feed formulations, as it constitutes a protein source while maize is an energy source. Although sunflower prices together with the time trend are not significant at the 5 % level, they are kept in the model for its overall significance and economic importance.

South Africa's change in maize stock (SAMSC) was modeled as a function of lagged maize production and real maize price in U.S. dollars, and a dummy variable for 1994 was also included to capture a large spike in the stock change caused by a severer drought in that year.

The South African maize sector was historically regulated through the maize board. From approximately 1939 maize producer prices were set by the maize board and approved by the minister of agriculture. The formulas for calculating the maize price over the years did vary, however a common thread in these formulas was the base price, which was the previous years maize producer price. The base price was adjusted in accordance with inflationary pressures of the main inputs. In 1991 however the Maize Board started taking the international maize price into account when setting the local price. The effect of the international maize price on the local price culminated in 1997 with the disbandment of the maize board. It is for this reason that the South Africa's real maize producer price was determined as a function of lagged price, South Africa's maize net trade position, the U.S. Gulf port maize price deflated with the South African producer price index, and a shift variable for 1994. All the variables are significant at the 5 % level and the signs meet the *a priori* expectations.

Equation 5.20: South Africa Maize Per Capita Domestic Human Consumption

$$SAMFOPC_t = +0.083$$
$$-0.00011*(47.05*RSAMPPD_t) + 0.000077*RSAGDPD_t$$
$$(-1.05) \qquad (0.48)$$
$$<-0.1871> \qquad <0.0834>$$
$$+0.00011*RSABCPD_t - 0.0111*DUM8789$$
$$(2.45) \qquad (-3.38)$$
$$<0.205>$$
$$R^2 = 0.69 \qquad D.W. = 2.33 \qquad D.F. = 6$$

Equation 5.21: South Africa Total Domestic Human Consumption

$SAMTFOU_t = SAMFOPC_t * SAPOP_t$

Equation 5.22: South Africa Maize Domestic Animal Consumption

$SAMFEED_t$ = + 1931196

$- 6236.11*RSAMPPD_t + 3285.8*RSAMEATPPD_t$

(-2.99) (2.15)

<-0.773> <0.510>

$+ 1452.1*RSASFPPD_t + 498931.2*LTT$

(1.65) (1.30)

<0.317>

$R^2 = 0.68$ D.W. = 1.32 D.F.= 3

Equation 5.23: South Africa Change in Maize Stock

$SAMSC_t$ = -1864300

$+ 0.284*SAMPR_{t-1} - 1271.14*RSAMPPD_t - 2376568*DUM94$

(3.15) (-1.19) (-1.99)

$R^2 = 0.43$ D.W. = 2.17 D.F.= 5

Equation 5.24:South Africa Maize Net Trade

SAMNT = SAMPR + SAMSC – SAMFO – SAMFEED - SAMOU

Equation 5.25: South Africa Maize Price

$RSAMPP_t$ = +147.03

$+0.699*RSAMPP_{t-1} - 0.000011*SAMNT + 0.141*USMPPSA$

(7.62) (-3.33) (3.93)

$+ 77.81*SHIFT94$

(2.90)

$R^2 = 0.99$ D.W. = 2.66 D.F.= 3

5.4 Tanzania Sub-model

Equations 5.26 to 5.29 are the Tanzania production block. Maize area harvested was estimated as a linear function of lagged area planted, lagged real maize producer price in U.S. dollars, real rice producer price, a shift variable for the period 1985-1990, and a dummy variable for 1991/1992. The dummy variable for 1985/1990 was included due to a change in maize price trend and the dummy variable for 1991/92 to capture a change in production trend. Alternative specifications were estimated, however equation 5.23 was chosen based on the sign of the estimated coefficients, R^2

and F-statistics. The maize area harvested was estimated as a function of the maize price in US dollars instead of the local currency because this rendered the model insignificant with parameter coefficients of the incorrect sign. The short run and long run supply elasticity are 0.0938 and 0.152 respectively.

The supply elasticity indicates that a 1 % increase in the real producer price of maize in U.S. dollars will cause a 0.094 % increase in area harvested, indicating that area planted is relatively inelastic to own price. Tanzanian maize production ($TAMPR_t$) is an identity and equal to area harvested times yield.

Equation 5.26:Tanzania Maize Area Harvested

$$
\begin{aligned}
TAMAH_t = \; & +937297.95 \\
& + \underset{(1.46)}{0.3826*TAMAH_{t-1}} + \underset{\substack{(1.224) \\ <0.094> \\ [0.152]}}{724.36*RTAMPPD_{t-1}} \\
& \underset{\substack{(-1.72) \\ <-0.127> \\ [-0.196]}}{-639.36*RTARPP} + \underset{(1.97)}{197094*DUM8590} + \underset{(2.93)}{314807*DUM9192}
\end{aligned}
$$

$R^2 = 0.77$ D.W. = 2.58 D.F.= 6

Equation 5.27: Tanzania Maize Production

$$TAMPR_t = TAMAH_t * TAYLDt$$

Equation 5.28: Tanzania Yield

$$TAMYLD_t = TAMPR_t / TAMAH_t$$

Equation 5.29:Tanzania Maize Per Capita Domestic Consumption

$$
\begin{aligned}
TAMFOPC_t = \; & +111.21 \\
& \underset{\substack{(-2.44) \\ <-0.1252>}}{-0.0030*RTAMCPD_t} + \underset{\substack{(0.11) \\ <0.0054>}}{0.00072*RTAGDPD_t} \underset{(-1.85)}{-8.01*DUM78} \\
& + \underset{(3.23)}{13.78*DUM81} - \underset{(-1.77)}{10.51*LTT}
\end{aligned}
$$

$R^2 = 0.93$ D.W. = 1.83 D.F.= 5

Equation 5.30: Tanzania Maize Total Domestic Consumption

$TAMTFOU_t \quad = \quad TAMFOPC_t * TAPOP_t$

Equation 5.31: Tanzania Change in Maize Stock

$$TAMSC_t = -272126.42 + 0.186*TAMPR_{t-1} - 434.06*RTAMPPD_t - 402577*DUM8990 - 177155*DUM85$$

(2.06) (-1.10) (-4.16) (-1.29)

$R^2 = 0.59$ D.W. = 1.88 D.F.= 4

Equation 5.32: Tanzania Maize Net Trade

$TAMNT \quad = \quad TAMPR + TAMSC - TAMFO - TAMOU$

Equation 5.33: Tanzania Maize Price

$$RTAMPPD_t = +344.41 - 0.00001*RENTTA_t - 209.23*DUM92 - 26.18*DUM80 - 9.309*TT$$

(-1.19) (-1.66) (0.27) (-2.47)

$R^2 = 0.79$ D.W. = 0.72 D.F.= 6

Tanzanian per capita maize consumption is modeled as a function of real maize price, per capita gross domestic product, a time trend to capture changes in tastes and preferences, and two dummy variables for the years 1978 and 1981. The 1978 dummy is included due to a spike in the exchange rate, while the 1981 dummy is included due to a spike in real maize consumer price. All variables show the correct sign, and although per capita gross domestic product has a very low significance in the model, it is kept for its economic and theoretical significance.

Tanzania's change in maize stock ($TAMSC_t$) was modeled as a function of lagged maize production and real maize price. A dummy variable for 1989-1990 was also included to capture a large spike in stock change.

Tanzania's maize producer price in U.S. dollars was estimated as a linear function of the regional net trade position, a time trend and two dummy variables for the years

1980 and 1992. All the variables show the correct sign, and although not all the variables are significant at the 5 % level, they are kept for the overall significance of the model.

5.5 Zambia Sub-model

Equation 5.34: Zambia Maize Area harvested

$$ZAMAH_t = +190110.85 + 0.582 * ZAMAH_{t-1} + 290.37 * ZAMPP_{t-1}$$

$$\qquad (4.35) \qquad (0.62)$$

$$\qquad \qquad <0.0708>$$

$$\qquad \qquad [0.1694]$$

$$+265139.76 * DUM8889 - 118115.8 * DUM91$$

$$(3.63) \qquad (-0.72)$$

$R^2 = 0.84$ D.W. = 1.81 D.F.= 6

Equation 5.35: Zambia Maize Production

$$ZAMPR_t = ZAMAH_t * ZAYLDt$$

Equation 5.36: Zambia Yield

$$ZAYLDt = ZAMPR_t / ZAMAH_t$$

Equation 5.37: Zambia Maize Per Capita Domestic Consumption

$$ZAMFOPC_t = +135.5 - 0.00009 * RZAMCPD_t + 0.00009 * RZAGNID_t$$

$$(-0.78) \qquad (3.09)$$

$$<-0.0752> \qquad <0.0972>$$

$R^2 = 0.90$ D.W. = 1.57 D.F.= 5

Equation 5.38: Zambia Maize Total Consumption

$$ZAMTFOU_t = ZAMFOPC_t * ZAPOP_t$$

Equation 5.39: Zambia Change in Maize Stock

$$ZAMSC_t = -247173 + 0.246 * ZAMPR_{t-1} - 826211 * DUM8889$$

$$(2.05) \qquad (-5.40)$$

$$+ 570135 * DUM95 + 1194 * TT$$

$$(2.70) \qquad (0.147)$$

$R^2 = 0.75$ D.W. = 1.83 D.F.= 5

Equation 5.40:Zambia Maize Net Trade

ZAMNT = ZAMPR + ZAMSC – ZAMFO – ZAMOU

Equation 5.41: Zambia Maize Price

$$RZAMPP_t = +65.07 + \underset{(1.93)}{0.995*USMPPZA_{t-1}} - \underset{(-2.51)}{0.00015*RENTZA} - \underset{(-2.88)}{65.168*SHIFT89} + \underset{(5.72)}{238.17*DUM90} - \underset{(-1.65)}{71.67*DUM96}$$

$R^2 = 0.97$ D.W. = 1.16 D.F.= 5

The maize production block for Zambia consists of equations 5.34 to 5.36. Maize area harvested ($ZAMAH_t$) was estimated as a linear function of lagged area harvested, lagged real maize producer price divided by the U.S. potash price in Zambian local currency, and three dummy variables for 1988-89, and 1991. The dummy variable for 1979 was included due to a change in maize price trend and the 1989 dummy to capture a spike in maize price. All the variables have the correct sign and are statistically significant at the 5 % level. The short run and long run elasticity of supply are 0.0708 and 0.1694 respectively. The own price elasticity indicates that a 1 % increase in the real producer price of maize divided by the U.S. potash will cause a 0.0708 % increase in area planted, indicating that area planted is relatively inelastic to own price

Maize per capita consumption in Zambia (ZAMFOPC) was estimated as a function of real maize price and per capita real gross national income as a proxy for disposable income. All the variables have the correct sign and although maize price is not significant at the 5 % level, it is maintained in the model because it has the correct sign and for the overall economic significance of the model. Both own price and income elasticities are low indicating that it is a staple food. Zambia's change in maize stock ($ZAMSC_t$) was modeled as a function of lagged maize production, a time trend and two dummies to capture major spikes in the stock change.

Zambia's maize producer price was estimated as a function of lagged real U.S. maize price, regional maize net trade position, a shift variable for 1989 due to a marked exchange rate devaluation, and two dummy variables for 1990 and 1996. All the variables have the correct sign, and all except the dummy 1996 and the U.S. maize price are significant at the 5 % level.

5.6 Zimbabwe Sub-model

Equations 5.42 to 5.45 are the production block of Zimbabwe. Maize area harvested ($ZIMAH_t$) was estimated as a linear function of lagged area harvested, lagged real maize producer price in U.S. dollars, a time trend, and a dummy variable for 1992. The dummy variable for 1992 was used to capture the large decrease in area planted caused by low real maize prices in 1990 and 1991. Alternative specifications, which included wheat, tobacco and cotton as competing crops, yielded very low coefficients and were statistically insignificant. The short run and long run elasticity of supply are 0.3605 and 0.4484 respectively. These elasticities compared to the other countries in the model are very high, the reason for this is however unclear. All the coefficients have the expected sign. Zimbabwe maize production ($ZIMPR_t$) is an identity and is equal to area planted times yield.

Equation 5.42: Zimbabwe Maize Area harvested

$$ZIMAH_t = + 125350.7 + 0.196 * ZIMAH_{t-1} + 3509.6 * RZIMPPD_{t-1} - 245989 * DUM92 + 28711 * TT$$

(1.46)   (4.78) <0.3605> [0.4484]   (-2.58)   (5.47)

$R^2 = 0.70$ D.W. = 2.18   D.F.= 5

Equation 5.43: Zimbabwe Maize Production

$$ZIMPR_t = ZIMAH_t * ZIYLDt$$

Equation 5.44: Zimbabwe Yield

$$ZIMYLDt = ZIMPR_t / ZIMAH_t$$

Equation 5.45: Zimbabwe Maize Per Capita Domestic Consumption

$$ZIMFOPC_t = + 119.84 - \underset{(-1.27)\ <-0.0752>}{0.0121*RZIMCPD_t} + \underset{(1.70)\ <0.0972>}{0.0025*RZIGNID_t} + \underset{(2.68)}{11.17*DUM8082} - \underset{(-2.15)}{7.60*DUM91}$$

R-Square =0.97 D.W = 2.52 D.F.= 5

Equation 5.46: Zimbabwe Maize Total Domestic Consumption

$$ZIMTOFU_t = ZIMFOPC_t*ZIMPOP_t$$

Equation 5.47: Zimbabwe Change in Maize Stock

$$ZIMSC_t = 353443 + \underset{(2.63)}{0.411*ZIMPR_{t-1}} - \underset{(-2.41)}{8539*RZIMPPD_t} - \underset{(-3.88)}{1419302*DUM8586} + \underset{(1.93)}{589092*SHIFT87}$$

$R^2 = 0.62$ D.W. = 1.76 D.F.= 4

Equation 5.48:Zimbabwe Maize Net Trade

$$ZIMNT = ZIMPR + ZIMSC - ZIMFO - ZIMOU$$

Equation 5.49: Zimbabwe Maize Price

$$RZIMPPD_t = 55.69 - \underset{(-1.06)}{0.00001*ZIMNT_t} + \underset{(3.98)}{0.57*USMPPZI_t} + \underset{(5.02)}{83.38*DUM8182}$$

$R^2 = 0.93$ D.W. = 1.52 D.F.= 4

The per capita domestic consumption is modeled as a function of real maize price, real per capita gross national income, and two dummy variables for the years 1980-1982 and 1991 to capture spikes and changes in price trends. Own price elasticity of demand is -0.142 and income elasticity is 0.137. Again all the coefficients have the expected sign.

Zimbabwe's change in maize stock ($ZIMSC_t$) was modeled as a function of lagged maize production, real producer's price, and a dummy variable in 1985/1986 to capture a spike in stock change. Zimbabwe's real maize producer price in U.S. dollars was estimated as a function of the U.S. maize Gulf port price, Zimbabwe's net trade position, and a dummy variable for the years 1981-1982.

5.7 Rest of SADC Sub-model

The rest of SADC, as previously stated, comprises Botswana, Lesotho, Mauritius, and Swaziland. The remaining four countries were not included due to data constraints. Although aggregating data for such diverse countries it was nevertheless done in order to include as many countries as possible in the study. Many different specifications were tested and the models below were the most statistically significant and economically correct.

Equations 5.50 to 5.52 are the production block of the rest of SADC. A single area harvested equation is estimated for the rest of SADC, which includes Botswana, Lesotho, Mauritius, and Swaziland. The rest of SADC maize area harvested is modeled as a function of lagged area harvested, lagged real U.S. maize Gulf port price, and three dummy variables. The dummy variables are included in the model to capture spikes in the U.S. Maize Gulf port price. Maize area has a positive relationship with lagged area harvested and lagged real US Maize Gulf Port price. The estimated short run and long run elasticity are 0.0841 and 0.1338. Equation 5.52 represent total production as area harvested times yield per hectare.

Equation 5.50: Rest of SADC Maize Area harvested

$$SDMAH_t = +107258.4 + 0.371*SDMAH_{t-1} + 14326.03*USMPPSD_t + 83970*DUM88$$

(1.56) (0.52) (2.31)

<0.0841>

[0.1338]

$$- 102774.7*DUM94 + 131933*DUM96$$

(2.61) (3.20)

$R^2 = 0.44$ D.W = 1.40 D.F.= 6

Equation 5.51: Rest of SADC Maize Production

$SDMPR_t \quad = \quad SDMAH_t * SDYLDt$

Equation 5.52: Rest of SADC Yield

$SDYLDt \quad = \quad SDMPR_t / SDMAH_t$

Equation 5.53: Rest of SADC Maize Per Capita Domestic Consumption

$$SDMFOPC_t = +0.066 \underset{(-1.31)\ <-0.0006>}{-0.00002*USMPPSD_t} \underset{(1.57)\ <0.0004>}{+0.0016*RSDGDPD_t} \underset{(3.19)}{+0.015*DUM8586}$$

$R^2 = 0.82 \qquad D.W = 0.73 \qquad D.F.= 5$

Equation 5.54: Rest of SADC Total Domestic Consumption

$SDMTFOU_t \quad = \quad SDMFOPC_t \ * SDPOP_t$

Equation 5.55: Rest of SADC Change in Maize Stock

$$SDMSC_t = -94063.8 \underset{(1.63)}{+0.441*SDMSC_{t-1}} \underset{(-0.64)}{-38.40*USMPPSD_t} \underset{(2.24)}{+112977*DUM9293}$$

$R^2 = 0.31 \qquad D.W. = 0.86 \qquad D.F.= 5$

Equation 5.56: Rest of SADC Maize Net Trade

$SDMNT \quad = \quad SDMPR + SDMSC - SDMFO - SDMOU$

Maize per capita consumption in the rest of SADC is mainly human, and is modeled as a function of the real US maize Gulf port price, real per capita gross domestic product and dummy 1985-1986. All the variables have the correct sign and although the per capita GDP is not significant it is kept in the model because it has the correct sign and its economic importance.

Equation 5.57: Malawi Regional Net Maize Trade

$RENTMA_t = MOMNT_t + SAMNT_t + TAMNT_t + ZAMNT_t + ZIMNT_t + SDMNT_t$

Equation 5.58: Mozambique Regional Net Maize Trade

$RENTMO_t = MAMNT_t + SAMNT_t + TAMNT_t + ZAMNT_t + ZIMNT_t + SDMNT_t$

Equation 5.59: South Africa Regional Net Maize Trade

$$RENTSA_t = MOMNT_t + MAMNT_t + TAMNT_t + ZAMNT_t + ZIMNT_t + SDMNT_t$$

Equation 5.60: Tanzania Regional Net Maize Trade

$$RENTTA_t = MOMNT_t + MAMNT_t + SAMNT_t + ZAMNT_t + ZIMNT_t + SDMNT_t$$

Equation 5.61: Zambia Regional Net Maize Trade

$$RENTZA_t = MOMNT_t + MAMNT_t + SAMNT_t + TAMNT_t + ZIMNT_t + SDMNT_t$$

Equation 5.62: Zimbabwe Regional Net Maize Trade

$$RENTZI_t = MOMNT_t + MAMNT_t + SAMNT_t + TAMNT_t + ZAMNT_t + SDMNT_t$$

Equation 5.63: Rest of SADC Regional Net Maize Trade

$$RENTSD_t = MOMNT_t + MAMNT_t + SAMNT_t + TAMNT_t + ZAMNT_t + ZIMNT_t$$

Equation 5.64: Market Clearing Identity

$$ROW_t = MAMNT_t + MOMNT_t + SAMNT_t + TAMNT_t + ZAMNT_t + ZIMNT_t + SDMNT_t$$

The above set of equations form the SADC maize model. The individual country's maize is in several cases linked with the US maize Gulf Port price and regional and local maize net trade position in a system to account for price transmission. The price transmission elasticities with respect to the US Gulf Port price range form 0.09 in Zambia to 0.59 in Zimbabwe. This indicates that not all changes in US maize price are transmitted to SADC producers.

5.8 Model Performance and Validation Results

After the estimation, the model was validated using static and dynamic simulations to assess the sample's tracking ability. Appendix B reports the actual and simulated values maize of production and use for SADC for the period 1986 to 1996. The differences between the actual and simulation values indicate that errors in percentage term are less than 5 % for most of the variables. The graphical representations of the actual and simulated production and consumption equations are in Appendix A. Table 5.1 reports the mean and the root mean square percentage errors. The Theil's inequality coefficients for the historical data period are presented in table 5.2.

Most of the endogenous variables have a low Root Mean Square Percentage Errors (RMS percentage). Variables that have high RMS percentage are SDMPR, ZAMSC, and SAMSC. Since some of the variables such as SDMPR, ZIMSC and SAMSC are of small magnitude thus any small error of prediction creates a high proportion of error when error is compared to the small actual values.

Theil's forecast errors of most of the simulation are from disturbance terms rather than from intercept or regression terms. As stated previously a value of U^M close to zero is desirable, and if U^M is not close to zero this indicates the presence of systematic error. U^S indicates the model's capability to replicate the degree of variability in the variable. A large U^S implies that the actual series has fluctuated considerably whereas the simulated variable has not or vice versa. U^C measures the unsystematic error. A value of $U^M = U^S = 0$ and $U^C = 1$ is ideal. From the table 5.2 it can be concluded that model performed satisfactorily.

Table 5.1: Mean Root Square

VARIABLE		MEAN ABSOLUTE % ERROR	RMS % ERROR
Area Harvested			
Malawi	MAMAH	3.87	4.64
Mozambique	MOMAH	7.95	9.31
South Africa	SAMAH	3.67	5.33
Tanzania	TAMAH	6.11	7.55
Zambia	ZAMAH	6.84	9.36
Zimbabwe	ZIMAH	7.89	9.82
Rest of SADC	SDMAH	12.63	17.52
Total SADC	TMAH	1.72	2.28
Production			
Malawi	MAMPR	3.8	4.59
Mozambique	MOMPR	8.08	9.37
South Africa	SAMPR	3.67	5.28
Tanzania	TAMPR	6.1	7.52
Zambia	ZAMPR	6.85	9.33
Zimbabwe	ZIMPR	7.88	9.8
Rest of SADC	SDMPR	12.65	*
Consumption			
Malawi	MAMFO	2.69	17.5
Mozambique	MOMFO	9.86	3.58
Tanzania	TAMFO	3.85	14.3
Zimbabwe	ZIMFO	2.07	4.93
Rest of SADC	SDMFO	7	9.3
Zambia	ZAMFO	3.11	3.71
South Africa (Human)	SAMFO	3.48	4.39
South Africa (Animal)	SAMFEED	8.15	9.61
Stock Change			
Malawi	MAMSC	139	272.1
Mozambique	MOMSC	*	*
Tanzania	TAMSC	*	*
Zambia	ZAMSC	87.82	119.7
South Africa	SAMSC	346.2	92.1
Zimbabwe	ZIMSC	*	*
Rest of SADC	SDMSC	202.5	388.3
Price			
Malawi	MAMPP	4.48	5.35
Mozambique	MOMPP	19.33	28.88
South Africa	SAMPP	11.49	4.21
Tanzania	TAMPP	36.34	49.83
Zambia	ZAMPP	19.34	25.78
Zimbabwe	ZIMPP	11.47	15.62

Note * means too small to report

Table 5.2: Theil's Statistics

VARIABLE		U^M	U^S	U^C
Area Harvested				
Malawi	MAMAH	0.00	0.22	0.78
Mozambique	MOMAH	0.00	0.18	0.82
South Africa	SAMAH	0.00	0.04	0.96
Tanzania	TAMAH	0.01	0.19	0.81
Zambia	ZAMAH	0.00	0.24	0.76
Zimbabwe	ZIMAH	0.00	0.10	0.90
Rest of SADC	SDMAH	0.01	0.21	0.79
Total	TMAH	0.13	0.01	0.86
Production				
Malawi	MAMPR	0.00	0.01	0.99
Mozambique	MOMPR	0.01	0.03	0.96
South Africa	SAMPR	0.00	0.00	1.00
Tanzania	TAMPR	0.00	0.28	0.72
Zambia	ZAMPR	0.00	0.29	0.71
Zimbabwe	ZIMPR	0.02	0.14	0.84
Rest of SADC	SDMPR	0.00	0.27	0.73
Consumption				
Malawi	MAMFO	0.00	0.03	0.97
Mozambique	MOMFO	0.01	0.02	0.96
Tanzania	TAMFO	0.01	0.00	0.99
Zimbabwe	ZIMFO	0.00	0.02	0.98
Rest of SADC	SDMFO	0.00	0.21	0.78
Zambia	ZAMFO	0.00	0.01	0.99
South Africa (Human)	SAMFO	0.00	0.13	0.87
South Africa (Animal)	SAMFEED	0.00	0.06	0.94
Stock Change				
Malawi	MAMSC	0.00	0.08	0.92
Mozambique	MOMSC	0.00	0.01	0.99
Tanzania	TAMSC	0.00	0.14	0.86
Zambia	ZAMSC	0.00	0.05	0.95
South Africa	SAMSC	0.00	0.22	0.78
Zimbabwe	ZIMSC	0.00	0.18	0.82
Rest of SADC	SDMSC	0.00	0.26	0.74
Prices				
Malawi	MAMPP	0.02	0.11	0.88
Mozambique	MOMPP	0.00	0.00	1.00
South Africa	SAMPP	0.00	0.05	0.95
Tanzania	TAMPP	0.08	0.39	0.53
Zambia	ZAMPP	0.01	0.10	0.89
Zimbabwe	ZIMPP	0.04	0.23	0.73

5.8.1 Impact Multipliers

To assess the performance of the model, the model is subject to exogenous shocks. The impact multipliers are computed to evaluate ex-ante performance of the model in response to changes in policy variables or response to exogenous shocks. The impact multipliers are computed as follows; first the model was simulated for period of 20 years past 1998 with all exogenous variables kept at their 1998 level. This procedure generates the base simulation. The model converged to a long-run equilibrium in the period 2008. The shock was then given to the chosen exogenous variable in that period and the model was simulated once again. The difference between base simulation and the simulation with the change in the exogenous variable in percentage term is the short run and long run multiplier. Table 5.3 and 5.4 report the changes in the actual values and the percentage change due to a 15 % increase in maize yield. Similarly, tables 5.5 and 5.6 report the change in the actual values and percentage change due to a 35 % increase of the inflation rate in each country.

The results from both simulations met the a priori expectations with respect to sign and impact of the two shocks. From tables 5.5 and 5.6 it is evident that an increase in yield in period 1 will cause production, stock change, and consumption to increase, while price will decrease due to an excess supply. Area harvested will as a consequence be reduced in the following periods. The extent and time periods it takes for each single country to return to normal depends on the various individual short and long run elasticities. Tanzania's maize price continues to decrease because it is in US Dollars and it is assumed that the currency will continue to devalue. The decrease in maize price in Tanzania also causes the Area harvested to decrease for a longer period than all the remaining countries. As far as the region as a whole is concerned, the regional net maize trade position increases by 30.80 % and 9.91 % in period 1 and 2. The subsequent periods however show a negative percentage change in the regional net trade position caused by the reduced area harvested and consequently production.

Table 5.3: Actual Change due to a 15 Percent Increase in Maize Yield

PERIOD	1	2	3	4	5	6
Area Harvested (Hectare)						
Malawi	0	-11347	-6662	-1619	-238	-7
Mozambique	0	-98	-58	-16	-3	0
Tanzania	0	-2701	-4046	-3923	-3279	-2544
Zambia	0	-23587	-15235	-5099	-1524	-327
South Africa	0	-8940	-6964	-3469	-1787	-968
Zimbabwe	0	-16212	-8720	-637	170	40
Rest of SADC	0	0	0	0	0	0
Maize Production (Tons)						
Malawi	297906	-16340	-9593	-2331	-342	-10
Mozambique	160349	-92	-55	-15	-3	0
Tanzania	1874941	-9317	-13960	-13533	-11313	-8776
Zambia	413030	-38212	-24681	-8261	-2468	-529
South Africa	176423	-18684	-14554	-7251	-3735	-2024
Zimbabwe	395282	-27561	-14824	-1083	288	68
Rest of SADC	34465	0	0	0	0	0
Maize Consumption (Tons)						
Malawi	925	260	-34	-21	-5	-1
Mozambique	4	1	0	0	0	0
Tanzania	2465	649	-76	-45	-27	-19
Zambia	20	4	-1	-1	0	0
South Africa (Human)	4883	4734	3223	2178	1463	978
South Africa (Animal)	27224	26392	17968	12143	8158	5454
Zimbabwe	590	202	-39	-11	0	0
Rest of SADC	0	0	0	0	0	0
Change In Stock (Tons)						
Malawi	2870	110687	-6133	-3603	-876	-130
Mozambique	0	12150	-7	-4	-1	0
Tanzania	14135	80811	-7569	-4863	-1695	-567
Zambia	0	43545	-4612	-3592	-1790	-922
South Africa	5549	538693	1012	-1496	-2187	-2106
Zimbabwe	39447	176121	-13951	-6816	-461	137
Rest of SADC	0	15226	0	0	0	0
Price(Local Currency/Ton)						
Malawi	-139	-39	5	3	1	0
Mozambique	-3818	-976	154	80	41	25
Tanzania (US Dollars)	-22	-21	-14	-10	-7	-4
Zambia	-19743	-5199	611	358	214	149
South Africa	-39604	-7806	2580	1025	317	123
Zimbabwe	-50	-17	3	1	0	0
Row	3378285	834787	-129965	-67092	-34173	-21273

Table 5.4: Percentage Change Due to a 15 Percent Increase in Maize Yield

PERIOD	1	2	3	4	5	6
Area Harvested (Hectare)						
Malawi	0.000	-0.845	-0.494	-0.120	-0.018	-0.001
Mozambique	0.000	-0.009	-0.005	-0.001	0.000	0.000
Tanzania	0.000	-0.075	-0.112	-0.109	-0.091	-0.071
Zambia	0.000	-1.390	-0.893	-0.297	-0.089	-0.019
South Africa	0.000	-1.596	-1.239	-0.613	-0.315	-0.170
Zimbabwe	0.000	-1.078	-0.577	-0.042	0.011	0.003
Rest of SADC	0.000	0.000	0.000	0.000	0.000	0.000
Maize Production (Tons)						
Malawi	13.253	-0.845	-0.494	-0.120	-0.018	-0.001
Mozambique	12.963	-0.009	-0.005	-0.001	0.000	0.000
Tanzania	13.098	-0.075	-0.112	-0.109	-0.091	-0.071
Zambia	12.903	-1.390	-0.893	-0.297	-0.089	-0.019
South Africa	12.917	-1.596	-1.239	-0.613	-0.315	-0.170
Zimbabwe	13.265	-1.078	-0.577	-0.042	0.011	0.003
Rest of SADC	12.782	0.000	0.000	0.000	0.000	0.000
Maize Consumption (Tons)						
Malawi	0.064	0.018	-0.002	-0.001	0.000	0.000
Mozambique	0.000	0.000	0.000	0.000	0.000	0.000
Tanzania	0.108	0.029	-0.003	-0.002	-0.001	-0.001
Zambia	0.002	0.000	0.000	0.000	0.000	0.000
South Africa (Human)	0.139	0.135	0.092	0.062	0.042	0.028
South Africa (Animal)	0.743	0.720	0.492	0.333	0.224	0.150
Zimbabwe	0.041	0.014	-0.003	-0.001	0.000	0.000
Rest of SADC	0.000	0.000	0.000	0.000	0.000	0.000
Change In Stock (Tons)						
Malawi	1.160	31.171	-2.574	-1.496	-0.360	-0.053
Mozambique	0.000	27.238	-0.021	-0.013	-0.003	-0.001
Tanzania	9.421	37.291	-5.898	-3.711	-1.263	-0.419
Zambia	0.000	37.462	-6.773	-5.198	-2.524	-1.285
South Africa	0.365	26.218	0.067	-0.099	-0.144	-0.139
Zimbabwe	12.155	38.188	-5.146	-2.450	-0.162	0.048
Rest of SADC	0.000	-145.23	0.000	0.000	0.000	0.000
Price(Local Currency/Ton)						
Malawi	-18.763	-4.652	0.578	0.357	0.091	0.020
Mozambique	-2.737	-0.686	0.107	0.055	0.028	0.018
Tanzania	-3.637	-3.524	-2.373	-1.592	-1.064	-0.709
Zambia	-14.395	-3.427	0.388	0.228	0.136	0.095
South Africa	-22.967	-3.822	1.202	0.481	0.149	0.058
Zimbabwe	-3.611	-1.205	0.230	0.063	0.001	-0.002
Row	30.802	9.910	-1.743	-0.892	-0.452	-0.281

The second simulation also met the a priori expectations. Inflationary pressures have the immediate effect of increasing nominal prices and thus decreasing consumption in the short run, as can be seen in table 5.6. As incomes and expenditures adjust, real prices tend to decrease and it is for this reason that area harvested is again reduced in period 2. The various effects of inflationary pressures on the individual countries after period 2 depends on the various short and long run elasticities. The increase in inflation in period 1 did however have the expected effect on all the countries in the study.

For SADC as a whole, area harvested and production are not affected in period 1 as farmers can only make their production decision for the following year. Total consumption will however decrease in period 1 by 2.096 % while stock change and net trade will increase by 9.15 and 6.55 % respectively. Most of these effects however begin to reverse themselves as inflation returns to normal and consumers and producers adjust to the new price levels.

Table 5.5: Actual Change Due to a 35 Percent increase in Inflation

PERIOD	1	2	3	4	5	6
Area Harvested (Hectare)						
Malawi	0	-18623	15874	6400	3030	1054
Mozambique	0	-949	796	276	97	34
Tanzania	0	-1199	-1456	-1328	-1079	-823
Zambia	0	16131	1492	2211	1967	1052
South Africa	0	-1787	-10099	-5070	-2803	-1593
Zimbabwe	0	-87391	-11046	1111	457	26
Rest of SADC	0	-5228	-1942	-721	-268	-100
Maize Production (Tons)						
Malawi	0	-26818	22859	9216	4363	1518
Mozambique	0	-892	748	260	92	32
Tanzania	0	-4137	-5022	-4581	-3721	-2839
Zambia	0	26132	2417	3582	3186	1704
South Africa	0	-3734	-21107	-10596	-5858	-3330
Zimbabwe	0	-148565	-18779	1888	777	44
Rest of SADC	0	-6064	-2253	-837	-311	-115
Maize Consumption						
Malawi	-3097	-126	-87	-10	2	1
Mozambique	-874	0	0	0	0	0
Tanzania	388	-171	-117	-31	-14	-9
Zambia	-49	20	-2	0	0	0
South Africa (Human)	-75365	1485	1009	680	456	305
SouthAfrica (Animal)	-231341	8281	5624	3793	2544	1699
Zimbabwe	-1218	-222	-119	-9	2	1
Rest of SADC	5809	0	0	0	0	0
Change in Stock						
Malawi	669	-10283	8160	3367	1616	564
Mozambique	0	-68	57	20	7	2
Tanzania	2804	3894	-220	489	515	264
Zambia	0	0	-922	-5210	-2615	-1446
South Africa	2464	1688	-31	-656	-785	-712
Zimbabwe	212638	-14826	-69102	-8309	932	356
Rest of SADC	9219	0	-2679	-995	-370	-137
Price(Local Currency/Ton)						
Malawi	264	19	13	2	0	0
Mozambique	43823	197	125	26	11	10
Tanzania	204	-7	-4	-3	-2	-1
Zambia	49627	1373	938	250	111	76
South Africa	63539	-40135	3571	651	167	112
Zimbabwe	137	19	10	1	0	0
Row	531964	-165336	-105148	-22202	-9550	-8040

Table 5.6: Percentage Change due to a 35 Percent Increase in Inflation

PERIOD	1	2	3	4	5	6
Area Harvested (Hectare)						
Malawi	0.000	-1.394	1.159	0.470	0.223	0.078
Mozambique	0.000	-0.083	0.069	0.024	0.008	0.003
Tanzania	0.000	-0.033	-0.040	-0.037	-0.030	-0.023
Zambia	0.000	0.929	0.087	0.128	0.114	0.061
South Africa	0.000	-0.315	-1.807	-0.899	-0.495	-0.281
Zimbabwe	0.000	-6.099	-0.732	0.073	0.030	0.002
Rest of SADC	0.000	-2.647	-0.967	-0.357	-0.132	-0.049
Maize Production (Tons)						
Malawi	0.000	-1.394	1.159	0.470	0.223	0.078
Mozambique	0.000	-0.083	0.069	0.024	0.008	0.003
Tanzania	0.000	-0.033	-0.040	-0.037	-0.030	-0.023
Zambia	0.000	0.929	0.087	0.128	0.114	0.061
South Africa	0.000	-0.315	-1.807	-0.899	-0.495	-0.281
Zimbabwe	0.000	-6.099	-0.732	0.073	0.030	0.002
Rest of SADC	0.000	-2.647	-0.967	-0.357	-0.132	-0.049
Maize Consumption						
Malawi	-0.214	-0.009	-0.006	-0.001	0.000	0.000
Mozambique	-0.088	0.000	0.000	0.000	0.000	0.000
Tanzania	0.017	-0.008	-0.005	-0.001	-0.001	0.000
Zambia	-0.004	0.002	0.000	0.000	0.000	0.000
South Africa (Human)	-2.200	0.042	0.029	0.019	0.013	0.009
South Africa (Animal)	-6.794	0.227	0.154	0.104	0.070	0.047
Zimbabwe	-0.085	-0.016	-0.008	-0.001	0.000	0.000
Rest of SADC	1.709	0.000	0.000	0.000	0.000	0.000
Change in Stock						
Malawi	0.273	-4.392	3.231	1.359	0.657	0.230
Mozambique	0.000	-0.209	0.174	0.061	0.021	0.007
Tanzania	2.022	2.786	-0.162	0.359	0.378	0.194
Zambia	0.000	0.000	-1.284	-7.720	-3.732	-2.029
South Africa	0.162	0.111	-0.002	-0.043	-0.052	-0.047
Zimbabwe	42.723	-5.486	-31.996	-3.002	0.326	0.125
Rest of SADC	-55.907	0.000	9.437	3.727	1.418	0.531
Price(Local Currency/Ton)						
Malawi	23.093	2.109	1.472	0.178	-0.036	-0.022
Mozambique	23.417	0.137	0.087	0.018	0.008	0.007
Tanzania	24.753	-1.080	-0.731	-0.492	-0.329	-0.220
Zambia	24.030	0.867	0.594	0.159	0.071	0.048
South Africa	23.056	-23.347	1.656	0.306	0.079	0.053
Zimbabwe	8.791	1.293	0.700	0.051	-0.014	-0.003
Row	6.550	-2.227	-1.405	-0.293	-0.126	-0.106

5.9 Summary

In this chapter the estimated results of the SADC maize sector are reported and discussed. The estimated equations were generally satisfactory. The fit measured by the R-Squared were reasonable, with fourteen equations having an R-Squared better than 0.8, whereas there were five equations with an R-Squared of 0.7, six equations had an R-square of 0.6, and the remaining three equations had an R-Squared below 0.5. Based on the performance tests and the model validation test, the results suggest that the model replicates the SADC maize sector quite well, i.e., the developed model has satisfactory predictability power. The relevant elasticities were computed at the mean of the variables. Table 4.6 summaries the relevant elasticities of the model.

Table 5.6: Summary of Elasticities

Country	Short Run Price Elasticity (Supply)	Long Run Price Elasticity (Supply)	Own Price Elasticity (Demand)	Income Elasticity
Malawi	0.0924	0.1331	-0.0613	0.0761
Mozambique	0.0439	0.0667	-0.1663	0.3313
Tanzania	0.0631	0.1339	-0.1252	0.0054
South Africa	0.0938	0.1519	-0.1871	0.0834
Zambia	0.0708	0.1694	-0.0225	0.0890
Zimbabwe	0.3605	0.4484	-0.0752	0.0972
Rest of SADC	0.0841	0.1338	-0.0006	0.0004

The estimated elasticities suggest some interesting observations. All short run supply elasticities were less than 0.09 with the exception of Zimbabwe, which has a supply elasticity of 0.3605. It is not clear why the elasticities of Zimbabwe are so high. The own price demand elasticities were in the range of –0.0006 to –0.1663, whereas income elasticities were in the range of 0.0004 to 0.3313, which suggest that maize is a basic necessity for SADC countries.

The ex-ante performance of the model was tested using impact multipliers. The results show that the model reacts to exogenous shocks in the expected manner. Tables 5.7 and 5.8 contain a summary of the expected actual and percentage changes of the endogenous variables given a 15 % increase in yield and a 35 % increase in inflation, respectively.

Due to the fact that the model tracks changes in exogenous variables adequately, it is possible to develop a baseline forecast and different policy scenarios using the model. The results of the baseline forecast and the policy scenarios are presented in the following chapter.

Table 5.7:SADC Actual and Percentage due to a 15 percent increase in yield

PERIOD	1	2	3	4	5	6
Change in Total Area (Hectares)	0	-62885	-41685	-14763	-6661	-3806
Total Area % change	0.00	-0.63	-0.41	-0.15	-0.07	-0.04
Change in Total Production (Tons)	3352397	-110205	-77666	-32474	-17574	-11272
Total Production % change	13.09	-0.50	-0.35	-0.15	-0.08	-0.05
Change in Total Change in Stock (Tons)	62000	977233	-31259	-20374	-7010	-3589
Change in Stock % change	2.67	30.18	-1.40	-0.91	-0.31	-0.16
Change in Total Food Use (Ton)	36111	32242	21040	14244	9588	6413
Total Food Use % change	0.242	0.216	0.141	0.096	0.064	0.043
Change in Net Trade (Tons)	3378285	834787	-129965	-67092	-34173	-21273
Net Trade % change	30.80	9.91	-1.74	-0.89	-0.45	-0.28

Table 5.8:SADC Actual and Percentage due to a 35 percent increase in Inflation

PERIOD	1	2	3	4	5	6
Change in Total Area (Hectares)	0	-3442	-77442	-15656	-915	-1553
Total Area % change	0	-0.03	-0.77	-0.15	-0.01	-0.02
Change in Total Production (Tons)	0	-1578	-136476	-34104	-6486	-5859
Total Production % change	0	-0.01	-0.62	-0.15	-0.03	-0.03
Change in Total Change in Stock (Tons)	227795	-19594	-64737	-11294	-700	-1109
Change in Stock % change	9.15	-0.87	-2.95	-0.50	-0.03	-0.05
Change in Total Food Use (Ton)	-305747	9267	6307	4422	2991	1996
Total Food Use % change	-2.096	0.062	0.042	0.030	0.020	0.013
Change in Net Trade (Tons)	531964	-165336	-105148	-22202	-9550	-8040
Net Trade % change	6.550	-2.227	-1.405	-0.293	-0.126	-0.106

CHAPTER SIX: "Policy Simulations" Analysis of Results

Based on the estimated model equations, simulations for plausible policy scenarios were performed in this chapter. First, a baseline simulation was generated following which two policy scenarios were evaluated. The first policy scenario evaluated the possible effects on SADC of a large decrease in area harvested in Zimbabwe given the current land restitution policies. The second scenario evaluated the effects of a two-year decrease in yield in South Africa, Southern Africa's breadbasket, on the region.

6.1 Baseline Forecast

The baseline forecast was generated for the period 2002 to 2007 based on several assumptions. Theoretically, the baseline can be considered as a plausible market outlook for the period 2002 to 2007, rather than as a forecast *per se.* In other words the baseline forecast can be considered as a benchmark for the SADC market outlook. The main assumptions of the baseline forecast were: no further expansion of SADC, SADC trade protocol of 1994 is yet to be implemented i.e., full implementation of the trade protocol will be achieved by 2004 by all member countries (no restrictions exist on the trade in maize), thus domestic maize price react to changes in world price. Values of the relevant macro variables for the forecast for South Africa were taken from FAPRI Outlook 2002, for the remaining countries it was assumed that exchange rates will follow the same trend as in South Africa as in FAPRI Outlook 2002 forecasts. All other relevant macro variables were assumed to have a growth rate equivalent to the average of the last five years. Forecasted U.S Gulf port maize price was from FAPRI Outlook 2002. For population it was assumed that population will grow at the average of the past five years growth. Finally, it was assumed that normal weather conditions will prevail during the forecast period.

Based on the above assumptions, total area harvested and production are expected to increase by approximately 3% over the five-year period, while consumption is expected to increase by approximately 6.5%. The net trade positions of Malawi, South Africa and Zimbabwe remained positive (Table 6.2), indicating that they are net exporters of maize. Although the net trade position of the region also remained positive, it decreased from 1.45 million ton to only 0.99, a definite downward trend. This is due to the fact that FAPRI forecasted a decrease in the supply of world maize for that period. However from table 6.2 some results do not meet our a priori expectations. The most obvious discrepancy being the Malawi producer price of maize, which decreases by almost 60% in the baseline period. These results do not fit with the theoretical discussion and it is clear that these results are at variance with the other countries examined. The reason for this discrepancy is unclear however it is likely that with more reliable data for the region, this problem could be overcome.

Table 6.1: Baseline Forecast: SADC

YEAR	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Total Area (Hectares)	10391423	10490551	10570704	10646137	10718543	10789693
Total Production (Tons)	18602297	18720511	18812384	18897307	18977931	19056585
Total Change in Stock (Tons)	1472553	1514689	1564389	1607650	1647984	1682544
Total Food Use (Ton)	16254528	16479338	16708528	16929507	17149961	17379199
Other Uses (Tons)	2367436	2367437	2367438	2367439	2367439	2367439
Net Trade (Tons)	1452886	1388426	1300807	1208011	1108514	992489

NB: Total food use includes animal feed use

The reader should note that production plus change in stocks less consumption less other uses yields exports less imports, thus net trade is defined as exports minus imports.

Table 6.2: Baseline Forecast: Country Level

Year	2002	2003	2004	2005	2006	2007
Area Planted (Ha)						
Malawi	1439796	1455561	1468218	1479475	1489726	1499002
Mozambique	1313835	1344560	1375379	1406232	1437099	1467974
South Africa	3474644	3468184	3462612	3457535	3452774	3448259
Tanzania	1855395	1868583	1876044	1881171	1885143	1888471
Zambia	556486	553253	553089	553800	555129	556714
Zimbabwe	1563234	1611948	1646626	1678975	1709648	1740226
Rest of SADC	188033	188462	188735	188949	189024	189047
Production (Ton)						
Malawi	2404459	2430788	2451924	2470723	2487843	2503333
Mozambique	1182452	1210104	1237841	1265609	1293389	1321177
South Africa	8651864	8635779	8621904	8609263	8597408	8586166
Tanzania	3339710	3363450	3376880	3386107	3393258	3399247
Zambia	834729	829879	829633	830700	832693	835072
Zimbabwe	1954042	2014934	2058282	2098718	2137060	2175282
Rest of SADC	235042	235577	235919	236186	236280	236309
Food Use (Ton)						
Malawi	1483646	1484734	1482899	1477895	1469464	1458391
Mozambique	829148	845812	862929	880047	897617	915639
South Africa	3750774	3737011	3716771	3688527	3654901	3618995
Tanzania	2974128	3093797	3218199	3347343	3482006	3622182
Zambia	1538865	1584881	1633606	1682330	1732409	1783841
Zimbabwe	1571552	1603191	1635953	1668662	1702514	1737511
Rest of SADC	441646	452112	462730	473559	484543	495638
South Africa (feed use)	3664770	3677800	3695443	3711143	3726508	3747001
Net Trade (Tons)						
Malawi	834261	868502	902921	936266	970518	1005187
Mozambique	55750	67521	78945	90405	101427	112007
South Africa	1444162	1432177	1420699	1420920	1427835	1432521
Tanzania	-850662	-903164	-952137	-998660	-1045287	-1092654
Zambia	235387	143297	36673	-80783	-206615	-339562
Zimbabwe	134296	190397	233735	269960	301182	326300
Rest of SADC	-400308	-410303	-420031	-430098	-440547	-451310
Maize Price (Local Currency/Ton)						
Malawi	3706	3471	3145	2701	2107	1335
Mozambique	253991	272634	292834	314687	338318	363920
South Africa	1158	1247	1330	1424	1525	1612
Tanzania	463095	511088	564292	622863	687485	758359
Zambia	710822	802882	885942	979713	1080451	1192740
Zimbabwe	12507	12749	13011	13229	13458	13757

6.2 SADC Maize Market Outlook : Effects of the Zimbabwe Crisis

To evaluate the possible impact of the current political crisis in Zimbabwe, the following policy scenario has been assumed: maize area harvested in Zimbabwe will decrease from its forecasted baseline level by 50% in 2002 (781617 hectares), followed by a 20% decrease in 2003 and a 10% decrease in 2004, after which it will return to normal. The remaining assumptions of the baseline were assumed to hold. Table 5.3 reports the SADC maize market outlook for the current Zimbabwe crisis.

Table 6.3: SADC Market outlook For Maize: Zimbabwe Crisis

YEAR	2002	2003	2004	2005	2006	2007
Total Area (Hectares)	9609806	10198465	10444036	10673636	10732584	10795551
Total Production (Tons)	17625276	18368018	18669630	18942710	19000892	19066004
Total Change in Stock (Tons)	1366286	1025019	1372174	1531329	1660583	1688822
Total Food Use (Ton)	16253094	16478224	16708051	16929410	17149968	17379203
Net Trade (Tons)	371033	547376	966316	1177190	1144067	1008182

Table 6.4: SADC Actual and Percentage changes Maize: Zimbabwe Crisis

YEAR	2002	2003	2004	2005	2006	2007
Change in Total Area (Hectares)	-781617	-292086	-126668	27499	14041	5858
Total Area % change	-7.52	-2.78	-1.20	0.26	0.13	0.05
Change in Total Production (Tons)	-977021	-352493	-142754	45403	22961	9419
Total Production % change	-5.25	-1.88	-0.76	0.24	0.12	0.05
Change in Total Change in Stock (Tons)	-106267	-489671	-192214	-76320	12599	6278
Change in Stock % change	-7.22	-32.33	-12.29	-4.75	0.76	0.37
Change in Total Food Use (Ton)	-1434	-1114	-477	-96	6	4
Total Food Use % change	-0.009	-0.007	-0.003	-0.001	0.000	0.000
Change in Net Trade (Tons)	-1081854	-841050	-334491	-30821	35554	15693
Net Trade % change	-74	-61	-26	-3	3	2

Due to the reduction in area harvested in Zimbabwe, the total SADC maize area harvested decreased from 10391423 hectares to 9609806 hectares in 2002, a reduction of 781617 hectares, lowering production by 977021 tons (Table 5.4). Similarly, for 2003 and 2004 total area of maize harvested for SADC decreased by

292080 and 126668 hectares, respectively. Production consequently decreased by 1.88 % and 0.76 % in 2003 and 2004, respectively. As a consequence of the reduced area harvested in Zimbabwe for 2002, 2003, and 2004, regional net trade in these years decreased by 74%, 61%, and 26%, respectively (Table 5.4). The region however, managed to maintain the status of net exporter.

Tables 5.5, 5.6, and 5.7 represent the baseline forecast for Zimbabwe, a market outlook for Zimbabwe given the decrease in area harvested, and the actual and percentage changes of several variables of interest.

Table 6.5: Baseline Forecast for Zimbabwe

YEAR	2002	2003	2004	2005	2006	2007
Area (Hectares)	1563234	1611948	1646626	1678975	1709648	1740226
Production (Tons)	1954042	2014934	2058282	2098718	2137060	2175282
Change in Stock (Tons)	294071	320919	353671	382170	408903	430795
Food Use (Ton)	1571552	1603191	1635953	1668662	1702514	1737511
Net Trade (Ton)	134296	190397	233735	269960	301182	326300
Price(Lc/Ton)	12507	12749	13011	13229	13458	13757

Table 6.6: Market outlook for Zimbabwe.

YEAR	2002	2003	2004	2005	2006	2007
Area (Hectares)	781617	1289558	1481963	1678975	1709648	1740226
Production (Tons)	977021	1611948	1852454	2098718	2137060	2175282
Change in Stock (Tons)	196465	-161504	150729	289019	408903	430795
Food Use (Ton)	1571142	1602903	1635839	1668640	1702514	1737511
Net Trade (Ton)	-939921	-694726	-174921	176832	301182	326300
Price (Lc/Ton)	13951	13975	13594	13366	13458	13757

Table 6.7: Actual and Percentage change on the Market outlook for Zimbabwe.

YEAR	2002	2003	2004	2005	2006	2007
Change in Area (Hectares)	-781617	-322390	-164663	0	0	0
Area % change	-50	-20	-10	0	0	0
Change in Production (Tons)	-977021	-402987	-205828	0	0	0
Production % change	-50	-20	-10	0	0	0
Change in Change in Stock (Tons)	-97606	-482424	-202942	-93151	0	0
Change in Stock % change	-33	-150	-57	-24	0	0
Change in Food Use (Ton)	-410	-288	-114	-22	0	0
Food Use % change	-0.03	-0.02	-0.01	0	0	0
Change in Net Trade (Ton)	-1074218	-885123	-408657	-93129	0	0
Net Trade % change	-800	-465	-175	-34	0	0
Change in Price (Lc/Ton)	1444	1226	583	137	0	0
Price % change	12	10	4	1	0	0

Area harvested and production had the expected percentage decreases. Both stock change and Zimbabwe's net trade position experienced large adjustments. Net trade became negative as the country moved from being a net exporter to net importer. With maize being a staple food, consumption was not severely affected as demand was met through imports. Maize price in Zimbabwe increased by 12%, 10% and 4% from the baseline forecast in 2002, 2003, and 2004, respectively. For the individual countries, prices increase by varying degrees depending on the effect of the regional net trade on individual country prices. The prices increase until 2005, after which they begin to return to normal. From the above tables it is clear that a long term decrease in area harvested in Zimbabwe would have a long standing negative effect on both Zimbabwe and the region as a whole.

6.3 SADC Maize Market Outlook: South Africa Yield Shock

Since South Africa is the largest maize producer in the SADC region, it was important to evaluate the impacts of a severe decrease in its maize yield levels over a few consecutive years. This was considered to be a plausible future scenario of likely impacts of climate change. The following assumptions were made for South Africa's yield decline scenario: a 25% decrease of the baseline forecast in 2002 and a 15%

decrease in 2003. This yield decline may for example be caused by two consecutive drought years caused by El Nino. Tables 6.8 and 6.9 present the market outlook and actual and percentage changes of the endogenous variables, with respect to the whole of SADC, given the above changes in maize yield in South Africa.

Table 6.8: SADC Market outlook for Maize: South Africa Yield Shock.

YEAR	2002	2003	2004	2005	2006	2007
Total Area (Hectares)	10391423	10511214	10597079	10660247	10724540	10792579
Total Production (Tons)	16448018	17474838	18861817	18925005	18990760	19063355
Total Change in Stock (Tons)	1458261	887765	1201827	1615558	1652387	1684514
Total Food Use (Ton)	16236107	16452792	16689110	16916977	17141802	17373888
Net Trade (Tons)	-697264	-457627	1007095	1256147	1133906	1006540

Table 6.9: SADC Actual and Percentage changes due to South Africa Yield Shock

YEAR	2002	2003	2004	2005	2006	2007
Change in Total Area (Hectares)	0	20663	26375	14111	5997	2886
Total Area % change	0.00	0.20	0.25	0.13	0.06	0.03
Change in Total Production (Tons)	-2154279	-1245673	49432	27699	12829	6770
Total Production % change	-11.58	-6.65	0.26	0.15	0.07	0.04
Change in Total Change in Stock (Tons)	-14292	-626925	-362562	7909	4403	1970
Change in Stock % change	-0.97	-41.39	-23.18	0.49	0.27	0.12
Change in Total Food Use (Ton)	-18421	-26545	-19418	-12529	-8160	-5311
Total Food Use % change	-0.11	-0.16	-0.12	-0.07	-0.05	-0.03
Change in Net Trade (Tons)	-2150150	-1846053	-293711	48137	25392	14051
Net Trade % change	-148	-133	-23	4	2	1

It is evident that a decrease in yield levels in South Africa will have profound effects on the region as a whole. The region became a net importer of maize for the years 2002 and 2003 and a net exporter again only in 2004. Area harvested increased in the region, but only by 0.2 % in 2003, 0.25 % in 2004, and 0.13 % in 2005, allowing production to recover in 2004. It is interesting to note that the regions' area harvested continued to increase well up to 2007, an almost over compensating effect. Similarly, food consumption continued to decrease due to the increase in prices. Tables 6.10 to

6.12 provide the baseline forecast, market outlook and actual and percentage changes caused by decreased yields for South Africa.

Table 6.10: Baseline Forecast for South Africa

YEAR	2002	2003	2004	2005	2006	2007
Area (Hectares)	3474644	3468184	3462612	3457535	3452774	3448259
Production (Ton)	8651864	8635779	8621904	8609263	8597408	8586166
Change in Stock (Ton)	80613	79309	78898	78623	78430	78232
Food Use (Ton)	3750774	3737011	3716771	3688527	3654901	3618995
Animal Feed (Ton)	3664770	3677800	3695443	3711143	3726508	3747001
Net Trade (Ton)	1444162	1432177	1420699	1420920	1427835	1432521
Price(Lc/Ton)	1158	1247	1330	1424	1525	1612

Table 6.11: Market outlook for South Africa

YEAR	2002	2003	2004	2005	2006	2007
Area (Hectares)	3474644	3469579	3465420	3460583	3455406	3450317
Production (Tons)	6497584	7355508	8628896	8616852	8603962	8591288
Change in Stock (Tons)	69215	69339	78714	81195	80340	79439
Food Use (Ton)	3747641	3732366	3713276	3686260	3653433	3618047
Animal Feed (Ton)	3650708	3656932	3679688	3700861	3719804	3742631
Net Trade (Ton)	-695789	-439605	1079565	1440952	1443352	1443934
Price(Lc/Ton)	1197	1312	1385	1465	1555	1634

Table 6.12: Actual and Percentage change on the Market outlook for South Africa.

YEAR	2002	2003	2004	2005	2006	2007
Change in Area (Hectares)	0	1395	2808	3048	2632	2057
Area % change	0	0.04	0.08	0.09	0.08	0.06
Change in Production (Tons)	-2154279	-1280271	6991	7589	6554	5122
Production % change	-24.9	-14.8	0.1	0.1	0.1	0.1
Change in Change in Stock (Tons)	-11398	-9970	-184	2573	1910	1207
Change in Stock % change	-14.1	-12.6	-0.2	3.3	2.4	1.5
Change in Food Use (Ton)	-3133	-4645	-3495	-2268	-1467	-948
% Food Use change	-0.1	-0.1	-0.1	-0.1	0	0
Change in Animal Feed	-14062	-20868	-15755	-10282	-6704	-4370
Animal Feed % change	-0.4	-0.6	-0.4	-0.3	-0.2	-0.1
Change in Net Trade (Ton)	-2139951	-1871782	-341135	20032	15517	11414
Net Trade % change	-148.2	-130.7	-24	1.4	1.1	0.8
Change in Price(Lc/Ton)	38.66	65.14	55.41	40.98	30.33	22.14
Price % change	3.3	5.2	4.2	2.9	2	1.4

Decreased maize yields caused a 25 % decrease in production for South Africa in 2002 that caused real maize price in that year to increase by 3.3% and 5.2 % in 2003. This increase in price prompted farmers to increase the area harvested by 0.04 % in 2003. However, 2003 also experienced a decrease in yield, and thus production fell again even though area harvested increased. As can be seen from table 5.12 the South African maize price continued to increase from the baseline projection well into 2007, and as a consequence, so did area harvested. This can be attributed to the depletion of stocks and the countries net maize trade position becoming negative.

CHAPTER SEVEN: Conclusions And Implications

It is of high interest to policy makers to be able to evaluate the implications of continuing market liberalization and deregulation in most SADC countries on the supply and availability of maize, the main food staple in the region. However, no comprehensive formal commodity models have been developed yet that provide adequate understanding of the functioning of maize markets and allow for study of the structural nature of their regional supply and demand components. This represents a serious knowledge gap limiting the ability of policy makers to properly plan for controlling the supply and availability of such a basic food commodity in the face of ever changing and uncertain economic and physical environments. The present research project made an attempt to develop and use a structural maize commodity model to address and analyse some of the said aspects for improved food security within the SADC region through regional integration of maize production and trade.

The developed SADC maize commodity model consists of 64 equations, of which 28 are behavioral equations and the remaining identities. The model is made up of three main blocks, a supply block, a demand block, and a price linkage block. As stated previously data limitation has been a major factor in formulating the model. Relying on data from the FAO Statistics, the specified model equations were estimated using the 2SLS technique. The market clearing identity for each country was net trade, which was then combined to give a regional net trade position with the rest of the world. The model was validated through a series of statistical tests, which showed that the model has a very good predictive power for forecasting changes in the conditions of regional supply and use of maize in the SADC countries.

Empirical estimation results showed that the SADC countries do respond to changes in the world price of maize. Estimated elasticities however, were low with all short and long run elasticities of maize supply and demand of less than one. Estimated short run supply elasticities for the individual countries ranged between 0.043 and 0.360, whereas the long run maize supply elasticities were between 0.066 and 0.448.

The estimated model was then used to evaluate the impacts of a few plausible future scenarios of changing economic and physical environments, which included:

1). The impact of the current Zimbabwe crisis.
2). A decrease in yield shock in South Africa in consequence to climate change impacts.
3). An increase in inflation across all SADC countries

The scenario simulations results indicated that political instability and climate fluctuations are important forces influencing the status of food availability and security in the SADC region. This is clear from the Zimbabwe crisis simulation results where a reduction in area of maize harvested in Zimbabwe had significant impacts on the status of maize supply and prices in the entire SADC region. Similarly, a yield shock caused by variations in climatic conditions had serious implications for maize supply and the net trade in maize position of the region. For instance, a decrease in maize yield in South Africa, the regions bread basket, caused the entire region to become food insecure relying heavily on imports. This also had important implications for the poor as increased reliance on imports, due to the fall in regional supply increased local maize prices, which given the fact that maize is the main food staple, would negatively affect the poor. This calls for creative measures of reserve stocks management to mitigate the negative effects of such factors of political instability and climate fluctuations.

7.1 Limitations of the Study and Future Research

As stated previously, for almost all countries in the Southern Africa region agricultural data are very imprecise in general and particularly very poor for the subsistence farming sector. This was the main reason behind the inability of this study to account for subsistence maize production and assess the sensitivity of maize availability to perturbations in this sector, which is a major maize supply sector in the SADC region. Given the fact that this study employed a partial equilibrium framework, it could not provide an assessment of the economy-wide effects of changes in maize availability and use. Modeling linkages with other agricultural commodities and non-agricultural economic activities would give a better picture of the impacts of movements in the SADC regional maize trade balances. Accordingly, future studies should strive to take into consideration some of the above described limitations of this work. The preliminary results of this study also suggest the importance of proper incorporation and measurement of weather factors and price risks elements in the structure of the SADC regional maize model. Finally this study assumes no trade restrictions on maize are in place in any SADC, hence future studies should account for plausible trade restrictions on maize movements within the region.

Taking into account the economic conditions of most of the SADC countries and the impact of imports of maize on the trade balance, most of these countries should focus on increasing maize productivity through improved trade regimes to enhance exploitation of comparative advantage in maize production in order to improve food security. Finally this model can be easily updated and hence has a great potential to be used to address a variety of policy questions other than those analyzed here.

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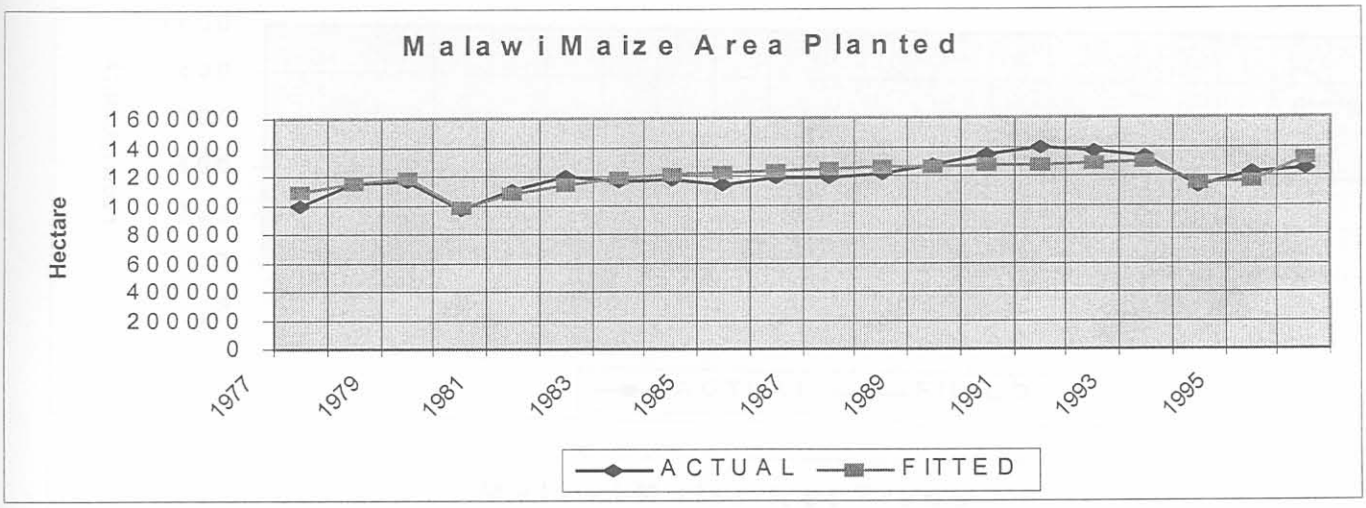
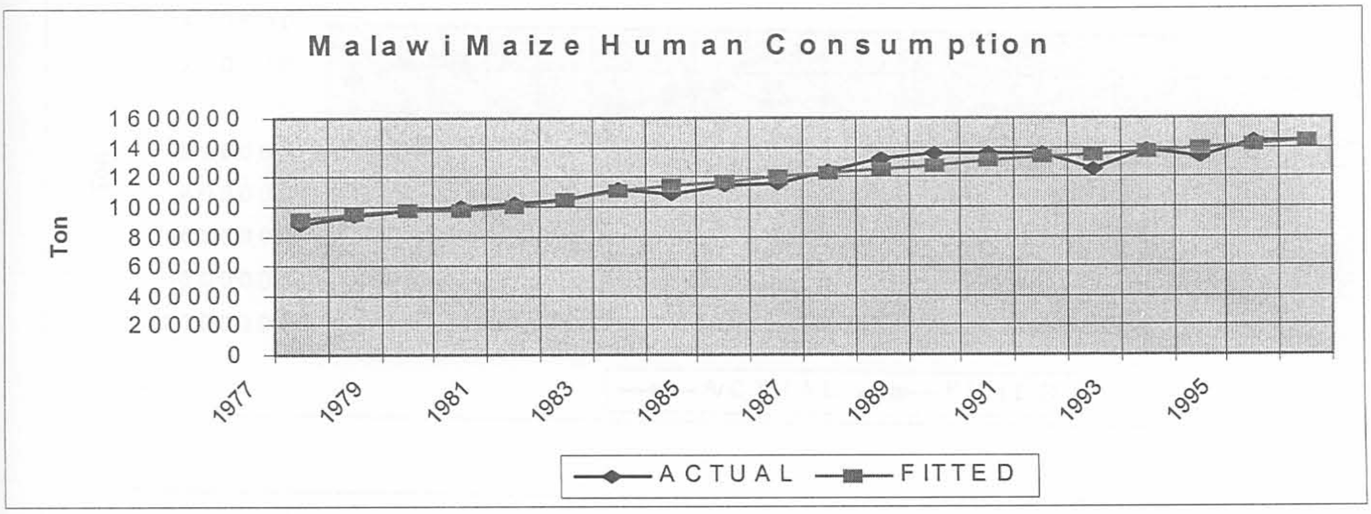
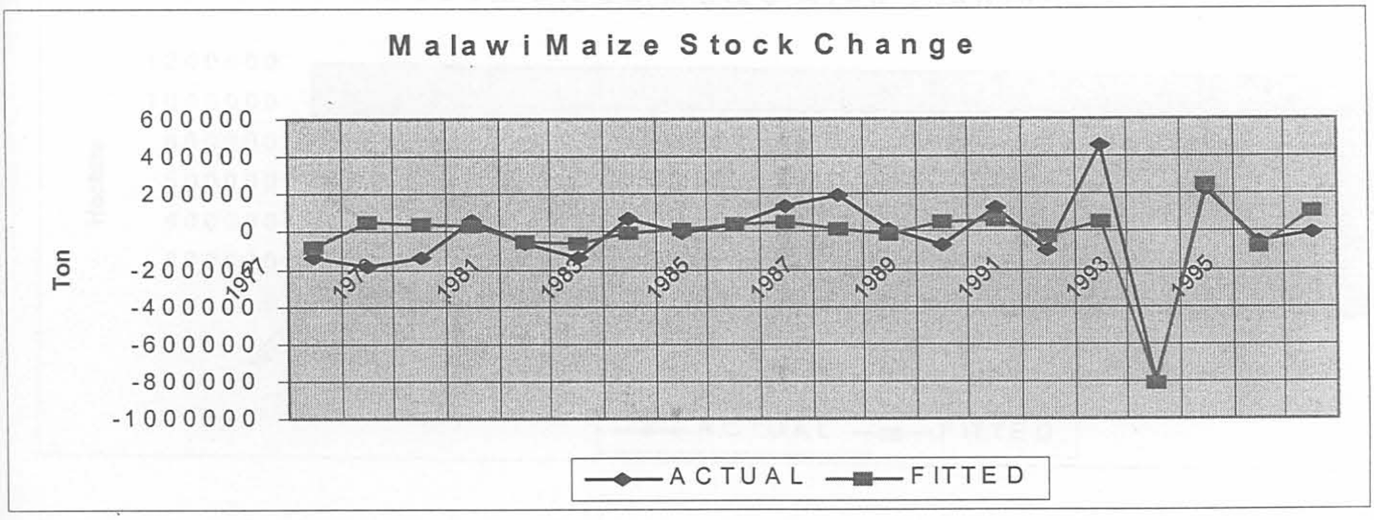
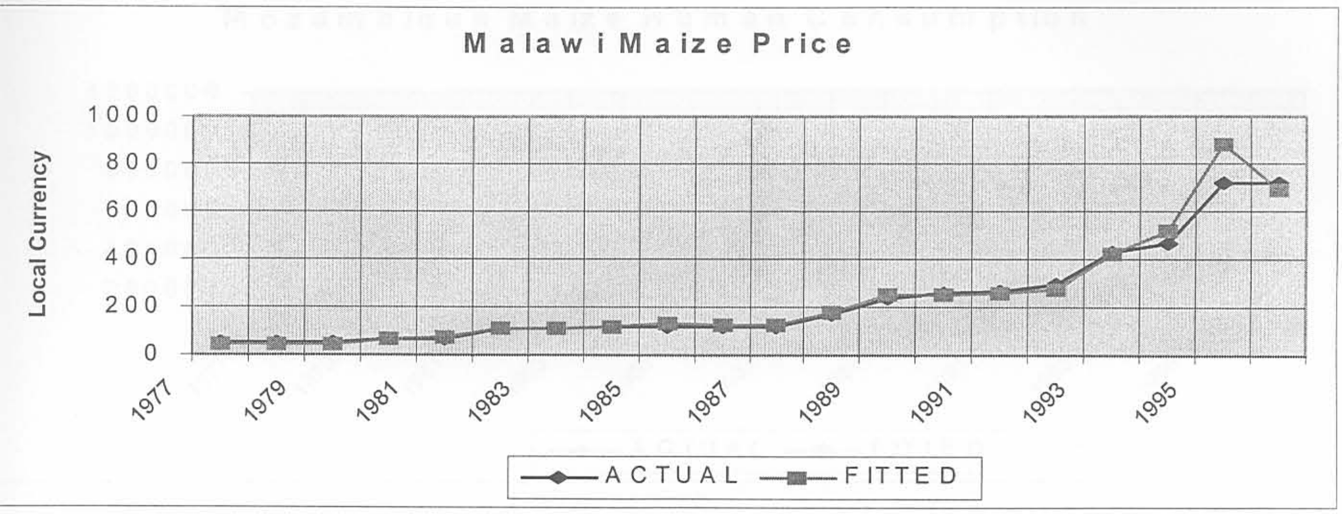
APPENDIX A

SIMULATION RESULTS








Malawi Maize Price
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1000
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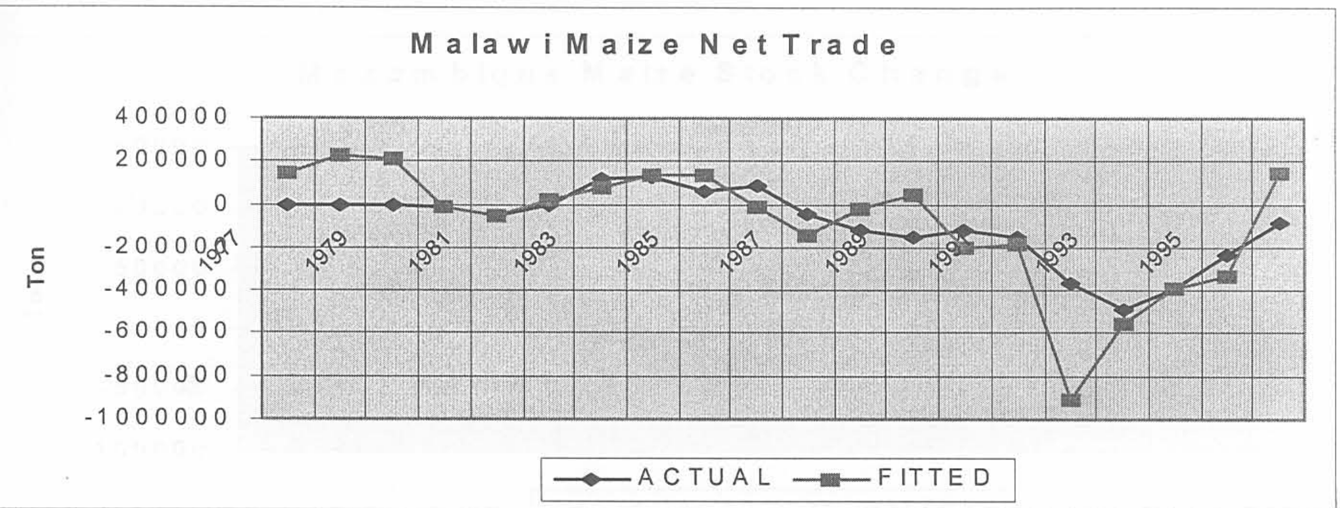
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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Ton
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200000
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-200000
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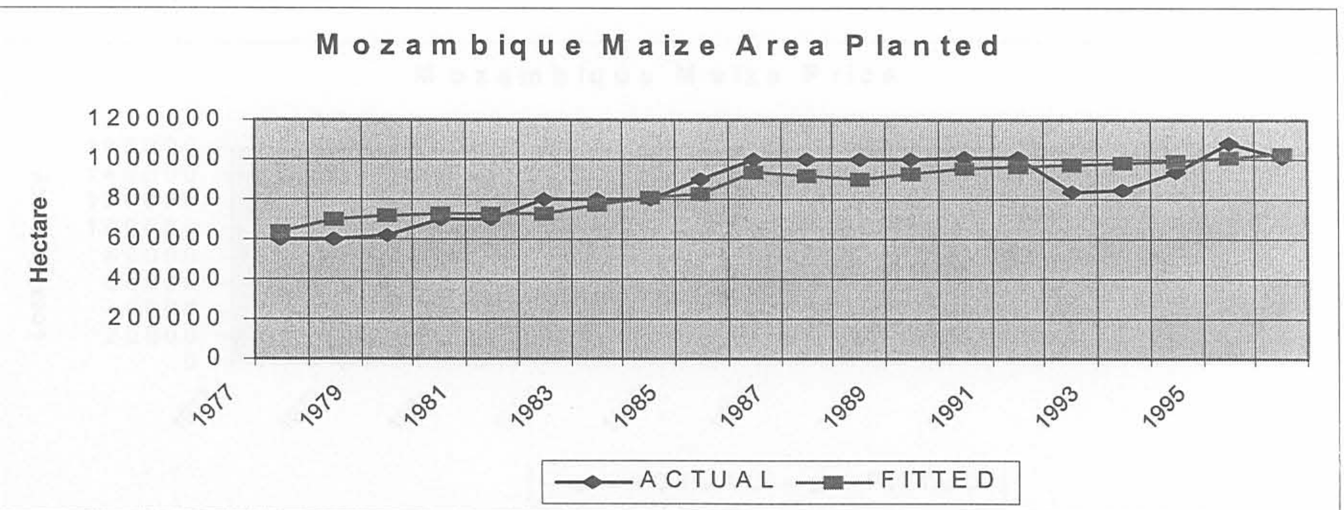
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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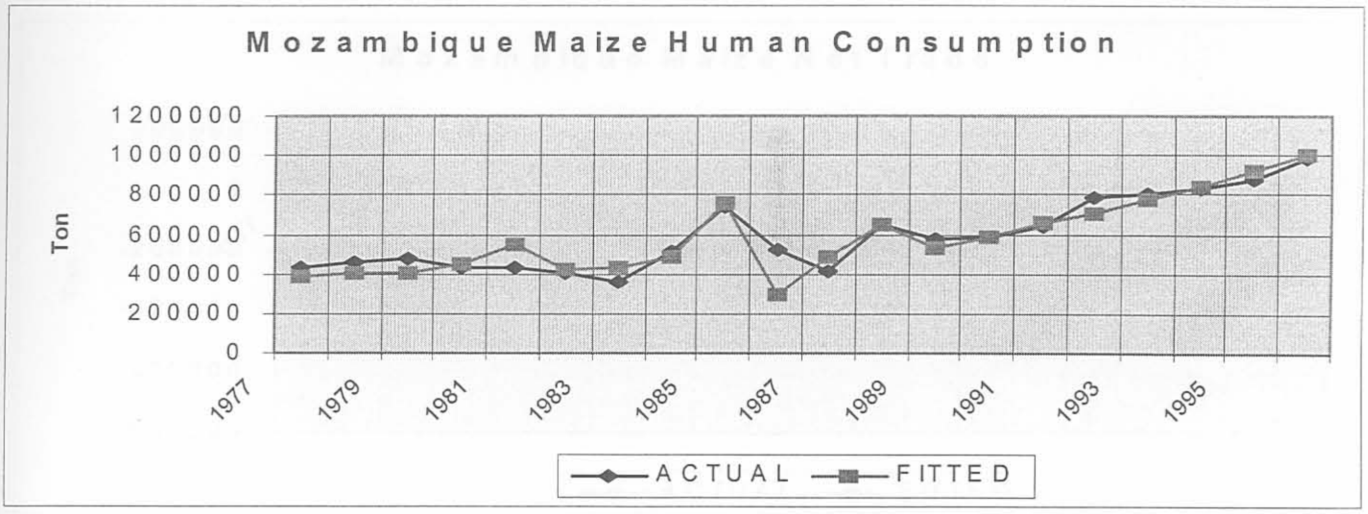
1200000
1000000
800000
600000
400000
200000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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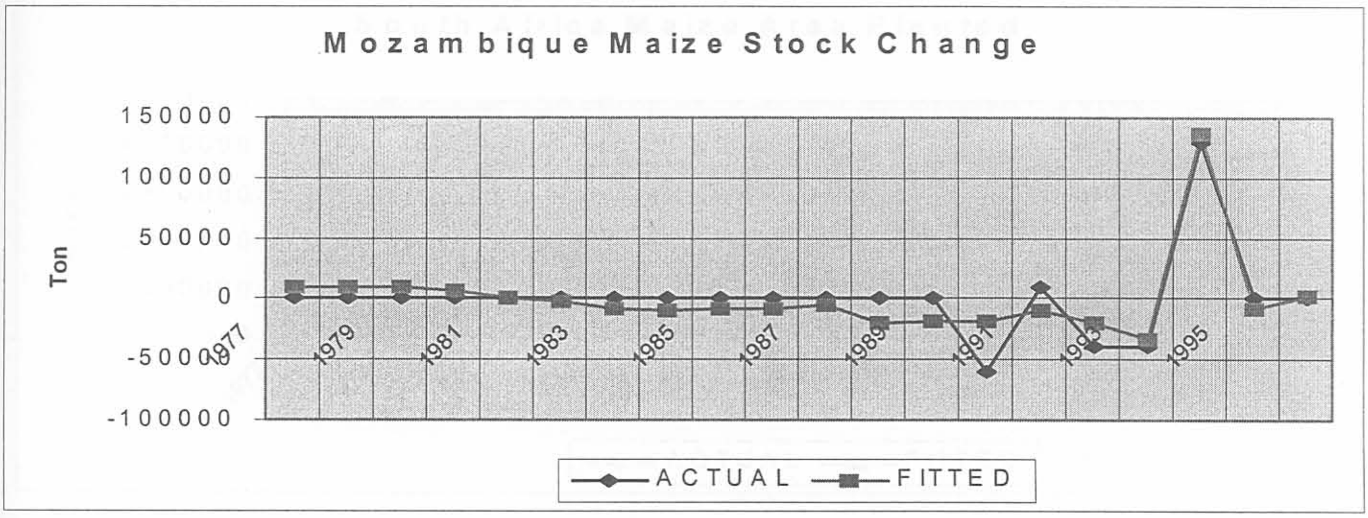
1200000
1000000
800000
600000
400000
200000
0
Ton
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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Ton
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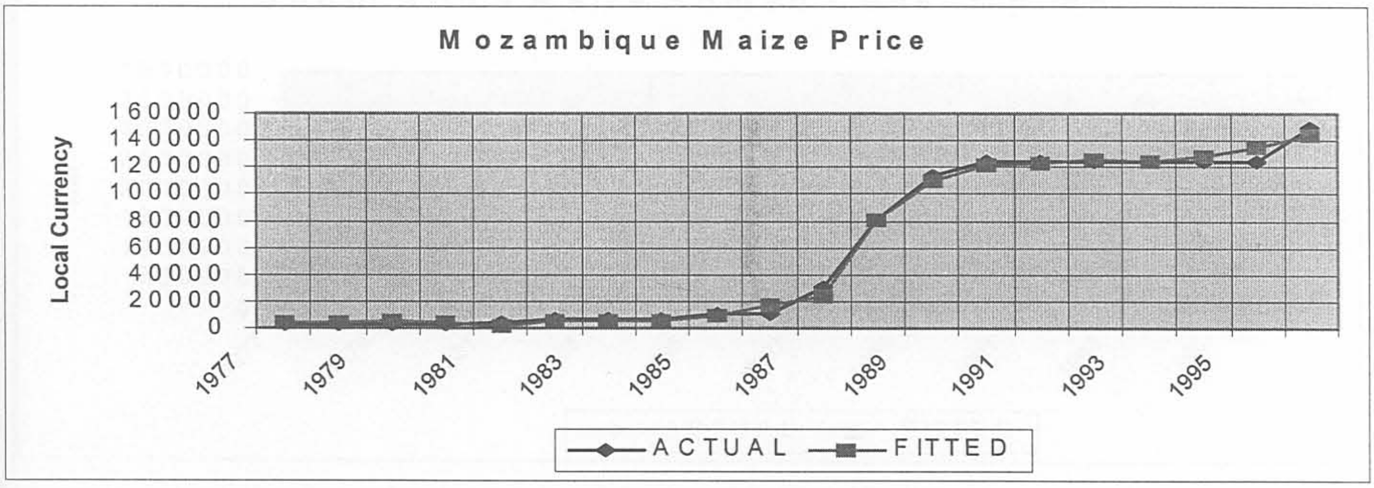
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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120000
100000
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60000
40000
20000
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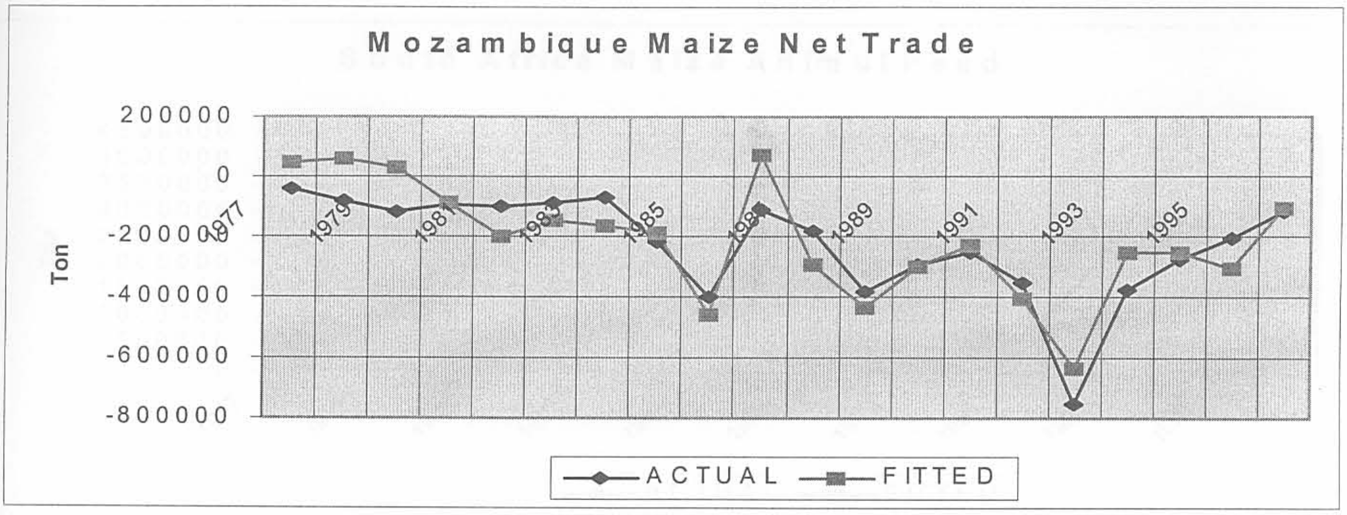
Local Currency
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED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Ton
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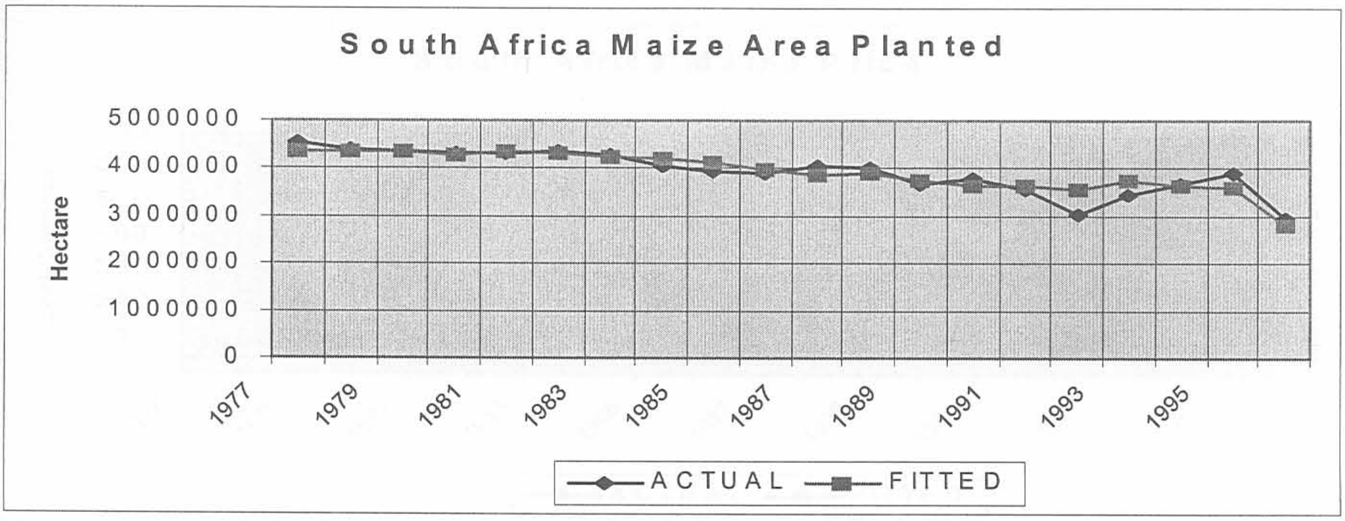
0
-200000
-400000
-600000
-800000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


South Africa Maize Area Planted
Hectare
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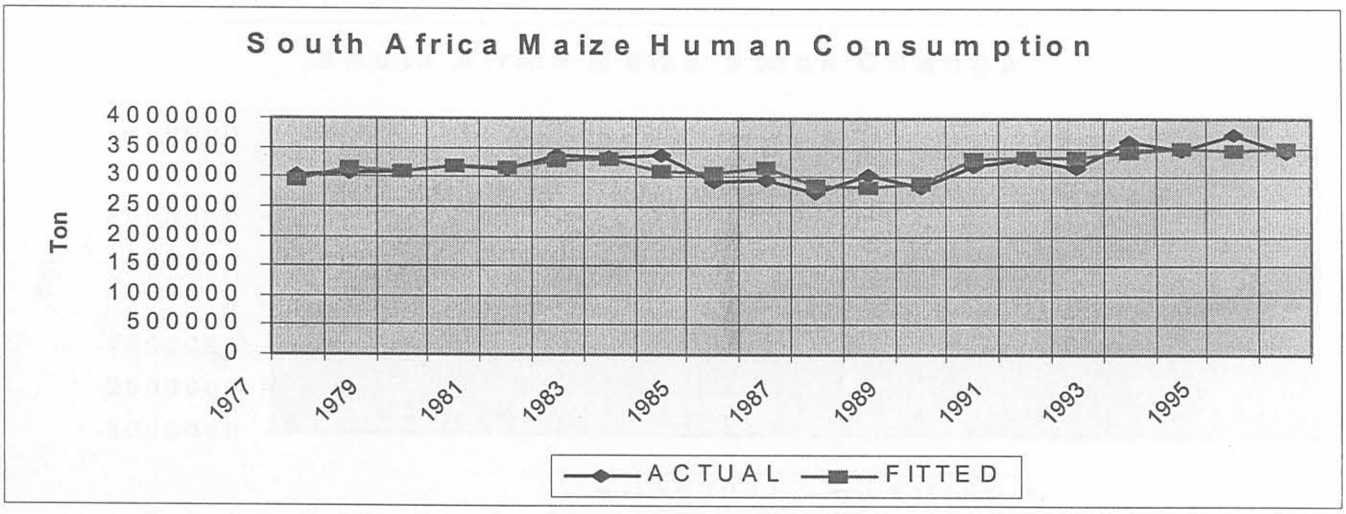
3000000
2000000
1000000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


South Africa Maize Human Consumption
Ton
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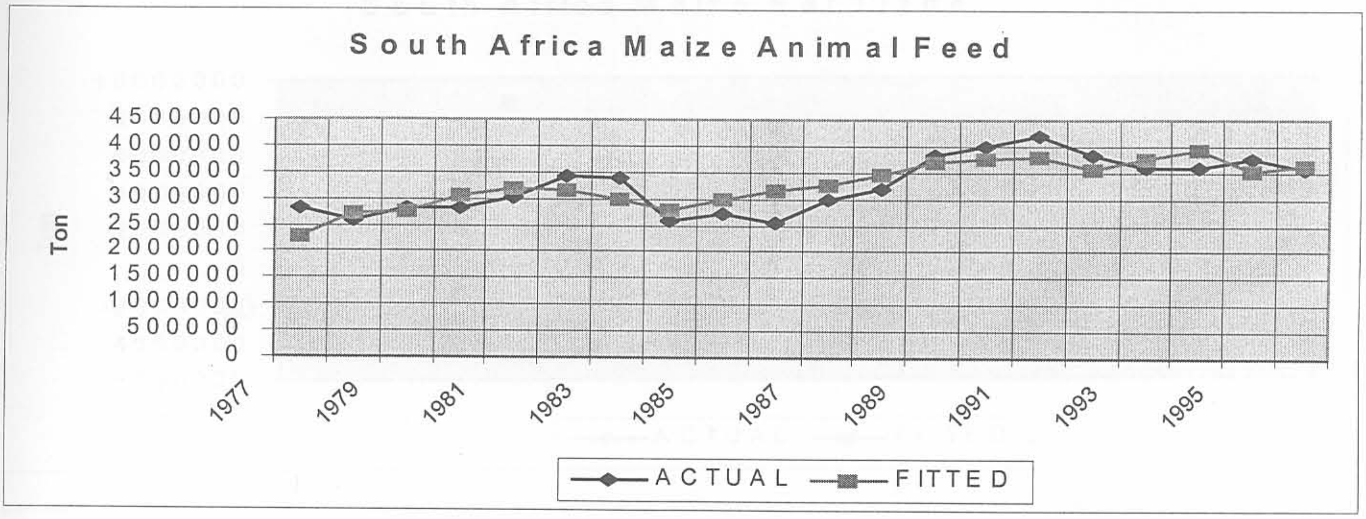
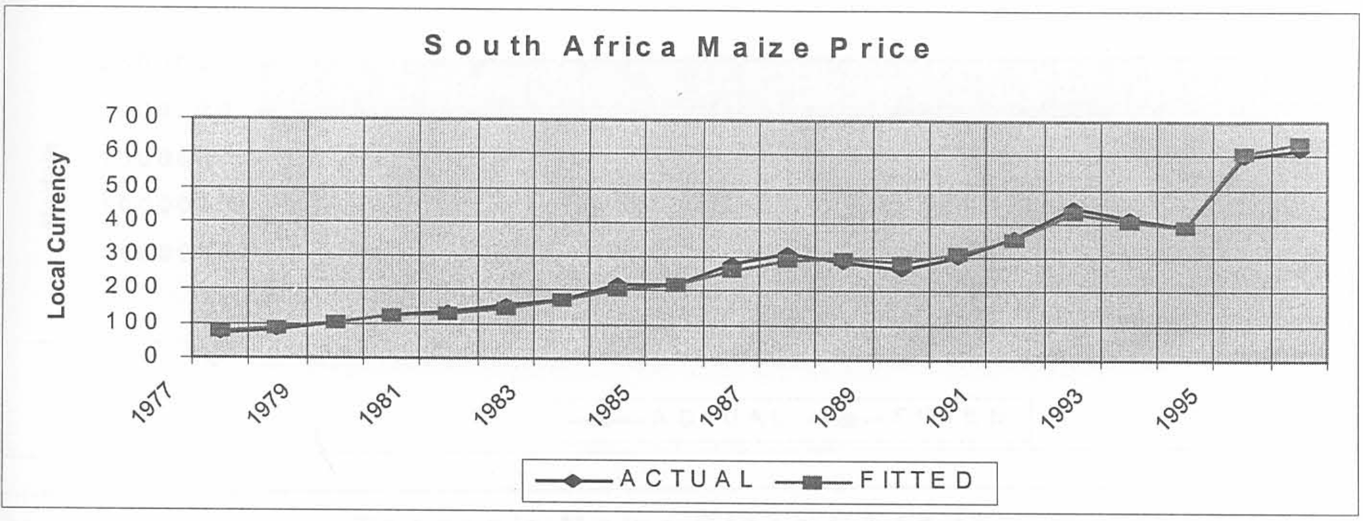
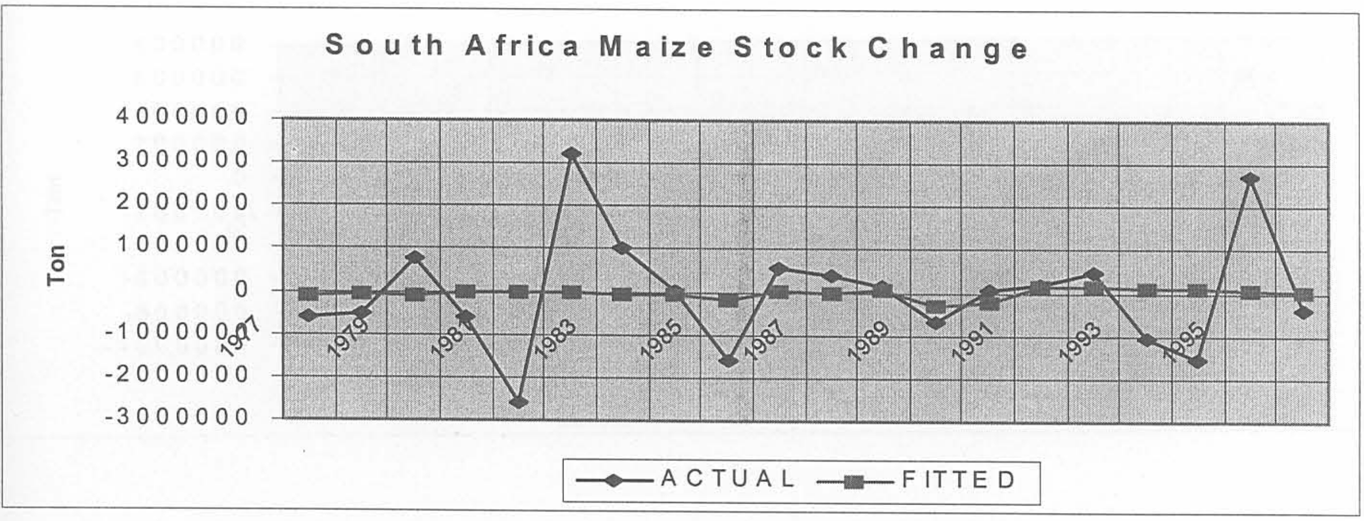
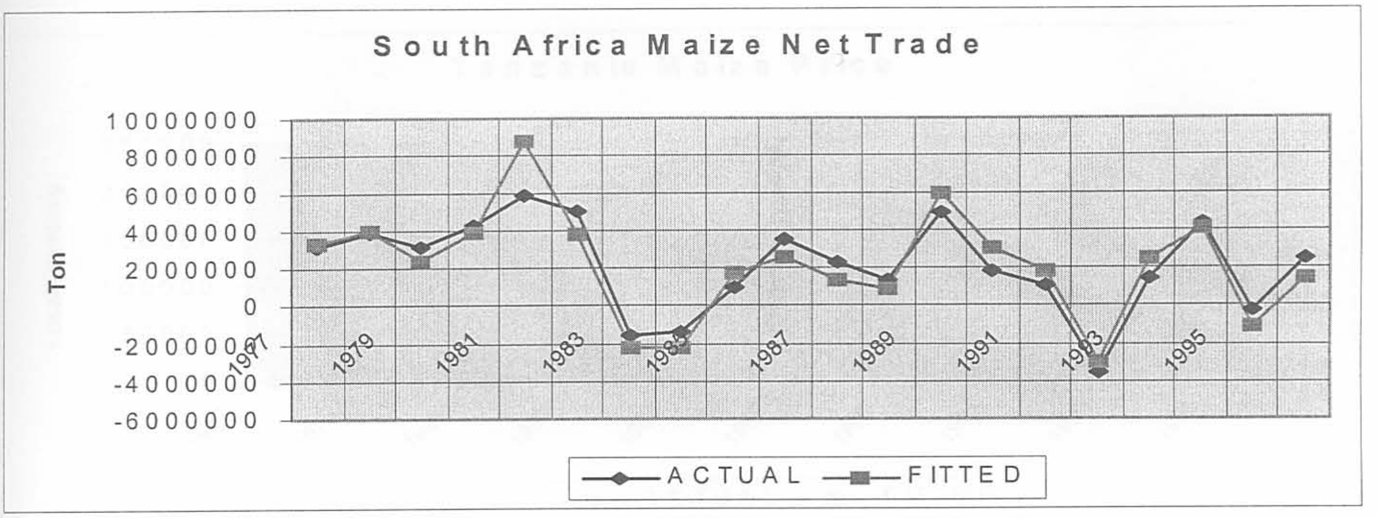
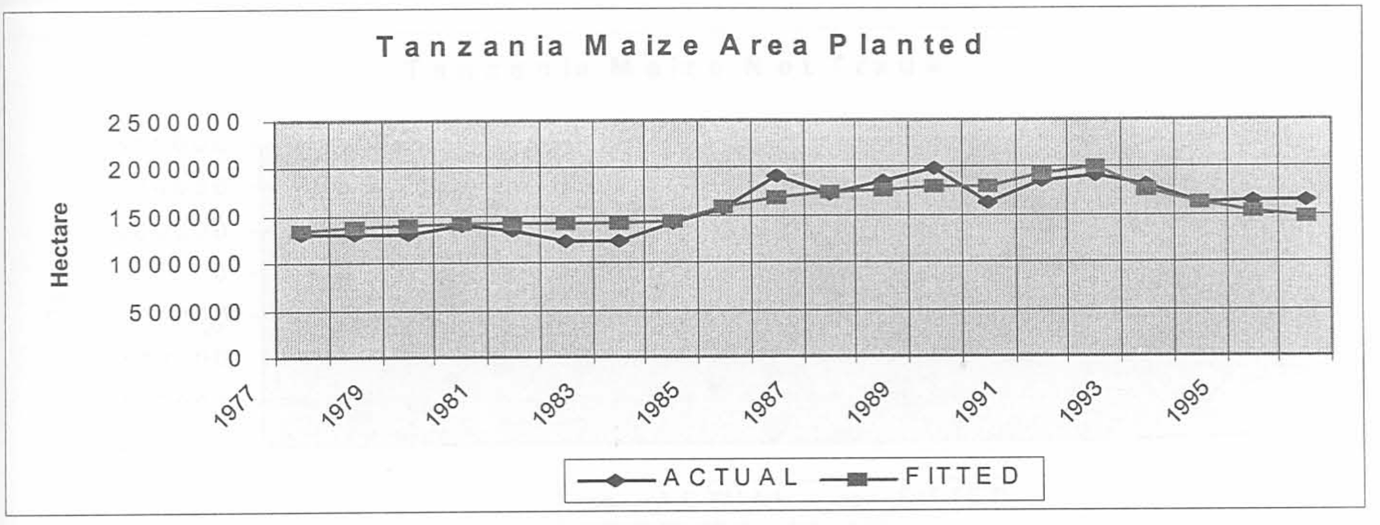
3000000
2500000
2000000
1500000
1000000
500000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

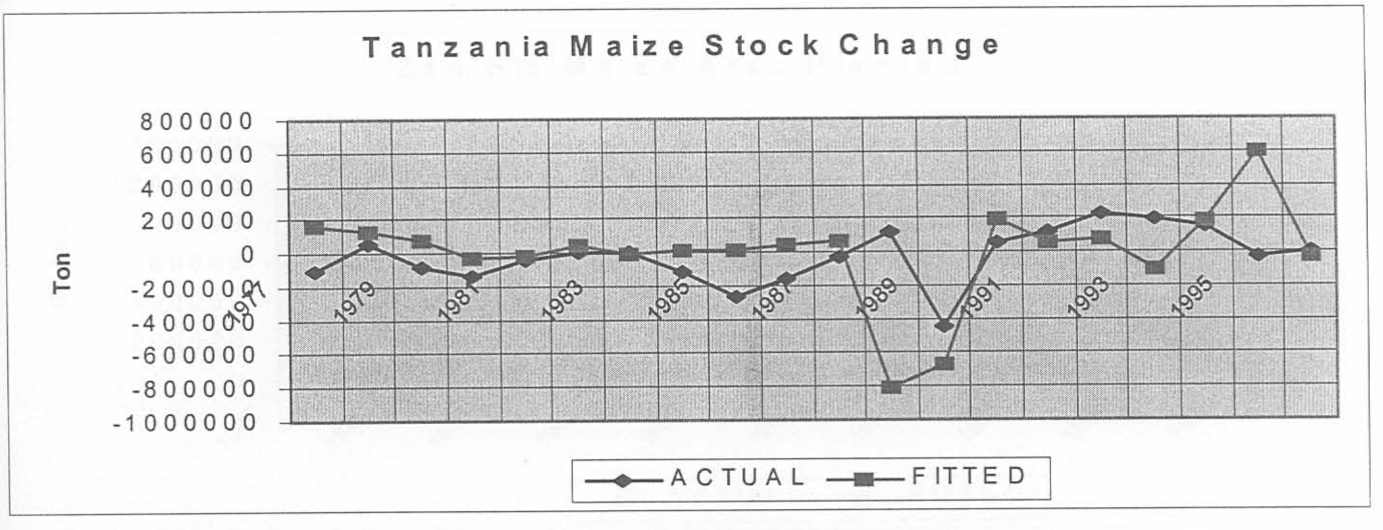

South Africa Maize Animal Feed
Ton
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

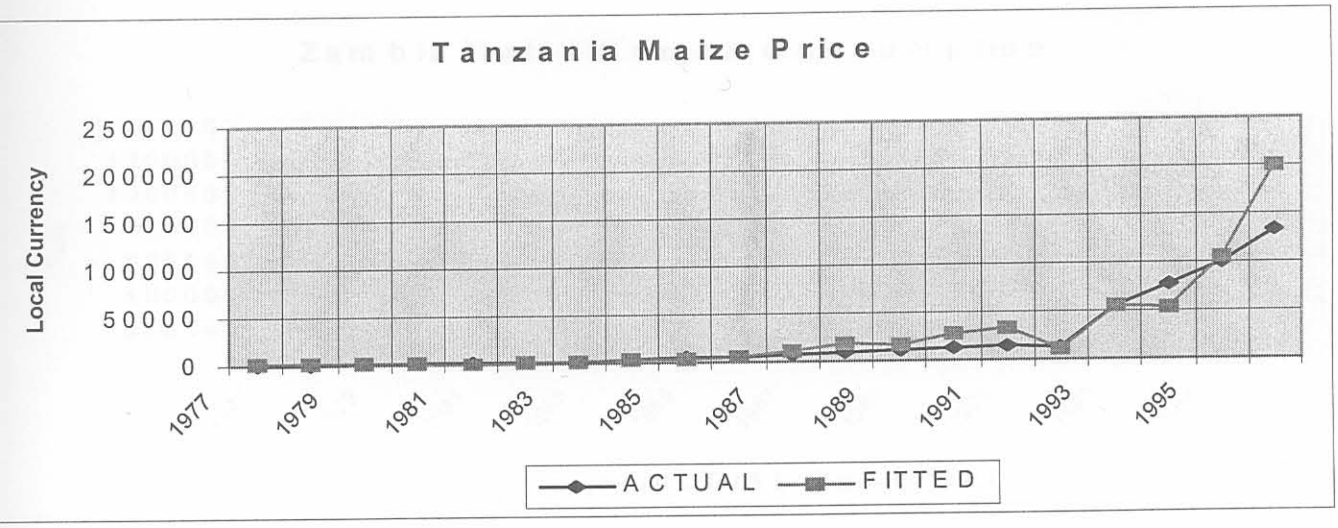

South Africa Maize Price
Local Currency
700
600
500
400
300
200
100
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

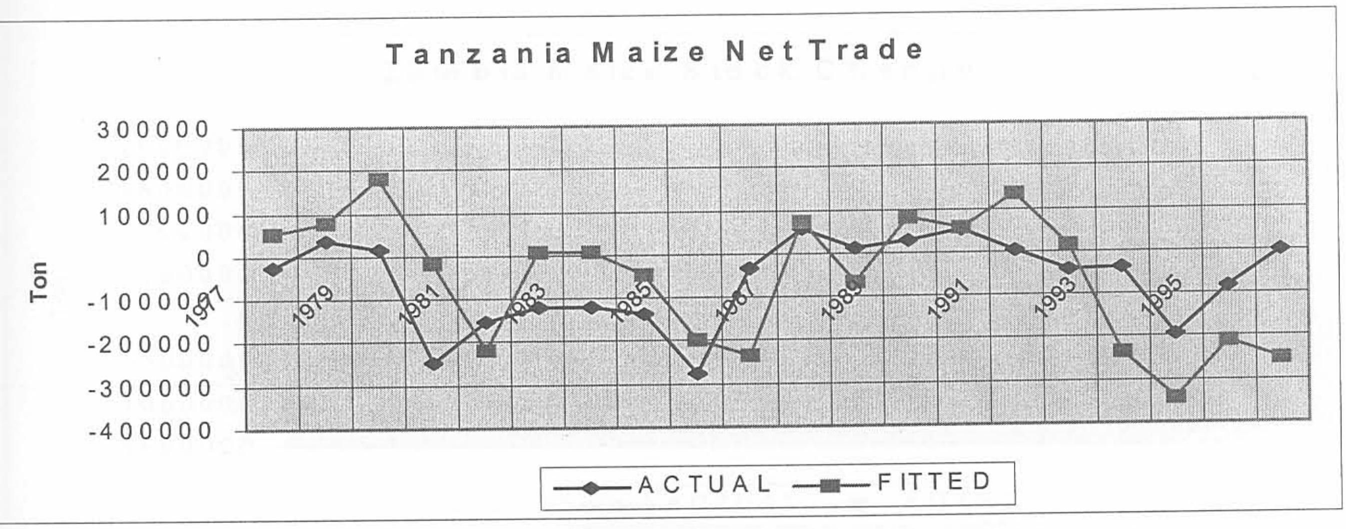

South Africa Maize Stock Change
Ton
4000000
3000000
2000000
1000000
0
-1000000
-2000000
-3000000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

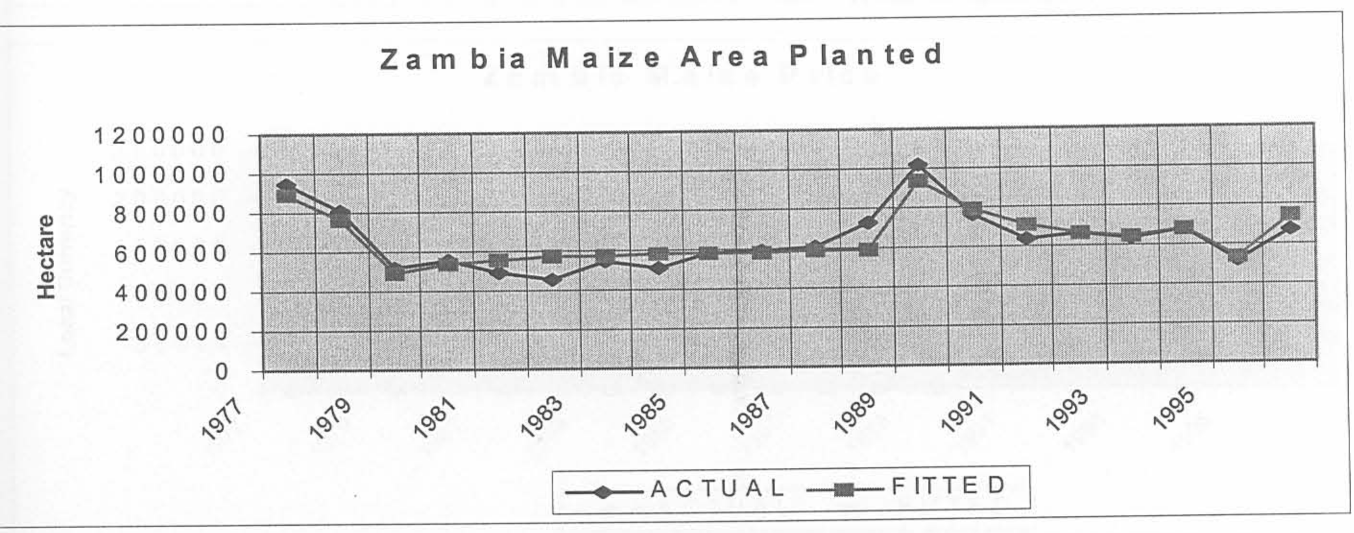

South Africa Maize Net Trade
Ton
10000000
8000000
6000000
4000000
2000000
0
-2000000
-4000000
-6000000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

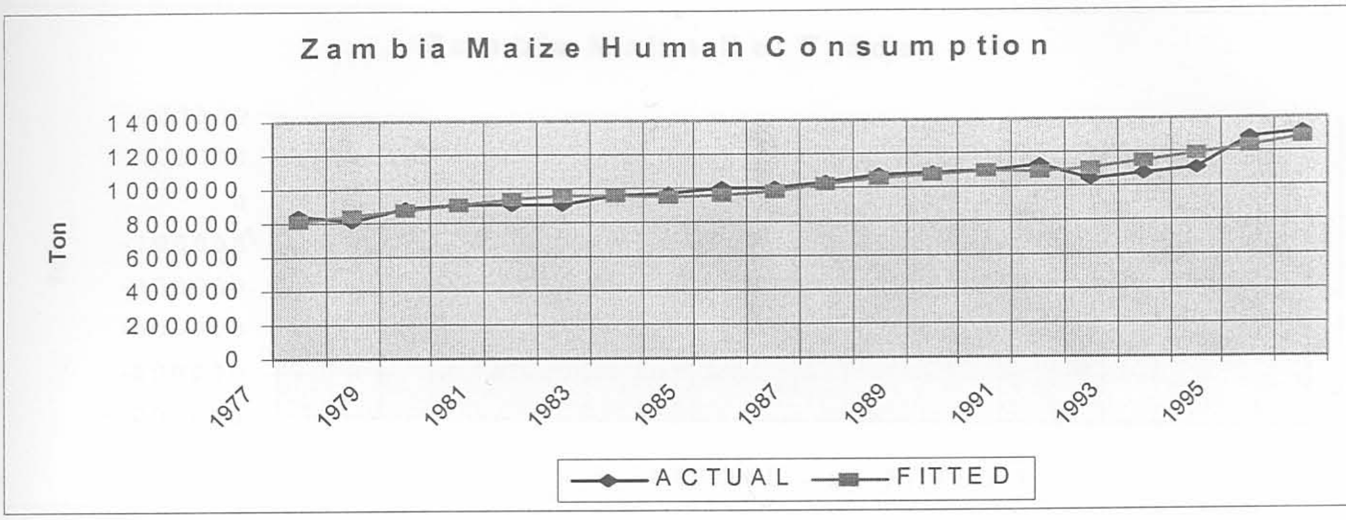

Tanzania Maize Area Planted
Hectare
2500000
2000000
1500000
1000000
500000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

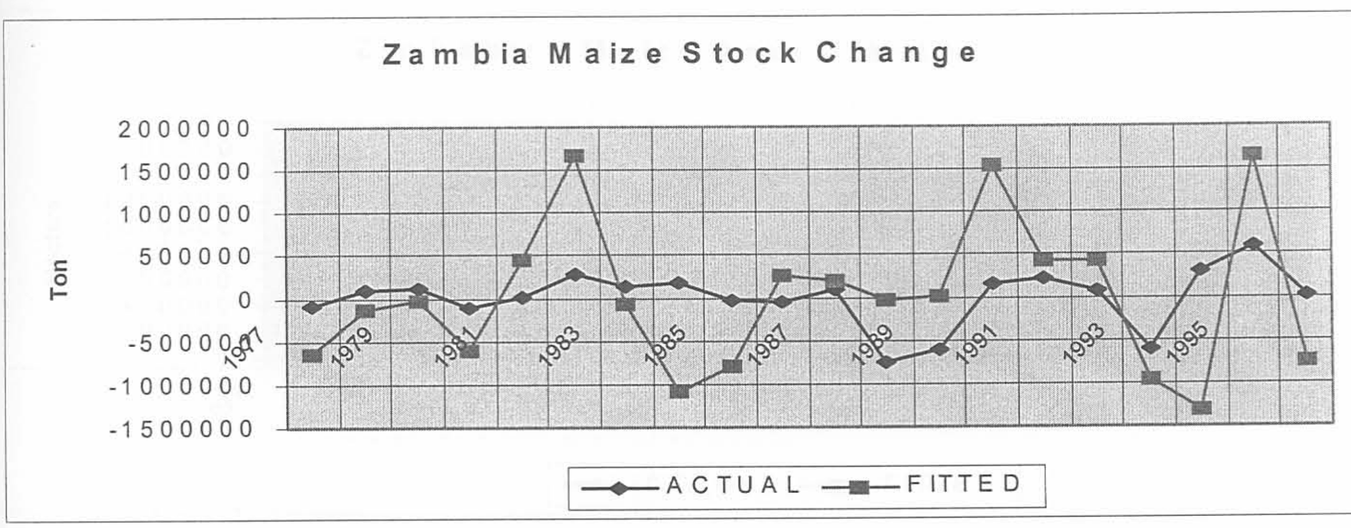

Tanzania Maize Stock Change
Ton
800000
600000
400000
200000
0
-200000
-400000
-600000
-800000
-1000000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

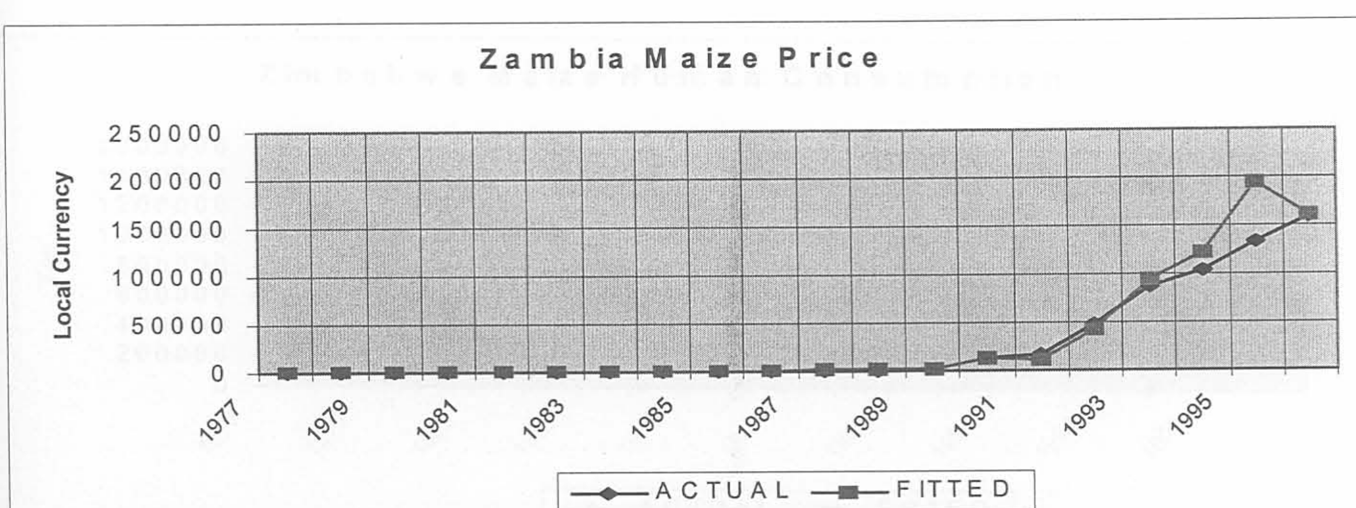

Tanzania Maize Price
Local Currency
250000
200000
150000
100000
50000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

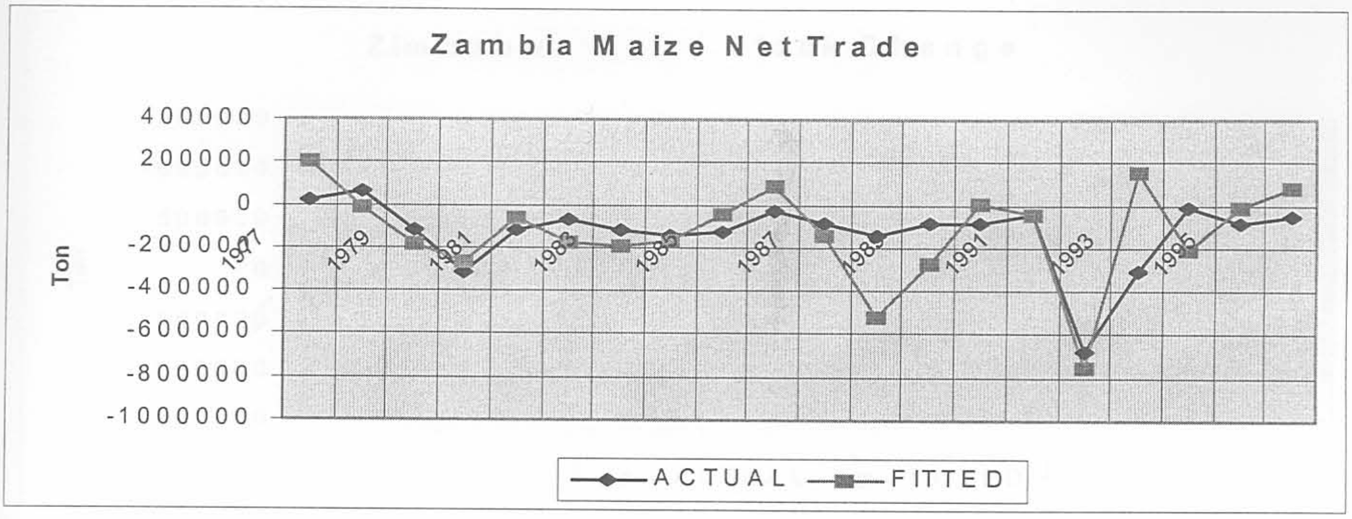

Tanzania Maize Net Trade
Ton
300000
200000
100000
0
-100000
-200000
-300000
-400000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

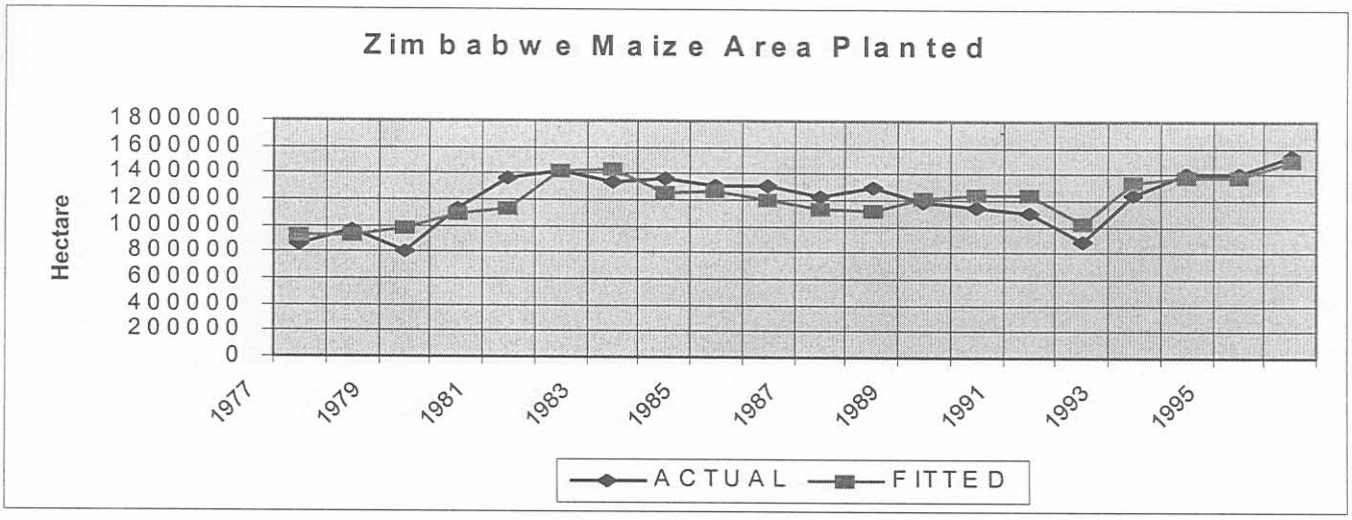

Zambia Maize Area Planted
Hectare
1200000
1000000
800000
600000
400000
200000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

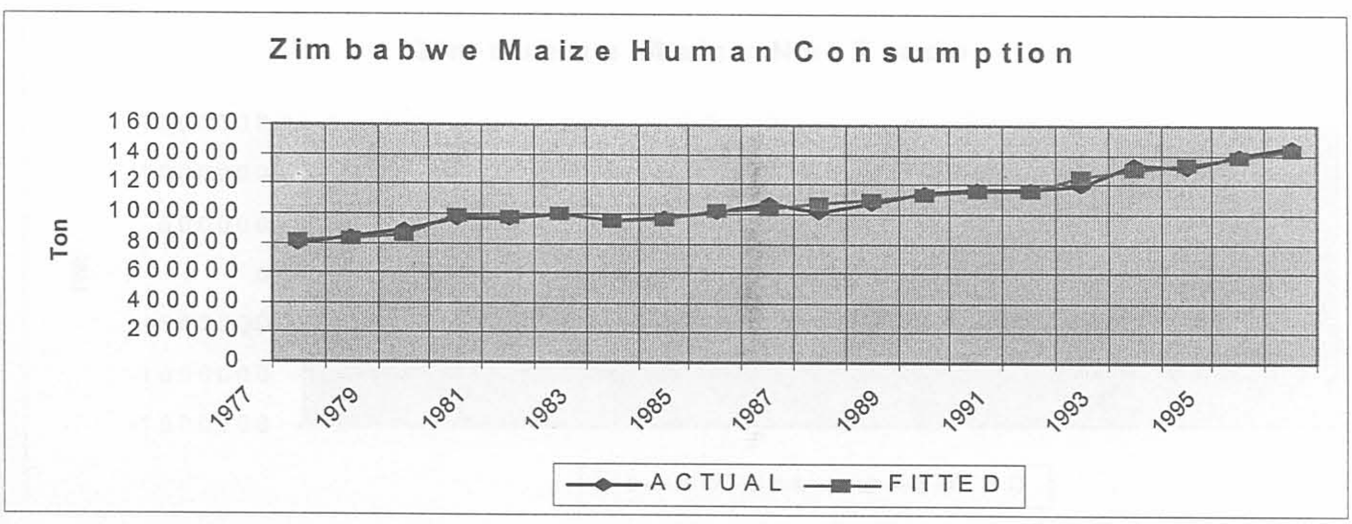

Zam bia M aize H um an C onsum ption
Ton
1400000
1200000
1000000
800000
600000
400000
200000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

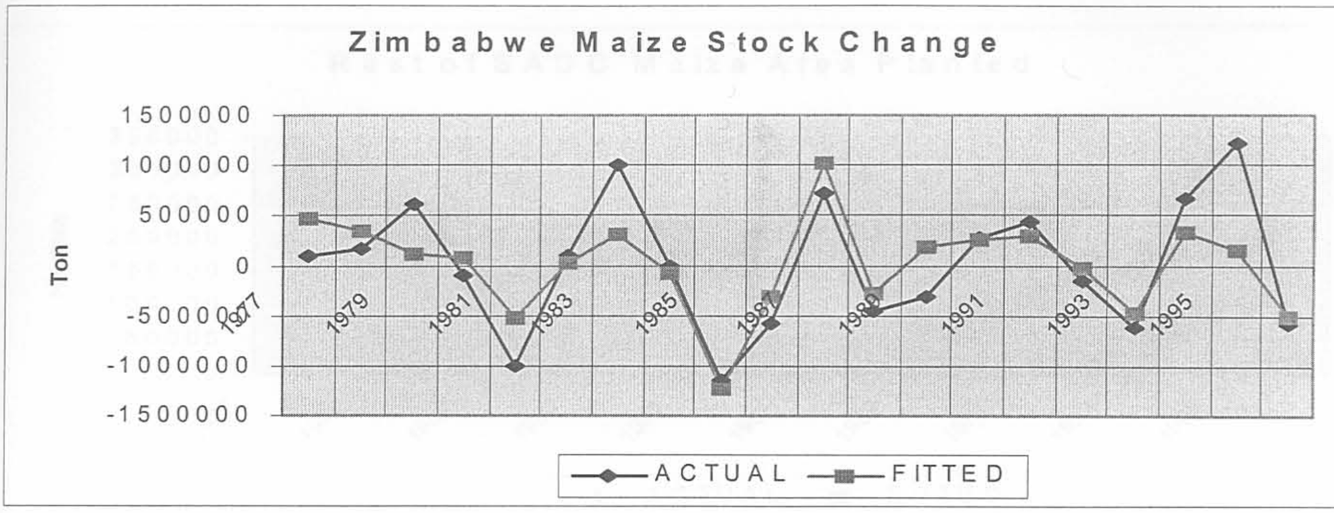

Zam bia M aize Stock Change
Ton
2000000
1500000
1000000
500000
0
-500000
-1000000
-1500000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

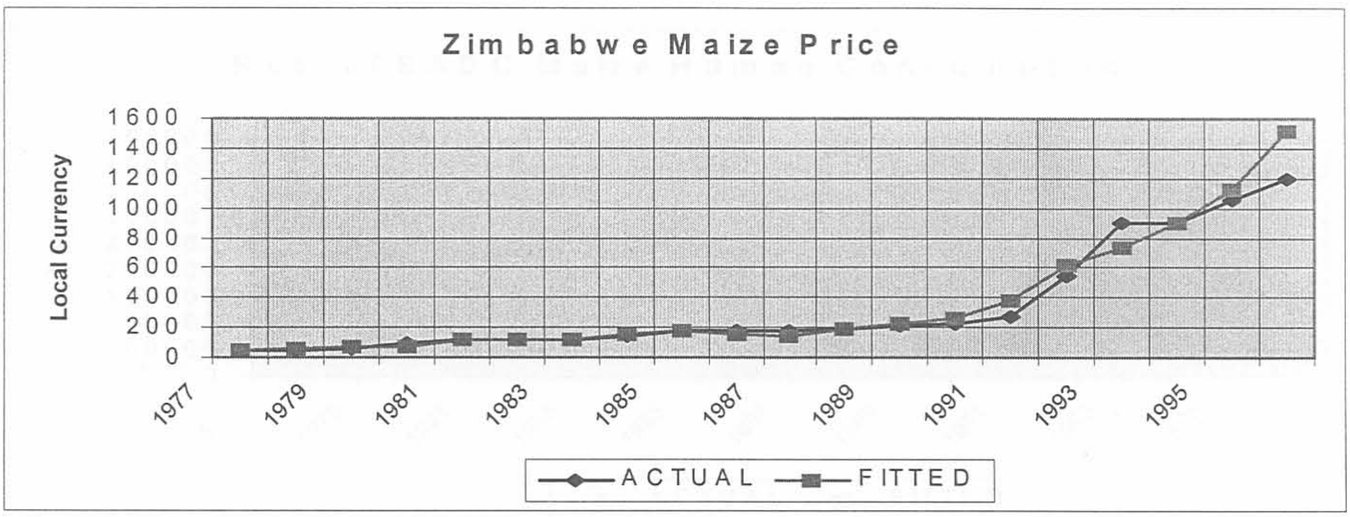

Zam bia M aize Price
Local Currency
250000
200000
150000
100000
50000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

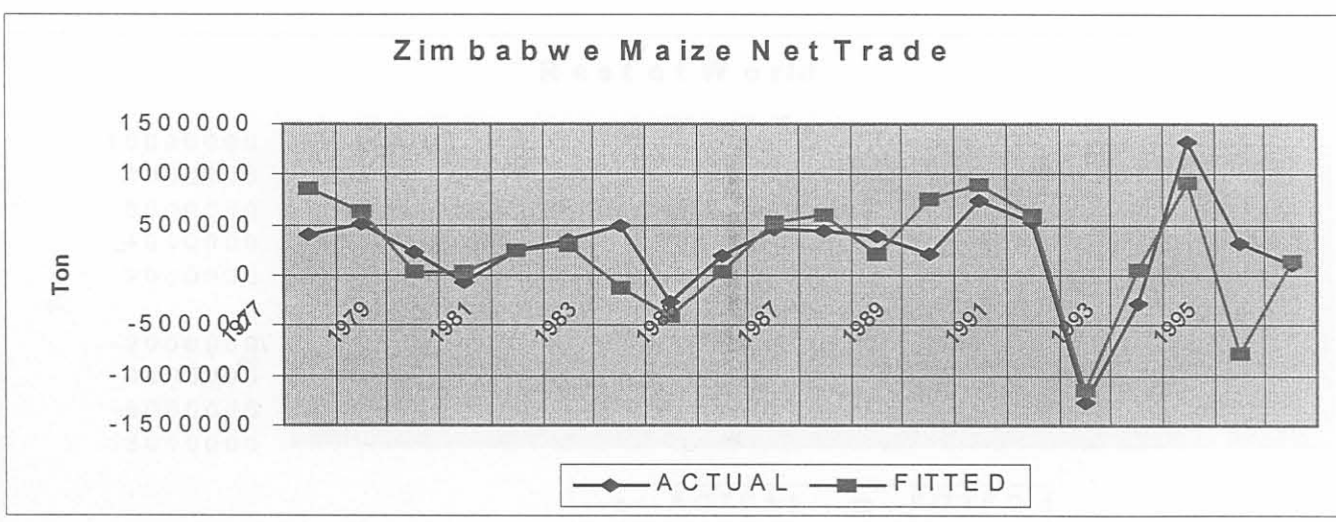

Zambia Maize Net Trade
Ton
400000
200000
0
-200000
-400000
-600000
-800000
-1000000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

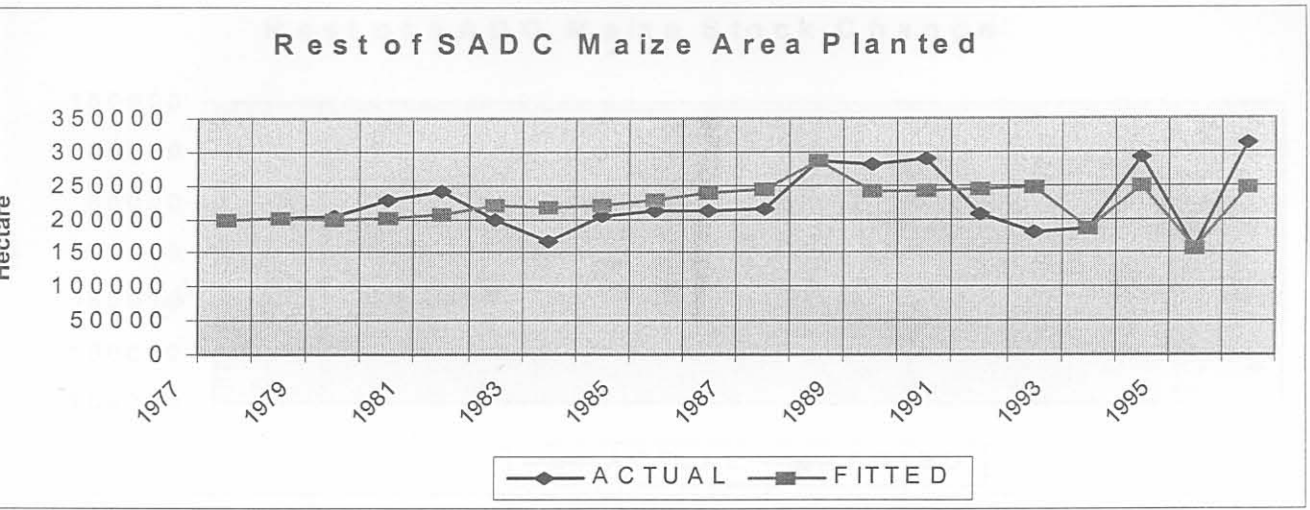

Zimbabwe Maize Area Planted
Hectare
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

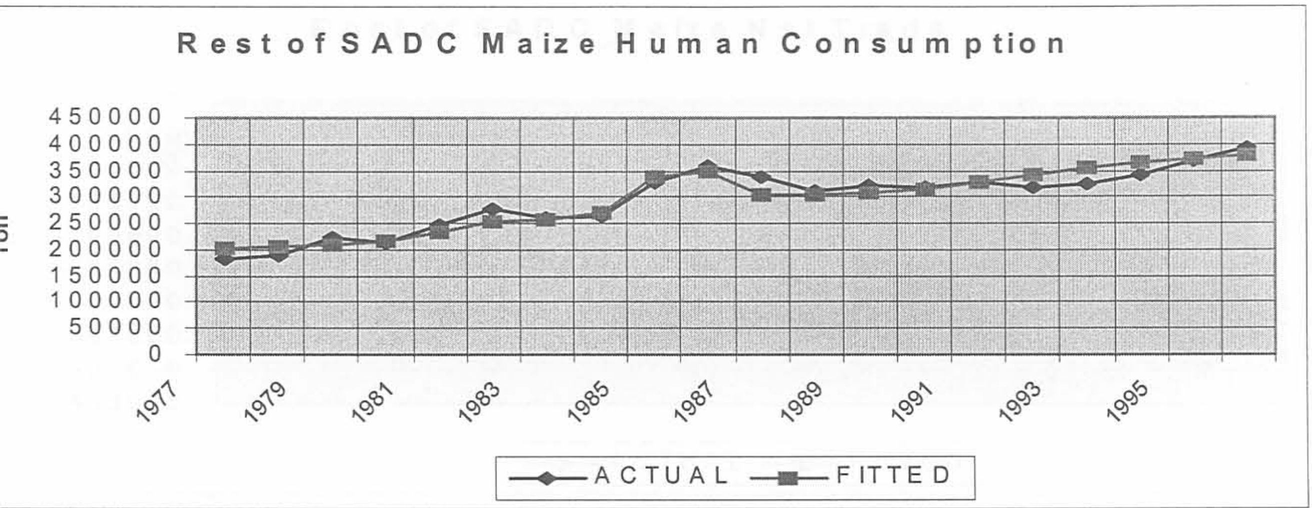

Zimbabwe Maize Human Consumption
Ton
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

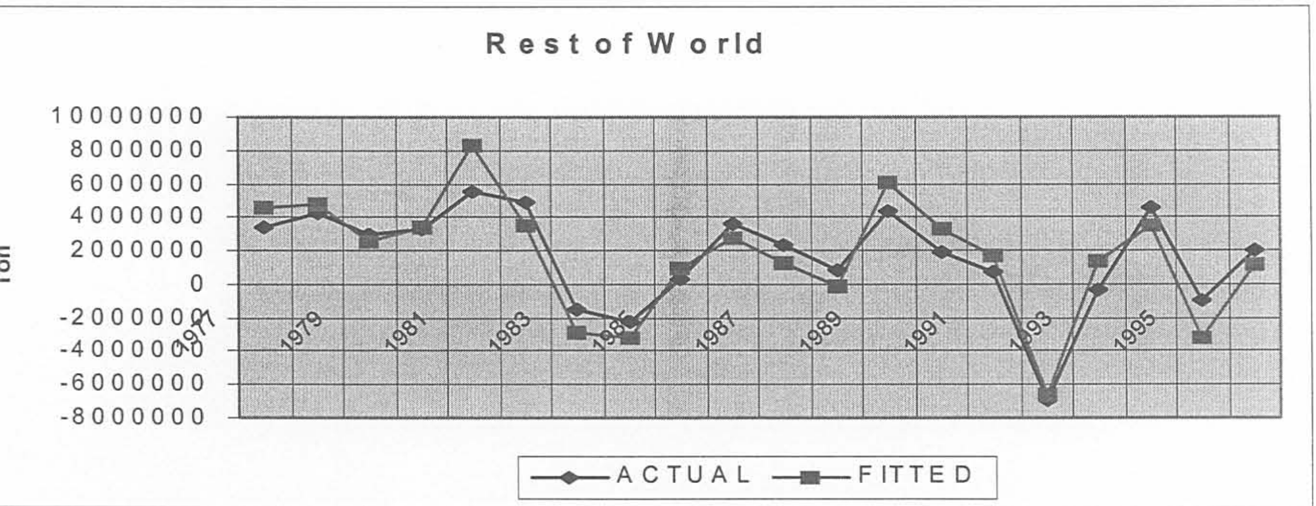

Zimbabwe Maize Stock Change
1500000
1000000
500000
0
-500000
-1000000
-1500000
Ton
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

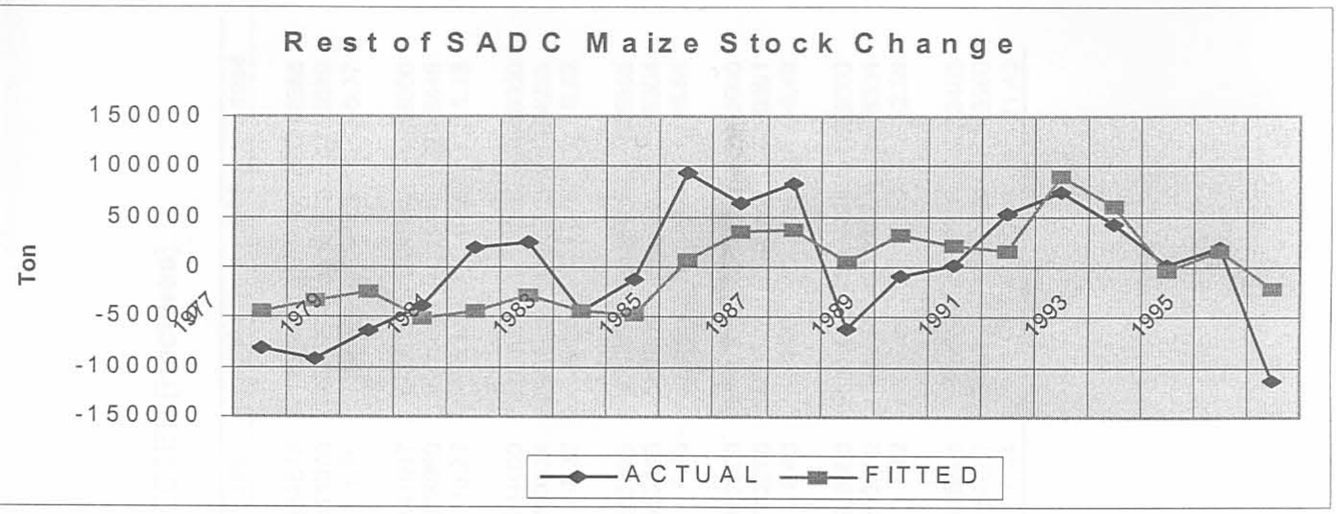

Zimbabwe Maize Price
1600
1400
1200
1000
800
600
400
200
0
Local Currency
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

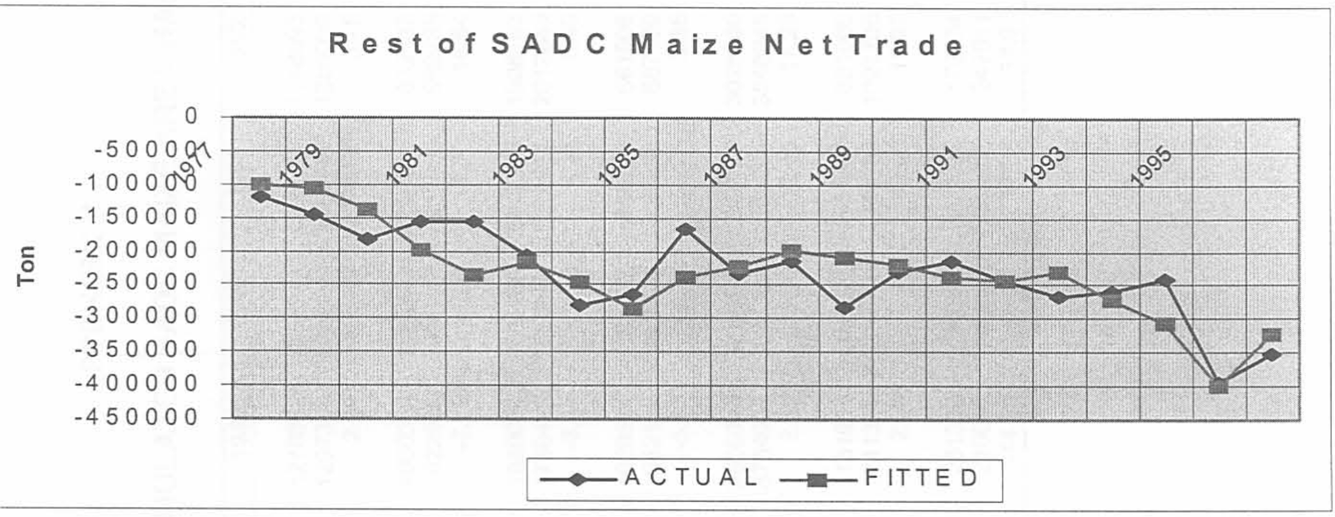

Zimbabwe Maize Net Trade
1500000
1000000
500000
0
-500000
-1000000
-1500000
Ton
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


Rest of SADC Maize Area Planted
350000
300000
250000
200000
150000
100000
50000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


Rest of SADC Maize Human Consumption
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


Rest of World
10000000
8000000
6000000
4000000
2000000
0
-2000000
-4000000
-6000000
-8000000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


Rest of SADC Maize Stock Change
Ton
150000
100000
50000
0
-50000
-100000
-150000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED


Rest of SADC Maize Net Trade
Ton
0
-50000
-100000
-150000
-200000
-250000
-300000
-350000
-400000
-450000
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
ACTUAL
FITTED

APPENDIX B

Table B1: ACTUAL AND SIMULATED SADC MAIZE AREA HARVESTED (Hectares).

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Malawi											
Actual	1193275	1182415	1215087	1270822	1343784	1391878	1368093	1334672	1129316	1229187	1242588
Fitted	1206290	1227598	1278473	1297380	1270148	1266942	1289050	1311370	1237777	1215799	1175889
Percentage change	1.09	3.82	5.22	2.09	-5.48	-8.98	-5.78	-1.75	9.60	-1.09	-5.37
Mozambique											
Actual	1000000	1000000	1000000	1000000	1010902	1009211	832132	841947	940013	1080437	1008000
Fitted	932947	912959	899826	922930	951247	963809	969735	978960	991182	1006412	1025446
Percentage change	-6.71	-8.70	-10.02	-7.71	-5.90	-4.50	16.54	16.27	5.44	-6.85	1.73
Tanzania											
Actual	1905000	1724000	1850000	1980000	1631260	1848300	1908163	1824000	1628900	1653600	1646000
Fitted	1682277	1733149	1767561	1790479	1789946	1924941	2012840	1763534	1624848	1530273	1484295
Percentage change	-11.69	0.53	-4.46	-9.57	9.73	4.15	5.49	-3.32	-0.25	-7.46	-9.82
Zambia											
Actual	588490	609529	723087	1020574	763277	639390	661606	633326	679355	520165	675565
Fitted	624162	620398	619200	962116	822446	720938	687109	663446	642234	495940	548304
Percentage change	6.06	1.78	-14.37	-5.73	7.75	12.75	3.85	4.76	-5.46	-4.66	-18.84
South Africa											
Actual	3887000	4044000	4014000	3656000	3778000	3548000	3026000	3452000	3663000	3904000	2952000
Fitted	3969069	3856797	3910625	3754091	3636324	3634261	3548948	3743086	3618412	3595441	2790361
Percentage change	2.11	-4.63	-2.58	2.68	-3.75	2.43	17.28	8.43	-1.22	-7.90	-5.48
Zimbabwe											
Actual	1314000	1232842	1295901	1181905	1145870	1101200	881000	1238000	1401200	1408700	1535000
Fitted	1204378	1134111	1113852	1211368	1234990	1243184	1021706	1333552	1372554	1373337	1498304
Percentage change	-8.34	-8.01	-14.05	2.49	7.78	12.89	15.97	7.72	-2.04	-2.51	-2.39
Rest of SADC											
Actual	212624	213910	286381	281370	288908	207631	179034	185865	292679	156756	312465
Fitted	238380	243278	286736	240050	241990	244282	247011	186687	248810	156225	245590
Percentage change	12.11	13.73	0.12	-14.69	-16.24	17.65	37.97	0.44	-14.99	-0.34	-21.40

Table B2: ACTUAL AND SIMULATED SADC MAIZE DOMESTIC CONSUMPTION (Tons).

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Malawi (Food)											
Actual	1154300	1233624	1328900	1363712	1363638	1358528	1247002	1377958	1338466	1444263	1445272
Fitted	1200182	1230516	1251355	1272514	1307113	1338682	1352420	1373791	1394672	1419846	1449223
Percentage change	3.97	-0.25	-5.84	-6.69	-4.15	-1.46	8.45	-0.30	4.20	-1.69	0.27
Mozambique (Food)											
Actual	521212	411300	647565	575432	587581	636092	781106	804829	826823	871890	985828
Fitted	301861	491411	647892	534174	584070	654846	708014	771971	840890	916249	998845
Percentage change	-42.08	19.48	0.05	-7.17	-0.60	2.95	-9.36	-4.08	1.70	5.09	1.32
Tanzania (Food)											
Actual	1677834	1841250	2009420	2156178	2008238	2029070	2077172	2093316	2088900	2207700	2244612
Fitted	1815765	1871889	1932006	1940888	1982374	2027992	2095700	2127218	2180934	2224795	2265239
Percentage change	8.22	1.66	-3.85	-9.98	-1.29	-0.05	0.89	1.62	4.41	0.77	0.92
Zambia (Food)											
Actual	1005201	1032776	1074447	1086857	1093843	1124194	1040181	1069894	1109080	1287433	1316565
Fitted	983240	1020493	1051488	1070946	1091782	1079071	1108860	1145143	1185843	1233107	1279128
Percentage change	-2.18	-1.19	-2.14	-1.46	-0.19	-4.01	6.60	7.03	6.92	-4.22	-2.84
South Africa (Human)											
Actual	2941000	2722000	3044000	2819000	3190000	3302000	3163000	3612000	3449000	3742000	3416000
Fitted	3153295	2858379	2835318	2892839	3311716	3337975	3352951	3429111	3477294	3461668	3496840
Percentage change	7.22	5.01	-6.86	2.62	3.82	1.09	6.01	-5.06	0.82	-7.49	2.37
South Africa (Animal)											
Actual	2556000	2992000	3203000	3836000	4001000	4204000	3841000	3604000	3601000	3775000	3570000
Fitted	3151988	3271965	3460312	3702313	3775789	3794092	3575495	3762643	3940820	3529423	3613321
Percentage change	23.32	9.36	8.03	-3.49	-5.63	-9.75	-6.91	4.40	9.44	-6.51	1.21
Zimbabwe (Food)											
Actual	1070710	1016495	1075974	1143902	1161215	1168771	1193878	1332306	1308866	1395500	1458582
Fitted	1040176	1072734	1098482	1125195	1153815	1157815	1249703	1293426	1338163	1380707	1426279
Percentage change	-2.85	5.53	2.09	-1.64	-0.64	-0.94	4.68	-2.92	2.24	-1.06	-2.21
Rest of SADC (Food)											
Actual	357936	337868	312556	320629	317374	329602	317597	323175	340946	369495	392858
Fitted	349564	303841	305289	309570	316342	327525	342448	356635	364366	371755	378442
Percentage change	-2.34	-10.07	-2.33	-3.45	-0.33	-0.63	7.82	10.35	6.87	0.61	-3.67

Table B3: ACTUAL AND SIMULATED SADC MAIZE PRICES (Lc).

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Malawi											
Actual	122	122	174	240	260	270	297	430	470	720	721.16
Fitted	129	123	174	250	254	262	274	423	519	884	690
Percentage change	5.44	1.10	0.22	4.37	-2.18	-2.87	-7.67	-1.57	10.49	22.84	-4.28
Mozambique											
Actual	10000	30000	81000	113400	124700	124700	124700	124700	124700	124700	149757
Fitted	16858	23809	80270	109081	121339	123595	126009	124615	128443	134403	144212
Percentage change	68.58	-20.64	-0.90	-3.81	-2.69	-0.89	1.05	-0.07	3.00	7.78	-3.70
Tanzania											
Actual	6300	8200	9000	11000	13158	15556	13333	55556	77778	100000	133333
Fitted	4879	10668	17619	16405	27668	34078	10581	55629	53884	106776	202854
Percentage change	-22.55	30.10	95.77	49.14	110.27	119.07	-20.64	0.13	-30.72	6.78	52.14
Zambia											
Actual	611	866	889	1200	13000	15900	48270	86464	102893	132732	159762
Fitted	869	923	959	1544	12788	11927	42936	93272	122964	195322	174955
Percentage change	42.31	6.62	7.85	28.68	-1.63	-24.99	-11.05	7.87	19.51	47.15	9.51
South Africa											
Actual	278	312	286	266	303	358	445	417	387	599	616
Fitted	260	291	295	284	310	354	430	406	391	608	639
Percentage change	-6.40	-6.79	3.28	6.89	2.27	-1.02	-3.47	-2.59	1.13	1.54	3.82
Zimbabwe											
Actual	180	180	195	215	225	270	550	900	900	1050	1200
Fitted	150	138	191	226	261	383	612	736	898	1121	1516
Percentage change	-16.67	-23.15	-1.92	5.34	15.92	41.98	11.34	-18.19	-0.19	6.73	26.37

APPENDIX C

Table C1: Meaning of Acronyms

	COUNTRY	DESCTIPTION	UNIT
AREA HARVESTED			
MAMAH	Malawi	Area Harvested	Hectares
MOMAH	Mozambique	Area Harvested	Hectares
SAMAH	South Africa	Area Harvested	Hectares
TAMAH	Tanzania	Area Harvested	Hectares
ZAMAH	Zambia	Area Harvested	Hectares
ZIMAH	Zimbabwe	Area Harvested	Hectares
SDMAH	Rest of SADC	Area Harvested	Hectares
YIELD			
MAMYLD	Malawi	Maize yield	Tons/Ha
MOMYLD	Mozambique	Maize yield	Tons/Ha
TAMYLD	Tanzania	Maize yield	Tons/Ha
ZAMYLD	Zambia	Maize yield	Tons/Ha
SAMYLD	South Africa	Maize yield	Tons/Ha
ZIMYLD	Zimbabwe	Maize yield	Tons/Ha
SDMYLD	Rest of SADC	Maize yield	Tons/Ha
PRODUCTION			
MAMPR	Malawi	Production	Tons
MOMPR	Mozambique	Production	Tons
SAMPR	South Africa	Production	Tons
TAMPR	Tanzania	Production	Tons
ZAMPR	Zambia	Production	Tons
ZIMPR	Zimbabwe	Production	Tons
SDMPR	Rest of SADC	Production	Tons
PER CAPITA CONSUMPTION			
MAMFOPC	Malawi	Per capita consumption	Kg/capita
MOMFOPC	Mozambique	Per capita consumption	Kg/capita
TAMFOPC	Tanzania	Per capita consumption	Kg/capita
ZIMFOPC	Zimbabwe	Per capita consumption	Kg/capita
SDMFOPC	Rest of SADC	Per capita consumption	Kg/capita
ZAMFOPC	Zambia	Per capita consumption	Kg/capita
SAMFOPC	South Africa (Human)	Per capita consumption	Kg/capita
SAMFEED	South Africa (Animal)	Animal consumption	Tons
FOOD CONSUMPTION			
MAMFO	Malawi	Food consumption	Tons
MOMFO	Mozambique	Food consumption	Tons
TAMFO	Tanzania	Food consumption	Tons
ZIMFO	Zimbabwe	Food consumption	Tons
SDMFO	Rest of SADC	Food consumption	Tons
ZAMFO	Zambia	Food consumption	Tons
SAMFO	South Africa	Food consumption	Tons
OTHER USES			
MAMOU	Malawi	Other Uses	Tons
MOMOU	Mozambique	Other Uses	Tons

TAMOU	Tanzania	Other Uses	Tons
ZIMOU	Zimbabwe	Other Uses	Tons
SDMOU	Rest of SADC	Other Uses	Tons
ZAMOU	Zambia	Other Uses	Tons
SAMOU	South Africa	Other Uses	Tons
STOCK CHANGE			
MAMSC	Malawi	Stock Change	Tons
MOMSC	Mozambique	Stock Change	Tons
TAMSC	Tanzania	Stock Change	Tons
ZAMSC	Zambia	Stock Change	Tons
SAMSC	South Africa	Stock Change	Tons
ZIMSC	Zimbabwe	Stock Change	Tons
SDMSC	Rest of SADC	Stock Change	Tons
NET MAIZE TRADE			
MAMNT	Malawi	Exports-Imports	Tons
MOMNT	Mozambique	Exports-Imports	Tons
TAMNT	Tanzania	Exports-Imports	Tons
ZAMNT	Zambia	Exports-Imports	Tons
SAMNT	South Africa	Exports-Imports	Tons
ZIMNT	Zimbabwe	Exports-Imports	Tons
SDMNT	Rest of SADC	Exports-Imports	Tons
POPULATION			
MAPOP	Malawi	Population	Millions
MOPOP	Mozambique	Population	Millions
TAPOP	Tanzania	Population	Millions
ZAPOP	Zambia	Population	Millions
SAPOP	South Africa	Population	Millions
ZIPOP	Zimbabwe	Population	Millions
SDPOP	Rest of SADC	Population	Millions
PRICES			
RMAMPPD	Malawi	Real maize producer price	U.S.$/Ton
RMAMPP	Malawi	Maize producer price divided by the US potash price	Lc/Ton
RMOMPP	Mozambique	Real maize producer price	Lc/Ton
MOMPP	Mozambique	Maize producer price divided by the US potash price	Lc/Ton
RSAMPPD	South Africa	Real maize producer price	U.S.$/Ton
RSAMPP	South Africa	Real maize producer price	Lc/Ton
RTAMPPD	Tanzania	Real maize producer price	U.S.$/Ton
RZAMPPD	Zambia	Real maize producer price	U.S.$/Ton
ZAMPP	Zambia	Maize producer price divided by the US potash price	Lc/Ton
RZIMPPD	Zimbabwe	Real maize producer price	U.S.$/Ton
USMPPSA	South Africa	U.S. Maize Gulf port price deflated with South Africa's GDPD	U.S.$/Ton
USMPPZA	Zambia	U.S. Maize Gulf port price deflated with Zambia's GDPD	U.S.$/Ton
USMPPZI	Zimbabwe	U.S. Maize Gulf port price deflated with Zimbabwe's GDPD	U.S.$/Ton
USMPPSD	Rest of SADC	U.S. Maize Gulf port price deflated with Rest of SADC's GDPD	U.S.$/Ton
CONSUMER PRICE			

RMAMCPD	Malawi	Real maize consumer price	U.S.$/Ton
RMOMCPD	Mozambique	Real maize consumer price	U.S.$/Ton
RSAMCPD	South Africa	Real maize meal consumer price	U.S.$/Ton
RTAMCPD	Tanzania	Real maize consumer price	U.S.$/Ton
RZAMCPD	Zambia	Real maize consumer price	U.S.$/Ton
RZIMCPD	Zimbabwe	Real maize consumer price	U.S.$/Ton
INCOME			
RMAGDPD	Malawi	Real GDP per capita	U.S.$/capita
RMOGDPD	Mozambique	Real GDP per capita	U.S.$/capita
RSAGDPD	South Africa	Real GDP per capita	U.S.$/capita
RTAGNID	Tanzania	Real GNI per capita	U.S.$/capita
RZAGNID	Zambia	Real GNI per capita	U.S.$/capita
RZIGNID	Zimbabwe	Real GNI per capita	U.S.$/capita
RSDGDPPC	Rest of SADC	Real GDP per capita	U.S.$/capita
OTHERS			
ROW	SADC Region	Regional Exports-Imports with the rest of the world	Tons
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DUM 80	dummy variable =1 in 1980 zero otherwise		
DUM 81	dummy variable =1 in 1981 zero otherwise		
DUM 82	dummy variable =1 in 1982 zero otherwise		
DUM 85	dummy variable =1 in 1985 zero otherwise		
DUM 88	dummy variable =1 in 1988 zero otherwise		
DUM 90	dummy variable =1 in 1990 zero otherwise		
DUM 91	dummy variable =1 in 1991 zero otherwise		
DUM 92	dummy variable =1 in 1992 zero otherwise		
DUM 93	dummy variable =1 in 1993 zero otherwise		
DUM 94	dummy variable =1 in 1994 zero otherwise		
DUM 95	dummy variable =1 in 1995 zero otherwise		
DUM 96	dummy variable =1 in 1996 zero otherwise		
DUM8082	dummy variable =1 from 1980 to 1982 zero otherwise		
DUM8182	dummy variable =1 from 1981 to 1982 zero otherwise		
DUM8586	dummy variable =1 from 1985 to 1986 zero otherwise		
DUM8687	dummy variable =1 from 1986 to 1987 zero otherwise		
DUM8789	dummy variable =1 from 1987 to 1989 zero otherwise		
DUM8889	dummy variable =1 from 1988 to 1989 zero otherwise		
DUM9192	dummy variable =1 from 1991 to 1992 zero otherwise		
DUM9293	dummy variable =1 from 1992 to 1993 zero otherwise		
DUM9496	dummy variable =1 from 1994 to 1996 zero otherwise		
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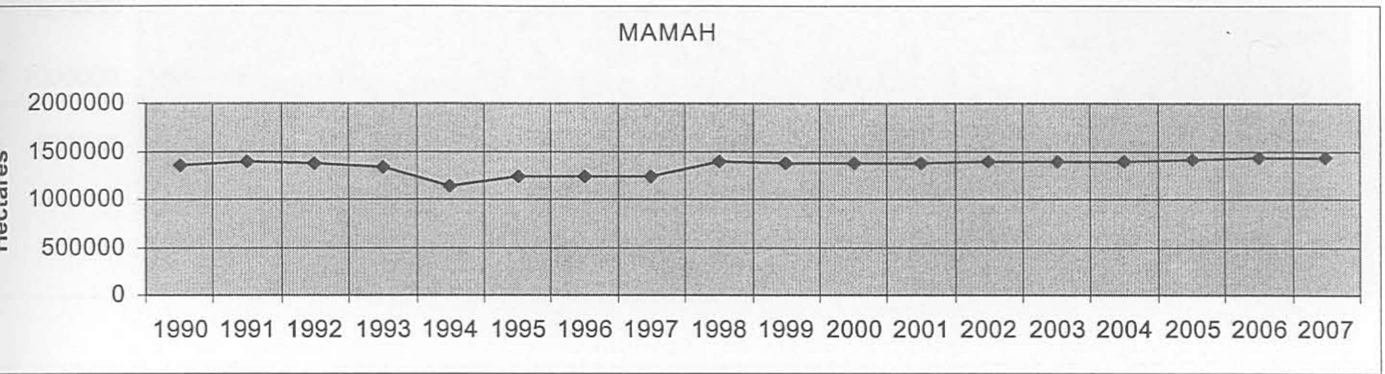
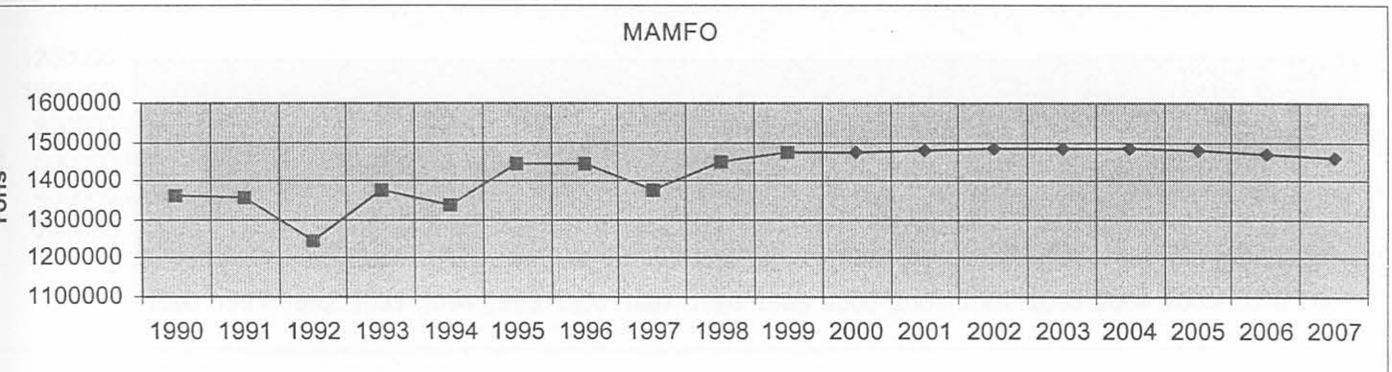
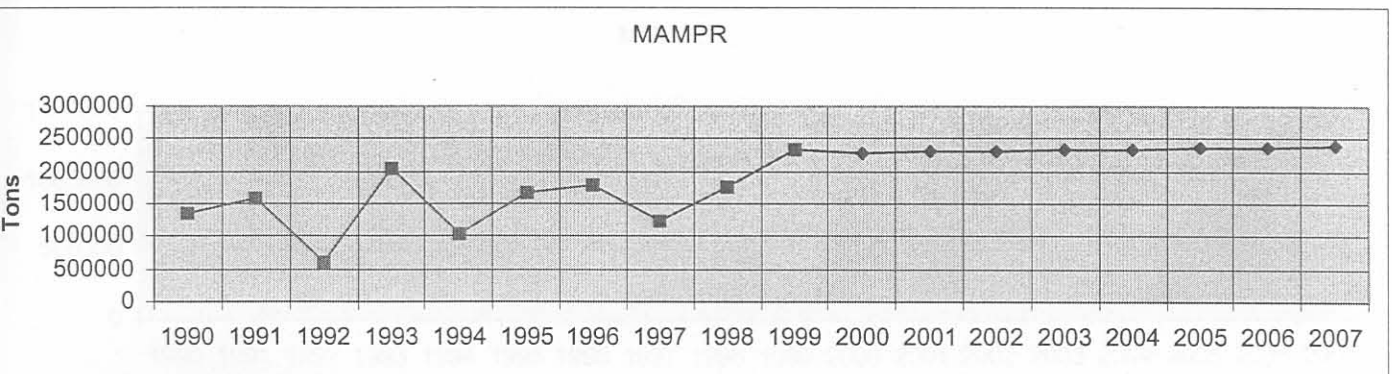
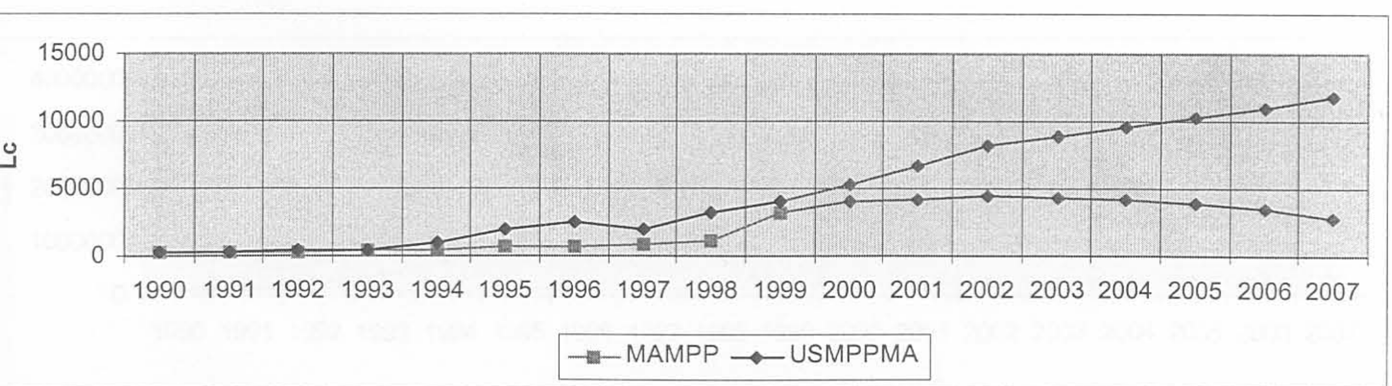
SHIFT85	SHIFT variable =1 if<= 1985, zero otherwise		
SHIFT87	SHIFT variable =1 if<= 1987, zero otherwise		
SHIFT89	SHIFT variable =1 if<= 1989, zero otherwise		
SHIFT94	SHIFT variable =1 if<= 1994, zero otherwise		
SHIFT8590	SHIFT variable =1 if >1985 and < 1990, zero otherwise		
RSABCPD	South Africa	Real bread consumer price	U.S.$/Kg
RSAMEATPPD	South Africa	Weighted average price of meat	U.S.$/Ton
RSASFPPD	South Africa	Real sunflower producer price	U.S.$/Ton

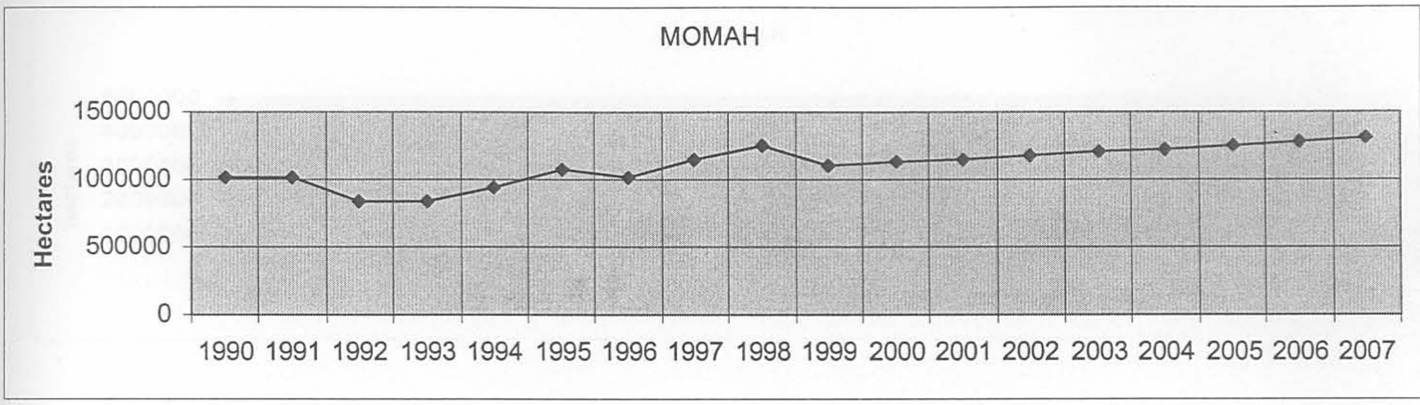
APPENDIX D
BASELINE AND FORECAST GRAPHS







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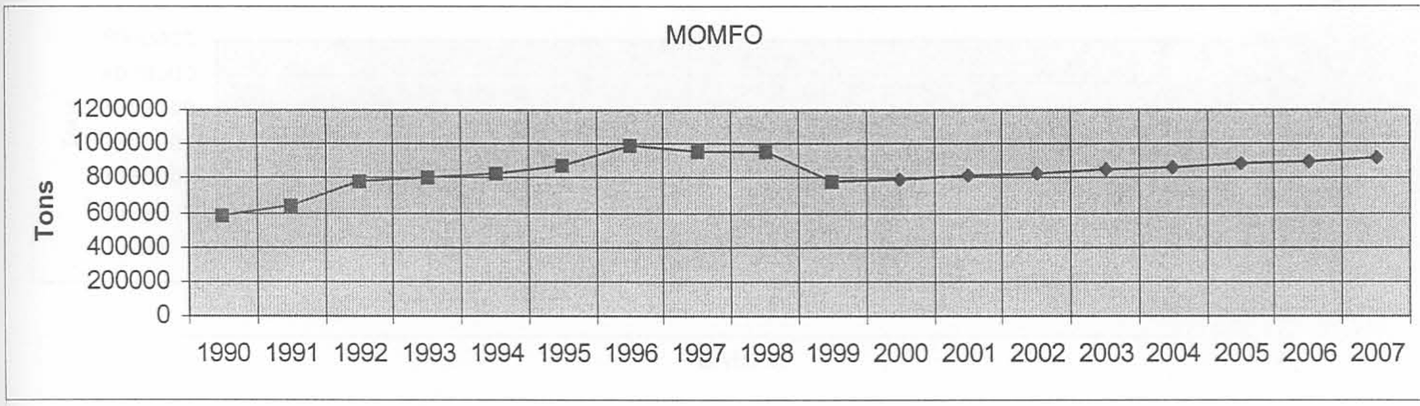
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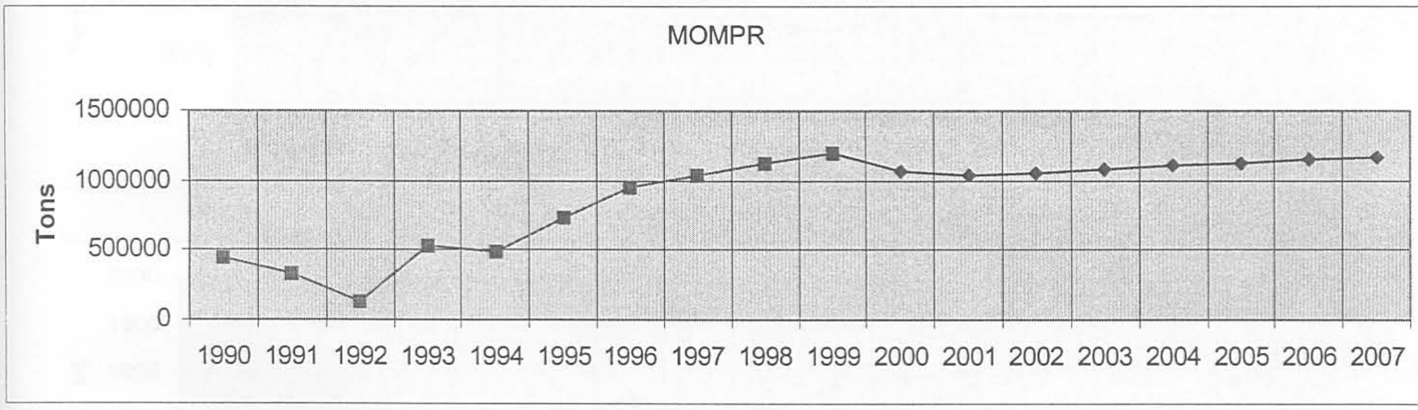
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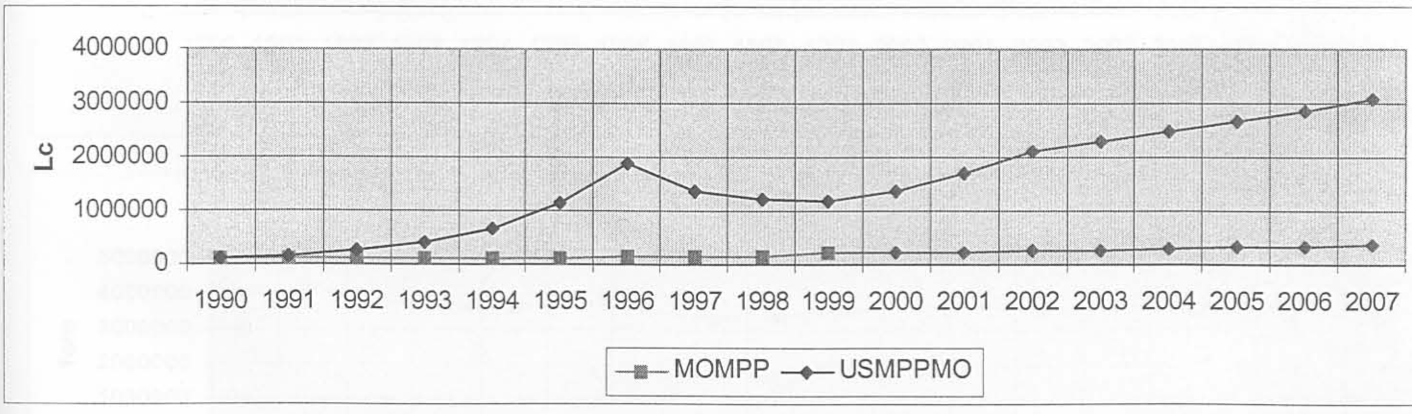
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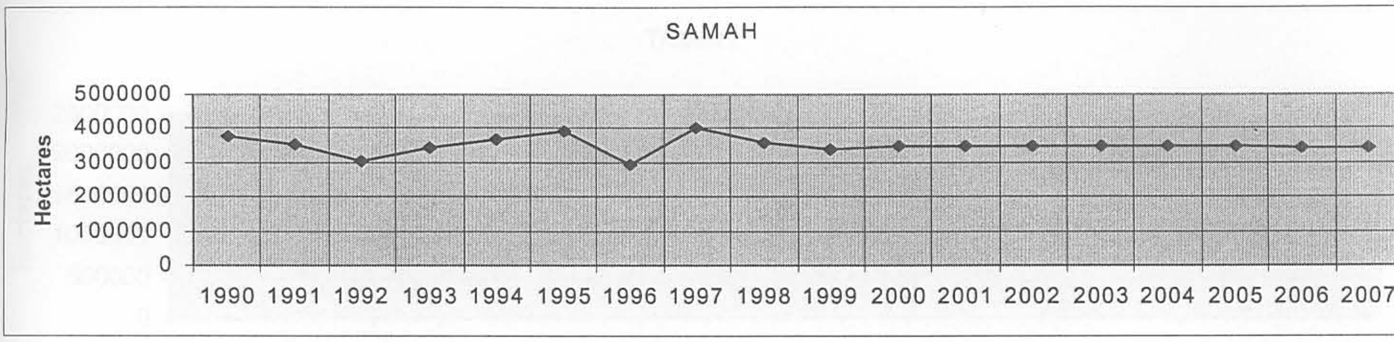
USMPPMO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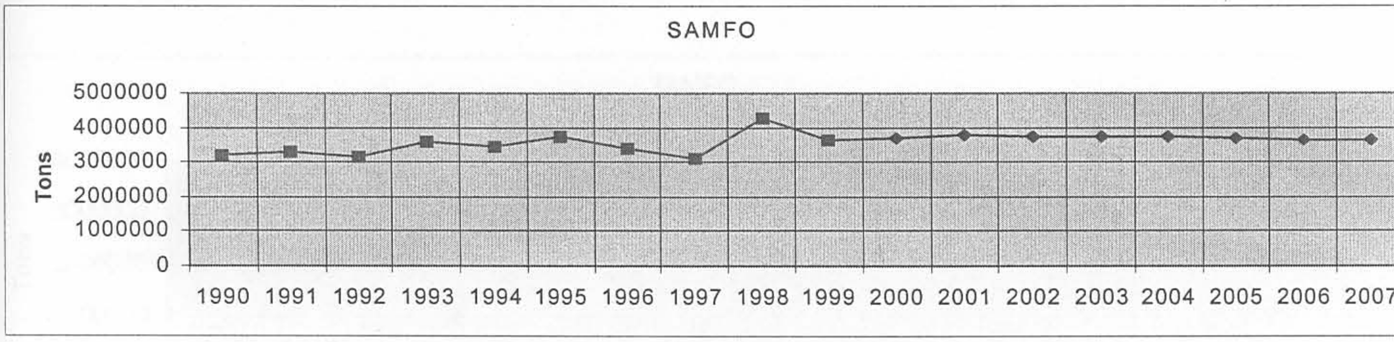
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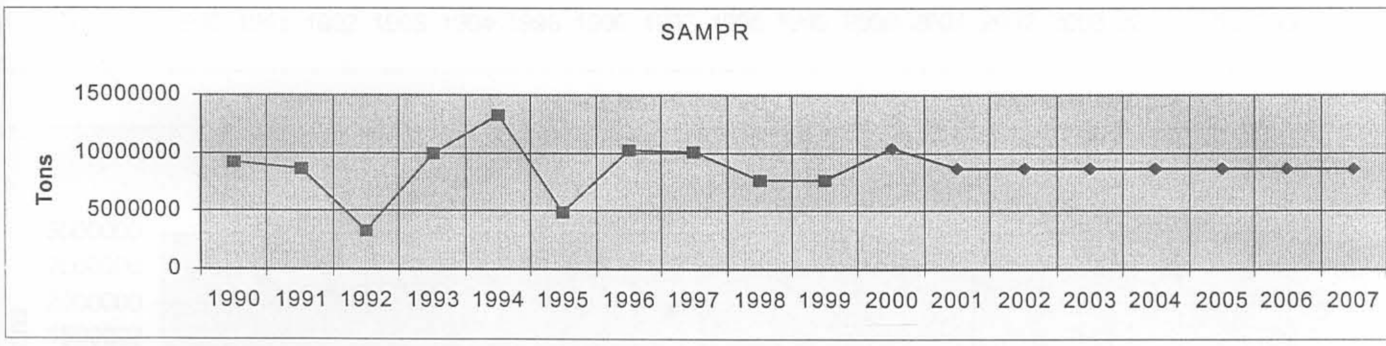
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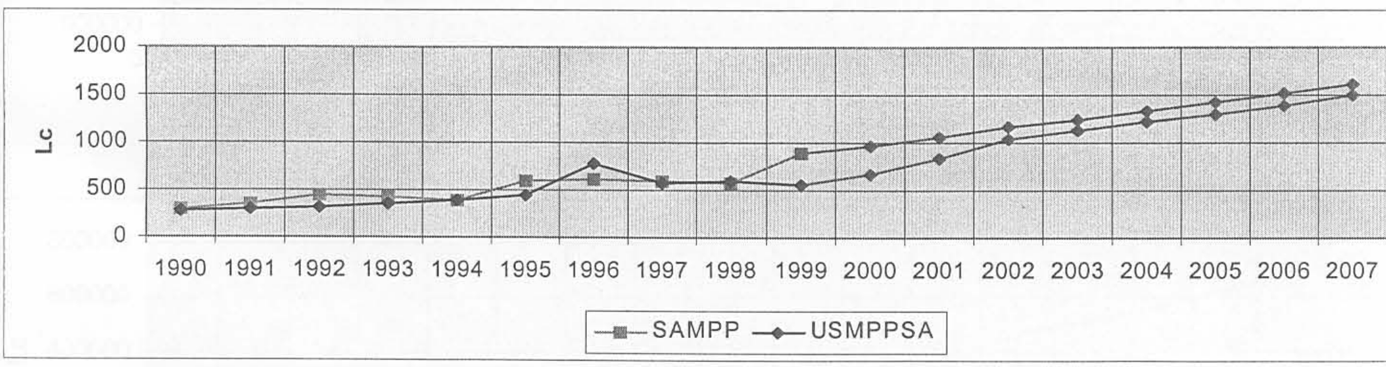
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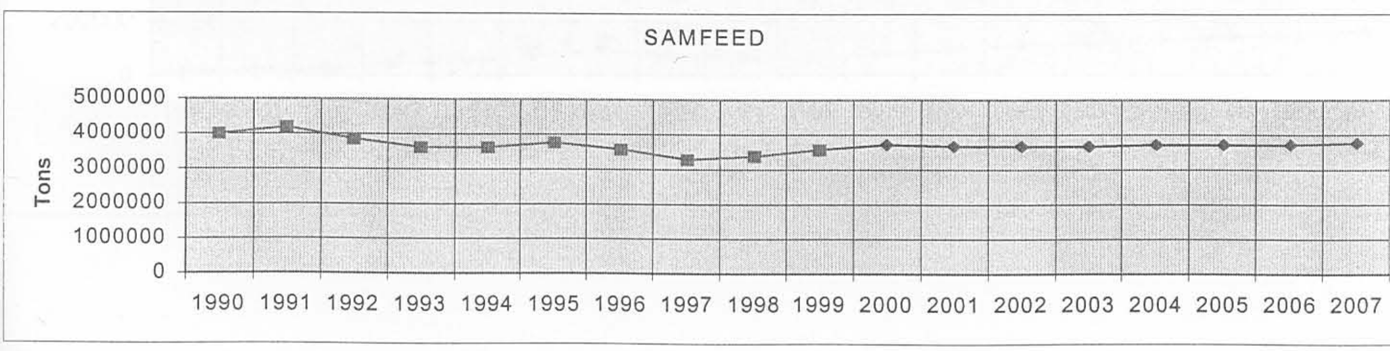
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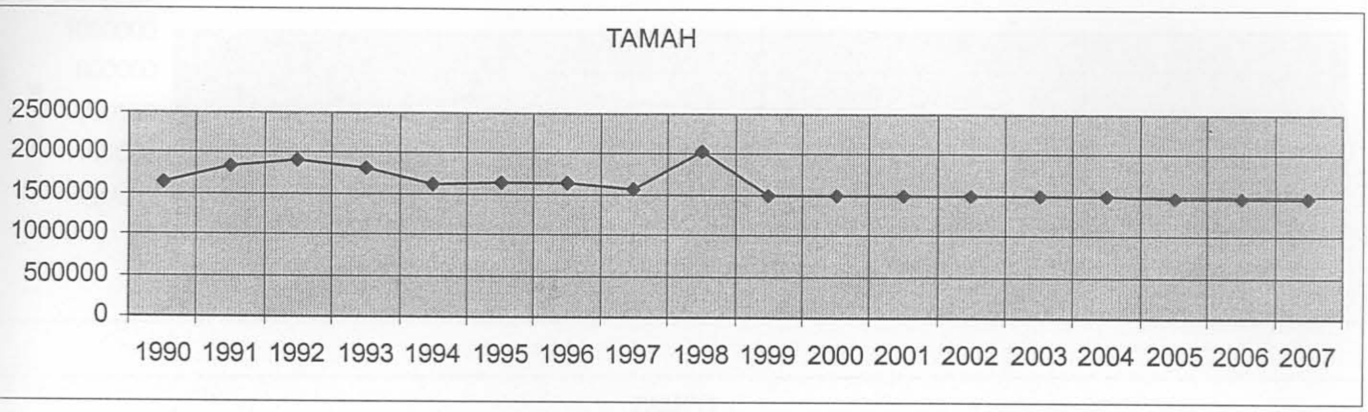

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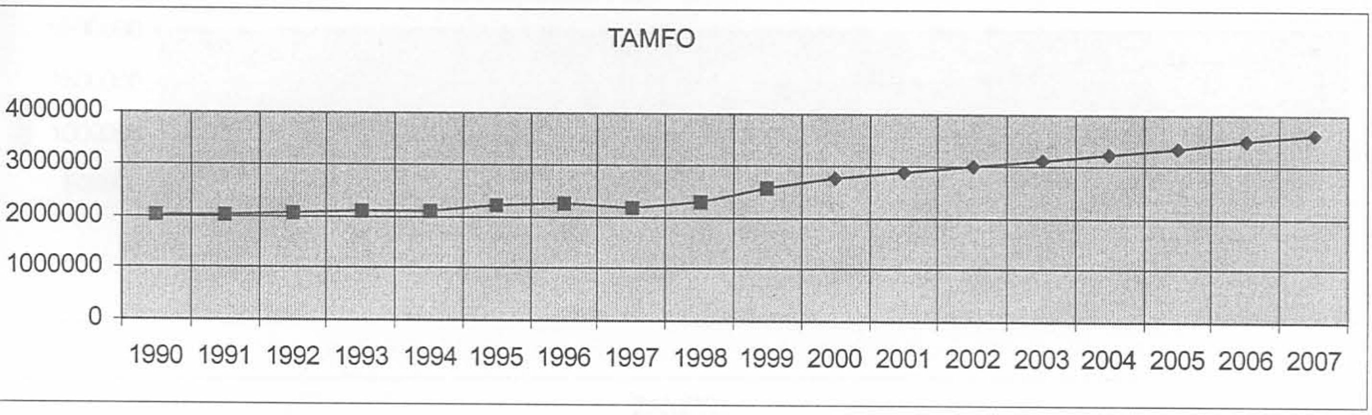

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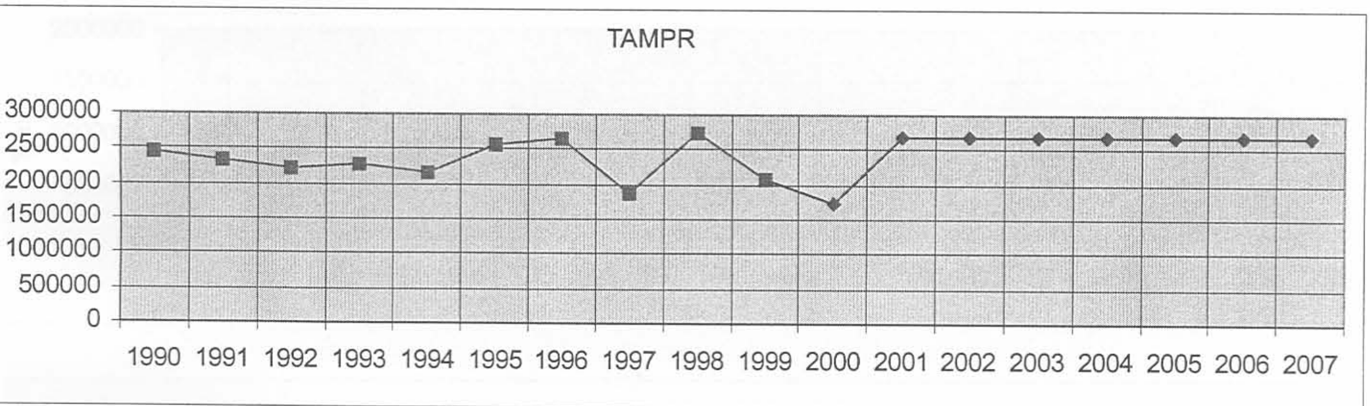

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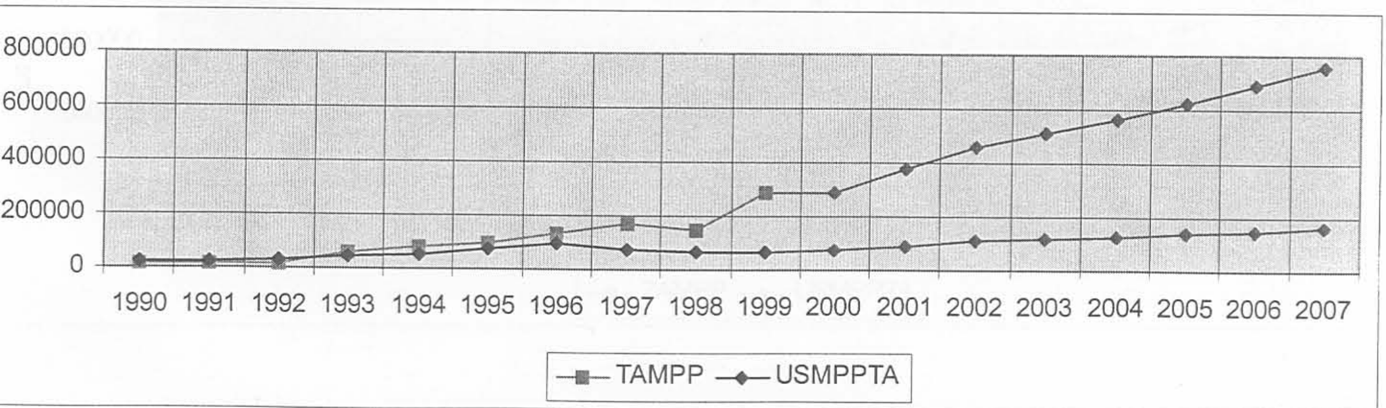

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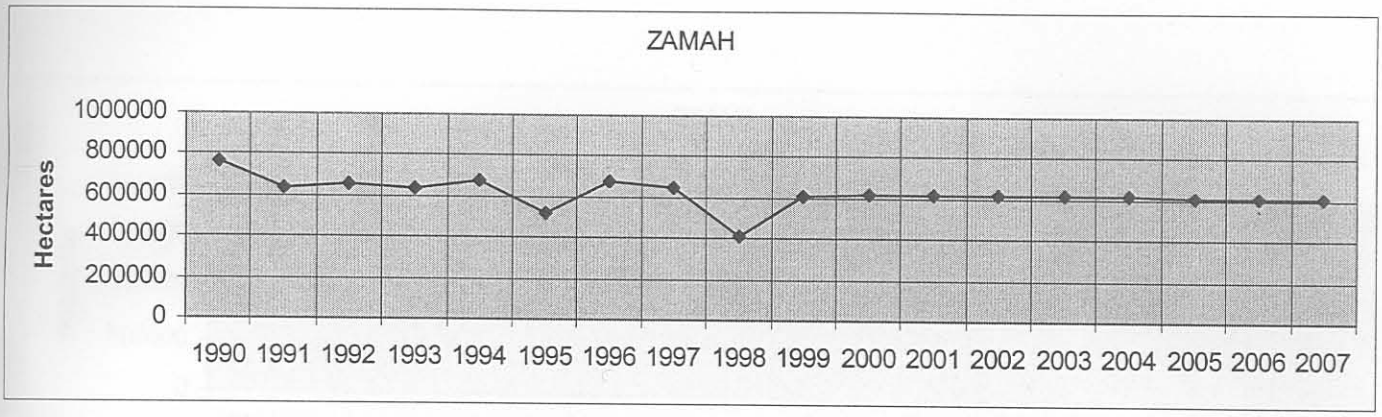

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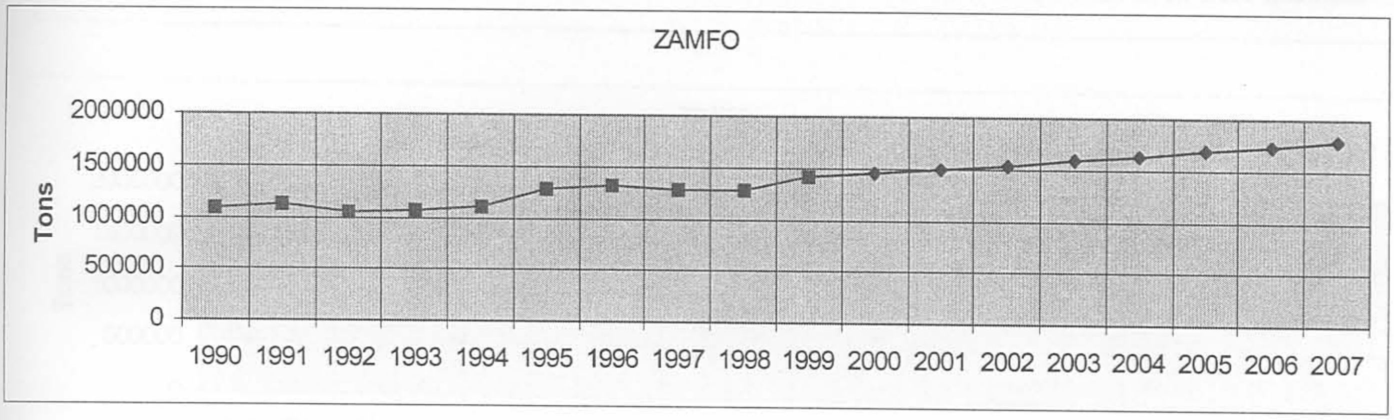

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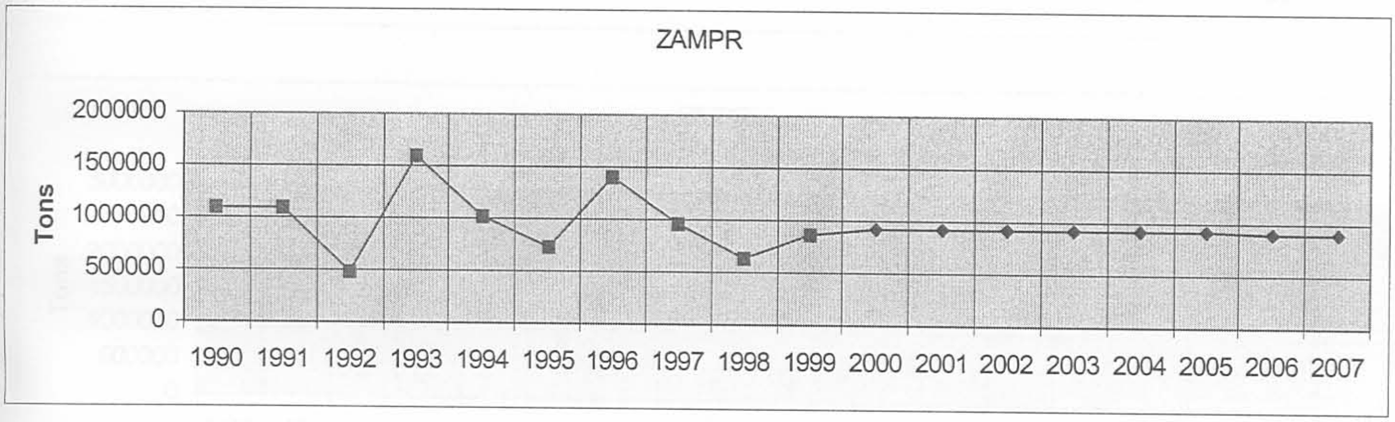

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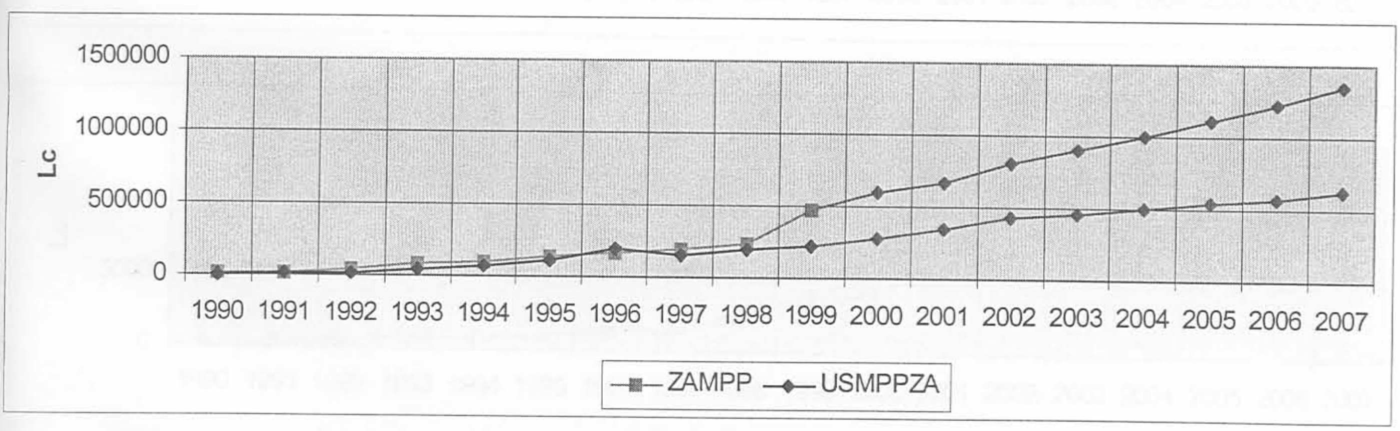

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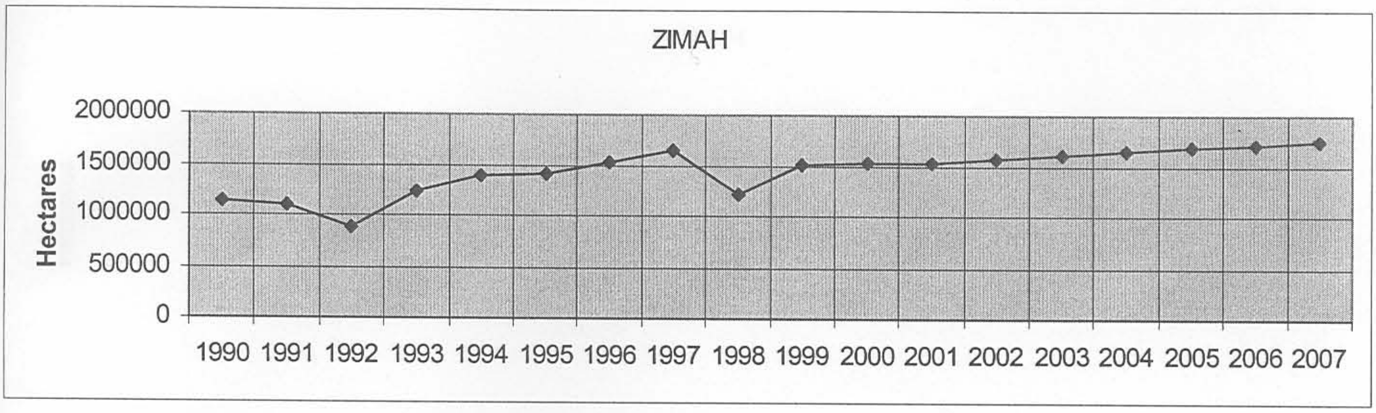
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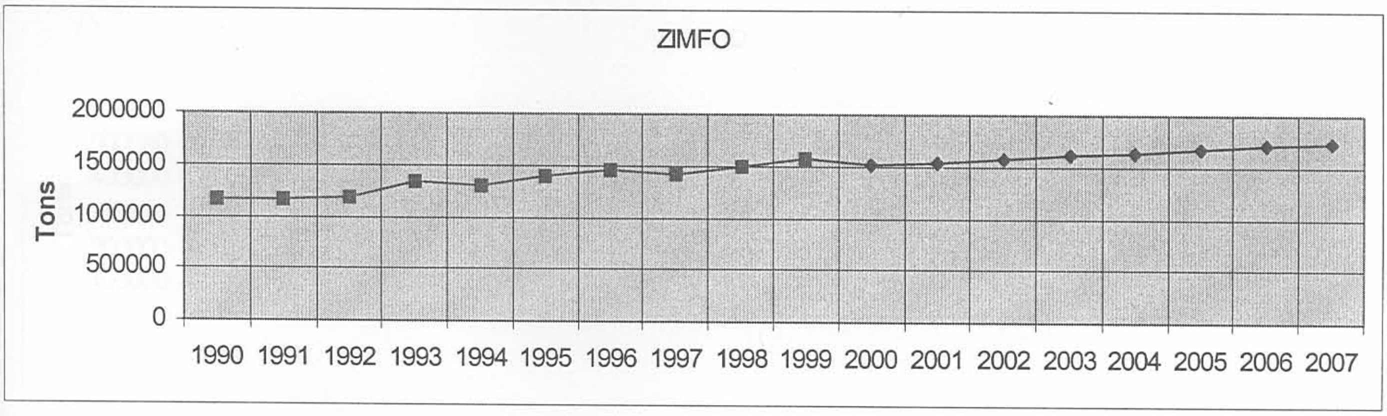
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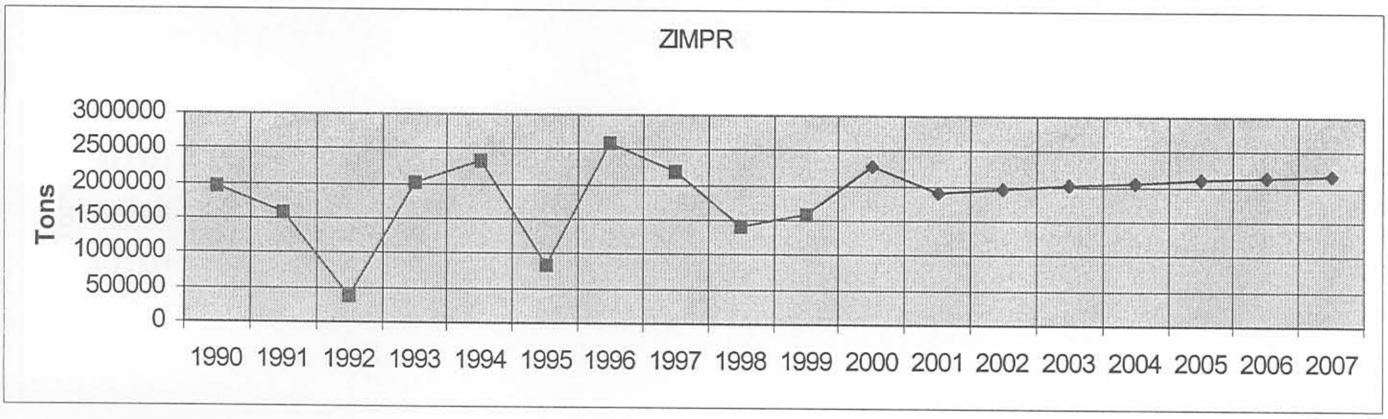
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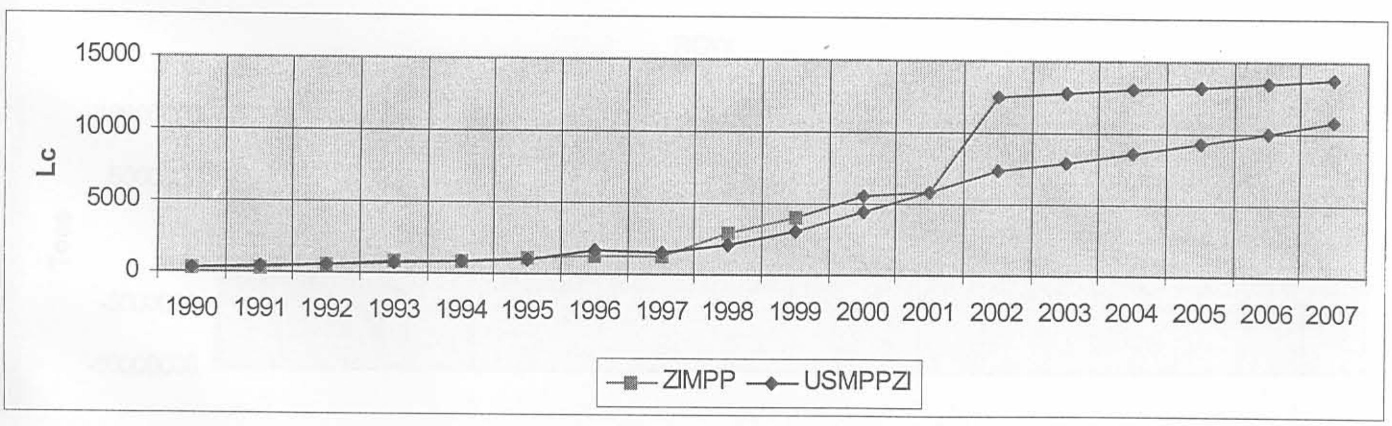
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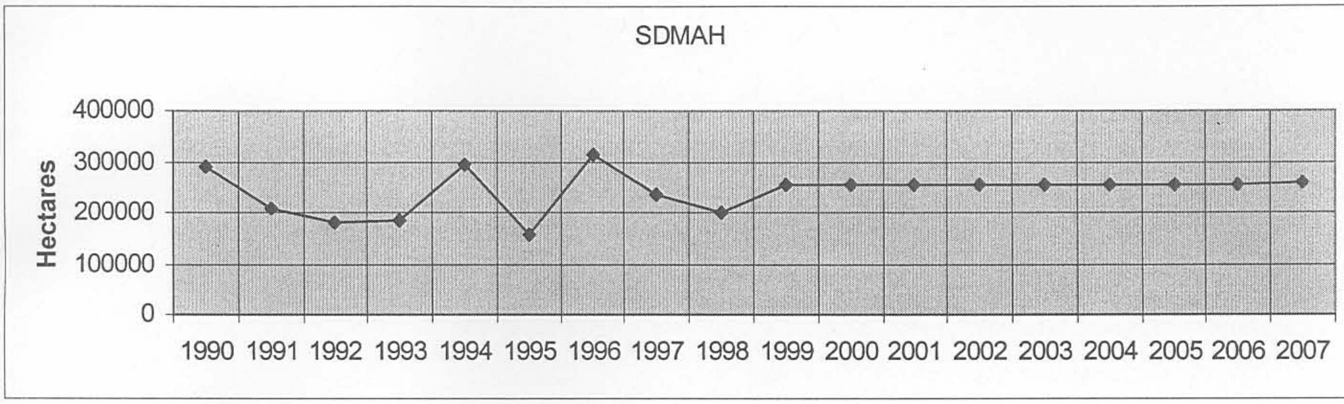
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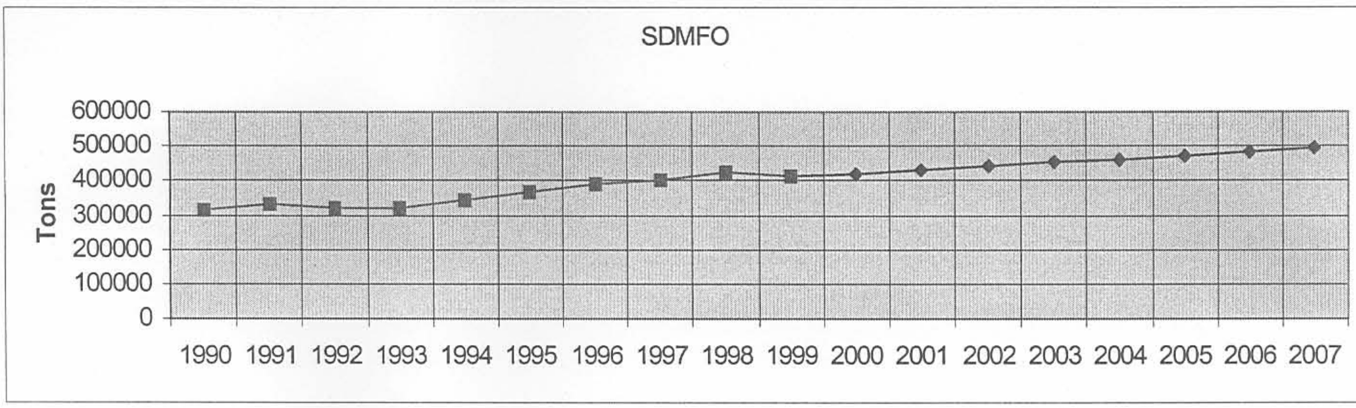
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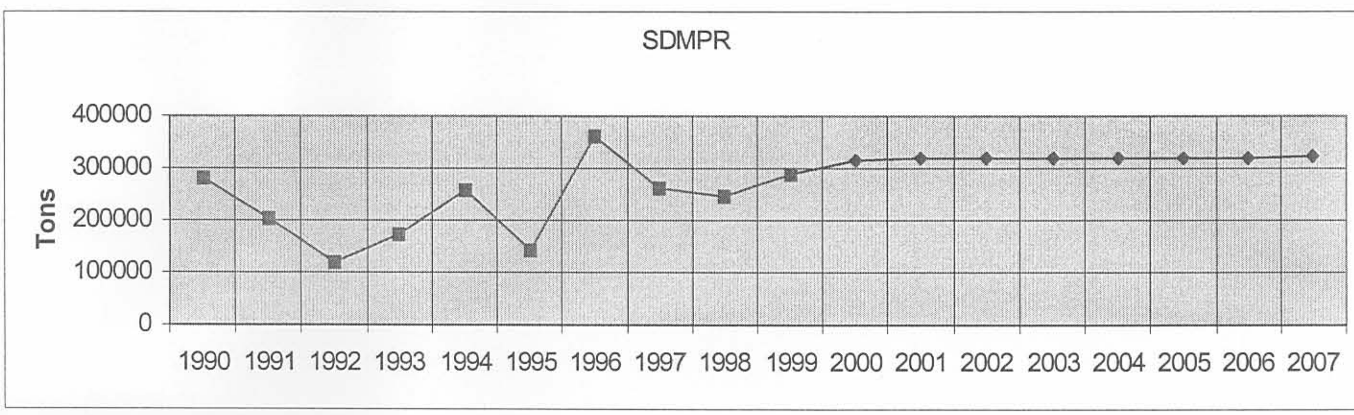
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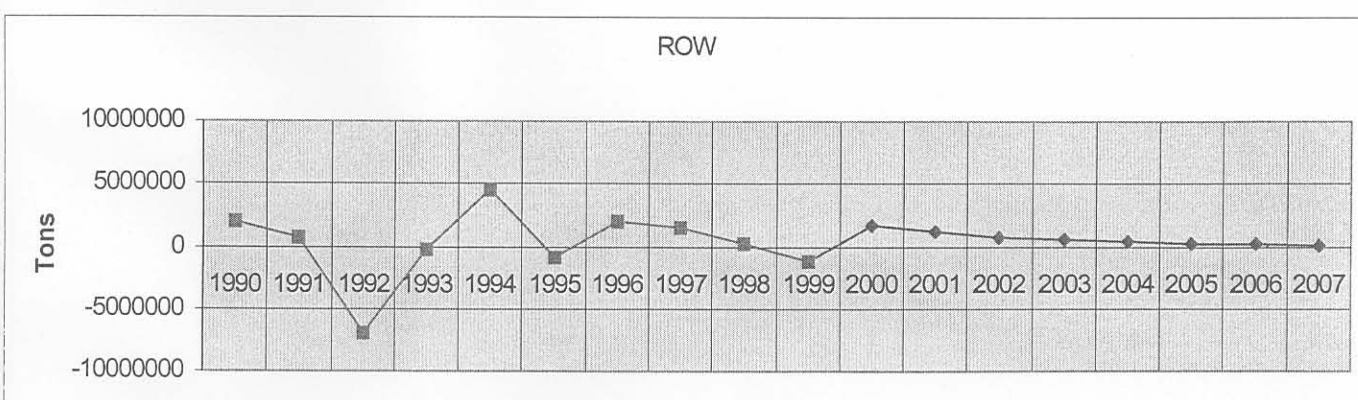
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