AN ECONOMETRIC MODEL OF THE SADC MAIZE SECTOR

by

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1. Introduction

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.

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 Structural Adjustment Programs (SAPs). Private sector participation in the supply of maize inputs (improved seed and fertilizer) and grain marketing has steadily increased during this same period (Hassan et al., 2000). The pace of change differed however from country to country, as did the impacts of the reforms.

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. Because of the regions internal trade relationships, what happens in one country, more often than not, has an effect on another country, as seldom a country is completely isolated. This is of particular interest when it involves food security. With white maize being the primary food staple within SADC, 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 to study and understand for designing policies that would promote food security.

Given the importance of the agricultural sector for the SADC region, research on commodity modeling (see Foster and Mwanaumo 1995; Heisey and 1999; Lyamachai *et al* 1997; Poonyth *et al* 2001; Smale and Heisly 1997; Sukume *et al* 2000; Townsend and Thirtle 1997; Van Zyl 1990; Zeller *et al* 1998) 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.

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. 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.

This paper is organized as follows. Section 2 reviews the maize sector in the SADC region. In section 3 the data and modeling procedures are described. The results are reported in section 4. The final summary and conclusion are in section 5.

2. Maize in the SADC Region

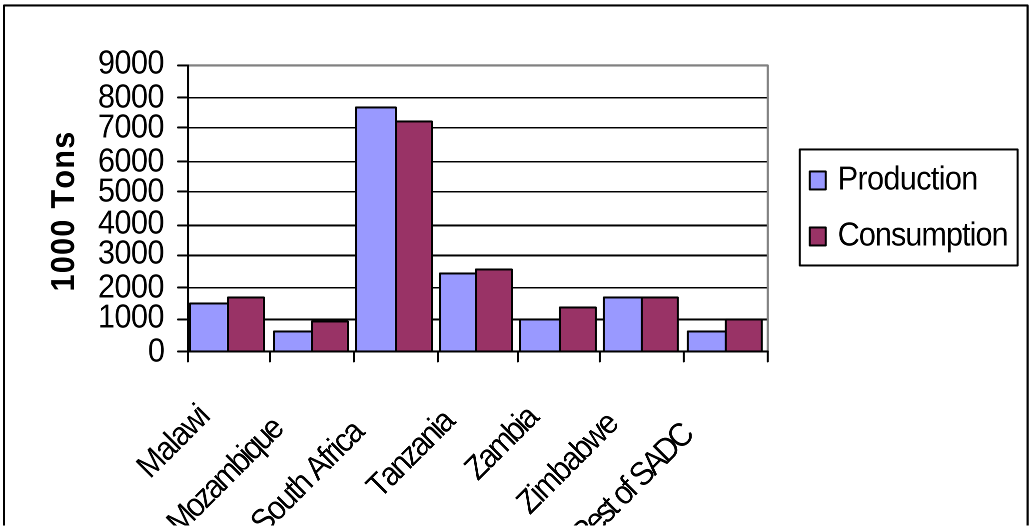
Maize, in particular white maize, is the dominant food staple throughout southern Africa, with its importance equaling that of rice and wheat in Asia. Although rice and wheat are also consumed, increases in supply are usually from imports while maize is generally a homegrown crop. Most maize is produced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

Clearly, South Africa is the regions largest producer of maize, producing 43 % of the total maize produced in the SADC region in 1999. 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.

This study includes 10 of the 14 SADC member countries. Four countries had to be excluded due to the gross lack of production, consumption, and general economic data in those countries. The remaining 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.

Overall, the SADC region is food-secure in terms of maize, this however is predominantly reliant on Zimbabwe and South Africa as they are the only countries that have a consistently positive net maize trade, namely they export more then they import. Figure 1 represents the average production and consumption of each SADC country between 1989 and 1999. From figure 1 it is clear that on average only South Africa and Zimbabwe are food secure in terms of maize.

Figure 1: Maize Production and Consumption in the SADC Region



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.

3. Data Sources and Research Methodology

The main objective of this study is to develop an econometric model for the maize commodity market in the SADC region. Structural commodity models use sets of equations designed to explain market structure and inter-linkages.

3.1 Theory

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. 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 the 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 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 GDP, the exchange rate and policy variables are considered as exogenous variables.

The structural econometric model of SADC maize 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 econometric model of the SADC maize sector expresses interdependence of variables that influence the supply and utilization of maize in 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 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.

Based on the estimated model equations, simulations for plausible policy scenarios were performed. First, a baseline simulation was generated for the years 2002 to 2007 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.

3.2 Data

For almost all countries in the Southern Africa region agricultural data are very sketchy 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. Thus this study relied mostly on time series data supplied by the FAO. Area harvested, maize production and utilization for most of the countries were obtained from the FAO statistical database. In the case of South Africa data were obtained from the National Department of Agriculture.

Data on macroeconomic variables such as exchange rates, gross domestic product (GDP), consumer prices 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.

4. Results

The estimated equations were generally satisfactory. The fit measured by the R-Square were reasonable, with fourteen equations having an R-Square better than 0.8, whereas there were five equations with an R-Square of 0.7, six equations had an R-square of 0.6, and the remaining three equations had an R-Square below 0.5. All the estimated coefficients had the expected sign and were statistically significant at reasonable levels. 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 mode1 has satisfactory predictability power. The relevant elasticities were computed at the mean of the variables. Table 2 in the appendix summaries the relevant elasticities of the model.

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. 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.

4.1 The 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 a forecast as *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, 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. The baseline forecast for the region is reported in table 3 in the appendix.

4.2. 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 4 in the appendix reports the SADC maize market outlook actual and percentage change for the current Zimbabwe crisis.

A similar table can be drawn up for each country in the region. Because Zimbabwe is the country directly affected the actual and percentage changes in the variables of interest are reported in table 5 in the appendix.

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. From the 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.

4.3. SADC Maize Market Outlook: South Africa Yield Shock

Since South Africa is the largest maize producer in the SADC region, it is 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. Table 6 in the appendix presents the 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.

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.

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 It is for this reason that the decrease in yield over two years had a profound and long lasting effect on South Africa as an individual country. The actual and percentage changes from the baseline forecast, for the South African maize market, are reported in table 7 in the appendix.

Decreased maize yields caused a 25 % decrease in production for South Africa in 2002 that caused 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 7 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.

5. Conclusion

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 to provide adequate understanding of the functioning of maize markets and for studying the structural nature of their regional supply and demand components. The present model made an attempt to develop and use a structural maize commodity model to address and analyze some of the said aspects for improved food security within the SADC region through regional integration of maize production and trade.

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.

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 This calls for creative measures of reserve stocks management to mitigate the negative effects of such factors of political instability and climate fluctuations.

References

Abstract of Agricultural Statistics (2001). National Department of Agriculture, Government of South Africa, Pretoria South Africa

FAO Stats CD Rom 1999, FOA, Rome.

Foster K. A. and Mwanaumo A., (1995). "Estimation of Dynamic Maize Supply Response in Zambia". Journal of Agric Economics Vol 12 pp 99-107

Heisey, P.W., and Edmeades G.O. 1999. "Maize Production In Drought-Stressed Environments: Technical Options And Research Resource Allocation". Part 1 Of *CIMMYT 1997/98 World Maize Facts And Trends; Maize Production In Drought-Stressed Environments: Technical Options And Research Resource Allocation.* Mexico. D.F: CIMMYT.

International Financial Statistics, CD Rom, A publication of International Monetary Funds, Washington D.C 2001..

Lyamachai C. J., Gillespie T. J., Brown D.M. (1997). "Estimating maize yield in northern Tanzania by adapting SIMCOY, a temperate-zone simulation model". Journal of Agriculture and Forest Meteorology Vol. 85

Poonyth, D., Hassan, R.M., and BenBelhassen, B.,(2001) "Acreage Response to Risk: The Case of Maize and Wheat in South Africa". AGREKON, Vol 40, No 4

Smale M. and Heisey P., W., (1997) "Maize Technology and Productivity in Malawi". In *Africa's Emerging Maize Revolution*. Edited by Byerlee D. and Eicher C. K. Lynne Rienner Publishers, Colorado.

Sukume D, Makudze E., Mabeza-Chimedza R., and Zitsanza N., (2000) "Comparative Economic Advantage of Crop Production in Zimbabwe". USAID SD Publication series, Office of Sustainable Development, Bureau for Africa. Technical paper No. 99.

Van Zyl (1990) "An Economic Analysis of Aspects of the South African Maize Market". Unpublished Ph.D. thesis, University of pretoria.

Zeller M., Diagne A., Mataya C., (1998). "Market access by smallholder farmers in Malawi: implications for technology adoption, agricultural productivity and crop income." Agricultural Economics Vol. 19

Appendix

Table 1: 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	2480	2057
Mozambique	1152	1.08	1246	1356
South Africa	3230	2.08	6716	7658
Tanzania	1764	1.39	2458	2643
Zambia	598	1.43	856	1460
Zimbabwe	1446	1.05	1520	2018
Rest of SADC	214	1.14	243	824
SADC Total	9804	1.42	15519	18016

Table 2: 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

Table 3: 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
Net Trade (Tons)	1452886	1388426	1300807	1208011	1108514	992489

NB: Total food use includes animal feed use

Table 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

Table 5: 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

Table 6: 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

Table 7: 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