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Master Thesis

Maize Production and Markets in Ghana
- the Impact of Agricultural Policy and Rising Prices

- A Multi-Market Model Approach -

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List of Abbreviations

ACDEP	Association of Church Development Projects
CIA	Central Intelligence Agency
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Statistical Database of the Food and Agriculture Organization
GAMS	General Algebraic Modeling System
GHc	Ghana Cedi
GSFP	Ghana School Feeding Programme
GSS	Ghana Statistical Services
IFPRI	International Food Policy Research Institute
NPK	Nitrogen, Phosphorus and Potassium
NRI	Natural Resources Institute
MMM	Multi-Market Model
MT	Metric tons
OECD	Organization for Economic Co-operation and Development
SNV	Development Organization from the Netherlands
SRID	Statistics, Research and Information Directorate
WTO	World Trade Organization

1. Introduction

The recent increase in world market prices for important food commodities, like wheat, maize and rice, has consequences for people all over the world (FAO/OECD, 2007). However, whereas people in developed countries, like Western Europe, spend 10 to 15 percent of their budget to food, households in developing countries spend between 50 and 60 percent on foodstuffs (VON BRAUN, 2008). Moreover, among the developing countries and within these countries the consequences are extremely heterogeneous. The majority of households in developing countries live at least partly from agricultural activities. So, they are affected twice, as seller of products and as consumer. The question, whether countries and households are net sellers or net buyers of food and to which extent they are determines highly whether they gain or loose from this situation. Unfortunately, the majority of households, especially the poor, are net buyers of food (VON BRAUN, 2008). This fact combined with the recent increase in food prices reveals the true catastrophe which most of the developing countries face. In the past decades the agricultural sector had often too less possibilities to develop and was not able to produce according to its potential. The consequence is that many countries are of necessity dependent on imports and cannot feed their own population. In order to reap the benefits of higher food prices, it is important to increase the agricultural production potential. Policy interventions may play an important role in this respect.

In this study, the impact of a number of common policy interventions and rising food prices will be analyzed for one specific case, namely maize in Ghana. Ghana is a country with favorable conditions for agriculture, and maize is the main staple which is produced by 89 percent of the households in Ghana (GSS, 2004). Moreover, the potentials in terms of production seem to be very high. The annual yield increase of maize in Ghana during the last fifteen years was only one percent (FAOSTAT, 2008) and could be improved through appropriate measures. In addition, further suitable land, at least in the North, seems to be available in abundant quantities. According to one source, only 20 percent of the suitable agricultural land in the Northern Region is currently under production (ACDEP, 2008). So, maize production could be extended largely, if the means would be available. Furthermore, the potentials of maize for poverty alleviation and reduction of hunger are huge, since maize is often used as the main staple in household consumption. A yield increase of 20 percent through better knowledge or availability of inputs means for many households 10 to 15 percent more to eat over the year according to interviews with different experts.

In order to improve the situation of the whole maize chain in Ghana with appropriate recommendations and measures, the current situation and conditions have to be analyzed. Therefore, the first main objective of this research is to investigate the efficiency and profitability of maize production and marketing. Due to the heterogeneity of Ghana, the analysis of production is for two regions, the North and the South. However, this serves only an overview and a good basis to find out, what are feasible and meaningful measures or interventions to improve the situation. Hence, the second objective of this study is to provide quantitative estimates of the impacts of policy interventions and rising prices that may support the decision process of possible interventions.

In order to reach the research objectives, the study focuses on the analysis of maize production, the maize chain and the markets in Ghana in Part One. In chapter two the farming conditions, the production and the marketing is described for the North and the South separately. In addition, for the North the results of a small case study, conducted from March to May 2008 in the Northern Region are described. In chapter three the profitability of maize production in different regions of Ghana is estimated and an analysis of marketing margins is provided.

In Part Two a multi-market model (MMM) is developed to provide quantitative estimates of the consequences of different policy interventions and rising prices on the maize and related markets as well as different household groups and the government. The main advantage compared to a partial equilibrium model (PEM) is the inclusion of the indirect effects of other markets. The PEM only considers the direct effects of changes in the maize market. In contrast, the MMM takes into account also the changes, which occur on other related markets, like rice or poultry. Therefore, the real changes are reflected much better with a MMM than with a PEM.

After the description of the model and discussion of the input data in chapter four, the results of four different model simulations are presented in chapter five. First, the marketing margins are assumed to decrease due to government investments in infrastructure and trading system. Second, the recent increase in world market prices and a long term price scenario are simulated. Third, a liberalization scenario and an enlargement of the current import tariffs are applied. Finally, it is assumed that the government focuses on productivity increase in the North, which leads in the first scenario to higher yields for all crops and in the second, to much higher rates only for maize. The results are analyzed with corresponding conclusions.

Part I: Analysis of the maize sector in Ghana

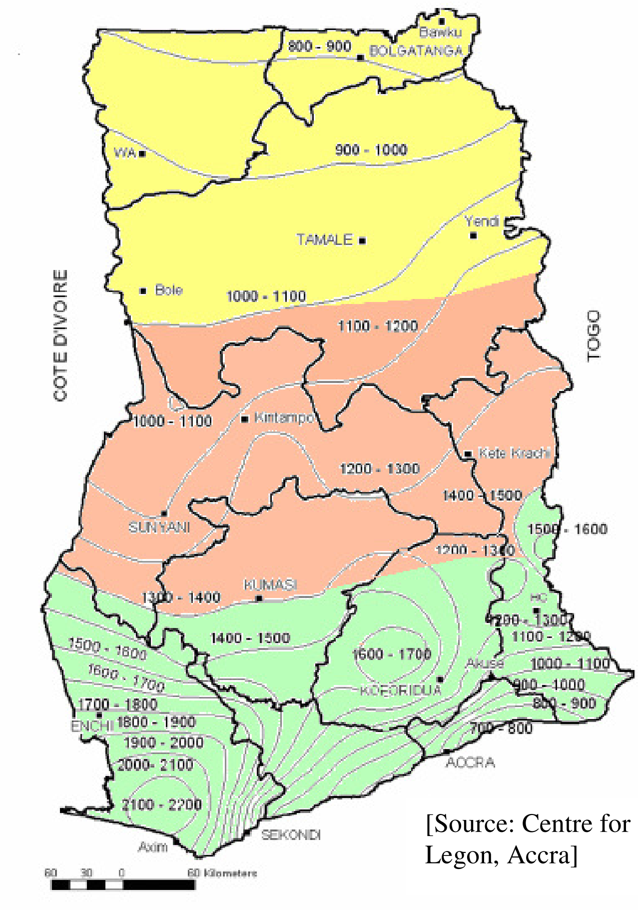
2. Descriptive analysis of the maize chain

This chapter describes the current situation of maize production and marketing in Ghana. The analysis is mainly based on field reports done by the International Food Policy Research Institute (IFPRI) in 2007 and some other literature sources, which describe the situation and conditions from different perspectives. In addition, own experiences during my field research in the region around Tamale from March to May 2008 are included. In this case study I interviewed farmers, traders and other stakeholders in the maize chain.

2.1 Agriculture in Ghana

Ghana is a very heterogeneous country, especially from an agricultural perspective. The South (in green in Figure 1) is characterized by a very humid climate with annual rainfall up to 2000 mm per year. Rain forest and a lot of wood define the picture of the landscape. Besides root and tubers, like cassava and cocoyam, the major crops are grown on trees like cocoa, oranges, coconuts or oil palm.

***Figure 1**: Climatic zones and annual rainfall in Ghana*



[Source: Centre for Geographic Information Systems, Universtiy of Legon, Accra]

The transition zone (in red), which mainly consists of the regions, Brong-Ahafo, Ashanti, the north part of the Volta region and the southern part of the Northern Region is the most suitable area for agriculture in Ghana. The soils are fertile and the climate with annual rainfall of 1000 – 1300 mm fits very well with crops like maize, cassava, yam and pepper. In both zones two harvests are possible due to the two rainy seasons (major: March-September; minor: October-December). The vegetation is mainly characterized by grass land and forest.

The savannah zone in the North consists of the Northern Region, Upper East and Upper West. This zone accounts for more than 40 % of the national land area. Over the last decades, the savannah zone from the North is more and more spreading into the current transition zone as a result of climate change. The conditions for agriculture are less favorable compared to the transition zone. The rainfall is around 900 mm per year, but the distribution is problematic. The dry season is long from November until April/May and in the rainy season the rain is heavy and the soil can often not absorb it all. Although the landscape is in contrast to the South flat, the erosion is quite high, due to the sparse groundcover and the bad farming practices (KOLAVALLI, FORTHCOMING). As a consequence of the conditions, the cultivated crops are mainly maize, sorghum, millet and groundnuts (SRID/MOFA, 2007).

Table 1: *Production and Value of Agricultural Products in Ghana*

Products	Value	Production
Crop Production	in 1,000 $	in MT
Yams	785,419	3,892,259
Cassava	701,779	9,738,812
Cocoa Beans	566,852	736,000
Plantains	528,098	2,380,858
Groundnuts in Shell	188,294	389,649
Taro (Coco Yam)	185,436	1,800,000
Maize	134,516	1,157,621
Chillies&Peppers, Green	93,174	270,000
Oranges	52,722	300,000
Rice, Paddy	51,507	241,807
Sorghum	48,711	399,300
Tomatoes	47,386	200,000
Coconuts	28,489	315,000
Millet	24,519	143,798
Animal Production		
Game Meat	93,341	57,000
Indigenous Cattle Meat	35,684	17,253
Indigenous Chicken Meat	34,176	29,300

[Source: FAOSTAT (2008)]

In Table 1 the most important agricultural products in Ghana as a whole are listed and ordered by their value. Root and tuber crops, particularly yam and cassava, are the most important crops in terms of value as well as production. As in most of the developing countries the agricultural sector contributes a large share to the national GDP. For Ghana it was 37.3 % in 2006 and it is declining over time, whereas the share of the industrial sector grows (from 15 to 25 % within the last ten years) (CIA, 2008). It shows that Ghana is still a developing country but with a tendency to transform its economy away from an agricultural-based one. Nowadays 56% of the official labour force works in the agricultural sector, but the unofficial figure is estimated to be much higher (CIA, 2008).

Over the last five years the agricultural sector has grown by 5.7 % on average. Among the crops cocoa leads the growth rate with 8.5 %, whereas maize as a subgroup of cereals and pulses contributes with 5.6 % and root and tubers with 2 %. These growth rates are mainly driven by area expansion; only one third of it is due to yield increases (CHAMBERLIN ET AL., 2007).

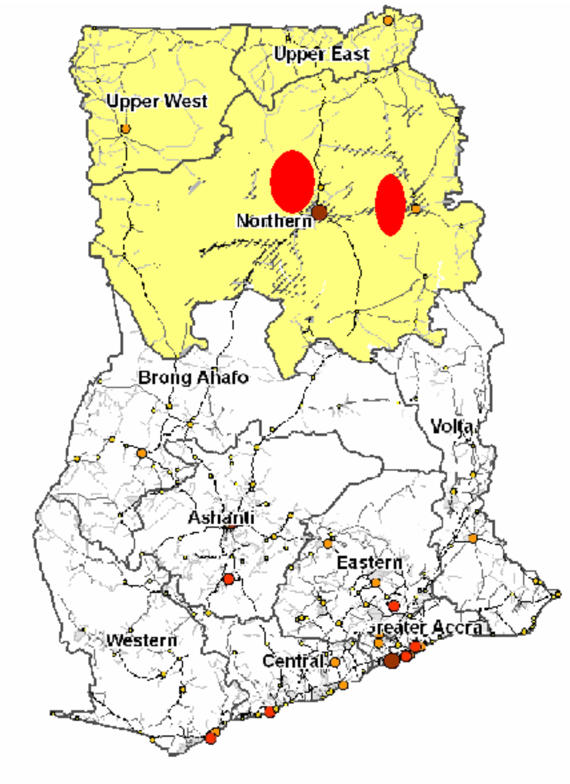
The farming sector is dominated by small farms throughout the country. Over 70 % of the farmers are not cultivating more than three hectares (CHAMBERLIN, 2007). The problem is often not that there is not enough land available, but that farmers have no means or not enough resources to cultivate more land.

2.2 Maize Production in the North of Ghana

2.2.1 Case Study

Throughout the thesis I distinguish between the North and the South of Ghana. In Figure 2 the yellow part represents the North (with the regions Upper East, Upper West and Northern), whereas the white part shows the regions belonging to the South. My field trip to Ghana was mainly to the North of Ghana and was done from March to May 2008. From the beginning of April to the second week of May I was in Tamale to conduct field interviews among farmers, traders and other stakeholders who are related to the maize sector (companies, NGO´s and the regional office of the Ministry of Food and Agriculture (MOFA)). The big red dots in the map (Figure 2) illustrate the regions where I carried out the interviews and the visits. Three districts were chosen according to their heterogeneity. The first, Tamale Municipal, is around the Tamale, the capital of the Northern Region. The farmers in this district are located close to the city and have generally access to good roads and infrastructure.

Figure 2: *Regions of Ghana*



Tolon/Kunbungu, the second district, is neighboring Tamale Municipal to the West. It is chosen because it is further away from the capital, the soils are not very fertile and the poverty level is one of the highest in Ghana (80-90 % according to World Bank figures (COULOMBE AND WODON, 2007)). The third district is Yendi, which is located to the east, between Tamale and the border of Togo. It is characterized by soils with good fertility, abundant land, sparse population and also high poverty rates. Table 2 gives an overview of the villages and the interviewed farmers during the field trip. The farmers in the village were chosen according to the target of getting a good overview of the conditions and the situation in the chosen village. In addition, we tried to get equal rates of female and male farmers.

All interviewed farmers are growing maize on around 40-50 % of their cultivated land. According to the Ghana Living Standards Survey Round Four (GLSS IV) done by the Ghana Statistical Service (GSS), 89% of the farmers in Ghana are cultivating maize (GSS, 2004). For most of the interviewed farmers it is the main staple food crop and only the quantity, which will be probably left over, is sold at the market. The application of fertilizer seems to be very high compared to average figures for African countries. The most recent figures for fertilizer use in Sub-Saharan Africa show an average application of 8 kg/ha and for Ghana only 4 kg/ha (MORRIS ET AL., 2007). The average use of fertilizer for the interviewed farmers is 48 kg/ha NPK (Nitrogen, Phosphorus and Potassium) and 24 kg/ha Ammonia. However, according to MOFA statements, it is still too low in order to maximize the yields and prevent soil degradation. In addition, the variation among the farmers is very high; some are applying the recommended minimum quantities for maize (100 kg NPK and 50 kg Ammonia sulfate per acre[1]) and some are applying nothing. Almost all farmers are aware of the benefits of using fertilizer, but some say that they cannot afford it and others say that the soil is good enough.

[1] One hectare equals 2.5 acres

The yield is varying according to the fertilizer use. Depending on the soil and the weather conditions, the yield without fertilizer is between 2 and 5 bags per acre. With the recommended quantities this could be more than the double quantity according to MOFA extension officers.

***Table 2**: Summary of basic data about the interviewed farmers*

Village	District	Farmers interviewed	Land		Fertilizer use (per acre) for maize		Maize yield	Biggest Constraints
			Acres	Maize	NPK	Ammonia	bags/acre	
Kasalgo	Tamale	5	6.5	50%	90 kg		5 – 6	Credit
Dulzo	Tolon/Kumbungu	4	9.5	50%	50 kg	12 kg	5 – 6	Credit, Fertilizer, Labour
Gummo	Tolon/Kumbungu	5	8	50%	55 kg	30 kg	4 – 6	Credit, Fertilizer, Seeds
Kukuo	Tamale	8	8.5	50%	65 kg	40 kg	6 – 8	Credit, Labour
Finihi	Tolon/Kumbungu	3	10	40%	n/a (no applicable)		8 – 10	Credit
Kuli	Tolon/Kumbungu	3	11	36%	25 kg	25 kg	6 – 8	Labour
Bontanga	Tolon/Kumbungu	2	10.5	48%	50 kg	50 kg	n/a	-
Kapalbagu	Yendi	3	9	42%	50 kg	0 kg	5 – 6	Credit
Sekpe	Yendi	5	8	43%	40 kg	10 kg	8 – 9	Credit, Labour
Total / Average		**38**	**9.0**	**45%**	**48 kg**	**24 kg**	**6 – 8**	

Note: Data on land, fertilizer use and maize yield represent averages for the interviewed farmers in a village

[Source: own interviews]

The biggest constraint for the interviewed farmers is the availability of credit. There are hardly any microfinance institutions which are focusing on small and poor farmers. Interviews with microfinance institutions (ACDEP - Association of Church Development Projects) and NGO´s (SNV - Netherlands Development Organization) resulted in various explanations. According to them, for most of the institutions the risks, either of agricultural production or of the farmer itself, and the transaction costs, which involve high procedure and monitoring costs, are too high. They are more likely to focus on relatively secure micro businesses, mostly done by women in the city. The filling of this gap at least partly is crucial for a more efficient and productive agriculture.

Land in the Northern Region is abundant and can be cultivated by anyone who wants to cultivate it. Except in Kukuo, which is a village very close to Tamale, land was no constraint to extent the farming activities. According to my interviews with the farmers in the region, the problem for the farmers is to have enough means to enlarge the farm. Labour, seeds, fertilizer and tractor services are mostly available, but too expensive for the farmers to afford.

2.2.2 Farming Conditions

As mentioned before the three Northern Regions account with 98,000 km² for 40 % of Ghana´s land area. With its climate, vegetation and landscape it resembles more the neighbour country Burkina Faso than the southern part of Ghana. It is much drier than the South with temperatures between 15 and 40 degrees Celsius. A quote of a farmer brings it to a point: "*The chief farmer is the rain!*" The rain and their allocation throughout the rainy season determine to a large extent the production and the income of the farmers. An upcoming problem during the last decade, especially for maize, is the appearance of a small dry period during the main growing phase (July, August).

The vegetation is characterized by grassland, bush and stand-alone trees. The rainfed land is cultivated between April and November, only irrigated land can be used also in the dry season. In general land is not a constraint in the Northern Region, where population density is low. According to ACDEP (a NGO based in Tamale) the Northern Region has a suitable area for agriculture of at least four million ha, whereas currently only around one million is used. The quality of the land is different and some farmers (have to) move to areas with a better soil fertility in order to increase their production and income.

Agriculture and maize production in the North are mostly done by hand, only a few farmers own and use animal traction for plowing or other difficult farming activities. Tractor service is available, but especially near bigger cities and less in remote areas. The tractors are often owned by richer people in the towns, who offer the service to farmers who are not able to invest in their own tractor. The costs of the tractor service (around 20 $ per acre plowing) are often too high for most of the farmers. So, they usually have to rely on their own labour. The most important source for this is the own household. If the household labour is not enough, additional labour can be hired, mostly from the own or the neighbour village (2-3 $ per day).

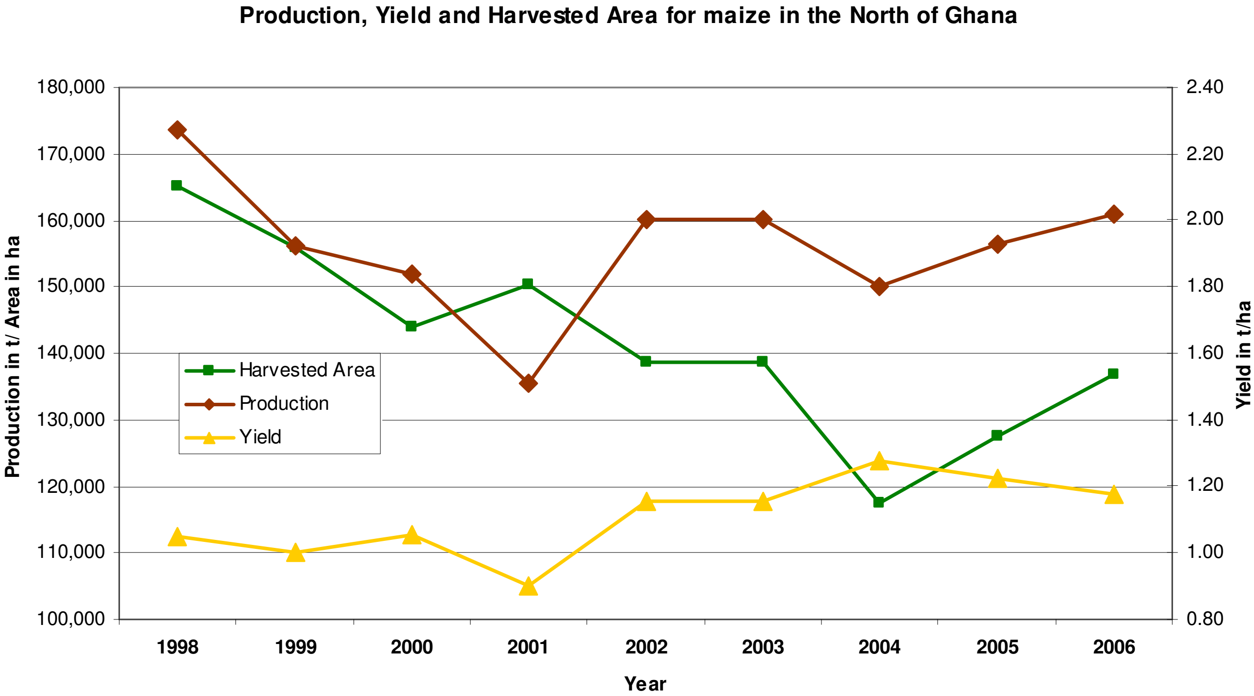
Tradition and religion in the North as well as in the South play an important role in everyday life. In general, the people trust on their ancestors, their traditional leaders and religious beliefs, more than on the modern society, the government or development agencies. It is difficult to implement a new way of doing certain things without considering the mentioned aspects (VAN VELUW, 2007). There are numerous examples and experiences, which support this view. One is from a village, where a NGO supported the building of boreholes. The NGO thought the best way is to build it as close as possible to the people. However, the women, who are responsible for the water, enjoy the walk over some distances, because it is the only possibility to talk to other women without any men close by. The quintessence from this is that no analysis can be done and no recommendations can be given without considering the people, their background and their culture.

2.2.3 Production

In the North maize can only be cultivated once per year. Planting time is May until the beginning of June, depending on the rain. The land will be prepared after the first two or three rains by hand, animal traction or tractor. The planting is done mostly by using own seeds. Only the minority of farmers uses the recommended improved or hybrid seeds (KOLAVALLI, FORTHCOMING). The Ministry of Food and Agriculture in Ghana (MOFA) advises to use every two years new seeds. Moreover according to MOFA, the farmer should use at least two bags (=100 kg) of NPK fertilizer per acre, which should be applied around three weeks after planting, and one bag of ammonia sulfate (= 50 kg), which should be applied two weeks later. According to most of the interviewed farmers the weeding is the most labour-intensive time and is when most labour shortages occur. The maize should be weeded two or three times at least. The harvest is again commonly done by hand. After harvesting the maize is dried in the sun, for which the grains are generally spread on a flat surface. Afterwards two methods of shelling are used. The traditional method is to do it with the thumb, then grinding two cobs against each other and threshing the cobs with a stick in a sack. The other, less used, variant is with a simple threshing machine. The final step is to winnow the grains and remove all undesired elements (KOLAVALLI, FORTHCOMING).

Overall the area allocated to maize in the three northern regions is declining over the years (see Figure 3) in favour of sorghum, groundnuts and yam. In 1998 165,000 ha was allocated to maize and in 2006 only 137,000 ha. Reasons could be the uncertain profitability under the prices between 2000 and 2006 or the less favorable production patterns, like higher loss of soil fertility or the lower drought resistance of maize. However, maize is still the most important staple, especially for the people in the North. Furthermore, the yield increased over time, so that despite the decline in area, the production decreased only slightly.

Figure 3: *Maize Production in the North of Ghana*



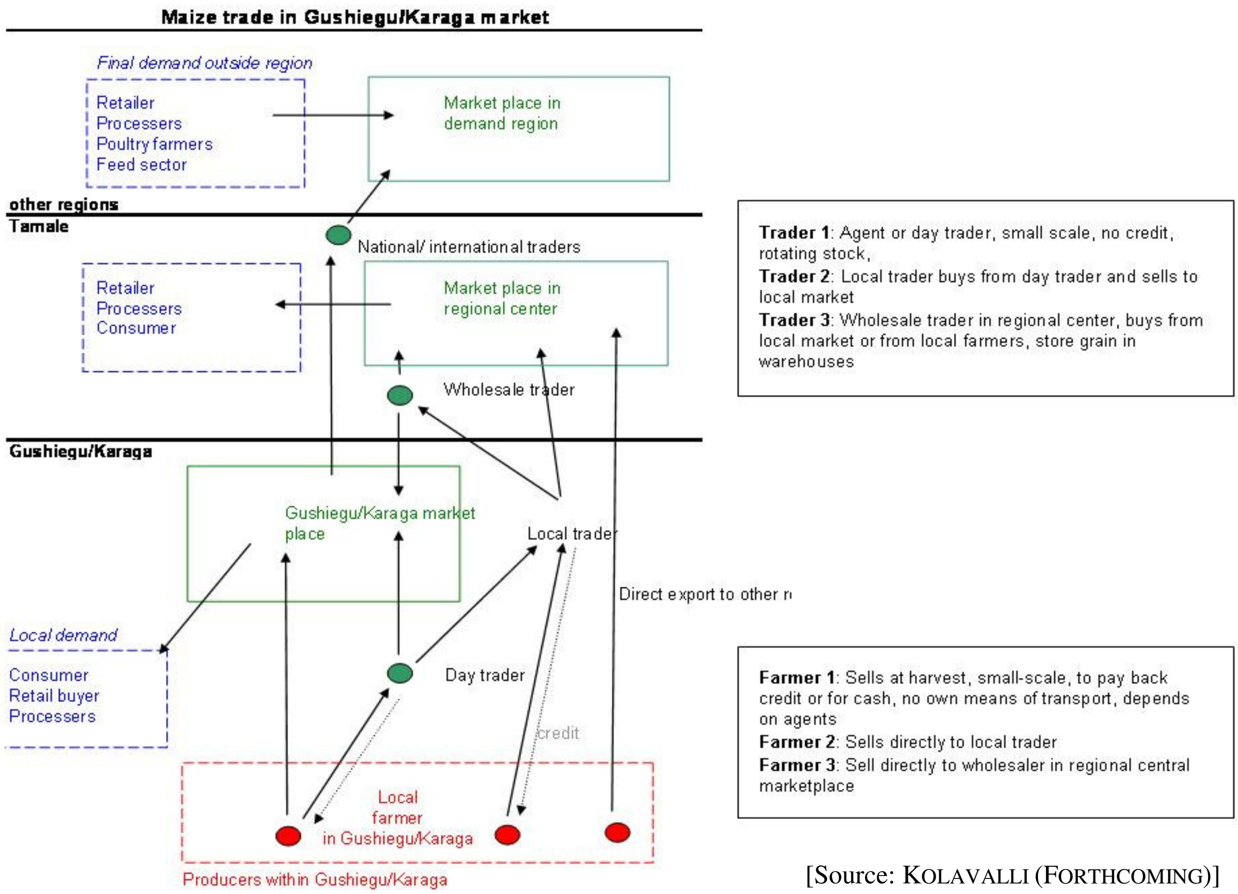
[Source: Based on data from MOFA]

2.2.4 *Marketing, Trade and Distribution*

Farmers have different possibilities to market their produce, as is illustrated in Figure 4 for farmers in Gushiegu/Karaga in the Tamale district.

They can market their produce directly at the markets (local or regional) or they use traders or so called market women. The traders buy the maize either within the village or at the market itself. The traders themselves can be categorized into day, local, wholesale and national traders. Primarily, the smaller traders have partly fixed "business" relationships to the farmers. They come regularly and some are also providing them credit or inputs. The risk is less, because they know and trust each other. The main reason for farmers to sell directly at the market is the feeling of being cheated by the trader. Some are also mentioning that they sell something, if they have to go to the town anyway. However, for most of the farmers there is often no choice. Many of them have no means to transport their produce to the next market. Other farmers are far away and only some or only one trader is coming to the village (KOLAVALLI, FORTHCOMING and own interviews).

Figure 4: *Different maize marketing chains in Gushiegu/Karaga, Tamale district*



[Source: KOLAVALLI (FORTHCOMING)]

The local traders mostly sell their products to wholesale traders or retailers from other regions or even from the bordering countries (Burkina Faso, Togo and Ivory Coast). The transportation is often rented, because the traders have no capital to invest in a truck. The final destinations of the maize are consumer markets, processing companies, or small shops and supermarkets.

2.3 Maize Production in the South of Ghana

2.3.1 Farming Conditions

As mentioned above, the South of Ghana is heterogeneous as well. The coast and southern regions are mainly in the forest zone, which is less suitable for maize production than the transition zone. With rainfall around 1000 mm/year and good soil fertility, maize yields can go up to 5 MT/ha in the transition zone. Because of the good conditions, the regions Brong-Ahafo and northern Ashanti are also called the "maize belt" of Ghana. Around 40 % of the maize in Ghana is cultivated in the "maize belt" (SRID/MOFA, 2007) and maize is the most important crop for the farmers. They produce much more than they consume, so that around 60-70 % of the produce is marketed (KOLAVALLI, FORTHCOMING). An explanation for this is also that in contrast to the North, maize is not the main staple crop for the South. Here, cassava and yam are the most popular staples. In the forest zone, especially the Eastern region, maize production is becoming more and more popular (KOLAVALLI, FORTHCOMING).

The technology adoption in the South is more developed than in the North, even if the availability is an often mentioned constraint. The cultivated plots are on average much larger and the use of tractor service is more common. Furthermore, use of herbicides is much more common in the South (used by around 70 % of the farmers), which indicates also the higher degree of commercialization of maize production. Another reason for the use of herbicides is the higher cost of labour (one labourer needs 4-5 days to weed one acre) and the smaller availability of it compared to the North. The availability of labour often determines the total cultivated area and the crop mix of the individual farms. The same is true for the availability of tractor service for ploughing. Many farmers complain that it is hard to find a tractor at the right time. The southern part of Ghana profits from two rainy seasons. Farmers can cultivate their land twice and often maize is cultivated twice or only in the minor season from October to December. The additional season allows the farmers to work more and generate more income, whereas the people in the North have hardly any possibilities to earn income during the dry season. In general, the South faces also better political conditions due to the fact that 85 % of the 23 million inhabitants (or potential voters) live in the south. The more densely populated areas allow also for better implementation of certain governmental or development programs (KOLAVALLI, FORTHCOMING).

2.3.2 Production

The land preparation starts in April for the major and in September/October for the minor growing season. Against the most common practice to plough the land, the Ministry of Food and Agriculture recommends reduced or no-tillage (see also Table 3). The most efficient way for planting is to do it in rows. According to the field interviews and discussions with MOFA officials, the adoption rates of the recommendations for improved seeds and fertilizer are quite low. One reason is that large yield differences are not observed by the farmers. A second one is the financing of it, especially fertilizer. Governmental programs, which provide the farmers with a kind of input credit are partly present, but not widely implemented.

Table 3: *Technologies and recommended practices by the national agricultural extension program (NAEP)*

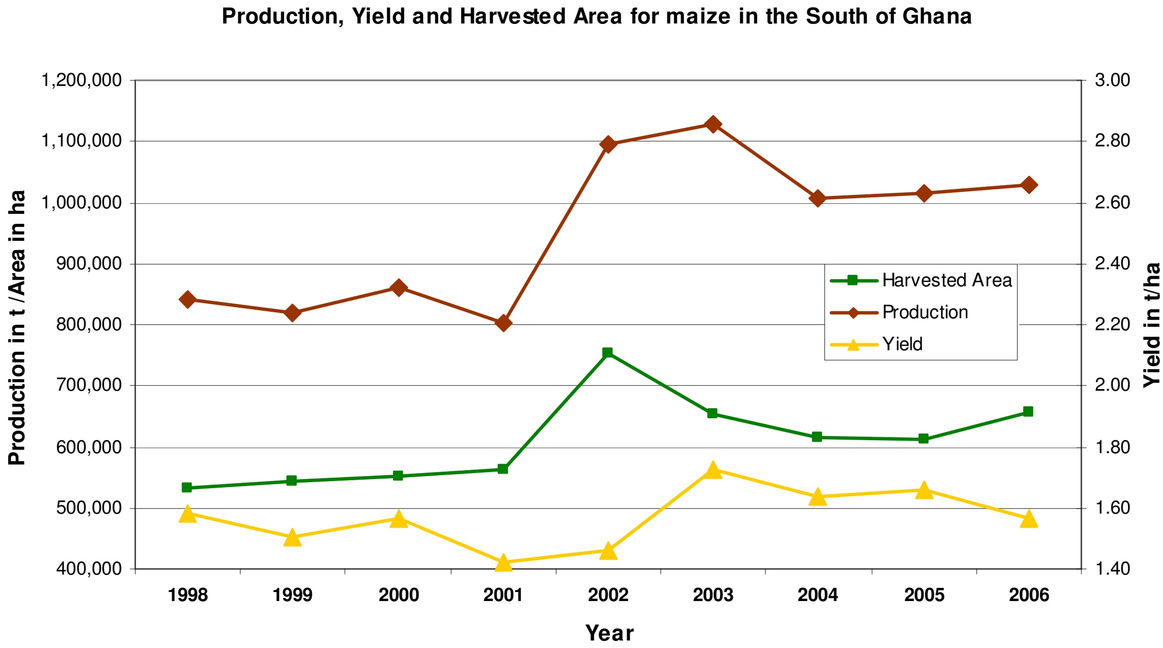
Agronomic activity	**Recommended rates or practices**
Land preparation	• Slash and no burn • Reduced tillage (no ploughing)
Planting	Row planting at 40cm between crops by 90cm between rows
Weeding (use of chemicals or human labour)	• 1st weeding about 4-6 days after land preparation • 2nd weeding about 4 weeks after sowing • 3rd weeding about 6 weeks after sowing (not in the south)
Improved seeds	2 to 3 seeds per hill or about 9 kg/acre
Artificial fertilizers	• Basal application: 100 kg of NPK per acre • Top dressing: 50 - 100 kg of ammonium phosphate per acre
Pesticides	Follow application instructions (often about 1–1.5 liters per acre)
Harvesting	Just before drooping of cob
Storage	More than one meter height from ground and permeable to air

[Source: KOLAVALLI (FORTHCOMING)]

The most labour-intensive time is the weeding phase. Three times weeding is usual in the transition area, whereas two times are most common in the south. However, the majority of farmers use herbicides to control for the weeds. Due to financial constraints this is often only possible for parts of the cultivated land. Additional labour therefore has to be hired. Especially from October to January migrants from the North are a major source of labour for the South.

Harvesting is generally done by hand, mostly by family labour. To avoid infestation with weevils the harvest should be done before dropping the cob. This is often seen as difficult since there is not enough labour available at this particular point of time. In general, the harvest is a tradeoff between lower risk of weevils (with early harvest) and drier maize (with late harvest). Post-harvest treatment includes mainly the drying of the grain. The storage afterwards is a big problem for many farmers. First, the storage facilities are often not optimal and improvised. Second, the treatment and the knowledge about it are usually not sufficient to store the produce over a longer time. Large quality losses, due to insects and not water-proof facilities are the consequences, leading many farmers to adopt short storage periods.

Figure 5: *Maize Production in the South of Ghana*



[Source: Based on data from MOFA]

Due to the better agricultural conditions, the average yield in the South is much higher than in the North. In contrast to the North, the area allocated to maize also increased in the South, so that the overall production increased from 1998 to 2006 from around 800,000 tons to over 1 million tons (see Figure 5). The biggest expansion rates during this period are documented for Brong-Ahafo (around 230,000 tons or 145 % increase) and the Eastern region (around 80,000 tons or 45 % increase) (SRID/MOFA, 2007).

2.3.3 Marketing, Trade and Distribution

The marketing chain for the South is comparable to the one described for the North. Only a few farmers sell their produce themselves at the market. Mostly, they are using intermediates, like agents or traders. The difference is that agents sell the produce immediately after they buy it from the farmer, whereas traders usually store it and wait for higher prices. They have to have working capital to finance it and also storage facilities. The capital is often borrowed from commercial banks with quite high interest rates, around 50-60 % (KOLAVALLI, FORTHCOMING). The profit of the intermediates is sometimes not calculated explicitly through the price but through quantity. That means that the trader buys 10 or 20% more but for the same price. For example the bag of maize contains not 100 kg, but 110 or 120 kg maize for the same price. The extra amount is then the profits for the trader. Another special feature is that traders or agents have sometimes interlinked transactions with farmers. For example traders provide farmers with small credits to buy inputs and get it back in kind after harvest.

Most of the traders and agents are also organized in official trader organizations. The organizations charge fixed fees, which are dependent on the size and the importance of the market. They try to combine the forces of the numerous small traders in order to increase their power on the much bigger buyers from other markets or the retail sector. Another source of costs for the traders is the hiring of storage or warehouse space at the market place, which is generally owned by the district assemblies.

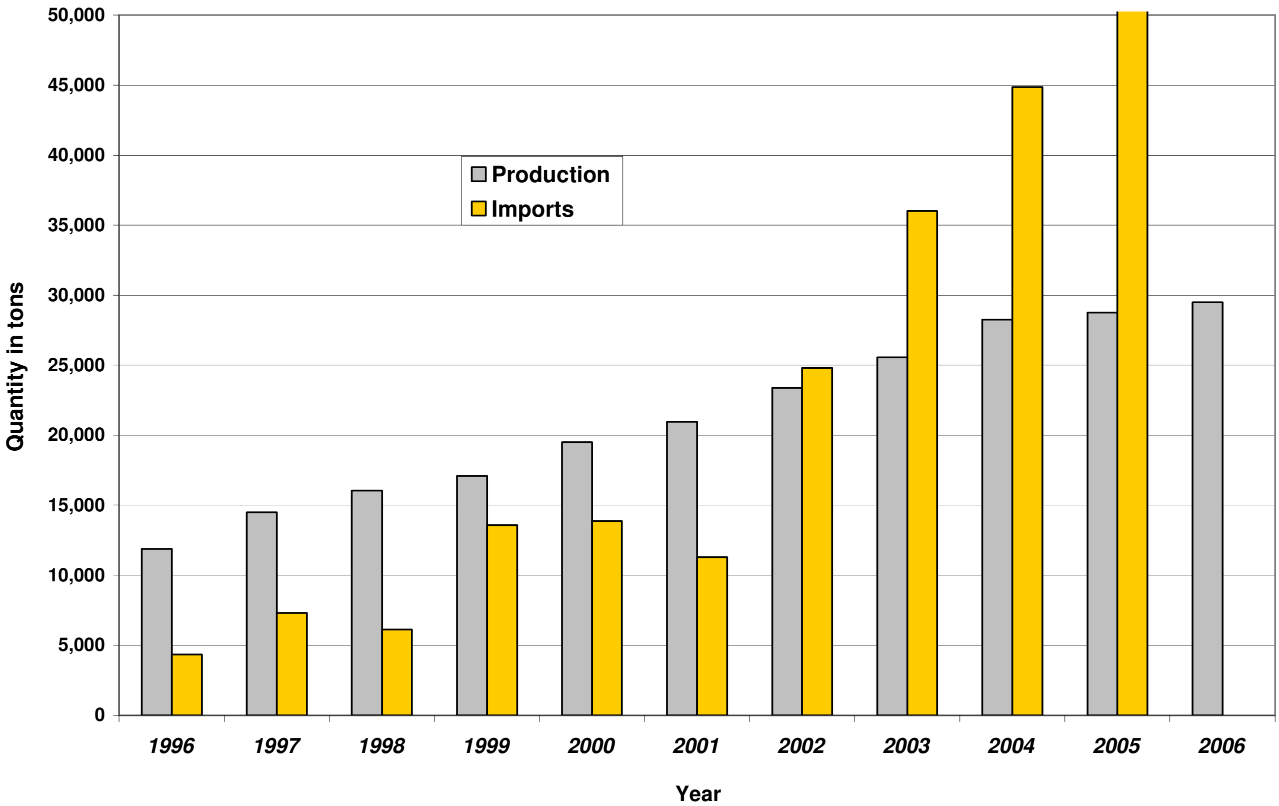
In the South the possibilities for processing maize or selling it to big poultry producers are much better than in the North. For the food processing industries the quality is very important. According to some companies the maize cultivated in the minor season has better quality characteristics than the maize from the major season. The buying price is close to the price of the nearest market. The extremely fluctuating prices are a big problem, because generally no contracts and price secure instruments exists. If the price is too high, they are forced to stop the processing and wait for lower prices (KOLAVALLI, FORTHCOMING and own interviews with two poultry producers).

Poultry producers have no specific quality requirements but prefer high protein rates. Maize is by far the most important feed for broilers and layers, with 1 kg of poultry requiring 3.5 kg of maize (MOFA, 2005). The profitability of poultry production during the last few years has gone down rapidly. The main reason is the strong increase of cheap poultry imports from Europe and USA. These imports are mostly dumped by the exporting countries (SHARMA, 2005; ATARAH, 2005).

From Figure 6 we see the enormous increase of poultry imports to Ghana from 2002 on. In

2001 the imports had around half the size of the production and only four years later the situation was almost the other way around with imports of more than 50,000 tons. The production increased until 2005 continuously by 1,000 to 2,000 tons per year but is almost stagnating since 2005.

Figure 6: *Production and Imports of Poultry Meat in Ghana*



[Source: Based on FAOSTAT (2008)]

3. Profitability and marketing margins in the maize chain

3.1 Profitability of maize production

3.1.1 Production Costs

The calculation of production costs is based on the results of my interviews and on the results of field trips done by IFPRI staff members. It has to be mentioned that the analysis does not consider any opportunity costs of maize production. Therefore, it is based purely on the observable costs. Table 4 shows the summary of the results for three different regions, the North, the transition region and the South. The calculation is based on average figures from 2006 and 2007. For the North, the figures for 2008 are added to illustrate the large increase of costs, mainly because of the fertilizer prices (based on own case study). We can assume that the percentage increase (around 70 %) in fertilizer costs is similar for the two other areas. Besides the fertilizer increase, we obtain only minor increases in the transport and the seeds.

Table 4: *Production Costs of One Acre of Maize in the Different Regions of Ghana (in GHc)*

Region	North		Transition	South
Year	2006 / 07	2008	2006 / 07	2006 / 07
Land preparation				
with Tractor	20.0	20.0	30.0	30.0
by Hand	10.0	10.0	20.0	20.0
1st Weeding	10.0	10.0	15.0	-
Planting + Maintenance				
Seeds (9kg)	7.0	8.0	10.0	4.0
Sowing	10.0	10.0	13.5	9.0
Fertilizer				
NPK (2 bags)	40.0	69.2	35.0	40.0
Ammoniasulpate (1 bag)	17.0	28.1	22.0	16.0
Fertilizer application	5.0	5.0	5.0	9.0
2nd Weeding	9.0	9.0	20.0	15.0
3rd Weeding	5.0	5.0	20.0	15.0
Harvesting				
Harvest	15.0	15.0	13.5	16.6
Sacks and other material	7.0	7.0	not applicable	3.1
Transport to farm	6.0	8.0	15.0	4.5
Production costs with tractor				
With fertilizer	**151.0**	**194.3**	**199.0**	**162.2**
Without fertilizer	**89.0**	**92.0**	**137.0**	**97.2**

[Source: Own calculation based on KOLAVALLI (FORTHCOMING) for 2007 and own data for 2008]

Between the regions the differences are large due to different production systems and input costs. The production costs in the transition zone (mainly Brong-Ahafo and Ashanti), where most of the maize is grown, are 15 to 30 % higher, especially due to higher labour and transport costs. One reason could be that the prices are related to the much better agronomic conditions, which allow for higher yield rates and a better profitability. For the South we calculate nearly the same total costs as for the North. However, the major cost components are quite different. Whereas tractor service and labour costs are more expensive in the South, farmers in the North have to weed three times instead of two.

In general, we can say that these are the most common production systems. However, there might be a lot of small variations. An important point is that only a minority of farmers in the North can pay the tractor service, so that they are forced to plough the land by hand. The costs are lower (around 10 Ghana cedis less), but the problem is the availability of labour during this time. Farmers can often only rely on their households, so that the availability of labour during land preparation and the weeding time determines the size of the cultivated land.

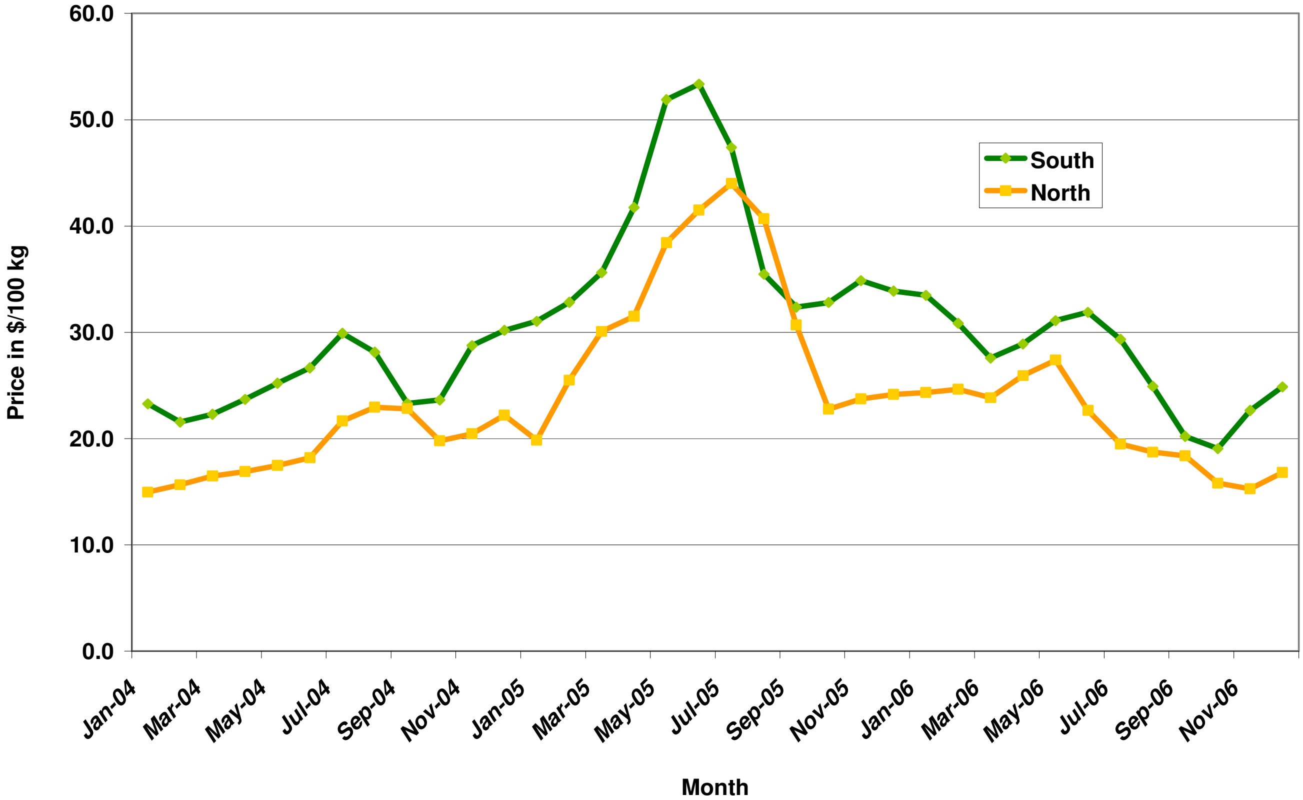
The fertilizer is responsible for 30 to 50 % of the production costs. In the near future fertilizer costs are likely to increase due to higher oil prices, which have a direct impact mainly on prices of nitrogen fertilizer. So, we can expect that the costs in the future more the costs in 2008 than the costs in the past (2006/07).

3.1.2 Market Prices and Profitability

Most of the farming households in Ghana are semi-subsistent. They produce mainly for own consumption, and everything which will be left over goes to the market. In our calculation the wholesale price minus transport costs and market margin is the farm gate price, which is the reference price for the farmers.

The wholesale price is related to the world market price and therefore, quite fluctuating. Especially since 2007, the world market price of maize increased enormously from 121.9 $/t in 2006 to 163.7 $/t in 2007 and 230.2 $/t in 2008 (WORLD BANK, 2008). The consequences for the domestic price can be seen in Table 5. However, in addition the influence of the local production is still large. The bad harvest in 2004 was the main reason for the sharp price increase afterwards (see Figure 7 for the price trend in 2004-2006). Another important point is the seasonality of the price development. The price is fluctuating according to the seasons in Ghana. After the harvest (around September-October) the price goes down and usually starts to increase in January to March until the beginning of the next harvest. Figure 7 shows the seasonal fluctuations of the maize price in the North and in the South. The North price is around 5 $ per 100 kg bag below the South price, but follows the South price trend with a small delay. The first reason of this seasonal fluctuation is the missing storage facilities and the low quality of storage at the farms. The second reason is the low income level of the farming households, which requires them to sell the produce as soon as possible to have some cash. Third, the low level of production and the selling of maize directly after the harvest lead to the so called hunger season in June - August, when many farm households need to purchase maize and prices usually go up sharply.

***Figure 7**: Wholesale Price in the North and South of Ghana*
n



[Source: Based on SRID/MOFA (2007)]

The wholesale prices of white maize for the current season on different markets in Ghana are given in Table 5. It shows the recent price increases from September 2007 to May 2008. Almost all prices increased by 100% or more during this period.

Table 5: *Maize Prices at Different Markets in Ghana (in GHc/100 kg)*

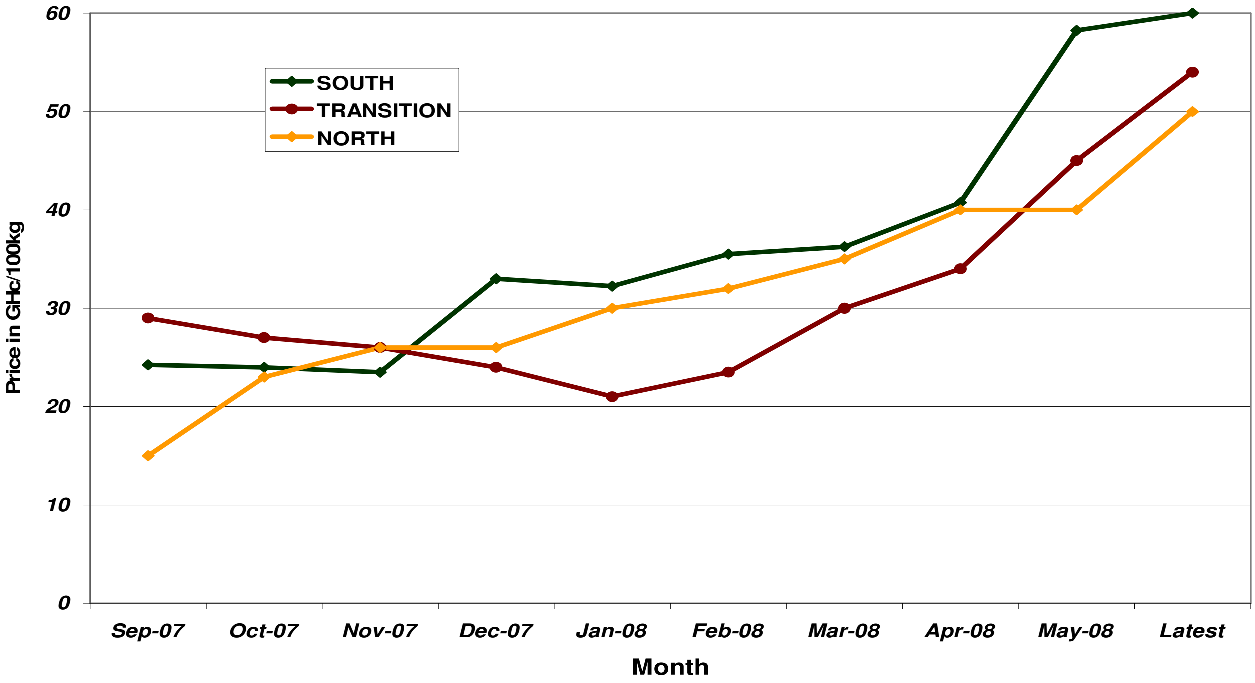
Markets	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08
SOUTH (Tradenet)									
Accra (Tema)	24	29	28	38	38	39	43	48	61
Hohoe	16	21	19	26	26	30	30	34	49
Koforidua	29	21	-	-	28	35	34	34	63
Sekondi	28	25	-	35	37	38	38	47	60
TRANSITION (Tradenet)									
Kumasi Central Market	29	27	26	24	25	28	33	40	52
Techiman					17	19	27	28	38
NORTH (MOFA North)									
Tamale	15	23	26	26	30	32	35	40	40

[Source: TRADENET, SRID/MOFA (2008)]

The large price differences between the regions may be explained to a large extent from the large transport and transaction costs which occur if traders and middlemen connect the markets. In chapter five this is explained more detailed.

Figure 8 illustrates the development of the average price in the three zones based on the prices in Table 5. The trend is the same and the course similar at all markets. We obtain that the prices are lower the longer the distance to one of the main markets in Accra or Kumasi. The prices in May are on dramatic highs, which is problematic for consumers and net buyers. Only farmers with net surpluses in maize can make extra profits out of this current situation.

Figure 8: *Average Price of Maize in the three Zones of Ghana*



[Source: Based on TRADENET, SRID/MOFA (2008)]

To calculate the profitability of maize, the prices are taken from the official observation of the Ministry of Food and Agriculture (SRID/MOFA, 2007 and 2008). Two options are available for making the profitability analysis for each region. First, we distinguish between farmers who use the recommended quantity of fertilizer and farmers who use no fertilizer, and second we distinguish between farmers who store the harvest until February and farmers who sell it immediately after the harvest.

Table 6: *Profitability of Maize Production*

Region	North		Transition	South
Year	2007	2008	2007	2007
Yield and Prices				
Yield with fertilizer (bag/acre)	8.0	8.0	12.0	9.0
Yield without fertilizer	3.5	3.5	6.0	4.0
Price in Sep (GHc/bag)	***22.0***	***35.0***	***24.0***	***24.0***
Price in Feb (GHc/bag)	***30.0***	***42.0***	***32.0***	***32.0***
Revenue				
With fertilizer in Sep (GHc/acre)	176.0	280.0	288.0	216.0
Without fertilizer in Sep (GHc/acre)	77.0	122.5	144.0	96.0
With fertilizer in Feb (GHc/acre)	240.0	336.0	384.0	288.0
Without fertilizer in Feb (GHc/acre)	105.0	147.0	192.0	128.0
Production Costs				
Costs for storage (GHc/bag/6 month)	1.0	1.0	1.5	1.5
With fertilizer (GHc/acre)	151.0	194.3	199.0	162.2
Without fertilizer (GHc/acre)	89.0	92.0	137.0	97.2
Profits				
With fertilizer in Sep (GHc/acre)	25.0	85.7	89.0	53.8
Without fertilizer in Sep (GHc/acre)	-12.0	30.5	7.0	-1.2
With fertilizer in Feb (GHc/acre)	71.5	121.6	154.0	101.8
Without fertilizer in Feb (GHc/acre)	6.9	45.8	37.2	18.6

*Note: Profits in February include storage costs and an annual inflation of 12 %

[Source: Own calculation based on KOLAVALLI (FORTHCOMING) for 2007 and own data for 2008]

From Table 6 it becomes clear that the transition region has the best conditions for maize production (with disregard of opportunity costs). The key difference is the much higher yield on average. The very suitable conditions make up for the higher production costs and generate higher profits than in the South and North. Profitability in the South is in between that in the transition zone and the North. Another observation is that the use of fertilizer is very profitable. In every case the value of the surplus yield it generates is much higher than the additional costs of the fertilizer. The same story holds for storage. Because of the relatively secure seasonal fluctuation, the price increase until February is under consideration of a 12 % inflation rate - much higher than the additional storage and handling costs per bag. The profitability of maize production in the North is questionable under the usual conditions (low fertilizer use and no storage). The price increase for 2008 will, however, improve the profitability. A major problem is the sharp rise in fertilizer prices. . The farmers have to invest much more money for applying the same amount of fertilizer on maize than one year before. Many farmers are not able to invest more. So the total amount of investment may remain the same and hence the quantity of fertilizer applied will be reduced. The consequences are lower yield rates, which lead to a lower overall production of maize. The change for the profitability of an average farmer in the North is calculated in the following:

We assume a farmer with three acres of maize, who applied the recommended quantity in 2007 but had a budget that was limited to this amount. In 2007 he had to pay 57 GHc for 100 kg of NPK and 50 Kg of Ammoniasulphate. Under consideration of 12 % inflation, he has a budget of 64 GHc for 2008. However, with the prices in 2008 he can only buy around 66 kg of NPK and 33 kg Ammoniasulphate. With this fertilizer the yield will most probably drop from 8 bags per acre in average to around 5.5 bags per acre. Assuming all other costs are as shown in the 2008 column of Table 6 and the price is around 35 GHc/bag as illustrated in the table, the total costs amount to 161 GHc/acre and the revenue to 192.5 GHc/acre. The profit for the farmer is 31.5 GHc/acre compared to a profit of 25 GHc/acre in 2007. So, the profit for the three acres of the farmer increased slightly by 18.3 GHc (corrected for inflation 16.3 GHc) but the production is reduced from 2400 kg to 1650 kg. However, this calculation only refers to the so called “cash crop farmers”, who sell large parts of their produce to the market. Most of the farmers, especially in the North, are consuming most of their produce and can be called “subsistence farmers”. For them it is more problematic because with a fixed budget they have also to reduce the fertilizer input with the result of lower production. So, they have less maize too consume and the household inventories for the year are reduced. This could have been serious consequences for the nutrition status of the household members.

To sum up, “subsistence farmers” loose from the situation because they are harmed by the higher input costs but do not profit from the higher output prices. In contrast, for the cash crop farmers the profits are higher than before, because they benefit from the higher output prices more than they are harmed by the input prices. The gain reduces, the lower shares of cash crops in the crop mix are. The overall effect on production is quite challenging to estimate. Whereas in developed countries one would expect higher production with rising prices, the effect in developing countries with many small farmers is more difficult to estimate. The key difference is that in developing countries farmers usually can finance higher input costs. So, we can expect at least the same input level than before when food and fertilizer prices increase. However, in Ghana a significant share of farmers is likely to reduce their inputs due to the price increase. The result is a lower production. So, the lack of working capital and the absence of credit markets reduce the expected production increase from higher maize prices.

3.2 Analysis of costs, prices and margins in the chain

The profitability of the whole maize chain has to be analyzed by examining the costs and profit margins of maize from the farm gate to the consumer. The analysis is difficult because of the heterogeneous general conditions. The profitability is influenced by the prices, the distances, the infrastructure, and the economic and natural environment. Distances and the local infrastructure play a significant role, especially in developing countries. The roads are often in bad conditions, and lack of suitable means of transport and remoteness of maize producing areas with hardly any connection to the bigger markets make it more challenging. Another major problem is the missing or insufficient storage facilities, which lead to an early selling of the produce or high costs for external storage. Also factors such as missing marketing or commercialization corporations play significant roles, which increase the costs of marketing the produce. Last but not least the missing competition among the traders and the unavailable market and price information, especially in remote areas, could lead to huge inefficiencies and higher costs.

In Table 7 two calculations of marketing margins are compared. The first is done by the Natural Resources Institute (NRI) based at the University of Greenwich and the second is based on results from the IFPRI field reports. Both are looking at the margins of maize for farmers located in Brong-Ahafo (not so far from Techinam) to a consumer market in Accra.

***Table 7**: Calculation of Margins for Maize from Farm gate to Consumer Market (GHc/bag)*

Analysis done by	NRI 1998	IFPRI 2007
Farm to Techinam market	***5.5***	***6.1***
Handling & other costs	1.7	1.1
Transport	0.6	1.6
Commission	0.6	0.2
Storage, interest, losses	1.1	1.7
wholesaler profit	1.5	1.5
Techinam to Accra	***4.1***	***5.9***
Handling & other costs	0.8	1.1
Transport	1.7	3.8
Storage, interest, losses	0.9	0.5
wholesaler profit	0.7	0.5
Margin till Accra	**9.6**	**12.0**

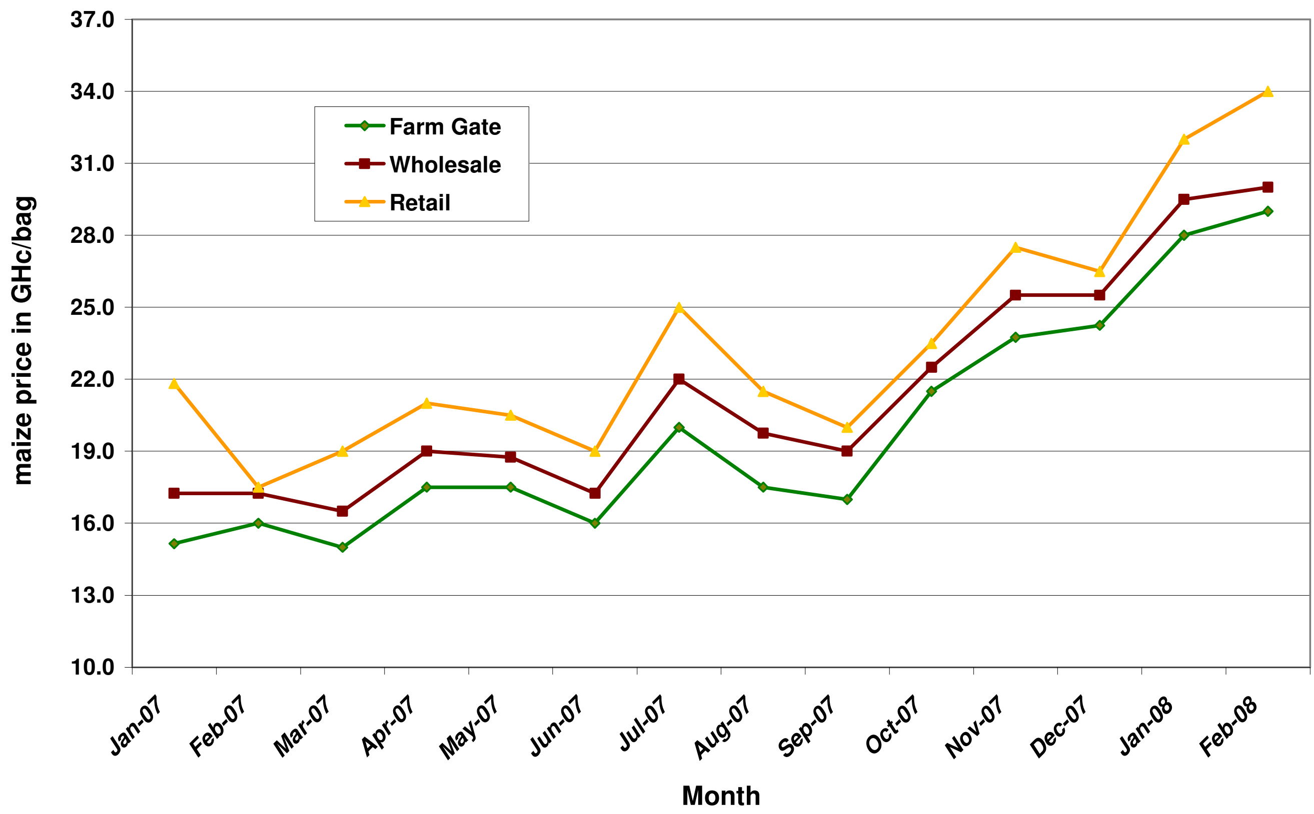
[Source: WORLD BANK (2007), KOLAVALLI (FORTHCOMING)]

The analysis of IFPRI results in higher marketing margins, mainly as a result of much higher transport costs. The other differences are of minor importance. Since Techinam is at the main road to Accra and the farmers are also not located in remote areas, we can assume that most of the maize farmers in Ghana face higher marketing costs in their chain. This results usually in lower producer or farm gate prices for the farmer as the consumer market prices may be considered as given.

For the North the marketing costs for selling at the market in Accra are, of course, also higher. Based on own interviews and IFPRI data (KOLAVALLI, FORTHCOMING), the costs and profit margins from Tamale to Accra are around 7 GHc/bag. Depending on the distance of the farmer from Tamale, another 6 to 7 GHc have to be added.

In Figure 9 farm gate, wholesale and retail prices for maize in the Northern region based on MOFA data are illustrated. The lines run almost parallel and the margins in between are almost constant. The farm gate - wholesale margin is around 1.5 GHc/bag and the wholesale - retail margin is around 2 GHc/bag.

***Figure 9**: Average prices for maize in the Northern Region*



[Source: Based on SRID/MOFA (2008)]

Part 2: Application of a multi-market model for maize in Ghana

4. Model description

Part two of this thesis focuses on the impact of different agricultural policy and price scenarios on selected agricultural markets, government revenue and the incomes of different household groups. The method of investigation is a multi-market model (MMM).
This chapter starts with an explanation and literature review of multi-market models. It is followed by a discussion of the structure of the model, where first, the product and household categories are defined and then the 323 equations are specified. Afterwards, the values of the elasticities and the base values of the endogenous variables, which are obtained from the different sources like GLSS IV, MOFA and DIAO (2005), are discussed. These values generate the baseline of the model. In section 4.4 the strength and weaknesses of the constructed MMM are analyzed and discussed. Next, different scenarios are simulated by varying the values of one or more exogenous variable in the model. The fourth simulation (Increase of productivity) is simulated by changing the constant of the yield equation. In chapter five the results of the scenario simulations are presented and discussed; starting with a reduction of the farmgate-market and North-South margin, then the increase of the world market prices and third, trade liberalization and a changing import tariff scenario. Finally, the last scenario focuses on the increase of productivity in the North.

4.1 Analysis with Multi-Market Models

A Multi-Market Model reflects direct and indirect linkages between a certain number of agricultural markets. In contrast to a partial equilibrium model, which reflects equilibrium in one market while assuming no changes in other markets, it shows the interactive effects between related markets. However, it does not have the power of a much more complicated and data-intensive computable general equilibrium model, which covers the complete economy of a country and includes all interactive effects between the sectors. So, the MMM stands between these two methods (ARULPRAGASAM AND CONWAY, 2003). However, the requirements to build a MMM are still high. Besides the detailed household characteristics (often examined thorough national surveys), the prices and quantities of the considered markets have to be discovered and balanced. With the production and consumption data for each household group and the corresponding elasticities the impacts of changes on income and expenditure, production and consumption prices and quantities as well as the trade balance and government revenues can be examined (SADOULET AND DE JANVRY, 1995).

ARULPRAGASAM AND CONWAY (2003) define four steps for building a multi-market model:

1) A market has to be defined, where the policy reform mainly takes place and which is of primary interest for various stakeholders. Then, the interlinked markets have to be defined. This happens through expert knowledge or data analysis.

2) A system of demand and supply functions has to be developed. Own-price and cross-price elasticities of demand and supply as well as income elasticities are required. These can be estimated from household and producer surveys, but in most cases are taken over from other studies or are best estimates and guesses from the researcher.

3) The modeler has to decide, which products are tradeables and non-tradeables. Then, supply and demand has to be balanced out. For non-tradeables this is done domestically by the price. For tradeables the world market price determines the domestic price and the quantity adjust by the size of trade (import or export).

4) Together with the household data these relationships between prices and quantities can examine the marginal effects of different policy scenarios on the different types of households.

The main focus of the MMM in this study is on the maize market. However, also the impact of policy scenarios on the other agricultural markets, millet and sorghum, rice, root and tubers, groundnuts and (especially) poultry, can be analyzed. Maize is one of the most important crops in Ghana and with higher productivity or better policy conditions it might be a powerful crop, especially for poor farmers, to generate higher income in rural areas. The main purpose of this MMM is to quantify these possibilities, taking into account potential positive and negative effects on related agricultural markets.

4.2 Structure of the Model

4.2.1 Product and Household Categories

In the MMM eight different types of households are defined: Four for the North of Ghana (*N*), which includes the previous described area with the regions Northern, Upper West and Upper East, and four in the rest of the country, called South (*S*). The four household groups in each of the two areas are urban non-poor (*URBRICH*), urban poor (*URBPOOR*), rural non-poor (*RURRICH*), and rural poor (*RURPOOR*).
In addition, as already mentioned, we analyze six product groups. The chosen crops belong to the most important crops according to production quantity and value in Ghana. In addition, a category for poultry is included in the model. This gives the following six product categories:

- Maize (*MAIZE*): Maize is one of the most important crops in Ghana, in terms of production and consumption. It is relatively balanced with a small tendency to import maize, but this is usually very low. In addition to human consumption it is the main input for poultry production.

- Millet/Sorghum (*MILLSOR*): Millet and sorghum are crucial crops for the North. They are relatively drought-resistant, and therefore used as a risk-reducing strategy. It is treated as a non-tradeable, since it is mainly a local market in the North.

- Rice (*RICE*): Rice production is more important in the North than in the South. The consumption of rice increased continuously, so that Ghana has to import a large share. The government and numerous NGO’s try to encourage farmers to produce more rice as a cash crop. The high water requirement is the biggest constraint.

- Roots and tubers (*ROOT*): This group encompasses cassava, yam, plantain and cocoyam. They are also non-tradeables and mainly consumed by the poor. The production takes place everywhere in the country, with cocoyam and plantain mainly in the South.

- Groundnuts (*GROUNDN*): In the North groundnuts are popular as a profitable cash crop. It is traded locally and is, therefore, a non-tradeable in the model.

- Poultry (*POULTRY*): Many farmers produce poultry and it contributes a significant share to the household consumption or income. Besides the numerous smallholder farmers mostly with a fistful of chicken, there are some commercial farms with thousands of chicken, producing them in intensive animal husbandries. Maize has the biggest share in poultry feed with a conversion rate of 3.5 kg per kg of chicken meat (MOFA, 2005)

Whereas maize, rice, root and tubers and poultry are produced in the North as well as in the South, millet and sorghum as well as groundnuts are mainly products of the North. They are included to investigate special impacts on poverty alleviation in the much poorer North of Ghana. The main cash crops of the South like cocoa, oranges, bananas and coconut are not considered, either because of less data availability or their limited impact nationwide.
Agricultural inputs are treated in different ways in the model. Since the land market is not clearly regulated and land is widely available in the North, land is considered as a variable input, but not as a traded commodity. Fertilizer, water and tractor use can unfortunately not be incorporated, since the available data for these inputs are not complete. Labour is also not considered, since it is used in many non-agricultural markets, which are not treated explicitly in the MMM. Therefore, the assumption is that labour supply is fixed and allocated in fixed proportions to each of the production activities (STIFEL AND RANDRIANARISOA, 2003). The seed is modeled as a fixed share of the output.

4.2.2 Model Equations

The equations connect all the data and relate them to each other. They are split up in five groups: prices, supply, consumption, income and equilibrium equations.
1) The price equations relate all prices, like world market price, border price, consumer and producer price, via the specific margins to each other.
2) The supply block represents the domestic production of food crops and poultry.
3) The consumption block shows household demand for food consumption.
4) The income equations describe household income as the sum of income derived from agricultural production and exogenous nonagricultural income.
5) Finally, the equilibrium conditions block contains equations equating domestic supply and net imports to demand for each of the six product categories.

Due to a lack of sufficient consumption data during different seasons, there is no seasonality of prices incorporated in the model.

The model contains 323 equations, which correspond to 323 endogenous variables as a requirement for the model to solve. These endogenous variables are the following:

1-48:	$PP_{c,h}$	= Producer Price of Household *h* for commodity *c*
49-51:	PM_t	= Import Price for tradeable *t*
52-63:	$PC_{c,urbpoor,l}$	= Consumer Price of the urban poor at *l* for commodity c^*
64-75:	$PC_{c,urbrich,l}$	= Consumer Price of the urban rich at *l* for commodity c^*
76-87:	$PC_{c,rurpoor,l}$	= Consumer Price of the rural poor at *l* for commodity c^*
88-99:	$PC_{c,rurrich,l}$	= Consumer Price of the rural rich at *l* for commodity c^*
100-139:	$SH_{h,f}$	= Share of land of household *h* allocated to crop *f*
140-179:	$YLD_{h,f}$	= Yield of crop *f* for household *h*
180-219:	$HSCR_{h,f}$	= Household specific supply of crop *f*
220-224:	SCR_f	= Total supply of crop *f*
225-232:	HSP_h	= Household specific supply of poultry
233:	SP	= Total supply of poultry
234-241:	$HDIN_h$	= Household specific demand for maize as feed
242:	DIN	= Total demand for maize as feed
243-290:	$HC_{h,c}$	= Household specific consumption of commodity *c*
291-296:	$CONS_i$	= Total consumption of commodity *c*
297-304:	EXP_h	= Total expenditure of household *h*
305-312:	$YHAG_h$	= Agricultural income of household *h*
313-320:	YH_h	= Total income of household *h*
321-322:	M_f	= Imports of crop *f* (only maize and rice)
323:	M_p	= Imports of poultry

In addition, 61 exogenous variables are included in the equations:

1-6:	$MARG_c$	= Farmgate-market margin of commodity *c*
7-9:	PW_t	= World market price of tradeable *t*
10:	ER	= Exchange rate (=2300 GHc/$)

11-13:	$RMARG_t$	= International marketing margin of tradeable *t*
14-16:	TM_t	= Import tariff of tradeable *t*
17-19:	$IMARG_t$	= Border-market margin of tradeable *t*
20-25:	$LMARG_c$	= North-South margin of commodity *c*
26-37:	$INTMARG_{c,l}$	= Rural-urban margin of commodity *c* for locality *l* *
38:	*AREA*	= Total area for the five crops
39-43:	$LOSS_f$	= Losses through seed use for crop *f*
44-48:	$CONV_f$	= Conversion factor for crop *f*
49-56:	$YNAG_h$	= Non-agricultural income of household *h*
57-61:	$FEED_f$	= Quantity of crop *f*, which is used as feed

* the subscript *l* represents the location North (N) or South (S)

Price Equations

The price equations relate the producer prices (*PP*) and consumer prices (*PC*) via the transaction costs to each other. The prices in the different regions, like North-South or rural-urban, are connected via different transaction and transport costs. Supply and demand determine the prices of the non-tradeables. For tradeable goods the domestic prices are determined by the world market prices, adjusted by margins for import and transport as well as the possible tariffs.

In this block 96 equations define the relationships between producer and consumer prices, world market prices and transaction and transport costs.

The difference between producer and consumer prices is the domestic marketing margin ($MARG_c$). Each household (*h*) and each commodity (*c*) faces a specific price, so that we have 8 x 6 = 48 different equations:

$$PP_{c,h} = \frac{PC_{c,h}}{1 + MARG_c} \qquad (1\text{-}48)$$

There is, of course, no difference in prices between poor and non-poor households. The model implications of this equality will be discussed below.

As explained the world market prices determine the consumer prices of the tradeable goods.

The market balance is generated by adjusting the domestic supply and demand by the net imports (which can be positive or negative). The first step is to link the world market price of the three importable products (*T*), maize, rice and poultry, with the border price (*PM*) via the exchange rate *(ER)*, import tariffs (*TM*), and the international marketing margin *(RMARG)*:

$$PM_t = \overline{PW}_t \cdot ER \cdot (1 + RMARG_t) \cdot (1 + TM_t) \qquad (49\text{-}51)$$

The second step is to define the relationship between the consumer prices and the border price via the commodity-specific border-to-market marketing margin *(IMARG)*, which is positive for all commodities:

$$PC_{t,urbrichs} = PM_t \cdot (1 + IMARG_t) \qquad (52\text{-}54)$$

Then for all products the consumer price for the urban rich in the South is defined. The margin between North and South (*LMARG*) determines the price of the commodity in the North:

$$PC_{c,urbrichn} = PC_{c,urbrichs} \cdot (1 + LMARG_c) \qquad (55\text{-}60)$$

For every product this margin is negative, since the general price level in the North is lower than in the South.

Rural consumer prices differ from urban consumer prices by an internal marketing margin for the North (*INTMARGN*) and the South (*INTMARGS*). Those margins count for the transportation and marketing costs, which differ by commodity and locality. In total there are 6 x 2 = 12 equations:

$$PC_{c,rurrichn} = PC_{c,urbrichn} \cdot (1 + INTMARGN_c) \qquad (61\text{-}66)$$

$$PC_{c,rurrichs} = PC_{c,urbrichs} \cdot (1 + INTMARGS_c) \qquad (67\text{-}72)$$

These margins are usually negative because the price in rural areas is lower than in urban areas. Only for products which are imported from other regions because there exists an excess demand in the region, like rice or millet and sorghum in the South, the margin has a positive value.

In the model we distinguish the different types of margins to capture different price levels more realistically. The urban-border margin (*IMARG*) focuses on the transport and transaction costs on the main roads, which are often much better maintained (e.g. the main road from Tamale via Kumasi to Accra). The urban-rural margin (*INTMARG*) can be reduced by improving the side roads to the smaller towns or villages. So, distinguishing between different types of margins makes it possible to examine the different effects of policies aimed at reducing these margins in more details.

As previously explained, we make no distinction between prices for households with different income levels within the same region. So, the prices for rural poor in the North are the same as for the rural rich there. Hence, we have to balance them with the following equations:

$$PC_{c,urbpoorn} = PC_{c,urbrichn} \qquad (73\text{-}78)$$

$$PC_{c,urbpoors} = PC_{c,urbrichs} \qquad (79\text{-}84)$$

$$PC_{c,rurpoorn} = PC_{c,rurrichn} \qquad (85\text{-}90)$$

$$PC_{c,rurpoors} = PC_{c,rurrichs} \qquad (91\text{-}96)$$

Supply Equations

The supply block consists of 143 equations, which focus on the production of agricultural crops and poultry by each of the eight household types. Crop production is modeled by specifying separate equations for the yield and the land allocated to the specific crop. This enables the simulation of different scenarios related to agricultural productivity.

The total available land area (*AREA*) is allocated to the five crops and the eight households. This is done by applying profit and welfare maximizing principles to each household. The producer or farm gate prices of all crops determine the household-individual shares of land (*SH*) through the following 8 x 5 = 40 equations (which, like the yield equations, are specified in log-linear form):

$$\log(SH_{h,f}) = \alpha^{s}_{h,f} + \sum_{ff} \beta^{s}_{h,f,ff} \cdot \log(PP_{ff,h}) \qquad (97\text{-}136)$$

Data on the own-price elasticities and cross-price elasticities β^s are given in section 4.4.3. The subscript *h* represents the household, *f* and *ff* represent the crops and the competing crops, respectively. The intercept of the share function is represented by α^s. The sum of shares ($\sum_h \sum_f SH_{h,f} = 1$) add up to one among the five crops. That means that all the land is allocated to the five crops.

The yield rates are not specific to the household categories. The availability of data allows us to distinguish only between the North and the South. However, due to be consistent with the previous equations in this block we define again 40 equations, rather than only ten (2x5). Because we do not have sufficient data on input use, yield is specified directly as function of producer prices (and therefore represents a reduced-form equation of a model consisting of a production function and input demand equations):

$$\log(YLD_{h,f}) = \alpha^{y}_{h,f} + \beta^{y}_{h,f,f} \log(PP_{f,h}) \qquad (137\text{-}176)$$

The parameters α^y and β^y are representing again the intercept and the own-price elasticities of the yield function.

For each household the specific amount of supply (*HSCR*) is calculated by multiplying the share of allocated land to the crop with the total land area, the yield and the losses through seeds (*LOSS*) and conversion (*CONV*). Again it results in 40 different equations:

$$HSCR_{h,f} = AREA \cdot SH_{h,f} \cdot YLD_{h,f} \cdot \overline{(1 - LOSS_f)} \cdot \overline{CONV_f} \qquad (177 - 216)$$

Total supply of each of the five food crops is the sum of household supply:

$$SCR_f = \sum_h HSCR_{h,f} \qquad (217 - 221)$$

For poultry the supply is specified directly as a function of the price elasticity of supply for each household:

$$\log(HSP_h) = \alpha^{p}_{h} + \beta^{p}_{h,p,p} \log(PP_{p,h}) \qquad (222 - 229)$$

The sum of the supply over all households results in total supply of poultry:

$$SP = \sum_h HSP_h \qquad (230)$$

The demand for maize as poultry feed is calculated from a fixed rate. MOFA (2005) estimated that in average 3.5 kg maize is used to produce one kg of living poultry. With a conversion rate of 55% from poultry to chicken meat, we get a rate of 6.35 kg maize for one kg of chicken meat. The following equations specify this relationship:

$$HDIN_h = HSP_h \cdot 6.35 \qquad (231\text{-}238)$$

$$DIN = \sum_h HDIN_h \qquad (239)$$

Consumption Equations

The household demand for each commodity *c* is determined by the own-price and cross-price elasticity of demand (β^h), consumer prices, the income elasticity (γ^h) and household income (*YH*) through a so-called Almost Ideal Demand System (AIDS) (see DEATON AND MUELBAUER, 1980). In total we obtain 8 x 6 = 48 different equations:

$$\log(HC_{h,c}) = \alpha^h_{h,c} + \sum_j \beta^h_{h,c,cc} \cdot \log(PC_{h,c}) + \gamma^h_{h,c} \cdot \log(YH_h) \qquad (240\text{-}287)$$

The subscripts c and cc represents the commodities in question and the rival commodity, respectively. The sum of the household demands is the total household demand for each commodity:

$$CONS_c = \sum_h HC_{h,c} \qquad (288\text{-}293)$$

The value the expenditure (*EXP*) is calculated as the product of household consumption and consumer price. The total household expenditure is the sum of the product-specific expenditures:

$$EXP_h = \sum_c HC_{h,c} \cdot PC_{h,c} \qquad (294\text{-}301)$$

Income Equations

The income from agricultural activities ($YHAG_h$) for each household is calculated as the sum of the total value of crop and poultry production. Due to a lack of data on inputs used in production, no input costs or other various costs can be subtracted from the income.

$$YHAG_h = \sum_f (PP_{f,h} \cdot SCR_{h,f}) + (PP_{p,h} \cdot SP_h) \qquad (302\text{-}309)$$

Total household income (YH_h) is the sum of agricultural income and non-agricultural income with the non-agricultural income being determined exogenously:

$$YH_h = YHAG_h + \overline{YHNAG}_h \qquad (310\text{-}317)$$

Equilibrium Equations

The most important equations are the equilibrium ones. They have to clear the markets as a requirement for working with the model. Total quantity which is domestically supplied plus net imports (*M*) (zero for non-tradeables) and beginning stocks has to be equal to domestic consumption by households and animals (*FEED*) plus the ending stocks. The stocks are incorporated as net stocks (*ST*):

$$SCR_f + M_f + ST_f = CONS_f + \overline{FEED}_f \qquad (318\text{-}322)$$

For poultry the change in net stocks is assumed to be zero:

$$SP_p + M_p = CONS_p \qquad (323)$$

The model is solved with the software General Algebraic Modeling System (GAMS) using non-linear programming. The GAMS code was programmed on the basis of the work of STIFEL AND RANDRIANARISOA (2003). The input code in GAMS is shown in the appendix.

4.3 Data

Three types of data are needed to calibrate the model to a baseline solution:

1. Production, consumption and income levels must be defined for all commodities and household groups.

2. Consumer and producer prices for each commodity and region. They also define the marketing margins.

3. Elasticities, which describe the supply and demand behavior of the households with changing prices and incomes. The demand and supply elasticities (β and γ) are estimated by previous studies (mainly DIAO, 2005) or best guesses based on related studies, if no data were available.

The following sections describe the values for the baseline situation. In addition the values of the exogenous variables are given. They can be obtained from the GAMS model in the appendix.

4.3.1 Classification and Variable Levels

The eight household groups, Urban Non-Poor, Urban Poor, Rural Non-Poor, and Rural Poor (each for North and South), are determined by the GLSS IV (Ghana Living Standard Survey Round Four) with 5,998 interviewed households. The distinction between rural and urban is done according to the size of the village or town, where the household is located (the critical amount of people in a town is 1,500). The distinction between poor and non-poor is done according to their average income level. The GLSS IV defined 31.7 percent of the population as poor. The value of welfare[3] for the group of very poor was at 700,000 GHc and for the poor at 900,000 GHc (GSS, 2004). The exchange rate for the dataset GLSS IV in 1998/99 was 2,300 GHc for one US dollar (GFD, 2008).

Table 8 summaries the characteristics of the households. We obtain that only 12% of the

[3] The value of welfare is only roughly defined as the available income. Unfortunately, no more explanations are given in GSS (2004).

households are located in the North, which represents 40% of the land area. 66.1% of the people in Ghana and 81.8 % of the poor people live in rural areas according to the GLSS IV data. The biggest household category is the Rural Non-Poor in the South and the smallest the Urban Poor in the North. The average annual income of the people in the North is 1,525,000 GHc (= 663 $ with an exchange rate of 2300 GHc/$) per person and in the South 2,287,000 GHc (= 994 $). The fact that the South has a higher income by one third is one indication for the welfare difference of the North and South in Ghana. The poorest household group is the Rural Poor in the North with an average annual income of 1,114,000 GHc (= 484 $).As expected, the income of the rural people is mostly generated from agricultural activities (over 60 %). Only the rural non-poor in the South have an agricultural share of only 19.4 %. Also the income of the urban people, especially in the North, consists for a significant share of agricultural activities. Another interesting aspect in this column is that the rural non-poor in the North have a slightly higher share of income generated from agriculture than the rural poor. One reason could be the high importance of agriculture also for the richer households. Another one might be that the poverty line is misleading this result. If a lot of people in the North are slightly over the line, they are contributing with a high agricultural share to the non-poor. Another reason is the higher importance of agriculture in the North compared to the South.

Table 8: *Household characteristics*

Household Categories	**Households** *in Ghana*	**Income** *in GHc/capita*	**Income** *in $/capita*	**Agr. Share** *in %*
1 Urban Poor North	34,209	1,597,058	694	32.9
2 Urban Non-Poor North	62,154	1,712,211	744	26.8
3 Rural Poor North	304,610	1,114,059	484	62.9
4 Rural Non-Poor North	111,323	2,596,542	1,129	64.3
5 Urban Poor South	199,616	1,398,063	608	30.4
6 Urban Non-Poor South	1,225,502	2,791,203	1,214	13.3
7 Rural Poor South	743,949	1,495,235	650	61.6
8 Rural Non-Poor South	1,470,151	2,387,415	1,038	19.4
Total	**4,151,515**	**2,192,644**	**953**	**41.0**

[Source: GLSS data, GSS (2004)]

The households interviewed (5,998) are representative for Ghana. The results are therefore projected to the total number households in Ghana (4,151,515) (GSS, 2004).

Supply and consumption of each household category is illustrated in Tables 9 and 10.

The larger share of maize is consumed in the southern regions. However, in per capita terms maize is much more popular in the North (82 kg/year/capita) than in the South (44 kg/year/capita). Millet and sorghum is more or less exclusively consumed in the North. The other crops are quite similar consumed all over the country. Poultry can be seen as a real luxurious good, since the poor consume only a marginal amount and the income elasticity is over one (see Table 9). The urban rich in the South represent 25 % of the population, but consume more than 60 % of the poultry meat in Ghana.

***Table 9**: Annual Household Consumption*

Production	Maize in t	Millet/Sorg. in t	Rice in t	Root/Tubers in t	Groundnut in t	Poultry in t
U Poor N	28,769	68,695	3,354	114,363	1,820	68
U Rich N	33,635	42,995	9,706	358,448	4,568	743
R Poor N	97,338	247,758	9,196	232,228	6,356	578
R Rich N	44,536	79,222	8,742	328,351	6,766	1,062
U Poor S	32,788	11	11,294	464,665	5,765	524
U Rich S	305,159	26,746	160,247	6,490,424	53,760	20,706
R Poor S	97,146	7,674	32,900	1,102,308	21,031	1,297
R Rich S	353,357	13,061	121,494	4,273,449	71,925	9,056
Total	**992,728**	**486,162**	**356,933**	**13,364,236**	**171,991**	**34,034**

[Source: GSS (2004) and SRID/MOFA (2007)]

***Table 10**: Annual Household Supply*

Production	Maize in t	Millet/Sorg. in t	Rice in t	Root/Tubers in t	Groundnut in t	Poultry in t
U Poor N	17,855	19,514	7,673	10,973	17,237	20
U Rich N	23,245	7,888	7,496	4,389	13,531	27
R Poor N	85,154	369,216	71,620	275,787	88,109	2,543
R Rich N	38,897	84,345	22,361	449,403	24,945	104
U Poor S	15,789	34	266	208,369	188	3
U Rich S	62,336	275	541	958,554	3,967	3,113
R Poor S	325,011	2,660	10,984	2,953,982	7,618	288
R Rich S	418,977	2,229	47,560	8,502,780	16,397	14,144
Total	**987,264**	**486,161**	**168,501**	**13,364,237**	**171,992**	**20,242**

[Source: GSS (2004) and SRID/MOFA (2007)]

The household supply of the crops is presented in Table 10. Millet and sorghum, rice and groundnuts are primary produced in the North. Root and tubers have by far the biggest share in terms of production and land allocation, which is due to cassava and yam.
If we contrast the tables with each other, we obtain that the rural households in the South are net sellers of maize and the urban households everywhere are on average net buyers to a large extent. It is surprising that according to the GLSS IV data, the North is a deficit region for maize in the years 1998/99. All household groups demand more on average than they supply. This is important for the analysis of increasing prices for maize, because it means that their net expenditure goes up under constant supply and demand conditions. It is also remarkable that rural households in the North are net sellers of all other products. One reason for this finding could be that around 1998/99 the prices of maize were low compared to the other crops and it was therefore more profitable to grow other products for the market and grow maize mainly for own consumption.

Table 11 presents the shares of total land allocated to the crops by the different household groups and the yield rates. In general the North has lower yield rates, especially for grains and root and tubers. Only for rice and groundnuts the average yield in the North is slightly higher. The share of total land allocated to the crops by the households varies, of course, according to the size of the household group. The rural poor in the North cultivate most of the land for all crops, except root/tubers, in the North. In the South the rural rich are the dominant group.

***Table 11**: Land allocated to crops of households groups and yield rates in North and South*

Percent of total area allocated to...	**Maize** in t	**Millet/Sorg.** in t	**Rice** in t	**Root/Tubers** in t	**Groundnut** in t
U Poor N	0.64%	0.77%	0.21%	0.04%	0.62%
U Rich N	0.84%	0.32%	0.21%	0.02%	0.49%
R Poor N	3.01%	13.81%	1.95%	1.13%	3.26%
R Rich N	1.37%	3.14%	0.58%	1.84%	0.89%
U Poor S	0.36%	0.00%	0.01%	0.71%	0.01%
U Rich S	1.43%	0.01%	0.01%	3.28%	0.14%
R Poor S	7.43%	0.08%	0.31%	10.11%	0.27%
R Rich S	9.61%	0.07%	1.33%	29.10%	0.59%
Yield N (t/ha)	1.05	1.01	2.24	8.64	1.10
Yield N (t/ha)	1.58	1.20	2.00	10.36	1.06
Yield Total	1.46	1.01	2.16	10.25	1.09

[Source: GSS (2004) and SRID/MOFA (2007)]

The production has to be corrected by the post-harvest loss through conversion (here rice to paddy and poultry to chicken meat) and seeds retention. This results in the domestic supply quantity. Adding imports and beginning stocks, it gives the total supply (see Table 12). The total demand is composed of human and animal consumption. The residual from this calculation is the ending stock.

***Table 12**: Illustration of Supply and Demand*

Production	Maize in t	Millet/Sorg. in t	Rice in t	Root/Tubers in t	Groundnut in t	Poultry in t
Domestic Supply	987,263	486,161	168,501	13,364,236	171,993	20,242
Import	5,466	0	176,431	0	0	13,792
Beginning Stocks	0	0	87,000	0	0	0
Total Supply	**992,729**	**486,161**	**431,932**	**13,364,236**	**171,993**	**34,034**
Human Cons.	866,218	486,161	356,932	13,364,236	171,993	34,034
Animal Cons.	126,511	0	0	not applicable	0	0
Total Demand	**992,729**	**486,161**	**356,932**	**13,364,236**	**171,993**	**34,034**
Ending Stocks	0	0	75,000	0	0	0

[Source: SRID/MOFA (2007), FAOSTAT (2008)]

The quantity of maize imports is low, whereas rice imports are higher than the domestic production. Maize is the only product, which is used as feed for animal consumption. Root and tubers are also used as feed, but no figures could be found. For rice the government made stocks, so that they are included in the calculation. The figures for the stocks are taken from FAOSTAT (2008).

4.3.2 Prices

The prices are based on data from the Ministry of Food and Agriculture and the GLSS IV survey. In Table 13 the consumer prices for the different products are given.

For all six product groups the prices in the South are higher than in the North. One reason is that we focus in our model in particular on products which are produced in the North and exported to the South. A second reason is that the general price level is lower in the North, because it is much poorer than the South. In almost all cases the urban prices are higher than the rural prices, because the products are mainly produced in rural areas and transported to urban centers. For millet and sorghum in the South this is the other way round, because in the

South hardly any millet and sorghum is produced. So, most of it is coming from the North, which is then cheaper in the urban areas than in the rural areas in the South. The same holds for rice in both areas, because a significant quantity is imported from third countries.

Table 13: *Average consumer prices in 1998/1999 in GHc/kg*

	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
North Urban	326.4	420.2	1133.4	374.6	1020.8	1426.1
North Rural	314.8	367.8	1291.5	290.8	996.5	1403.0
South Urban	432.5	684.0	1138.1	488.8	1369.5	1587.9
South Rural	387.5	739.3	1175.1	466.9	1281.2	1548.7

[Source: GSS (2004) and SRID/MOFA (2007)]

4.3.3 Elasticities

Price elasticities for the share of land allocated to crops and for per hectare yields of crops are a combination of direct estimates from DIAO (2005) and best guesses based on similar studies. Consumption and income elasticities are taken also from DIAO (2005).

The price elasticity of the share of land allocated to each crop is in the share equations (see equations 97 -136). The intercepts (α) are derived from the model, given the data on land shares, prices and price elasticities.
The price elasticity can be interpreted as the percentage change in the share of land allocated to crop *f* resulting from a one percent change in the producer price of crop *ff*. These own- and cross-price elasticities are estimates obtained from DIAO (2005), and shown in Table 14.

Table 14: *Price elasticities of land share allocation*

Share of land allocated to	Outputprice Maize	Millet/Sor	Rice	Root/Tubers	Groundnuts
Maize	0.196	-0.004	-0.002	-0.014	-0.004
Millet/Sor	-0.006	0.21	-0.008	-0.008	-0.033
Rice	-0.006	-0.011	0.137	-0.015	-0.013
Root/Tubers	-0.009	-0.001	-0.004	0.15	-0.006
Groundnuts	-0.006	-0.028	-0.008	-0.009	0.152

[Source: DIAO (2005)]

The own price elasticities are all positive with values between 0.14 and 0.21. The cross price elasticities are all negative with very small values. Hence there are no complementary crops, and competition between crops is limited. Maize is the crop which has the lowest cross-price elasticities (and hence competes least with other crops).

The own-price elasticity of yield $\left(\beta^{y}_{h,f,f}\right)$ can be interpreted as the percentage change in the yield of crop *f* resulting from a one percent change in the producer price of that crop. The values are given in Table 15.

***Table 15**: Price elasticities of yield*

Crop	Maize	Millet/Sor	Rice	Root/Tubers	Groundnuts
Own-price elasticity	0.06	0.07	0.10	0.09	0.07

[Source: DIAO (2005)]

For poultry we have a price elasticity of supply, which amounts to 0.05 (DIAO 2005).

Finally, for the demand equations we need information on the price elasticities $\left(\beta^{h}_{h,i,j}\right)$ and the income elasticities of demand $\left(\gamma^{h}_{h,i}\right)$. Their values are shown in Table 16 and Table 17.

***Table 16**: Price elasticities of demand*

Outputprice	Maize	Mill/Sor	Rice	Root	Groundnuts	Poultry
URBAN Demand						
Maize	**-0,20**	0,00	0,00	0,00	0,00	0,00
Millet/Sor.	0,00	**-0,12**	0,00	0,00	0,00	0,00
Rice	0,00	0,00	**-0,81**	0,00	0,00	0,00
Root/Tubers	0,00	0,00	0,00	**-0,11**	0,00	0,00
Groundnuts	0,00	0,00	-0,01	0,00	**-1,18**	0,00
Poultry	0,00	0,00	-0,01	0,00	0,00	**-1,57**
RURAL Demand						
Maize	**-0,40**	-0,01	-0,01	0,00	0,00	0,00
Millet/Sor.	0,00	**-0,20**	0,00	0,00	0,00	0,00
Rice	-0,01	-0,01	**-0,87**	0,00	0,00	0,00
Root/Tubers	0,00	0,00	0,00	**-0,36**	0,00	0,00
Groundnuts	-0,02	-0,02	-0,02	-0,01	**-1,13**	0,00
Poultry	-0,02	-0,02	-0,02	-0,01	0,00	**-1,41**

[Source: DIAO (2005)]

For all products except groundnuts and poultry the price elasticities of demand are higher (in an absolute sense) in rural areas than in urban areas. The reason is that urban citizens are on average richer than rural citizens, and therefore their demand elasticities for food are higher. Especially poultry is a luxurious good, which is mainly consumed by the richer groups (see Table 16). Therefore, the demand elasticities in urban areas are higher.

Table 17: *Income elasticities of demand*

	Income group	
Demand	*Urban*	*Rural*
Maize	0,20	0,42
Millet/Sorg.	0,12	0,21
Rice	0,82	0,91
Root/Tubers	0,15	0,35
Groundnuts	1,20	1,22
Poultry	1,60	1,52

[Source: DIAO (2005)]

Table 17 presents the income elasticities. Except for poultry, all elasticities are larger in rural areas than in urban areas. Using an income elasticity of one as the dividing line, maize, millet and sorghum and root and tubers are staple goods in both rural and urban areas while poultry and groundnuts are luxurious food products.

4.4 Strengths and Weaknesses of the Model

After the specification of the model and calibration of the baseline, different policy scenarios can be simulated. However, before this is done in chapter five, the advantages and drawbacks of the model should be discussed.

An advantage is certainly the relative high number of households that is used to map the different categories of households as good as possible. With the distinction between North and South, main aspects of the heterogeneous picture in Ghana are captured quite well. Strength is the decomposition of supply. With the distinction between yield and land share functions and their corresponding elasticities, the impact of price changes on production decisions can be analyzed in a much better way than without such a decomposition (STIFEL AND RANDRIANARISOA, 2003). Moreover, the quality of data basis for the model is relatively good. The Ghana Living Standard Survey is a detailed survey taken over one year, which provided the model with all the needed household specifications. The data from the Ministry of Food and Agriculture helped me to picture the real market and price situation for the modeled products in certain years. And finally according to the modeling results, the elasticities, estimated by DIAO (2005), seem to reproduce the real elasticities quite well. The only drawback concerning the data is that at the moment of working on the model the new survey GLSS V for the years 2005/06 was not available. As a result, the base year for the simulations is 1998/99. This is rather old for simulating the impact of policy changes that may take place during the coming years.

The general drawbacks of a MMM are already discussed in section 4.1. However, it is worthwhile to mention again that the effects, for example on income or government budget, are not complete and are only related to the modeled products. Since in this model only six product groups are included, this would be a possible extension for the future. Moreover, due to data restrictions no inputs, like fertilizer or traction, are included, which would certainly lead to more realistic simulations and different results. The same holds for the seasonality of agricultural production. Storage is an important topic and the improvement of storage facilities would certainly have a positive impact on the agricultural income of the households (STIFEL AND RANDRIANARISOA, 2003). Another point, which has to be mentioned, is that elasticities usually work with small changes in prices. Some scenarios assume relatively large price changes, which could lead to questionable model results.

5. Simulation and Results

After calibration of the baseline model, which is described in chapter four, different scenarios can be examined by changing the values of one or more exogenous variables. As a consequence of this the endogenous variables adjust to their new equilibrium. The new figures will be interpreted according to their extent and relation to each other.
In the following sections we describe four different groups of simulations: First, a reduction of price margins, second, a change in world market prices, third, a different tariff policy and finally, an improvement of productivity in the North.

5.1 Reduction of transaction costs

5.1.1 Description

The prices in different regions and for different groups are connected via various margins. As in chapter three already explained they can consist of transport costs, transaction costs, like information, communication and contract costs, market tolls and profit margins. The size of the margins within a chain determines to a large extent how efficient the chain is. The size of the farmgate-market margin, for instance, is responsible for the share of the consumer price which is paid to the producer. In other words: the higher the margins in the chain, the lower the farm gate price for the producer.
Especially in developing countries the margins are relatively high compared to developed countries. Reasons are worse roads and transport possibilities and communication infrastructure, higher profit margins due to monopolistic competition and less organization in producer or marketing associations. To examine the effects of public investments in a margin reduction, we simulate two different scenarios.

5.1.2 Simulation and Interpretation

The first scenario in this group assumes a reduction of the farmgate-market margin by 25 %. Reasons could be improvement of roads or helping farmers to group in producer associations to have more market power against the traders. The second scenario reduces the North-South margin by 25%. Again investments in the road infrastructure or better transport possibilities can reach this target. However, the size of the North-South margin is mainly determined by the size of trade between these two regions. Tables 18 to 20 illustrate the results:

Table 18: *Changes in Production, Consumption and Trade Data after Reductions of Margins (Simulation one)*

Variable	Scenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Production	Base	987.3	487.0	168.5	13362.9	171.9	20.2
	Farmgate-Market	***0.4%***	***0.2%***	***0.3%***	***0.3%***	***0.6%***	***0.5%***
	North-South	***0.3%***	***0.0%***	***-0.1%***	***0.0%***	***0.7%***	***0.5%***
Consumption	Base	992.5	487.0	356.7	13362.9	171.9	34.0
	Farmgate-Market	***0.1%***	***0.2%***	***0.2%***	***0.3%***	***0.6%***	***0.3%***
	North-South	***-0.2%***	***0.0%***	***0.1%***	***0.0%***	***0.7%***	***0.0%***
Net Imports	Base	5.3	0.0	176.2	0.0	0.0	13.8
	Farmgate-Market	2.1		176.5			13.8
	North-South	0.4		176.7			13.7
Governmental	Base	0.4	0.0	34.8	0.0	0.0	4.7
Revenue	***Farmgate-Market***	0.2		34.8			4.7
	North-South	0.0		34.8			4.7

Note: The baseline scenario and the simulations for imports and governmental revenue are given in absolute figures (1,000 t)

[Source: own calculations]

Table 19: *Price Effects after Reductions of Margins (in percentage change compared to baseline)*

Variable	Szenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Producer Price	***Farmgate-Market***	***2.5 %***	***2.2 %***	***3.2 %***	***2.8 %***	***4.8 %***	***4.3 %***
Consumer Price		***0 %***	***-2.1 %***	***0 %***	***-1.9 %***	***-0.5 %***	***0 %***
North Prices	***North-South***	***8 %***	***1.8 %***	***0.1 %***	***7 %***	***7 %***	***3.2 %***
South Prices		***0 %***	***-12 %***	***0 %***	***-0.5 %***	***-1.8 %***	***0 %***

[Source: own calculations]

Table 20*: Changes in Income and Expenditure after Reductions of Margins (Simulation one)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Total Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
	Farmgate-Market	***0.4%***	***0.2%***	***0.8%***	***0.6%***	***0.1%***	***0.1%***	***0.5%***	***0.6%***
	North-South	***0.5%***	***0.3%***	***0.9%***	***1.3%***	***0.0%***	***0.0%***	***-0.1%***	***-0.2%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
	Farmgate-Market	***1.2%***	***0.9%***	***1.2%***	***0.9%***	***0.5%***	***0.6%***	***0.8%***	***3.4%***
	North-South	***1.6%***	***1.3%***	***1.5%***	***2.0%***	***-0.1%***	***-0.2%***	***-0.2%***	***-0.8%***
Food Expenditure	Base	87.1	180.1	208.9	158.2	263.6	3607.7	625.4	2389.1
	Farmgate-Market	***-1.6%***	***-1.6%***	***-1.2%***	***-1.3%***	***-1.7%***	***-1.7%***	***-1.3%***	***-1.3%***
	North-South	***4.7%***	***5.6%***	***3.8%***	***4.6%***	***-0.5%***	***-0.5%***	***-0.5%***	***-0.5%***

Note: The baseline scenario is given in absolute figures (billion GHc)

[Source: own calculations]

The following conclusions can be obtained from these results:

- The effects on production and consumption are minor in size. Besides the tradeables, groundnuts are affected most, with higher production and consumption levels of 0.6 to 0.7%. The reduction of the North-South margin of rice causes a slight reduction of rice production of about 200 t. This is because the margin in the baseline is almost zero (0.4%) and so the effects are hardly measurable. The reason for the low North-South margin is that the supply is quite balanced between the North and the South. The South has a low production but high imports and the North has a high production. So, the prices do not differ a lot. In contrast the margins for groundnuts are high because it is mainly produced in the North and has to be transported to the South.
- For maize, rice and poultry, trade adjusts to reach equilibrium. Only for maize the changes in imports are sizable, because production increases significantly more than consumption. Therefore, net imports are reduced from 5,000 tons to 2,100 tons in scenario one and to 400 tons in scenario two. As a consequence, the governmental revenues from the maize import tariffs are reduced to almost zero.
- Interesting results are shown in Table 19, where the percentage changes of different prices compared to the baseline are shown. In scenario one the consumer price and producer price changes differ a lot. Whereas the producer price, as expected, increases between two and five percent, the consumer price stays unchanged, except for the non-tradeables. The reason is that the consumer price for the tradeables in the model is fully determined by the world market prices and therefore, the change in the margin only affects the producer price. In contrast, changes ion the margins of non-tradeables also affect the consumer price. Here the price decreases by two percent for millet/sorghum and root/tubers and by a half percent for groundnuts. The reduction of the North-South margin has the same effects on consumer and producer prices, but, of course, different effects on the location. As expected the North prices increase all. This is because the North-South margin by definition leads to higher prices in the North with increasing values (see equations 55-60 in section 4.2.2). The values of change are between zero (for rice) and eight percent for maize. The South prices decrease a lot for millet/sorghum (-12%) while prices of the other non-tradeables change less than 2 percent.
- The consequences for the incomes are different. It has to be mentioned again that only the nominal changes of income are calculated. The incomes of the rural groups increase much more than those of the urban groups, because the share of income from agricultural sources is higher. So, the income increase in scenario one for the rural groups is between

0.5 and 0.8%, whereas the increase for urban groups is only 0.1 – 0.4%. Scenario two shows the highest increases of 0.9% for the rural poor in the North and 1.3% for the rich. In the South the rural incomes decrease when the North-South margin is reduced. The reason is the price decrease of the non-tradeables, which lead to lower agricultural incomes (see Table 19). The effects on the agricultural incomes are, of course, larger than the total income effect, since the non-agricultural income is treated as fixed and exogenous. Because rural rich in the South have the highest per capita production of root/tubers, they have also the biggest percentage increase in scenario one (+3.4%). In scenario two the rural rich in the North benefit most (+2.0%). The main causes are the high per capita production rates of maize, root/tubers and groundnuts for this group, which prices all rise by 7 to 8%. In scenario two all agricultural incomes in the South decrease because of the lower prices.

- Concerning the food expenditure, which only reflect the expenditure for the six product groups, the picture is very heterogeneous. Because of the decrease in consumer prices in scenario one, the food expenditure decreases among all household groups. The same accounts for the South in scenario two. Only in the North the food expenditure for the six products increases between 3.8 and 5.6% when the North-South margin decreases, because here the consumer prices increase to the same extent as the producer prices.

It can be concluded that the effects of the 25 % reduction in farmgate-market and the North-South margin are small, but generally positive. Whereas from scenario one both producers and consumers gain, in scenario two producers in the North and to a lesser extent consumers in the South are the main beneficiaries. In both scenarios the food production increases at least slightly, which is a positive development. The evaluation of the two measures concerning their cost and benefits is rather difficult, since the costs of such investments in the reduction of the margin are hard to estimate. In summation, a more efficient post-harvest treatment from the farm to the market would have positive effects all over the country, whereas a better integration of the North would help mainly the (relatively poor) producers in the North.

5.2 Changing World Market Prices

5.2.1 Description

The world market prices of the tradeables, maize, rice and poultry, determine the consumer price and therefore also the producer price. The following equation shows the relationship:

$$PC_{t,urbrichs} = \overline{PW}_t \cdot ER \cdot (1 + RMARG_t) \cdot (1 + TM_t) \cdot (1 + IMARG_t)$$

The world market price (*PW*) is transferred into the local currency (Ghana Cedi = GHc) via the exchange rate (*ER*). Then, the consumer price increases by the margin from third countries (*RMARG*), the import tariff (*TM*) and the marketing margin on imports (*IMARG*). For the other three modeled products, millet and sorghum, groundnuts and root and tubers, the world market price has no direct effect since we handle them as non-tradables. However, they are also influenced by the prices of the tradables and so, all markets in Ghana are to a different extent dependent on the market situation in the world.
Since the world market price is given exogenously, we can simulate easily different scenarios. It is an interesting variable because of its high impact on the endogenous variables and its strong fluctuation in reality. Especially, within the last couple of years the prices of most of the international traded commodities increased by enormous rates (VON BRAUN, 2008). The baseline simulation is run for the years 1998/99. So, all prices and other data are from these years. In the simulations we assume different price situations, which are described in the following section.

5.2.2 Simulation and Interpretation

Two different scenarios are modeled. First, the current price situation of the season 2007/08 (July 2007 – June 2008) is assumed. The prices for scenario 1, called "2007/08", are taken from the World Bank (World Bank, 2008). This shows a world market price for maize of 460 $/t, for rice of 736 $/t and for poultry of 820 $/t. Scenario two shows the situation under average prices, which are predicted by FAO and OECD for the coming years until 2016. The outlook forecasts average price increases of 40 % for maize, 20 % for rice and 20 % for poultry compared to the situation in 1998/99 (OECD/FAO, 2007). Tables 21 to 23 show the results of the simulation:

Table 21: *Changes in Production, Consumption and Trade Data after Changing World Market Prices (Simulation two)*

Variable	Scenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Production	Base	987.3	487.0	168.5	13362.9	171.9	20.2
	2007/08	***22.3%***	***0.0%***	***6.8%***	***-0.4%***	***-0.8%***	***0.5%***
	FAO/OECD	***6.7%***	***0.0%***	***2.3%***	***-0.1%***	***-0.3%***	***1.0%***
Consumption	Base	992.5	487.0	356.7	13362.9	171.9	34.0
	2007/08	***-14.6%***	***0.0%***	***-19.6%***	***-0.4%***	***-0.8%***	***-6.5%***
	FAO/OECD	***-5.1%***	***0.0%***	***-7.1%***	***-0.1%***	***-0.3%***	***-12.6%***
Net Imports *	Base	5.3	0.0	176.2	0.0	0.0	13.8
	2007/08	-359.5		94.8			11.4
	FAO/OECD	-111.5		146.9			9.2
Governmental	Base	0.4	0.0	34.8	0.0	0.0	4.7
Revenue *	***2007/08***	0.0		32.1			4.3
	FAO/OECD	0.0		34.8			3.8

Note: The baseline scenario and the simulations for imports and governmental revenue are given in absolute figures (1,000 t)

[Source: own calculations]

Table 22: *Price Effects after Changing World Market Prices (in percentage change compared to baseline)*

Variable	Szenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Producer Price	***2007/08***	***-182 %***	***13 %***	***72 %***	***12 %***	***16 %***	***10 %***
	FAO/OECD	***40 %***	***2 %***	***20 %***	***2 %***	***1 %***	***20 %***
Consumer Price	***2007/08***	***-182 %***	***13 %***	***72 %***	***12 %***	***16 %***	***10 %***
	FAO/OECD	***40 %***	***2 %***	***20 %***	***2 %***	***1 %***	***20 %***

[Source: own calculations]

Table 23: *Changes in Income and Expenditure after Changing World Market Prices (Simulation two)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Total Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
	2007/08	***5.5%***	***5.1%***	***8.6%***	***6.0%***	***1.3%***	***0.6%***	***5.2%***	***4.0%***
	FAO/OECD	***1.2%***	***1.1%***	***2.1%***	***1.4%***	***0.3%***	***0.1%***	***1.1%***	***0.9%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
	2007/08	***16.9%***	***19.0%***	***13.6%***	***9.3%***	***4.2%***	***4.7%***	***8.5%***	***20.9%***
	FAO/OECD	***3.8%***	***4.2%***	***3.3%***	***2.2%***	***0.9%***	***1.1%***	***1.8%***	***4.9%***
Food Expenditure	Base	87.1	180.1	208.9	158.2	263.6	3607.7	625.4	2389.1
	2007/08	***23.3%***	***16.4%***	***26.7%***	***18.4%***	***14.6%***	***11.9%***	***14.6%***	***13.5%***
	FAO/OECD	***5.7%***	***4.2%***	***6.6%***	***4.7%***	***3.8%***	***3.2%***	***3.8%***	***3.6%***

[Source: own calculations]

Note: The baseline scenario is given in absolute figures (billion GHc)

The different world market prices of the scenarios are given in Table 24:

Table 24: *World Market Prices under different scenarios*

Szenario	*PW maize*	*PW rice*	*PW poultry*
Base	163 $/t	429 $/t	744 $/t
2007/08	460 $/t (180 %)	736 $/t (72 %)	820 $/t (10 %)
FAO/OECD	228 $/t (40 %)	514 $/t (20 %)	893 $/t (20 %)

[Source: own calculations]

The price changes in scenario one are very different for the three commodities. Whereas maize increases by 180 % compared to nine years ago, rice increases by 72 % and poultry only by 10 %. The main reason for the large difference is that maize was relatively cheap in the years 1998/99 and poultry was relatively expensive (SRID/MOFA, 2007). In contrast, the long-term outlook by the FAO and OECD is more moderate. They assume the current situation is not sustainable and the prices will decrease. However, prices are still much higher than in 1998/99. Poultry is an exception, mainly because the sharp increase in demand during the last few years is expected to sustain in the near future and the supply is not able to fulfill it completely (OECD/FAO, 2007).

Following results can be obtained from the simulations:

- Maize production (+220,000 t) is affected most due to the highest increase in world market price (+22 %). Rice production rises by 11,500 t (+ 7 %). Poultry production rises only marginally (+0.5 %) due to the moderate price increase and its low price elasticity of supply (0.05). Production of the other products changes only slightly; millet/sorghum increases and root/tubers as well as groundnuts decrease, although their producer prices increase is between 10 and 16 % (see Table 22). In contrast to production, consumption decreases significantly for maize (-15 %), rice (-20 %) and poultry (-6 %). These different magnitudes in responses may be explained from the fact that rice and poultry consumers are more price elastic than the producers, whereas for maize it is almost balanced (see price elasticities presented in chapter four). Moreover, maize can be seen as one of the most important staples since a price increase of 182 % leads only to an decrease in consumption of 15 %. For the second scenario with OECD/FAO prices, the direction of the effects is the same, but the magnitudes are smaller.
- As expected, imports are reduced due to the higher production and lower consumption levels. Moreover, for maize Ghana changes from a net importer to a net exporter. The

export figures should, however, be treated carefully, since export margins are not included in the model. A further observation for poultry is that due to the higher prices in scenario two the imports decreases by 4.6 t (-33 %) mainly due to the lower consumption. The governmental revenues from the imports are affected heavily and are reduced by 3.5 billion GHc for scenario one and 1.3 billion GHc for scenario two.

- The increase in nominal income is higher in the North than in the South because especially rice is mainly produced in the North. The reason behind this is that higher rice prices influence the incomes significantly due to the high per capita rice production in the North. For scenario one the highest increase in total income is obtained for the rural poor in the North (+9 %), mainly due to their high share of agricultural income, whereas the highest increase in agricultural income is seen for the rural rich in the South (+21 %) with the same explanation as in simulation one. Scenario two shows again the same tendencies but with smaller magnitudes.
- However, it has to be taken into account that these are nominal changes. The calculation of real income changes can be done by considering the household-individual inflation. It is calculated by multiplying the change in price by the share of consumption for the product. The real income changes are illustrated in the appendix. With high price changes, the decrease in real income is higher for households, who consume high shares of the considered products. In our case the rural poor in both regions have the highest increase. Therefore, under consideration of the real changes, our results show that the poorest are the looser of the higher world market prices.
- Food expenditure for the six product groups increases between 12 and 27 % in scenario one. The main reasons are the higher income and the huge consumer price increases of maize and rice, which are directly affected by the higher world market prices. The food expenditure in scenario two increases by 3 to 7 % with the same explanation.

In conclusion it can be said that the higher world market prices have enormous effects on all groups in the country. Of course, the main effects can be obtained for the tradeables, which are directly dependent on the world market price. But also the prices of the non-tradeables are affected significantly due to indirect effects. The nominal incomes of all household groups increase, while the incomes of the rural groups, of course, are stimulated most. The real income level decreases with the highest decrease for the poorest groups.

However, it is not possible to calculate the exact net welfare change for the single household groups since not all expenditures are captured in the model. This holds especially for the more and more expensive inputs, like fertilizer and oil, which affect mostly the agriculture-dominant households, who are the main gainer of the higher output prices.

In section 3.1.2 the consequences of the higher prices for a single farming household were calculated. Whereas the above simulation comes out with high production increases for the tradeables, the observation of the single-farmer perspective results that many farmers have to reduce their inputs due to the rising prices and their budget constraints. This leads to lower production rates. For farmers, who sell a large share, the higher costs of inputs can be paid by the higher producer prices, but farmers, who are not able to sell much of the produce, are the looser of the higher prices. Due to data limitations, it is not possible to capture the effect of higher input prices in the model.

5.3 Liberalization / Changing Import Tariff

5.3.1 Description

In history the agricultural tariff policies changed quite often. Before the early 1980s Ghana's policy was marked by a continuous change of the government via coups or undemocratic elections, which led to a big decline of the economy. With the military government led by Jerry Rawlings in 1982 a more open economic policy started. With the help of the International Monetary Fund (IMF) and the World Bank a four-year Economic Recovery Programme (ERP) started (1983), followed by a Structural Adjustment Programme (SAP) in 1987 (ASUMING-BREMPONG, 2003). The aim of the SAP was to open and liberalize the economy to the world markets. Among other economic reforms, tariffs and subsidies should be decreased in order to increase trade from and to third countries. These measures predominantly aimed to allocate the domestic agricultural resources in an efficient way to those commodities where Ghana has a comparative advantage. After a successful recovery of the economy in the 1980s, the picture turned around in the 1990s, where the general conditions changed and the reforms proofed to be unfavorable. For the agricultural sector in particular the removal of input subsidies, especially for fertilizer, led to a big reduction in input use and therefore, in production. In addition, the increased food imports were often much cheaper, so that many farmers could not compete with the foreign production. With the Medium Term Agricultural Development Programme (MTADP) starting in 1991, the agricultural sector should generate yearly growth rates of 4 %. More private participation, free market pricing and stimulating of trade were the main measures of this reform packet (ASUMING-BREMPONG, 2003). However, the discussions remain whether more liberalization or higher import tariffs to encourage production are the right way for the agricultural development of Ghana. In the years 1998/99 the government had implemented a 20 % import tariff, amongst others for maize, rice and poultry (WTO, 2001). This tariff leads to higher domestic prices and to higher production and lower consumption than before.

5.3.2 Simulation and Interpretation

In this section we analyze the consequences of changes in the tariffs. In the first scenario we simulate the situation of liberalization of the three tradeables. That means import tariffs are set to zero. The second scenario is the opposite situation, where the tariffs are increased to 60 %. Tables 25 to 27 illustrate the results of the simulation.

Table 25: *Changes in Production, Consumption and Trade Data after Increase of Yield (Simulation four)*

Variable	Scenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Production	Base	987.3	487.0	168.5	13362.9	171.9	20.2
	Liberalisation	***-3.5%***	***0.0%***	***-2.3%***	***0.1%***	***0.3%***	***-0.5%***
	60 % increase	***5.7%***	***0.0%***	***3.8%***	***-0.1%***	***-0.3%***	***1.5%***
Consumption	Base	992.5	487.0	356.7	13362.9	171.9	34.0
	Liberalisation	***2.9%***	***0.0%***	***7.9%***	***0.1%***	***0.3%***	***15.0%***
	60 % increase	***-4.3%***	***0.0%***	***-11.1%***	***-0.1%***	***-0.3%***	***-19.4%***
Net Imports *	Base	5.3	0.0	176.2	0.0	0.0	13.8
	Liberalisation	68.3		208.4			19.0
	60 % increase	-94.0		130.1			6.8
Governmental	Base	0.4	0.0	34.8	0.0	0.0	4.7
Revenue *	***Liberalisation***	0.0		32.1			4.3
	60 % increase	0.0		77.0			7.0

Note: The baseline scenario and the simulations for imports and governmental revenue are given in absolute figures (1,000 t)

[Source: own calculations]

Table 26: *Price Effects after Tariff Changes (in percentage change compared to baseline)*

Variable	Szenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Producer Price	***Liberalisation***	***-17 %***	***-1.1 %***	***-17 %***	***-0.8 %***	***-0.3 %***	***-17 %***
	60 % increase	***33 %***	***2.1 %***	***33 %***	***1.5 %***	***0.8 %***	***33 %***
Consumer Price	***Liberalisation***	***-17 %***	***-1.1 %***	***-17 %***	***-0.8 %***	***-0.3 %***	***-17 %***
	60 % increase	***33 %***	***2.1 %***	***33 %***	***1.5 %***	***0.8 %***	***33 %***

[Source: own calculations]

Table 27: *Changes in Income and Expenditure after Tariff Changes (Simulation three)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Nominal Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
	Liberalisation	***-0.7%***	***-0.6%***	***-1.3%***	***-0.9%***	***-0.1%***	***-0.1%***	***-0.8%***	***-0.5%***
	60 % increase	***1.4%***	***1.2%***	***2.8%***	***1.8%***	***0.2%***	***0.1%***	***1.0%***	***0.9%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
	Liberalisation	***-2.2%***	***-2.3%***	***-2.2%***	***-1.4%***	***-0.4%***	***-0.5%***	***-0.8%***	***-2.5%***
	60 % increase	***4.5%***	***4.7%***	***4.5%***	***2.8%***	***0.8%***	***1.0%***	***1.6%***	***4.8%***
Food Expenditure	Base	87.1	180.1	208.9	158.2	263.6	3607.7	625.4	2389.1
	Liberalisation	***-3.0%***	***-2.4%***	***-3.5%***	***-2.7%***	***-2.1%***	***-1.8%***	***-2.1%***	***-2.0%***
	60 % increase	***5.5%***	***4.3%***	***6.6%***	***4.9%***	***3.8%***	***3.3%***	***3.8%***	***3.6%***

Note: The baseline scenario is given in absolute figures (billion GHc)

[Source: own calculations]

Following results can be obtained:

- Production in scenario one decreases by 3 % for maize, 2 % for rice and 0.5 % for poultry. As already seen in the previous simulations, poultry producers have the lowest responses to price changes. Production of the other three (non-tradable) products increases slightly due to substitution effects, which result from the low cross-price elasticities shown in section 4.3.3. For consumption the size of change for the three tradables is opposite to the changes in production. The poultry demand increases by 15 % or 5,100 t, rice by 8 % or 28,200 t and maize by 3 % or 28,900 t. These differences in magnitudes reflect the stronger own-price elasticity of demand for poultry than for rice and maize. It is obvious that in scenario two the effects are opposite to scenario one. However, it is also interesting to note that the effects for the production are twice as big, but the consumption decrease rate is only slightly bigger than in scenario one.
- The net imports adjust for the tradables. In scenario one the maize imports increase by 63,000 t, the rice imports by 32,200 t and the poultry imports by 5,200 t. As a consequence of the liberalization, the governmental revenues are, of course, zero. In scenario two Ghana exports maize, the rice imports are reduced by 46.1 t and poultry imports by 7,000 t. The governmental revenue increases by 44.1 billion GHc to 84 billion GHc from imports.
- The prices in the liberalization scenario decrease by 17 % for the tradables because the tariff of 20 % is reduced for all three products to zero. The price effect for the non-tradables is only marginal. In scenario two the prices for maize, rice and poultry increase by 33 % and for millet/sorghum by 2 %, root/tubers by 1.5 % and groundnut by 0.8 %.
- Again the nominal income of households in the rural North and rural South are most affected. The agricultural incomes in scenario one decrease by 2 % or less, and under scenario two they increase by 4 % or less. The expenditure for food adjusts accordingly to the changes in income. In scenario one small decreases between 2 and 3 % and in scenario two increases by 3 to 7 % can be observed.
- As in the previous simulations the real incomes have the opposite sign (see appendix), except for the rural rich in the South, who produce a lot compared to their consumption of the six products. The effects are highest for the poorer household groups.

As a conclusion, the changing of the import tariff has similar results as the changing of the world market price. The major difference is that a tariff change affects the government revenues directly to a large magnitude and that the tariff only affects the three products, maize, rice and poultry. In contrast, the higher world market prices affect more markets and through the increased oil and fertilizer price the whole agricultural sector.

In general, two different attitudes towards the tariff policy face each other. First, the liberalists, who argue that under liberalized conditions the available resources are used in the most efficient way. This theory, represented amongst others by the IMF and the World Bank, led, for instance, to the Structural Adjustment Programs in the 1980s and 1990s in many developing countries. The other view, which is often represented by the national governments, argues that certain sectors need tariff protection to develop itself. Economists call this infant industry tariff. Another reason is often that the sectors are too weak to compete with the world market, but the country has a certain interest to have the production in the country. The pro and cons argument list is long and will not be discussed at this place.

In our case, the real net welfare effect (the sum of producer surplus, consumer surplus and change in government budget) can not be obtained by the model. Not all changes in expenditure are considered and also not the costs of implementing a higher tariff. Moreover, negative consequences from third countries and donors can occur.

5.4 Higher productivity of agriculture production in the North

5.4.1 Description

As described in chapter two, the North of Ghana is much poorer and from agricultural perspective at a disadvantage compared with the South. The average yields of crops are usually much lower and the occurrence of natural catastrophes, especially droughts, makes farming much more risky. Another point is the higher support for the southern and richer parts of Ghana. Many people in the North are complaining that the government neglects the northern regions with lower attention and action. The capital and seat of government is at the coast in Accra. So, people in the South are much closer and have more influence on the government. Moreover, they are by far the majority, which is not unimportant with regard to the elections. One example of this phenomenon is the Ghana School Feeding Programme (GSFP), which is half paid by the Dutch and half by the Ghanaian government and started in 2005. The government in Ghana is responsible for the administration. The target to distribute the supporting schools equally among the regions and districts failed completely after three years. 70 % of the supported schools lie in the three richest districts of Ghana, which are all in the South. This is one of the main reasons for the early withdrawal of the Dutch government after three years of support (SNV, 2008)

More support for the North of Ghana is needed to close the gap or at least stop the enlargement of the gap. There are numerous measures possible. We concentrate on the possibilities of increasing the yield of agriculture products. With the higher production on the same amount of land, all production factors are used more efficiently. The potential in the North is huge, since many farmers are not using any fertilizer, have no access to extension service and no access to credit to finance more or improved inputs.

5.4.2 Simulation and Interpretation

Again two scenarios are distinguished. First, we simulate a general productivity increase in the North of all crops of 12 % (scenario one called “12 % general”). This can be reached, for example, by improving the agricultural extension service or by broad-based research. The second scenario assumes a 30% increase of maize yield in the North (called “30 % maize”). A possible measure for this could be an implementation of a credit program for maize to increase the use of fertilizer and tractor service. Both simulations are shown in Tables 28 - 30.

Table 28: *Changes in Production, Consumption and Trade Data after Increase of Yield (Simulation four)*

Variable	Scenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Production	Base	987.3	487.0	168.5	13362.9	171.9	20.2
	12 % general	***2.3%***	***4.2%***	***8.7%***	***0.3%***	***9.9%***	***0.0%***
	30 % maize	***5.0%***	***0.0%***	***0.0%***	***0.0%***	***0.1%***	***0.0%***
Consumption	Base	992.5	487.0	356.7	13362.9	171.9	34.0
	12 % general	***0.0%***	***4.2%***	***0.0%***	***0.3%***	***9.9%***	***0.0%***
	30 % maize	***0.0%***	***0.0%***	***0.1%***	***0.0%***	***0.1%***	***0.0%***
Net Imports	Base	5.3	0.0	176.2	0.0	0.0	13.8
	12 % general	-17.4		161.6			13.8
	30 % maize	-43.9		176.5			13.8
Governmental	Base	0.4	0.0	34.8	0.0	0.0	4.7
Revenue	***12 % general***	0.0		31.9			4.7
	30 % maize	0.0		34.8			4.7

Note: The baseline scenario and the simulations for imports and governmental revenue are given in absolute figures (1,000 t)

[Source: own calculations]

Table 29: *Price Effects after Increase of Yield (in percentage change compared to baseline)*

Variable	Szenario	Maize	Millet/Sorg	Rice	Root/Tubers	Groundnut	Poultry
Producer Price	***12 % general***	***0 %***	***-38 %***	***0 %***	***-3 %***	***-15 %***	***0 %***
	30 % maize	***0 %***	***0 %***	***0 %***	***0.1 %***	***0.1 %***	***0 %***
Consumer Price	***12 % general***	***0 %***	***-38 %***	***0 %***	***-3 %***	***-15 %***	***0 %***
	30 % maize	***0 %***	***0 %***	***0 %***	***0.1 %***	***0.1 %***	***0 %***

[Source: own calculations]

Table 30: *Changes in Income and Expenditure after Increase of Yield (Simulation four)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Total Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
	12 % general	***-0.4%***	***0.1%***	***-1.5%***	***0.4%***	***-0.2%***	***-0.1%***	***-0.7%***	***-0.9%***
	30 % maize	***0.4%***	***0.4%***	***0.5%***	***0.4%***	***0.0%***	***0.0%***	***0.0%***	***0.0%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
	12 % general	***-1.0%***	***0.3%***	***-2.5%***	***0.6%***	***-0.7%***	***-0.9%***	***-1.1%***	***-4.5%***
	30 % maize	***1.3%***	***1.6%***	***0.7%***	***0.6%***	***0.0%***	***0.0%***	***0.0%***	***0.0%***
Food Expenditure	Base	87.1	180.1	208.9	158.2	263.6	3607.7	625.4	2389.1
	12 % general	***-14%***	***-6.1%***	***-17%***	***-8.3%***	***-2.9%***	***-3.0%***	***-2.9%***	***-2.7%***
	30 % maize	***0.0%***	***0.1%***	***0.1%***	***0.1%***	***0.0%***	***0.0%***	***0.0%***	***0.0%***

[Source: own calculations]

Note: The baseline scenario is given in absolute figures (billion GHc)

The results are very heterogeneous and can be interpreted as follows:

- Production in scenario one increases for all crops as a result of the higher yield in the North. The rate of increase is determined by the share of the North production in total production and the elasticities of supply. For instance, millet/sorghum production increases only by 4.2 %, although we expect a rate close to 12 % because only a minor part of millet/sorghum is produced in the South. The reason for the relatively small increase is the high price elasticity of land share (see model in appendix). The price of millet/sorghum decreases by 38 % due to the increase in productivity, resulting in a decrease of the share of land allocated to millet/sorghum by 5.3 %. For the tradeable products such areas declines will not take place, because their prices are determined by the world market price and remain unchanged. The effect for root/tubers and groundnuts is less because their prices decrease only by 3 and 15 % respectively and the price elasticities of land share are also lower. The highest increase of production is achieved for groundnuts (+ 9.9 %) and rice (+ 8.7 %). Consumption has, of course, the same rates of change for the non-tradeables and stays constant for the tradeables, due to the constant price.
- In scenario two the situation is different because everything remains unchanged except the yield rates for maize in the North, which increase by 30 %. The total effect on production is only 5 %, because only 17 % of the maize in Ghana is produced in the northern regions. Due to the small substitution elasticities, production of the other crops is hardly affected. The prices do not differ significantly compared to the baseline and therefore, consumption stays almost constant for all products.
- The effect on the nominal income of the different household groups is interesting. In the North the rural poor face the highest decrease in agricultural income (-2.5 %), due to the fact that their crop mixture consists mainly of millet/sorghum and groundnuts, which have the highest price decreases. In the South the rural rich are hurt most, with a fall in agricultural income of 4.5 %. The main reason is the same. Their per capita-production of root/tubers is by far the highest and they also are the leading producers of groundnuts. Since millet/sorghum and groundnuts are mainly consumed in the North, the food expenditure decreases in the North much more than in the South. The highest rates are obtained for the rural and urban poor, because their cut in income is the highest in the North.
- The income and expenditure effects in scenario two are much lower due to the marginal price effects. The highest increase in agricultural income can be obtained for the urban

rich in the North followed by the urban poor, because maize has the highest share in their production portfolio. The effects on expenditure are negligible.

In conclusion, the effects on the household groups in the North are less clear than expected. In scenario one the enormous fall of the price for millet/sorghum and groundnuts reduces the incomes in the North seriously. On the other hand the consumer prices are also decreasing, which has positive effects for the consumers. To sum up, the strongest gainer in the North of an overall increase in productivity would be the households that are producing the tradeables and buying the non-tradeables.

The 30 % increase of maize yields in scenario two has generally positive consequences for the incomes of the northern households, whereas the prices are only marginally influenced. Besides the income effect, the domestic production increases and no imports are needed anymore. If export is possible, it would generate additional national income. If it is not possible, the domestic price would increase with the consequences comparable to the non-tradeables in scenario one.

6. Conclusion

During times of increasing prices for staples and basic needs and higher awareness of the scarcity of crucial resources, every country has the duty in its own interest to use the available resources in a responsible and efficient way. Ghana has enormous resources and potentials, especially for agricultural production. Maize, as the main staple in Ghana, is one of the important crops and gets more and more attention with higher world market prices. The analysis in this thesis confirms the statement that Ghana has enormous potentials to increase maize production and to improve the efficiency of the whole chain and that these could and should be used in future.

In particular the North of Ghana with its abundant land resources could extent agricultural production easily. The challenge is the nature of agriculture. Farming requires investments before and during the season in order to obtain higher revenues after harvest. But especially in the poor North the people cannot finance the inputs or maintenance to increase their production and the storage facilities needed to benefit from seasonal price fluctuations. Only few governmental programs and some microfinance initiatives provide some farming households with the needed credit or inputs. The natural risk of agriculture and the poor connection and infrastructure avoid that banks and companies do business with farmers.

Another cause for the relatively low maize production is the profitability as a cash crop. Under the prices received before 2008, the achieved revenue in the North was often too low to reach a reasonable profit. This is often caused through insufficient rates of fertilizer application and the lack of storage facilities. As a consequence, farmer shift to other food or cash crops. In general the profitability for maize is best in the transition zone, where 50 percent higher average yields result in for good profits. With the recent price increases the terms for maize production improved compared with the non-tradeable crops. “Cash crop farmers”, who sell a large share of their produce, profit from this situation. In contrast, “subsistence farmers”, who produce mainly for their own consumption, loose, because they will produce less as a consequence of the higher input costs. The overall effect on the production level is positive but hard to specify, since various effects influence the situation.

The analysis of marketing margins has two main outcomes. First, the transport costs have by far the biggest share and are, therefore, the best way to reduce the margins. Second, the highest potential for reduction have the high distance margins (e.g. North-South margin), not only because of the higher transport costs but also because of the higher trader profits. This could be explained as an information deficiency, where the trader uses this as an arbitrager.

However, the analysis, done in section 3.2 is too rudimentary and it requires a much more detailed analysis to draw proper conclusions from a margin analysis.

In order to fulfill the second research objective of providing quantitative estimates of the impacts of policy interventions and rising prices, a multi-market model was developed that considers six products and eight household groups. The data were taken mainly from GSS (2004), SRID/MOFA (2007) and DIAO (2005). Four different simulations were carried out. Under consideration of the restrictions of the model, which are explained in section 4.4, the results can be summarized as follows. A reduction of the farmgate-market and North-South margin by 25 percent has generally positive but small effects on producers and consumers. In the North-South scenario the producers in the North are the main beneficiaries. If the 25 percent reduction in margins is easily and relatively cheap reachable, this is a worthwhile investment. The second simulation is the application of higher world market prices. The recent price increase in the season 2007/08 has fundamental consequences on production, consumption and welfare of the households. Production rises and consumption falls sharply, in the first instance for the tradeables and to a lower extent for the non-tradeables. The nominal incomes increase, whereas the real incomes decrease. The poorest people are hurt most by the price shock. The long-term projections of OECD and FAO assume a lower price level than the current one. This results in similar effects, but with more moderate figures.

The third simulation focuses on the change of import tariff, which affects, of course, mostly the tradeables. The results of a higher tariff are similar to the scenarios with higher world market prices. However, the government revenues are affected more strongly and the general attitude towards protection plays a crucial role for the decision. In contrast, to the change in prices, this decision is the hands of the government and influenced by the numerous lobby and stakeholder groups. The final simulation is an investment in the productivity of agriculture in the North. The effects are dependent on whether the crop in question is a tradeable or a non-tradeable commodity. The strongest beneficiaries in the North of an overall increase in crop yields would be the households, which are producing the tradeables and buying the non-tradeables. These are generally not the poorest farmers. A boost of maize productivity in the North through special input credits or a fertilizer subsidy would increase the incomes in the North and lead to a higher production of maize.

In order to increase the efficient use of resources for agricultural and particularly maize production, Ghana should focus on investments in a higher productivity. This can be reached through various measures. Cheap availability of inputs, credit programs for farmers, better extension and education and more investment in agricultural research are the most important ones. Besides these measures, investments in infrastructure and market information or the increase of cultivated land can support the agricultural production. All these measures can be initiated by the government of Ghana, which probably has the highest influence on the agricultural development of its country. However, this requires that agriculture gets more political will and attention as in the past.

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Appendix

A. Real and Nominal Income changes of the second and third simulation

Table A1: *Real and Nominal Income Changes after Changing of World Market Prices (Simulation two)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Total Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
(Nominal)	2007/08	***5.5%***	***5.1%***	***8.6%***	***6.0%***	***1.3%***	***0.6%***	***5.2%***	***4.0%***
	FAO/OECD	***1.2%***	***1.1%***	***2.1%***	***1.4%***	***0.3%***	***0.1%***	***1.1%***	***0.9%***
(Real)	2007/08	***-15.7%***	***-10.1%***	***-22.6%***	***-18.7%***	***-12.5%***	***-7.8%***	***-14.7%***	***-6.7%***
	FAO/OECD	***-2.2%***	***-1.2%***	***-4.5%***	***-3.8%***	***-1.9%***	***-0.9%***	***-2.9%***	***-0.3%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
(Nominal)	2007/08	***16.9%***	***19.0%***	***13.6%***	***9.3%***	***4.2%***	***4.7%***	***8.5%***	***20.9%***
	FAO/OECD	***3.8%***	***4.2%***	***3.3%***	***2.2%***	***0.9%***	***1.1%***	***1.8%***	***4.9%***
(Real)	2007/08	***-22.2%***	***-13.1%***	***-28.6%***	***-23.8%***	***-22.1%***	***-17.9%***	***-19.1%***	***-3.2%***
	FAO/OECD	***-4.5%***	***-2.5%***	***-6.5%***	***-5.4%***	***-5.1%***	***-4.1%***	***-4.4%***	***0.6%***

[Source: own calculations]

Table A2: *Real and Nominal Income Changes after Changing of Import Tariff (Simulation three)*

Variable	Szenario	U N Poor	U N Rich	R N Poor	R N Rich	U S Poor	U S Rich	R S Poor	R S Rich
Nominal Income	Base	362.3	458.7	1616.8	919.4	1502.7	12769.6	6521.0	13820.9
(Nominal)	Liberalisation	***-0.7%***	***-0.6%***	***-1.3%***	***-0.9%***	***-0.1%***	***-0.1%***	***-0.8%***	***-0.5%***
	60 % increase	***1.4%***	***1.2%***	***2.8%***	***1.8%***	***0.2%***	***0.1%***	***1.0%***	***0.9%***
(Real)	Liberalisation	***0.2%***	***0.2%***	***1.3%***	***1.7%***	***0.8%***	***0.2%***	***1.6%***	***-0.2%***
	60 % increase	***-1.7%***	***-1.1%***	***-3.6%***	***-3.7%***	***-2.0%***	***-1.0%***	***-3.3%***	***-0.4%***
Agric. income	Base	119.1	123.0	1017.1	591.0	456.3	1695.7	4016.0	2672.9
(Nominal)	Liberalisation	***-2.2%***	***-2.3%***	***-2.2%***	***-1.4%***	***-0.4%***	***-0.5%***	***-0.8%***	***-2.5%***
	60 % increase	***4.5%***	***4.7%***	***4.5%***	***2.8%***	***0.8%***	***1.0%***	***1.6%***	***4.8%***
(Real)	Liberalisation	***1.4%***	***1.3%***	***2.2%***	***2.7%***	***3.0%***	***2.8%***	***2.7%***	***-0.4%***
	60 % increase	***-3.8%***	***-2.6%***	***-5.3%***	***-5.4%***	***-5.5%***	***-4.8%***	***-5.0%***	***0.1%***

[Source: own calculations]

B. Input Code of the Multi-market Model in GAMS

```
*----------------------------------------------------------------------*
*               GHANA MAIZE MULTIMARKET MODEL                          *
*       Model includes 6 commodities and 8 household groups            *
*----------------------------------------------------------------------*

*-- Commodity set definitions --*

*--------------------------------*
            SETS
*--------------------------------*

        C     commodities / MAIZE             1 maize
                            MILLSOR           2 coarse grains eg sorghum millet
                            RICE              3 rice
                            ROOT              4 roots and tubers
                            GROUNDN           5 groundnuts
                            POULTRY           6 poultry  /

        F(C)   food products less poultry
                          / MAIZE, MILLSOR, RICE, ROOT, GROUNDN  /

        WM(C)  food products and maize
                          / MILLSOR, RICE, ROOT, GROUNDN, POULTRY  /

        MA(F)  maize    / MAIZE /

        P(C)   poultry  / POULTRY /

        T(C)   tradeable products
                          / MAIZE, RICE, POULTRY /

        H      households  /  URBPOORN
                              URBRICHN
                              RURPOORN
                              RURRICHN
                              URBPOORS
                              URBRICHS
                              RURPOORS
                              RURRICHS  /

        UH(H)   urban hh    / URBRICHS, URBPOORS, URBRICHN, URBPOORN /
        RH(H)   rural hh    / RURRICHS, RURPOORS, RURRICHN, RURPOORN /

        UHS(H)  urban hh S  / URBRICHS, URBPOORS  /
        UHN(H)  urban hh N  / URBRICHN, URBPOORN  /
        RHS(H)  rural hh S  / RURRICHS, RURPOORS  /
        RHN(H)  rural hh N  / RURRICHN, RURPOORN  /

        L      locality   / N, S /

 ALIAS (C,CC)
 ALIAS (F,FF)
 ALIAS (P,P2)
 ALIAS (H,H2)
 ALIAS (UHS,UUHS)
 ALIAS (RHS,RRHS)
 ALIAS (UHN,UUHN)
 ALIAS (RHN,RRHN) ;


TABLE HHCHAR( *, H ) Base per capita income by HH (GHc per cap) and households (in '000)
          URBPOORN   URBRICHN    RURPOORN   RURRICHN  URBPOORS  URBRICHS   RURPOORS   RURRICHS
YHCAP0     1597058   1712211      1114059    2596542   1398063   2791203    1495235    2387415
YHAGCAP0    525113   459386        700520    1669057    424592    370672     921065     461965
YHAGSHR0     0.33     0.27          0.63       0.64      0.30      0.13       0.62       0.19
HH0         34.21     62.15        304.61     111.32    199.62   1225.50     743.95    1470.15
POPHH0     226.82    267.87       1451.23     354.08   1074.83   4574.94    4361.16    5789.06
HHSize       6.37     3.18          6.09       3.93      6.46      2.77       8.88       3.79
;
```

```
TABLE PRODCH0(H,C) Production per capita (kg per cap)
             MAIZE       MILLSOR        RICE           ROOT          GROUNDN         POULTRY
URBPOORN    83.4197      96.1912       57.4899        48.0524        84.1448          0.1389
URBRICHN    92.4472      33.8578       50.1049        16.0949        56.3122          0.1528
RURPOORN    61.5900     270.3213       85.1035       190.0448        69.7807          2.7074
RURRICHN   114.8681     251.7456      104.1168      1269.4073        78.3245          0.4525
URBPOORS    14.9121       0.0048        0.4338       193.7526         0.2036          0.0040
URBRICHS    13.9248       0.0689        0.1846       209.5036         0.9134          1.0414
RURPOORS    76.1494       0.6187        4.0223       677.3043         1.8720          0.1014
RURRICHS    74.1842       0.4022       13.0291      1468.7364         3.0123          3.7516
;

TABLE CONCH0 (H,C) Household per capita consumption (human)
            MAIZE        MILLSOR        RICE          ROOT           GROUNDN         POULTRY
URBPOORN   126.2715      302.8721       14.7467      504.2026         8.0286          0.2688
URBRICHN   124.9515      160.5115       36.1348     1338.1277        17.0590          2.4905
RURPOORN    57.6761      170.7357        6.3186      160.0200         4.3819          0.3617
RURRICHN   124.0491      223.7527       24.6150      927.2830        19.1131          2.7234
URBPOORS    30.4698        0.0103       10.4776      432.3057         5.3646          0.4376
URBRICHS    63.0751        5.8464       34.9271     1418.6552        11.7533          4.0645
RURPOORS    21.8956        1.7597        7.5215      252.7415         4.8237          0.2700
RURRICHS    48.0555        2.2562       20.9233      738.1350        12.4266          1.4202
;

TABLE SEEDF(H,F) Seed use per food item

                MAIZE       MILLSOR       RICE         ROOT        GROUNDN
URBPOORN        0.055        0.106        0.093        0.000        0.097
URBRICHN        0.060        0.130        0.139        0.000        0.103
RURPOORN        0.046        0.059        0.107        0.000        0.130
RURRICHN        0.042        0.054        0.066        0.000        0.101
URBPOORS        0.014        0.000        0.095        0.000        0.097
URBRICHS        0.020        0.096        0.018        0.000        0.048
RURPOORS        0.020        0.018        0.035        0.000        0.066
RURRICHS        0.023        0.046        0.029        0.000        0.060
;

TABLE SHARE0(H,F)  Share of land devoted to food crop production by hh type
                 MAIZE         MILLSOR        RICE          ROOT          GROUNDN
URBPOORN        0.00638        0.00768        0.00206        0.00045        0.00615
URBRICHN        0.00835        0.00319        0.00212        0.00018        0.00486
RURPOORN        0.03014        0.13805        0.01953        0.01131        0.03263
RURRICHN        0.01371        0.03137        0.00583        0.01843        0.00894
URBPOORS        0.00359        0.00001        0.00008        0.00713        0.00007
URBRICHS        0.01426        0.00009        0.00015        0.03280        0.00140
RURPOORS        0.07435        0.00080        0.00310        0.10108        0.00274
RURRICHS        0.09614        0.00069        0.01334        0.29095        0.00586
;

TABLE YIELD0(H,F)  Yield rates of land devoted to food crop production by hh type (tons per
ha)
                 MAIZE         MILLSOR        RICE           ROOT           GROUNDN
URBPOORN        1.05121        1.00727        2.24151         8.64314        1.10000
URBRICHN        1.05121        1.00727        2.24151         8.64314        1.10000
RURPOORN        1.05121        1.00727        2.24151         8.64314        1.10000
RURRICHN        1.05121        1.00727        2.24151         8.64314        1.10000
URBPOORS        1.58332        1.20000        2.00415        10.35866        1.05501
URBRICHS        1.58332        1.20000        2.00415        10.35866        1.05501
RURPOORS        1.58332        1.20000        2.00415        10.35866        1.05501
RURRICHS        1.58332        1.20000        2.00415        10.35866        1.05501
;

* NOTE!!! PRODUCTION OF CROPS BY HH DERIVED BY AREA TIMES SHARE TIMES YIELD

TABLE PAM( * , C ) Prices and margins (in GHc per kg)
            MAIZE        MILLSOR         RICE           ROOT           GROUNDN          POULTRY
PC0       435.63420     683.73286    1146.14064      488.99469      1369.00692      1587.91000
PW0       163.06522     404.35274     428.64348      400.00000       600.00000       744.00000
INTMARGn   -0.03564     -0.12484       0.13946       -0.22379        -0.02375        -0.01889
INTMARGs   -0.10409      0.08073       0.03255       -0.04481        -0.06454        -0.02595
MARGIN      0.11000      0.20000       0.14000        0.20000         0.25000         0.20000
IMARGIN     0.15000      0.15000       0.15000        0.15000         0.15000         0.15000
RMARGIN     0.05000      0.05000       0.05000        0.05000         0.05000         0.05000
LMARGIN    -0.24529     -0.38570      -0.00410       -0.23354        -0.25467        -0.11444;
```

```
TABLE SDT( * , C ) Supply-Demand (in '000 tons) and Tariffs (in %)
           MAIZE        MILLSOR       RICE         ROOT          GROUNDN        POULTRY
XPROD    1015.02900    517.68800    281.11100   13363.64400    193.17100       31.09091
CONV        1.00000      1.00000      0.65000       1.00000      1.00000        0.55000
CONSHUM   884.73767    486.19051    355.88928   13363.64400    172.02898       30.68200
SEED       26.47315     31.49749     19.62220       0.00000     21.14202        0.00000
STOCKS      0.00000      0.00000     12.00000       0.00000      0.00000        0.00000
IMPORTS     5.00000      0.00000    180.78933       0.00000      0.00000       13.58200
EXPORTS     0.00000      0.00000      0.00000       0.00000      0.00000        0.00000
TM          0.20000      0.20000      0.20000       0.00000      0.00000        0.20000
;


*----------------------------*
*      Elasticities          *
*----------------------------*

* Land Share Equations *

*-- Beta --*

TABLE ESHR(F,FF)   Share elasticities - estimates
           MAIZE        MILLSOR        RICE        ROOT        GROUNDN
MAIZE       0.1360      -0.0038        -0.0022     -0.0140     -0.0038
MILLSOR    -0.0057       0.1400        -0.0084     -0.0080     -0.0327
RICE       -0.0058      -0.0112         0.0370     -0.0150     -0.0126
ROOT       -0.0088      -0.0007        -0.0036      0.0600     -0.0055
GROUNDN    -0.0057      -0.0277        -0.0082     -0.0090      0.0820
;


* Yield Equations *

*-- Beta --*

TABLE EYLD(F,FF) Crop yield elasticities
           MAIZE    MILLSOR      RICE        ROOT       GROUNDN
MAIZE      0.06      0.00        0.00        0.00        0.00
MILLSOR    0.00      0.07        0.00        0.00        0.00
RICE       0.00      0.00        0.10        0.00        0.00
ROOT       0.00      0.00        0.00        0.09        0.00
GROUNDN    0.00      0.00        0.00        0.00        0.07
;


* POULTRY and MAIZE DEMAND *

*-- Beta --*

TABLE EP(P,P2)  Price elasticity of Poultry supply
             POULTRY
POULTRY       0.05
;


TABLE EPIN(P,MA)  Maize user price elasticity of Poultry supply
              MAIZE
POULTRY       -0.03
;


*************************
* Consumption Equations *
*************************

*-- Beta --*

TABLE EDU(C,CC) Price demand elasticities URBAN
               MAIZE        MILLSOR        RICE         ROOT        GROUNDN        POULTRY
MAIZE         -0.1960       -0.0002       -0.0015     -0.0004       -0.0001         0.0000
MILLSOR        0.0002       -0.1220       -0.0011     -0.0010       -0.0001         0.0000
RICE          -0.0018       -0.0007       -0.8090     -0.0020       -0.0005        -0.0001
ROOT          -0.0002       -0.0001       -0.0007     -0.1100       -0.0001         0.0000
GROUNDN       -0.0028       -0.0011       -0.0086     -0.0020       -1.1800        -0.0001
POULTRY       -0.0026       -0.0007       -0.0112     -0.0020       -0.0008        -1.5695
;
```

```
TABLE EDR(C,CC) Price demand elasticities RURAL
               MAIZE        MILLSOR        RICE        ROOT        GROUNDN        POULTRY
MAIZE         -0.3990      -0.0079       -0.0057     -0.0022      -0.0006         0.0000
MILLSOR       -0.0028      -0.1980       -0.0034     -0.0004      -0.0005         0.0000
RICE          -0.0094      -0.0080       -0.8650     -0.0045      -0.0012        -0.0001
ROOT          -0.0035      -0.0001       -0.0045     -0.3600      -0.0004         0.0000
GROUNDN       -0.0158      -0.0202       -0.0175     -0.0064      -1.1300        -0.0001
POULTRY       -0.0198      -0.0243       -0.0226     -0.0075      -0.0025        -1.4100
;

*-- Gamma --*

TABLE EY(H,C)  Income elasticities
              MAIZE        MILLSOR       RICE         ROOT         GROUNDN       POULTRY
URBPOORN       0.240        0.144        0.984        0.180        1.440         1.920
URBRICHN       0.160        0.096        0.656        0.120        0.960         1.280
RURPOORN       0.504        0.252        1.092        0.420        1.464         1.824
RURRICHN       0.336        0.168        0.728        0.280        0.976         1.216
URBPOORS       0.230        0.138        0.943        0.173        1.380         1.840
URBRICHS       0.150        0.090        0.615        0.113        0.900         1.200
RURPOORS       0.483        0.242        1.047        0.403        1.403         1.748
RURRICHS       0.315        0.158        0.683        0.263        0.915         1.140
;

*----------------------------------------------------------------------*
*-- Identity matrices used to ensure proper dimension in equilibrium --*
*----------------------------------------------------------------------*

TABLE IDEN1(C,F)   Identify matrix to ensure proper eq for supply
               MAIZE    MILLSOR   RICE    ROOT  GROUNDN
MAIZE            1        0        0       0      0
MILLSOR          0        1        0       0      0
RICE             0        0        1       0      0
ROOT             0        0        0       1      0
GROUNDN          0        0        0       0      1
POULTRY          0        0        0       0      0
;

TABLE IDEN2(C,P)    Identity column to ensure proper eq for poultry supply
             POULTRY
MAIZE            0
MILLSOR          0
RICE             0
ROOT             0
GROUNDN          0
POULTRY          1
;

*--------------------------------*
         PARAMETERS
*--------------------------------*

*-- Structural parameters --*

*   Price Block    *

 PP0(H,C)       Producer price                                  (GHc per kg)
 PC0(H,C)       Consumer price                                  (GHC per kg)
 PU0(H,MA)      User price                                      (GHc per kg)
 PM0(C)         Import price                                    (GHc per kg)
 ER0            Real exchange rate base                           (GHc per $)
 PW0(C)         World price for tradeables                         ($ per ton)
 TM(C)          Import tariff                                       (Unity)

 RMARG0(C)      Margin from rest-of-world
 IMARG0(C)      Marketing margin on imports                         (Unity)
 MARG0(C)       Marketing margin farmgate to market                 (Unity)
 INTMARG0(C,L)  Marketing margin urban to rural                     (Unity)
 LMARG0(C)      Margin from South to North                          (Unity)


*   Supply Block    *

 XH0(H,F)      Household production of food crops             ('000 tons)
 PRDCHK(H,F)   Production check (should be zero)
```

```
 HSCR0(H,F)    Household supply of food crops              ('000 tons)
 SCR0(F)       Supply of food crop by hh type
 LOSS(C)       Losses factor                                   (Unity)
 CONV(C)       Conversion factor from raw input to final product
 SP0(P)        Supply of poultry
 HSP0(H,P)     Household supply of poultry                 ('000 tons)
 DIN0(MA)      Demand of maize for feed
 HDIN0(H,MA)   Household demand of maize for feed          ('000 tons)


*   Consumption Block    *

 HC0(H,C)      Initial consumption of good i per hh         ('000 tons)
 CONS0(C)      Total consumption                            ('000 tons)

*   Income Block    *

 YH0(H)        Household income                           (billion GHc)
 YHAG0(H)      Household agriculture income               (billion GHc)
 YHNAG0(H)     Household non-agricultural income          (billion Ghc)
 YHAGCOR(H)    Household agric income correction


*   Market Clearing    *

 CONCH0(H,C)    Human Consumption per capita by household h     (kg)
 M0(C)          Imports                                    ('000 tons)
 STOCKS(C)      Net stocks                                 ('000 tons)


*  (Checks)

 CHKEQUF(F)     Check food equil
 CHKEQUP(P)     Check poultry equil
 CHKPROD(C)     Check for production data
 YHAG3(H)       Test of ag value added                              (billion GHc)
 CHQPROD(C)     Check Production Equilibrium
 CHQCONS(C)     Check Consumption Equilibrium
 CHQTRAD(T)     Check Trade Equilibirum
 CHQYH(H)       Check Total income
 CHQYHAG(H)     Check AGr. Income
 CHQHC(H)       Check Household Consumption
 CHQGOV(T)      Check Government
 CHQALL         Total Check
 GOVALL         Check of net government revenue

*  (Elasticities)

 EDU(C,CC)      Price elasticity of demand urban
 EDR(C,CC)      Price elasticity of demand rural
 ED(C,CC,H)     Price elasticity of demand for household h          (Unity)
 EY(H,C)        Income elast of demand for household h              (Unity)

 DF0(C)         Total demand of commodities
 HCVALSHR(H,C)  Part of good i in the consumption value of HH
 HH(H)          Number of households                         (in '000)
 HCVALTOT0(H)   Total value of consumption                   (in billion GHc)
 HCVAL0(H,C)    Value of consumption = Expenditure
 NETM(C)        Net imports
 SEED0(C)       Seed use                                     (%)
 SEEDF(H,F)     Seed use per food item
 POP(H)         Population of household group h              (in '000)
 PRODCH0(H,C)   Total production of prod by hh               ('000 tons)
 SF0(C)         Total domestic supply of commodities
 SIZE(H)        People per household                         (each)
 TOTCONS(H)     Total value of consumption                   (in billion GHc)
 X0(C)          Total production                             ('000 tons)
 YHAGCAP0(H)    Household per capita agricultural income     ('000 GHc)
 YHCAP0(H)      Annual per capita household income           ('000 GHc)
 YAGSHR(H)      Share of agricultural income in total income
 SUMSHARE       Summation of land shares
 NETINC0(H)     Net income
;


* Base Data

 SCALAR
```

```
 ER0       Exchange rate                              (GHc per dollar)     / 2300      /
 AREA      Area dedicated to agricultural production         ('000 ha)     / 2821.165 /
 Y0        National income                               (billion GHc)
 YAG0      Agricultural income                           (billion GHc)
 YAGV      Agricultural income using va shares
 YNAG0     Non-agricultural income                       (billion GHc)
;


*-- Structural parameters --*

************* Price Block *************

 RMARG0(C)   = PAM("RMARGIN",C) ;
 PW0(T)      = PAM("PW0",T);
 LMARG0(C)   = PAM("LMARGIN",C) ;
 MARG0(C)    = PAM("MARGIN",C) ;
 INTMARG0(C,"N") = PAM("INTMARGn",C) ;
 INTMARG0(C,"S") = PAM("INTMARGs",C) ;
 TM(C) = SDT("TM",C) ;

* (Initial Variable Values) *

 PC0(UHS,C) = PAM("PC0",C) ;
 PC0(UHN,C) = PC0("URBRICHS",C)*(1+LMARG0(C)) ;
 PC0(RHS,C) = PC0("URBRICHS",C)*(1+INTMARG0(C,"S")) ;
 PC0(RHN,C) = PC0("URBRICHN",C)*(1+INTMARG0(C,"N")) ;

 PM0(T)  = PW0(T) *(ER0*(1+RMARG0(T))*(1+TM(T)))/1000 ;
 IMARG0(T)  = 1 - (PM0(T) / PC0("URBRICHS",T)) ;

 PP0(H,C) = PC0(H,C)/ (MARG0(C)+1);
 PU0(H,MA)= PC0(H,"MAIZE") * 0.9;

 DISPLAY PC0, PP0, PU0, PW0, PM0, IMARG0 ;


************* Supply Block *************

 SEED0(C)   = 0 ;
 SEED0(C)   = SDT("SEED",C)/SDT("XPROD",C) ;
 CONV(C)    = SDT("CONV",C) ;
 POP(H)     = HHCHAR("POPHH0",H) ;

* (Initial Variable Values) *

 XH0(H,F)    = AREA*SHARE0(H,F)*YIELD0(H,F) ;
 PRDCHK(H,F) = XH0(H,F) - (PRODCH0(H,F)*POP(H)/1000) ;

 HSCR0(H,F)  = AREA*SHARE0(H,F)*YIELD0(H,F)*(1-SEEDF(H,F))*CONV(F) ;
 SCR0(F)     = SUM(H,HSCR0(H,F)) ;
 HSP0(H,P)   = PRODCH0(H,P)*POP(H)*CONV(P)/1000 ;
 SP0(P)      = SUM(H,HSP0(H,P)) ;
 HDIN0(H,MA) = HSP0(H,"POULTRY")*6.35 ;
 DIN0(MA)    = SUM(H,HDIN0(H,MA)) ;

 DISPLAY HSCR0, HSP0, HDIN0, SCR0, SP0, DIN0, XH0, PRDCHK ;


************* Consumption Block *************

 HC0(H,WM)     = CONCH0(H,WM)*POP(H)*1000/1000000   ;
 HC0(H,MA)     = (CONCH0(H,MA)*POP(H)*1000/1000000) + HSP0(H,"POULTRY")*6.25    ;
 CONS0(C)      = SUM(H,HC0(H,C)) ;

 DISPLAY HC0, CONS0 ;

 HCVALTOT0(UHS) = SUM(C,PC0(UHS,C)*HC0(UHS,C))/1000 ;
 HCVALTOT0(RHS) = SUM(C,PC0(RHS,C)*HC0(RHS,C))/1000 ;
 HCVALTOT0(UHN) = SUM(C,PC0(UHN,C)*HC0(UHN,C))/1000 ;
 HCVALTOT0(RHN) = SUM(C,PC0(RHN,C)*HC0(RHN,C))/1000 ;

 HCVALSHR(UHS,C) = PC0(UHS,C)*HC0(UHS,C)/1000/HCVALTOT0(UHS) ;
 HCVALSHR(RHS,C) = PC0(RHS,C)*HC0(RHS,C)/1000/HCVALTOT0(RHS) ;
 HCVALSHR(UHN,C) = PC0(UHN,C)*HC0(UHN,C)/1000/HCVALTOT0(UHN) ;
 HCVALSHR(RHN,C) = PC0(RHN,C)*HC0(RHN,C)/1000/HCVALTOT0(RHN) ;

 HCVAL0(H,C) = PC0(H,C)*HC0(H,C)/1000 ;
```

```
 TOTCONS(H)  = SUM(C,PC0(H,C)*HC0(H,C))/1000;

 DISPLAY HCVALTOT0, HCVALSHR ;


************* Income Block *************

 YHAG3(H)     = SUM(F,PP0(H,F)*HSCR0(H,F)/1000 )
              + SUM(P,PP0(H,P)*HSP0(H,P)/1000 ) ;
 YH0(H)       = HHCHAR("YHCAP0"  ,H) * POP(H) / 1000000 ;
 YHAG0(H)     = HHCHAR("YHAGCAP0",H) * POP(H) / 1000000 ;
 YHAGCOR(H)   = YHAG0(H) - YHAG3(H) ;
 YHNAG0(H)    = YH0(H) - YHAG0(H) ;
 YAGV         = SUM(H,YHAG0(H));
 YNAG0        = SUM(H,YHNAG0(H));
 Y0           = YAGV+YNAG0;

 YAGSHR(H)    = 100 * YHAG0(H) / YH0(H) ;
 NETINC0(H)   = YH0(H) - HCVALTOT0(H) ;

 DISPLAY  YHAG0, YHAG3, YHAGCOR, YHNAG0, YNAG0, Y0, YH0, YAGSHR ;


************* Market Clearing Block *************

 M0(C) = SDT("IMPORTS",C);
 NETM(C) = M0(C) ;
 STOCKS(C) = SDT("STOCKS",C);

 DISPLAY M0, NETM, STOCKS ;


************* Miscellaneous *************

* Population
 HH(H)   = HHCHAR("HH0",H) ;
 SIZE(H) = (POP(H)/HH(H))$HH(H) ;


** Equilibrium conditions **

 DF0(F)  = CONS0(F) ;
 DF0(P)  = CONS0(P) ;
 SF0(F)  = SCR0(F)  + M0(F) + STOCKS(F) ;
 SF0(P)  = SP0(P)   + M0(P) ;

 CHKEQUF(F)   = SF0(F) - DF0(F)  ;
 CHKEQUP(P)   = SF0(P) - DF0(P)  ;

 DISPLAY DF0, SF0, CHKEQUF, CHKEQUP ;

************* Demand Checks *************

 ED(C,CC,UH) = EDU(C,CC) ;
 ED(C,CC,RH) = EDR(C,CC) ;


*-----------------------------------------*
*    Pre- and Post-simulation values      *
*-----------------------------------------*


PARAMETERS

*-- Pre-simulation --*

 PP1(H,C)           Original producer price
 PC1(H,C)           Original consumer price
 PU1(H,MA)          Original user price
 PM1(C)             Original import price
 PW1(C)             Original world price
 SH1(H,F)           Original share allocation hh
 YLD1(H,F)          Original yield allocation hh
 HSCR1(H,F)         Original crop supply for hh
 SCR1(F)            Original total crop supply
 HSP1(H,P)          Original poultry supply for hh
 SP1(P)             Original total poultry supply
 HDIN1(H,MA)        Original maize demand for feed
```

```
 DIN1(MA)           Original total maize demand
 CONS1(C)           Original consumption
 HCY1(H,C)          Original hh consumption
 HC1(H,C)           Original hh consumption
 HCVALTOT1(H)       Original expenditure
 HCVAL1(H,C)        Original household expenditure
 X1(C)              Total supply
 M1(C)              Original net imports
 DF1(C)             Total demand of commodities
 SF1(C)             Total supply of commodities
 YH1(H)             Original total hh income
 YAG1(H)            Original ag income
 YNAG1(H)           Original nonag income
 NETINC1(H)         Original net income
 GOVREVM1(T)        Initial government revenue from importables (mill GHc)
 GOVNET1            Initial net gov't revenue (mill GHc)

*-- Post-simulation --*

 PP2(H,C)           New producer price
 PC2(H,C)           New consumer price
 PU2(H,MA)          New user price
 PM2(C)             New import price
 PW2(C)             New world price
 MARG2(C)           New farm gate - market margin
 SH2(H,F)           New share allocation hh
 YLD2(H,F)          New yield allocation hh
 HSCR2(H,F)         New crop supply for hh
 SCR2(F)            New total crop supply
 HSP2(H,P)          New poultry supply for hh
 SP2(P)             New total poultry supply
 HDIN2(H,MA)        New maize demand for feed
 DIN2(MA)           New total maize demand
 CONS2(C)           New consumption
 HC2(H,C)           New hh consumption
 HCVALTOT2(H)       New expenditure
 HCVAL2(H,C)        New household expenditure
 X2(C)              Total supply
 M2(C)              New net imports
 DF2(C)             New demand of commodities
 SF2(C)             New supply of commodities
 YH2(H)             New total hh income
 YAG2(H)            New ag income
 YNAG2(H)           New nonag income
 NETINC2(H)         New net income
 GOVREVM2(T)        New government revenue from importables (mill GHc)
 GOVNET2            New net gov't revenue (mill GHc)
;

* Computation of initial values to pre-simulation

* Note: if there are significant deviations between the XX0 values and the
*       values computed in the base, the calculations below will use the BASE!!!

 PP1(H,C)       = PP0(H,C) ;
 PC1(H,C)       = PC0(H,C) ;
 PU1(H,MA)      = PU0(H,MA) ;
 PM1(C)         = PM0(C) ;
 PW1(C)         = PW0(C) ;
 SH1(H,F)       = SHARE0(H,F) ;
 YLD1(H,F)      = YIELD0(H,F) ;
 HSCR1(H,F)     = HSCR0(H,F) ;
 SCR1(F)        = SCR0(F) ;
 HSP1(H,P)      = HSP0(H,P) ;
 SP1(P)         = SP0(P) ;
 HDIN1(H,MA)    = HDIN0(H,MA);
 DIN1(MA)       = DIN0(MA);
 CONS1(C)       = CONS0(C) ;
 HCY1(H,C)      = HC0(H,C) ;
 HC1(H,C)       = HC0(H,C) ;
 HCVAL1(H,C)    = HCVAL0(H,C) ;
 HCVALTOT1(H)   = HCVALTOT0(H) ;
 X1(C)          = SUM(F,IDEN1(C,F)*SCR1(F)) + SUM(P,IDEN2(C,P)*SP1(P));
 M1(C)          = NETM(C) ;
 DF1(C)         = DF0(C) ;
 SF1(C)         = SF0(C) ;
 YH1(H)         = YH0(H) ;
 YAG1(H)        = YHAG3(H) ;
```

```
 YNAG1(H)      = YHNAG0(H) ;
 NETINC1(H)    = NETINC0(H) ;

 GOVREVM1(T)$(M0(T) GE 0) = (TM(T)*M1(T)*PW1(T)*ER0)/1000  ;
 GOVNET1 = SUM(T,GOVREVM1(T)) ;

 Display TM ;
 Display GOVREVM1, GOVNET1 ;


*-------------------------------------------*
*-- Calculation of coefficients in model --*
*-------------------------------------------*

*-------------------------------*
        PARAMETERS
*-------------------------------*

* Supply Parameters

 SBETA(F,FF,H)     Price elasticity of land share
 SALPHA(H,F)       Intercept in share function

 YBETA(H,F)        Own-price elasticity of yield
 YALPHA(H,F)       Intercept in yield function

 PBETA(H,P)        Own-price elasticity of poultry
 PALPHA(H,P)       Intercept in poultry supply equation
 PDELTA(H,P)       Cross-price elasticity of maize demand

* Demand Parameters

 URBSBETA(C,CC,UHS) Price elasticity in urban South demand equation
 URBSGAMMA(UHS,C)   Income elasticity in urban South demand equation
 URBSALPH(UHS,C)    Intercept in urban South demand equation

 RURSBETA(C,CC,RHS) Price elasticity in rural South demand equation
 RURSGAMMA(RHS,C)   Income elasticity in rural South demand equation
 RURSALPH(RHS,C)    Intercept in rural South demand equation

 URBNBETA(C,CC,UHN) Price elasticity in urban North demand equation
 URBNGAMMA(UHN,C)   Income elasticity in urban North demand equation
 URBNALPH(UHN,C)    Intercept in urban North demand equation

 RURNBETA(C,CC,RHN) Price elasticity in rural North demand equation
 RURNGAMMA(RHN,C)   Income elasticity in rural North demand equation
 RURNALPH(RHN,C)    Intercept in rural North demand equation

* Tests

 STEST(H,F)   Should be same as SHARE0
 YTEST(H,F)   Should be same as YIELD0
 PTEST(H,P)   Should be same as HSP0
;

*-- Definitions --*

* Supply Parameters *

 SBETA(F,FF,H) = ESHR(F,FF) ;
 SALPHA(H,F)$SHARE0(H,F) = LOG(SHARE0(H,F)) -
                              SUM(FF,SBETA(F,FF,H)*LOG(PP0(H,FF))) ;
 STEST(H,F) = EXP(SALPHA(H,F) + SUM(FF,SBETA(F,FF,H)*LOG(PP0(H,FF)))) ;

 YBETA(H,F)              = EYLD(F,F) ;
 YALPHA(H,F)$YIELD0(H,F) = (LOG(YIELD0(H,F))- YBETA(H,F)*LOG(PP0(H,F))) ;
 YTEST(H,F) =              EXP(YALPHA(H,F) + YBETA(H,F)*LOG(PP0(H,F)));

 PBETA(H,P)             = EP(P,P) ;
 PDELTA(H,P)            = EPIN(P,"MAIZE");
 PALPHA(H,P)$HSP0(H,P)  = LOG(HSP0(H,P)) - PBETA(H,P)*LOG(PP0(H,P))  -
PDELTA(H,P)*LOG(PU0(H,"MAIZE")) ;
 PTEST(H,P)             = EXP(PALPHA(H,P)+ PBETA(H,P)*LOG(PP0(H,P))  +
PDELTA(H,P)*LOG(PU0(H,"MAIZE")));


 DISPLAY SBETA, SALPHA, YALPHA, YBETA, PALPHA ;
 DISPLAY SHARE0, STEST, YIELD0, YTEST, HSP0, PTEST ;
```

```
* Demand parameters *

 URBSBETA(C,CC,UHS)          = 0.5*ED(C,CC,UHS) ;
 URBSGAMMA(UHS,C)            = 0.5*EY(UHS,C) ;
 URBSALPH(UHS,C)$HC0(UHS,C)  = LOG(HC0(UHS,C)) - SUM(CC,URBSBETA(C,CC,UHS)*LOG(PC0(UHS,CC)))
                                     -       URBSGAMMA(UHS,C)* LOG(YH0(UHS)) ;

 RURSBETA(C,CC,RHS)          = 0.5*ED(C,CC,RHS) ;
 RURSGAMMA(RHS,C)            = 0.5*EY(RHS,C) ;
 RURSALPH(RHS,C)$HC0(RHS,C)  = LOG(HC0(RHS,C)) - SUM(CC,RURSBETA(C,CC,RHS)*LOG(PC0(RHS,CC)))
                                     -       RURSGAMMA(RHS,C)* LOG(YH0(RHS)) ;

 URBNBETA(C,CC,UHN)          = 0.5*ED(C,CC,UHN) ;
 URBNGAMMA(UHN,C)            = 0.5*EY(UHN,C) ;
 URBNALPH(UHN,C)$HC0(UHN,C)  = LOG(HC0(UHN,C)) - SUM(CC,URBNBETA(C,CC,UHN)*LOG(PC0(UHN,CC)))
                                     -       URBNGAMMA(UHN,C)* LOG(YH0(UHN)) ;

 RURNBETA(C,CC,RHN)          = 0.5*ED(C,CC,RHN) ;
 RURNGAMMA(RHN,C)            = 0.5*EY(RHN,C) ;
 RURNALPH(RHN,C)$HC0(RHN,C)  = LOG(HC0(RHN,C)) - SUM(CC,RURNBETA(C,CC,RHN)*LOG(PC0(RHN,CC)))
                                     -       RURNGAMMA(RHN,C)* LOG(YH0(RHN)) ;


 DISPLAY URBSALPH, RURSALPH, URBNALPH, RURNALPH  ;
 DISPLAY URBSBETA, RURSBETA, URBNBETA, RURNBETA, ED ;
 DISPLAY URBSGAMMA, RURSGAMMA, URBNGAMMA, RURNGAMMA, EY ;

*------------------------------------------------------------------------------*

*-- Definition of model --*


*-----------------------------------*
           VARIABLES
*-----------------------------------*

*-- Price block (99 endogenous variables) --*

   PP(H,C)      Producer price                            (GHc per kg)
   PC(H,C)      Consumer price                            (GHc per kg)
   PU(H,MA)     User price                                (GHc per kg)

   IMARG(C)     Marketing margin on imports               (percent)
   RMARG(C)     Marketing margin from or to ROW           (percent)
   MARG(C)      Domestic marketing margin                 (percent)
   LMARG(C)     Margin from South to North                (percent)
   INTMARG(C,L) Marketing margin from urban to rural      (percent)

   PM(C)        Import price                              (GHc per kg)
   PW(C)        World price - fixed                       ($ per ton)


*-- Supply block (141 endogenous variables) --*

   SH(H,F)          Percentage share of area
   YLD(H,F)         Yield                                        ('000 tons per ha)
   HSCR(H,F)        Crop supply by hh                            ('000 tons)
   SCR(F)           Total supply                                 ('000 tons)
   HSP(H,P)         Poultry supply by hh                         ('000 tons)
   SP(P)            Total poultry supply                         ('000 tons)
   HDIN(H,MA)       Maize demand for feed by hh                  ('000 tons)
   DIN(MA)          Total maize demand for feed                  ('000 tons)


*-- Consumption block (62 endogenous variables) --*

   CONS(C)        Total consumption                               ('000 tons)
   HC(H,C)        Household consumption                           ('000 tons)
   HCVAL(H,C)     Household expenditure
   HCVALTOT(H)    Expenditure


*-- Income block (16 endogenous variables) --*

   YH(H)          Household income                                   (Bn GHc)
   YHAG(H)        Household agricultural income                      (Bn GHc)
```

```
   YHNAG(H)       Household non-agricultural income                 (Bn GHc)

*-- Trade - Market Clearing Block (3 endogenous variables) --*

   M(C)          Net Imports                                     ('000 tons)


*-- Objective function --*

   OMEGA          Objective function
   ;


*----------------------------------*
         EQUATIONS
*----------------------------------*

*----------------------------------*
*--------- Equation Names ---------*
*----------------------------------*

*-- Price block (104 Equations) --*

   PPDEF(H,C)      Def of annual average producer price             (GHc per kg)

   URSPCMDEF(T)    Def of cons price for importable urb rich south  (GHc per kg)
   URNPCDEF(C)     Def of cons prices for urban rich north          (GHc per kg)
   RRNPCDEF(C)     Def of cons prices for rural rich north          (GHc per kg)
   RRSPCDEF(C)     Def of cons prices for rural rich south          (GHc per kg)
   UPNPCDEF(C)     Def of cons prices for urban poor north          (GHc per kg)
   UPSPCDEF(C)     Def of cons prices for urban poor south          (GHc per kg)
   RPNPCDEF(C)     Def of cons prices for rural poor north          (GHc per kg)
   RPSPCDEF(C)     Def of cons prices for rural poor south          (GHc per kg)
   PMDEF(T)        Definition of import price for importables       (GHc per kg)

*-- Supply block (134 Equations: 105-238) --*

   SHARE(H,F)      Share equation                                   (percentage)
   YIELD(H,F)      Yield equation                                   ('000 t per ha)
   HCSUPPLY(H,F)   Crop supply by hh                                ('000 tons)
   TCSUPPLY(F)     Total crop supply                                ('000 tons)

   HPSUPPLY(H,P)   Poultry supply by hh                              ('000 tons)
   TPSUPPLY(P)     Total poultry supply                              ('000 tons)
   HINDEMAND(H,MA) Maize demand as feed                              ('000 tons)
   TINDEMAND(MA)   Total maize demand as feed                        ('000 tons)


*-- Consumption block (54 Equations: 239-292) --*

   UHSCONDEF(UHS,C)   Urban South household consumption eqn            ('000 tons)
   RHSCONDEF(RHS,C)   Rural South household consumption eqn            ('000 tons)
   UHNCONDEF(UHN,C)   Urban North household consumption eqn            ('000 tons)
   RHNCONDEF(RHN,C)   Rural North household consumption eqn            ('000 tons)
   CONDEF(C)          Consumption equation                             ('000 tons)
   HCVALDEF(H,C)      Household Expenditure
   HCVALTOTDEF(H)     Expenditure

*-- Income block (16 Equations: 293-308) --*

   YHAGDEF(H)     Ag income equation                                (Bn GHc)
   YHDEF(H)       Household income equation                         (Bn GHc)

*--  Equilibrium condition  (6 Equations: 309-314) --*

   FEQUIL(F)      Food equilibrium equation
   PEQUIL(P)       Livestock equilibrium equation 1

*-- Objective function --*

   OBJ            Objective function

* TOTAL (314 plus the objective function)
   ;
```

```
*-----------------------------*
*--------- Equations ---------*
*-----------------------------*

*-- Price block (104 Equations) --*

 PPDEF(H,C)..
    PP(H,C)    =E= PC(H,C) / (1 + MARG(C)) ;

 URSPCMDEF(T)..
     PC("URBRICHS",T) =E=  PM(T)*(1 + IMARG(T)) ;

 URNPCDEF(C)..
    PC("URBRICHN",C)  =E= PC("URBRICHS",C)*(1 + LMARG(C)) ;

 RRNPCDEF(C)..
    PC("RURRICHN",C) =E= PC("URBRICHN",C) * (1 + INTMARG(C,"N")) ;


 RRSPCDEF(C)..
    PC("RURRICHS",C) =E= PC("URBRICHS",C) * (1 + INTMARG(C,"S")) ;

 UPNPCDEF(C)..
    PC("URBPOORN",C) =E= PC("URBRICHN",C) ;

 UPSPCDEF(C)..
    PC("URBPOORS",C) =E= PC("URBRICHS",C) ;

 RPNPCDEF(C)..
    PC("RURPOORN",C) =E= PC("RURRICHN",C) ;

 RPSPCDEF(C)..
    PC("RURPOORS",C) =E= PC("RURRICHS",C) ;

 PMDEF(T)..
    PM(T) =E= PW(T)*ER0*(1+RMARG(T))*(1 + TM(T))/1000 ;



*-- Supply block (143 Equations: 105-247) --*


 SHARE(H,F)$SHARE0(H,F)..
        LOG(SH(H,F)) =E= SALPHA(H,F) + SUM(FF,SBETA(F,FF,H)*LOG(PP(H,FF))) ;

 YIELD(H,F)$YIELD0(H,F)..
        LOG(YLD(H,F)) =E= (YALPHA(H,F) + YBETA(H,F)*LOG(PP(H,F))) ;

 HCSUPPLY(H,F)..
        HSCR(H,F) =E= AREA*SH(H,F)*YLD(H,F)*(1-SEEDF(H,F))*CONV(F) ;

 TCSUPPLY(F)..
        SCR(F) =E= SUM(H,HSCR(H,F)) ;

 HPSUPPLY(H,P)$HSP0(H,P)..
        LOG(HSP(H,P)) =E= PALPHA(H,P) + PBETA(H,P)*LOG(PP(H,P)) -
PDELTA(H,P)*LOG(PU(H,"MAIZE")) ;
*230-237

 TPSUPPLY(P)..
        SP(P) =E= SUM(H,HSP(H,P)) ;

 HINDEMAND(H,MA)$HDIN0(H,MA)..
        HDIN(H,MA) =E= HSP(H,"POULTRY")*6.35  ;

 TINDEMAND(MA)..
        DIN(MA) =E= SUM(H,HDIN(H,MA)) ;



*-- Consumption block (61 Equations: 248-309) --*


 UHSCONDEF(UHS,C)..
     LOG(HC(UHS,C)) =E= URBSALPH(UHS,C)
                     + SUM(CC,URBSBETA(C,CC,UHS)*LOG(PC(UHS,CC)))
                     + URBSGAMMA(UHS,C)*LOG(YH(UHS)) ;
```

```
 RHSCONDEF(RHS,C)..
      LOG(HC(RHS,C)) =E= RURSALPH(RHS,C)
                        + SUM(CC,RURSBETA(C,CC,RHS)*LOG(PC(RHS,CC)))
                        + RURSGAMMA(RHS,C)*LOG(YH(RHS)) ;

 UHNCONDEF(UHN,C)..
     LOG(HC(UHN,C)) =E= URBNALPH(UHN,C)
                       + SUM(CC,URBNBETA(C,CC,UHN)*LOG(PC(UHN,CC)))
                       + URBNGAMMA(UHN,C)*LOG(YH(UHN)) ;

 RHNCONDEF(RHN,C)..
      LOG(HC(RHN,C)) =E= RURNALPH(RHN,C)
                        + SUM(CC,RURNBETA(C,CC,RHN)*LOG(PC(RHN,CC)))
                        + RURNGAMMA(RHN,C)*LOG(YH(RHN)) ;

 CONDEF(C)..
      CONS(C) =E= SUM(H,HC(H,C)) ;

 HCVALDEF(H,C)..
      HCVAL(H,C) =E= HC(H,C)*PC(H,C)     ;

 HCVALTOTDEF(H)..
      HCVALTOT(H) =E= SUM(C,HCVAL(H,C))     ;



*-- Income block (16 Equations) --*

 YHAGDEF(H)..
       YHAG(H) =E=  YHAGCOR(H)
                 + SUM(F, PP(H,F)           *HSCR(H,F) /1000 )
                 + SUM(P, PP(H,P)           *HSP(H,P) /1000 )  ;

 YHDEF(H)..
    YH(H) =E= YHAG(H) + YHNAG(H)  ;



*--  Equilibrium condition  (6 Equations) --*

 FEQUIL(F)..
    SCR(F) + M(F) + STOCKS(F) =E= CONS(F) ;


 PEQUIL(P)..
    SP(P) + M(P) =E= CONS(P) ;


*-- Dummy Objective function --*

 OBJ..             OMEGA =E= 10 ;

*----------------------------------*
*-- Initialization of the model --*
*----------------------------------*

*-----------------------------------------*
* Set lower bounds on positive variables *
*-----------------------------------------*

 PP.LO(H,C)    = 1 ;
 PC.LO(H,C)    = 1 ;
 PU.LO(H,MA)   = 1 ;
 PM.LO(C)      = 1 ;
 PW.LO(C)      = 1 ;
 SH.LO(H,F)    = 0.00000001 ;
 YLD.LO(H,F)   = 0.001 ;
 HSCR.LO(H,F)  = 0.001 ;
 SCR.LO(F)     = 0.001 ;
 HSP.LO(H,P)   = 0.001 ;
 SP.LO(P)      = 0.001 ;
 HDIN.LO(H,MA) = 0.001 ;
 DIN.LO(MA)    = 0.001 ;
 HC.LO(H,C)    = 0.001 ;
 HCVAL.LO(H,C) = 0.001 ;
 HCVALTOT.LO(H)= 0.001 ;
 CONS.LO(C)    = 0.001 ;
 YHAG.LO(H)    = 0.001 ;
```

```
 YHNAG.LO(H)   = 0.001 ;
 YH.LO(H)      = 0.001 ;


*----------------------------------*
* Set initial values of variables *
*----------------------------------*

*-- Price Block --*

 PP.L(H,C)       = PP0(H,C) ;
 PC.L(H,C)       = PC0(H,C) ;
 PU.L(H,MA)      = PU0(H,MA) ;

 IMARG.L(C)      = IMARG0(C) ;
 MARG.L(C)       = MARG0(C) ;
 RMARG.L(C)      = RMARG0(C) ;
 INTMARG.L(C,L)  = INTMARG0(C,L) ;
 LMARG.L(C)      = LMARG0(C) ;

 PM.L(C)         = PM0(C) ;
 PW.L(C)         = PW0(C) ;

*-- Supply Block --*

 SH.L(H,F)       = SHARE0(H,F) ;
 YLD.L(H,F)      = YIELD0(H,F) ;
 HSCR.L(H,F)     = HSCR0(H,F) ;
 SCR.L(F)        = SCR0(F) ;
 HSP.L(H,P)      = HSP0(H,P) ;
 SP.L(P)         = SP0(P) ;
 HDIN.L(H,MA)    = HDIN0(H,MA) ;
 DIN.L(MA)       = DIN0(MA) ;

*-- Consumption Block --*

 HC.L(H,C)       = HC0(H,C) ;
 HCVAL.L(H,C)    = HCVAL0(H,C) ;
 HCVALTOT.L(H)   = HCVALTOT0(H) ;
 CONS.L(C)       = CONS0(C) ;

*-- Income Block --*

 YH.L(H)         = YH0(H) ;
 YHAG.L(H)       = YHAG0(H) ;
 YHNAG.L(H)      = YHNAG0(H) ;

*-- Market Clearing Block --*

 M.L(C)        = M0(C) ;

*-- Objective Function --*


 OMEGA.L = 10 ;
```