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Policy modeling of maize marketing operations in Zambia

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by

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CHAPTER I. INTRODUCTION

Geographical Location

Zambia is a landlocked country neighboring eight countries. It covers 750,000 square kilometers of land mass and has access to the sea through rail, air and road networks linking Zambia with Zaire and Angola to the north, Zimbabwe, Botswana, South Africa and Mozambique to the south and with Malawi and Tanzania to the east and north-east respectively. After 70 years of British rule, Zambia gained self rule in 1964. At independence, Zambia's population stood at about three million. With annual average population growth rates of 2.5% between 1963 and 1969, 2.9% between 1969 and 1974, 3.1% between 1974 and 1980, and 3.4% between 1980 and 1985, Zambia's population has grown to an estimated seven million. Almost 50% of the people live in urban areas giving Zambia one of the biggest urban/rural population ratios in Africa.

Objectives of the Study

The main objective of the research study is to address cost reduction concerns by applying economic modeling to the maize marketing operations in Zambia, with a view of suggesting ways of increasing the efficiency of policies in such areas as stocking, purchasing, sales and trade. These cost reduction concerns are addressed with the use of a dynamic optimization model to derive least cost values of government decision variables. However, it should be emphasized that the model formulation presented in this study does not incorporate stochastic specifications that may be necessary for long term strategy planning. The model is strictly deterministic in nature and assumes that the scenarios specified below are known to occur well in advance by the policy makers. In reality, however, this is not usually the case, especially for the unpredictable environmental factors such as drought. To this end, therefore, the model should not be used as a blueprint for long term marketing operations strategy planning. However, it could be used on a yearly basis to determine the least cost levels for the government decision variables. This would take the form of solving the model in each year without involving future transmission effects.

Specifically, the objectives of the study are as follows:

1. To investigate the effects of changes in important environmental and policy variables on such government decision variables as maize procurement, opening and closing stocks, sales to millers, imports and exports.
2. To obtain projections of the changes in maize procurement, opening and closing stocks, sales to millers, imports and exports through the year 2000.
3. To analyze the short term as well as the longer term policy implications of the simulations in the study with a view of suggesting more rational policies, especially in the areas of inventory control and international trade policies. This would take the form of analyzing the tradeoffs between the main concerns of policy makers in Zambia, namely cost reduction, ensuring adequate consumption, maintaining food security reserve stocks, and achieving self reliance by reducing dependence on imports and economizing on the use of scarce foreign exchange resources.

The projections in the study will be made using four scenarios:

1. In the basic scenario, rainfall is normal every year.
2. In the basic and foreign exchange scenario, rainfall is normal

but there is a 10 to 20% decline in the foreign exchange reserves (or aid).

3. In the drought scenario, rainfall is 10 to 20% below normal in some of the 16 projection years.
4. In the drought and foreign exchange scenario, a 10 or 20% decline in foreign exchange reserves (or aid) will be added to the rainfall shortfall.

The last three scenarios indicate the impact of the two major external shocks, i.e., rainfall and foreign exchange availability that affect the maize sector in Zambia.

Data Sources and Methodology

This study utilizes secondary data collected during a research trip to Zambia between June and August of 1988. In Zambia, the difficulties in collecting data and in some cases the nonavailability of it is a well documented fact. The data were collected from institutional documents as well as by way of interviews with officials in these institutions. The main sources were: (1) Planning Division, Ministry of Agriculture, (2) Central Statistical Office, (3) NAMBOARD, (4) ZCF and the Provincial Cooperative Unions, (5) the then Ministry of Cooperatives, (6) Bank of Zambia, (7) Meteorological Department, and (8) Ministry of Planning and Finance.

Unfortunately, the big gaps in the time series data collected could not enable the proper and adequate estimation of policy variable equations using econometrics techniques. In some cases, time series data observations only went as far back as 1982. It is possible that a more coordinated data collection effort coupled with more time provision for data analysis to look for and accommodate substitute and complementary data, could have yielded more data to warrant the inclusion of an econometric analysis.

CHAPTER II. GENERAL CONDITIONS

The Economy

Since the 1930s when large scale extraction of mineral resources was started, Zambia's economy has traditionally relied on the mining industry, specifically the copper industry which provides more than 90% of all foreign exchange earnings. The high copper prices that prevailed in the 1960s and 1970s provided Zambia with huge foreign exchange reserves and encouraged the development of a highly import oriented and capital intensive production and consumption economic structure. However, while the mining sector and the Zambian economy in general experienced great prosperity, growth in some of the other sectors, more especially in the agricultural sector, slowed down and even stagnated in some cases. Since 1973, however, copper prices on the world market have continued to fall drastically and this has led to a tremendous depletion of Zambia's export earnings and foreign exchange reserves resulting in tremendous adverse effects on the mining industry and on the Zambian economy in general. The situation has been aggravated by the steady rise in the costs of imported inputs, and this has made Zambia's import oriented economy very vulnerable to these external shocks. It has also led to a sharp deterioration in Zambia's terms of trade during the last decade, thereby greatly reducing the country's ability to import.

Fiscal and monetary adjustments were started by the government as a way of redressing the economic situation. In 1983, the government introduced major macroeconomic policy changes that included price decontrols, relaxation of interest rate ceilings and devaluation of the currency (23). However, price controls on maize and fertilizer still remained in place.

In 1985, a foreign exchange auction system was introduced. Through the auction of the foreign exchange, the value of the Zambian Kwacha was allowed to be freely determined by the supply and demand situation prevailing in each week. As a result, the exchange rate fell from K2.20 per US $1 before the auction to K5.15 per US $1 in the first auction to K8.07 per US $1 in mid-July 1986 (23), and eventually reached a high of K21.00 per US $1 by 1987 before the government finally intervened to fix the exchange rate at K8.00 per US $1.

Table 1. Index of import and export prices and terms of trade (1970 = 100)[a,b]

Year	Import Price Index	Export Price Index	Terms of Trade Index
1970	100	100	100
1971	105	78	74
1972	111	80	72
1973	126	117	93
1974	157	134	85
1975	194	84	43
1976	217	100	46
1977	248	97	39
1978	299	103	35
1979	374	185	50
1980	486	201	41
1981	584	198	34
1982	695	180	26

[a]ZNCDP (34).

[b]World Bank (29).

The Agricultural Sector

The diminishing ability for Zambia to import due to low copper earnings has brought renewed impetus to the need for the diversification of the economy and also to encourage greater use of the domestic resource base. As a result, the Third National Development Plan targeted agriculture as the priority sector in the transformation of the economy (35). The economic development strategy for Zambia was aimed at making the agricultural sector the mainstay of the economy in place of the mining industry. The main argument for this strategy is that the agricultural sector can play a major role in the transformation process given that it is the least dependent sector on imported inputs and that Zambia's agricultural potential has only been marginally exploited. This is evident in the fact that less than 5% of the land area is under permanent cultivation despite the inherent fertility of most of Zambia's soils (38). The development of this sector would not only amount to substantial savings of foreign exchange through food import substitution, it would also generate the much needed foreign exchange through increases in agricultural exports which at present account for less than 2% of Zambia's total exports (23).

Of all the crops grown, maize is by far the most important crop in Zambia since it is the staple food for the great majority of Zambians. As a result, maize policy forms the backbone for agricultural policy in Zambia.

Much attention has been devoted to increasing production and productivity in the maize sector by way of instituting support programs aimed mainly at the small scale farmers who are yet to enter the maize market. The emergence of this abundant resource base into surplus producers for the market is perceived not only to play a significant role in eliminating maize imports, it is also seen as having great potential to provide more maize surpluses for exports. Import substitution of maize would, therefore, amount to big savings in foreign exchange, and maize surpluses, which culminate into exports, would provide foreign exchange earnings for the country.

Maize marketing arrangements

Commercial maize production in Zambia is known to have been taking place as far back as the 1890s even though a controlled pricing system was never in place then. However, during the depression of the 1930s when all but two mines were closed (6), demand for maize drastically dropped leaving an excess supply of the commodity. This situation also put downward pressure on maize prices and was interpreted by the colonial government as a threat to the welfare of the white settler farmers.

As a remedy for this situation, the colonial government established a Maize Control Board in 1936 with the purpose of regulating maize marketings. Through the Maize Control Board, the colonial government introduced a quota system in which white settler farmers were guaranteed three quarters (3/4) of the maize market share and higher prices for their produce. On the other hand, indigenous farmers were allocated the remaining one quarter (1/4) of the maize market share and were offered lower prices for the same produce.

In this way, the colonial government intended to support maize producer prices above world prices for white settler farmers and also remove the threat of competition from indigenous farmers. This was consistent with the colonial government's efforts to attract and retain white settler farmers in Zambia, then Northern Rhodesia. To this end, the best land was allocated to settler farmers and indigenous black farmers who lived in areas deemed desirable for white settlers were forced to migrate to other parts of the country (6).

One of the most notable constraints to increased maize production and productivity in Zambia is marketing. Increasing the effectiveness of the marketing system, therefore, can have a tremendous positive impact on the efficiency of the maize sector and the overall agricultural sector in general. Efficient marketing arrangements play a major role in agricultural development through (5):

1. providing farmers with signals about products and crops in which to specialize.
2. easing access to new technologies for farmers by providing the necessary inputs if and when needed.
3. managing an efficient distribution system of the food surpluses needed from the widely distributed and sparse rural population to feed the large urban population. Given that Zambia is one of the most urbanized African countries with almost 50% of the population living in urban areas and that maize is the staple food for most Zambians, this function of the marketing system is of particular importance in serving the urban population which does not directly engage in food production.

At the time of Zambia's independence in 1964, maize marketing was being administered by the Grain Marketing Board (GMB), the Agricultural Rural Marketing Board (ARMB), and a number of producer cooperatives. The Agricultural Rural Marketing Board and the producer cooperatives operated maize buying points throughout the country and acted as middlemen between producers and the Grain Marketing Board which controlled the storage facilities.

Since 1969, however, maize marketing in Zambia has been governed by an act of parliament that brought into existence the National Agricultural Marketing Board (NAMBOARD). NAMBOARD had the exclusive statutory powers to purchase maize from farmers and sell it to millers who process it into maize meal for sale to consumers. NAMBOARD also had the responsibility of importing maize in times of shortages and exporting maize in times of surpluses. In addition to this, NAMBOARD was placed in charge of maintaining strategic national food reserves. In 1981, however, NAMBOARD's responsibility as the sole buyer of maize from farmers was curtailed and restricted only to interprovincial transfers of maize and also to deal with maize imports or exports if a deficit or surplus occurs. Purchase of maize in each of the nine provinces became the responsibility of the Provincial Cooperative Unions. NAMBOARD's role in the domestic market was reduced to that of buying excess maize supplies in the surplus provinces and make it available to the deficit provinces in addition to its statutory responsibility for importing or exporting maize as well as importing fertilizers based on the national requirements. The imported fertilizers are stored in the NAMBOARD main depots and are sold from there to Provincial Cooperative Unions and private traders who in turn make the fertilizers available to the farmers.

In spite of all these changes, however, the government continued to fix producer prices of maize and the retail prices for consumers. Since 1980, nominal producer prices have been increased considerably but the government still faces the awkward situation of wanting to set high producer prices in order to encourage increased production to meet domestic food, employment and development needs but at the same time, due to strong political pressure from urban consumers and also humanitarian considerations for the low income consumers, the government would like to keep retail prices low enough for these diverse interest groups. This state of affairs has resulted into a

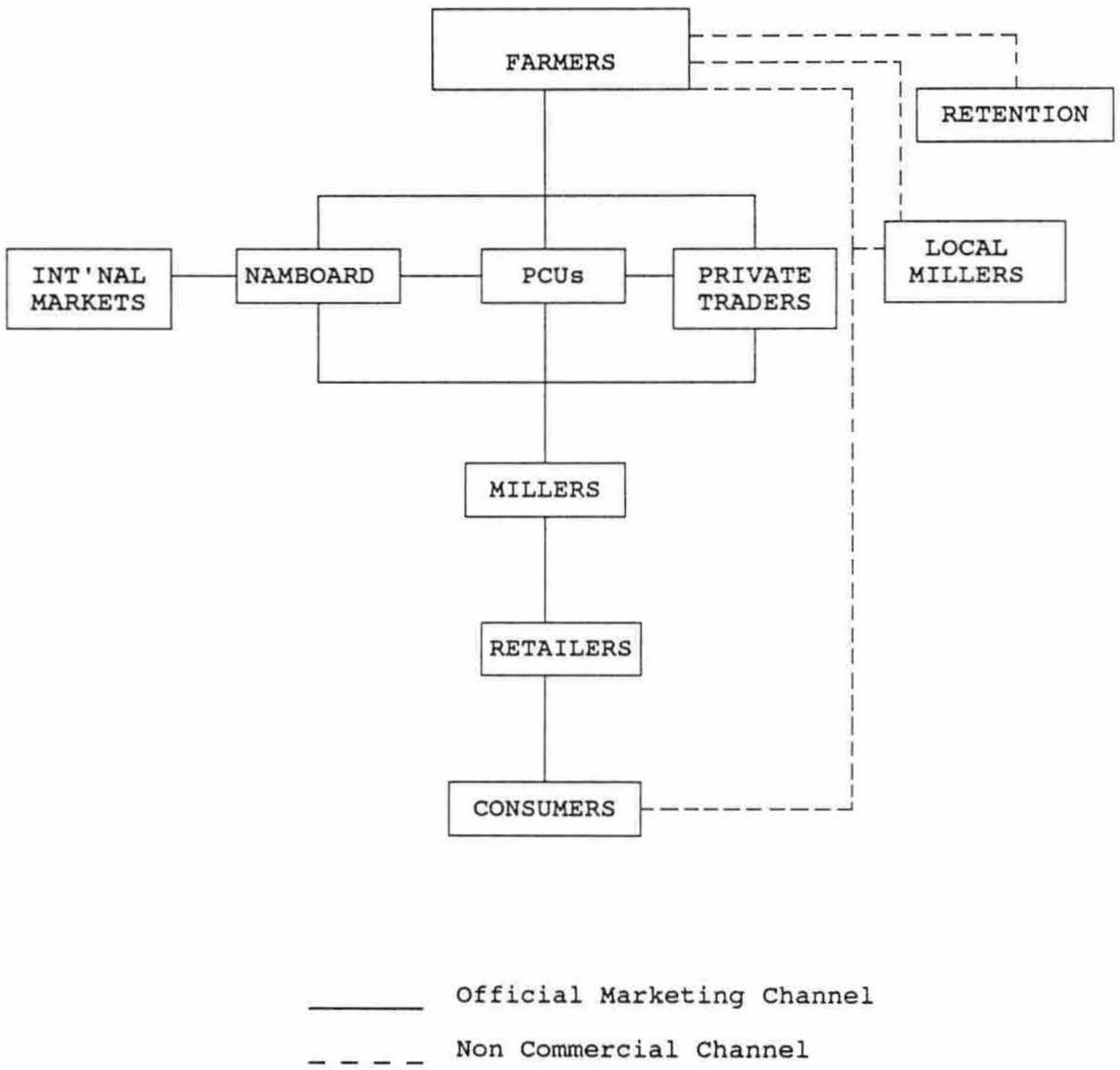

Figure 1. Maize marketing channel in Zambia

complex system of subsidies in maize marketing operations and at very high cost to the government.

Major policy reforms have been pronounced in an effort to redress this situation. The most significant one was the liberalization of maize marketing in 1986. Under this new arrangement, private individuals within each province were invited to participate in the marketing of maize, and NAMBOARD only remained with the responsibility of acting as the buyer of last resort and also dealing with imports or exports. Liberalizing the market was expected to provide the necessary competition needed to allow for efficiency in maize marketing and thus reduce marketing costs not only for government agents but for the entire system as well. However, in spite of all these marketing reforms, government marketing costs have continued to rise. Maize marketing operations in Zambia incur high marketing costs mainly due to the following factors pertaining:

1. the sparse population of Zambia (one person per five square kilometers), makes it more costly to distribute inputs and produce.
2. the poor state of rural roads and communications.
3. high real interest rates payments by government marketing agencies to commercial banks on funds borrowed to facilitate marketing operations. This situation arises partly due to the delay in government restitutions to these agencies.
4. huge storage losses due to inadequate proper storage facilities.
5. poor maintenance and operation of processing facilities especially in the light of Zambia's current problems in acquiring working capital or spare parts.

Pricing policy

During the colonial period, marketing services were restricted to Southern, Central and later Eastern Provinces, leaving farmers in other provinces with no government guaranteed markets (17). After independence, marketing services were expanded with the inception of NAMBOARD in the 1968/69 crop season. Deliberate efforts were now made towards providing extensive and guaranteed markets for agricultural produce in the other provinces as well.

Price discrimination practices in favor of settler farmers were discontinued at independence time in 1964 and for the 1968/69 crop season, a regional pricing system covering the whole country was put in place. This price regime offered higher producer prices to farmers in deficit regions and lower prices to farmers in surplus regions. Offering higher prices in the deficit regions was intended to act as a catalyst to increase maize production in those regions. Consequently, increased production in those regions would greatly reduce the amount of maize imports from the surplus regions and therefore reduce the huge gross expenditure on maize haulage.

For the 1970/71 crop marketing season, a floor price of K3.20 for a 90 kilogram bag was guaranteed for farmers in all regions (17). This floor price was higher than the prevailing prices in the surplus provinces under the regional pricing system. This new arrangement of guaranteeing a minimum price for farmers in all regions was intended to stimulate more production in all regions in light of the decline in maize production in the previous year.

In April 1973, a uniform pricing system was adopted. Under this system, producer prices in all regions were fixed at the same level. Equity considerations among farmers were cited to support the introduction of a uniform pricing system. However, this is difficult to justify given that different regions face different production costs (17). A more equitable system might be to provide higher prices to farmers in higher production cost areas so that income levels even out. Nevertheless, under the uniform pricing system, the government continued to adjust the fixed prices based on perceived changes in the cost of production.

In 1984, a floor (minimum) pricing system was introduced for all agricultural commodities except maize. Under this system, producers were guaranteed minimum prices for their produce, and they were free to negotiate for higher prices with marketing agents. However, in the case of small scale farmers, lack of organized power to negotiate for higher prices has resulted in a situation whereby the floor prices still constitute the selling prices for these farmers (9).

The 1986 liberalization of marketing arrangements in Zambia did not change much of maize pricing policy. Pricing of maize still remained the prerogative of the government to set producer prices based on perceived accounting production costs incurred by farmers and also allowing for a margin of profitability.

Maize supplies in the official marketing system

Maize supplies in the official marketing system come from three primary sources:

1. maize procurement.
2. carry-over stocks from the previous year.
3. imports whenever there is a shortfall in domestic sources.

Maize procurements Maize procurements are a major source of supplies accounting for over 95% of available supplies in a given good year. In times of environmental disruptions such as too little rainfall or too much of it, maize imports have been used to fill in the shortfall arising from inadequate marketings and stocks. Since maize production in Zambia is heavily dependent on rainfall, procurements share of total supplies have been fluctuating from year to year in response to fluctuations in maize production.

Table 2. Statutory producer prices of grain maize (per 90 kg bag) for various grades (A,B,C,D,E) over the years[a]

Year	Grade A (K)	B (K)	C (K)
1964/65	3.72	3.68	3.58
1965/66	3.32	3.28	3.18
1966/67	3.10	3.05	2.95
1967/68	2.90	2.85	2.75
1968/69	3.20	3.15	3.05
1969/70	3.50	3.45	3.35
1970/71	4.00	3.95	3.85
1971/72	4.30	4.25	4.15
1972/73	4.30	4.25	4.15
1973/74	4.30	4.25	4.15
1974/75	5.30	4.95	4.85
1975/76	6.30	6.20	6.05
1976/77	6.30	6.20	6.05
1977/78	6.80	6.75	6.70
1978/79	9.20	9.10	8.95
1979/80	11.70	11.60	11.40
1980/81	13.50	13.45	13.25
1981/82	16.00	15.90	15.85
1982/83	18.30	18.20	18.05
1983/84	24.50	24.35	24.15
1984/85	28.50	28.35	28.15
1985/86	55.00		

[a]Planning Division, Ministry of Agriculture.

<u>Maize stock holdings</u> In considering the need for national food security, the government's objective has been to set up and maintain an adequate maize buffer stock to counter the seasonal supply fluctuations. This buffer stock is required to ensure the availability of maize supply, equivalent to three to six months of maize market demand, within the country at any given time of the year

(19). The relief provided by this buffer stock in times of shortages would allow enough time for the government to arrange for the importation of additional maize supplies (19). In recent pronouncements, however, a specific figure of 2.5 million 90 kilogram bags of maize has been referred to as the targeted minimum maize reserve stock level. This is equivalent to about four months' supply of maize market demand.

The parastatal marketing agency, NAMBOARD, is the appointed administrator of this maize reserve stock since it already has the necessary infrastructure as well as the management potential to manage such maize stock levels.

The Food and Agriculture Organization (FAO) Food Security Assistance Scheme has particularly been very active in giving advice on how best to arrange such maize reserve stocks. The main elements of the FAO stockholding guidelines are that (28):

1. On 1st November, after domestic crop procurement are completed, an estimate be made of national stocks that would exist on 1st June in the following year based on historical consumption trends;
2. If the 1st June carry over stock amounted to less than three months market demand, grain would be imported to bring 1st June stocks up to three months supply;
3. If the 1st June stocks were estimated to exceed six months demand, an export programme to remove the surpluses would be organized.

<u>Past trends in actual stockholding</u> The government has tried to ensure the stability of the national food security situation by instituting an early warning system through which the government

tries to estimate expected production levels as well as expected crop procurement. By utilizing this system, necessary import or export arrangements are initiated to take care of the anticipated shortfall or surplus.

Maintaining minimum stock levels of 2.5 million 90 kilogram bags[1] of maize at the end of May has been hard to realize since 1979. Import requirements have increased during the 1980s, and security reserve stocks at the end of May have been equivalent to one month maize supply or less for all the years, except during 1982 when an equivalent of about two months maize supply was in reserve at the end of May (28).

Inefficient management of maize stocks arising mainly from lack of adequate proper storage facilities and constraining financial outlays, in particular foreign exchange, has been cited as hampering the realization of the official goal of maintaining a stable maize reserve stock at all times.

Maize trade policy: international NAMBOARD is the only marketing agent authorized to deal with international maize markets. In times of anticipated shortfalls, NAMBOARD, in consultation with the government, is required to import maize into the country in good time to avert maize shortages. In the same way, NAMBOARD carries out the function of exporting maize whenever there is more than the required domestic surpluses. Lack of adequate proper storage facilities puts more pressure on the need to export during a big surplus year.

Maize trade policy: domestic Despite the liberalization of the marketing system in 1986 to include private agents as well,

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[1]The Prime Minister referred to this stock level in March 1986.

movement of maize from province to province in response to demand and supply situations is done only by NAMBOARD in accordance with the stipulations of the government. NAMBOARD purchases maize in the surplus regions and transfers it for sale in the deficit regions. NAMBOARD, in this instance, carries out the function of watchdog in seeing to it that maize requirements in each region are satisfied. NAMBOARD's maize sales are restricted to registered millers and a small number of industrial processors. The latter group is allocated maize for commercial purposes only after the demand for maize by millers for meali-meal requirements have been satisfied.

Table 3. Imports of maize into Zambia, 1980-1985[a,b]

	1980	1981	1982	1983	1984	1985
Tonnes	288,000	93,000	68,000	101,000	126,000	109,000
000 bags	3,200	1,033	756	1,122	1,400	1,211

[a]NAMBOARD Grain Marketing Department.

[b]World Bank (28).

Table 4. NAMBOARD's transportation costs (K'000)[a,b]

Year	Maize	Fertilizer
1978	15,115	6,575
1979	12,488	4,705
1980	16,000	8,000
1981	13,464	6,000
1982	21,000	7,425

[a]NAMBOARD (21).

[b]Chella, S. S. V. (3).

Table 5. Grain maize exports to selected countries, 1968-1978[a,b]

Year	Country	Quantity (Metric Tonnes)	Value (K=Kwacha)
1968	China	21,762	963,304
	Botswana	270	9,000
	Zaire	41,462	1,865,615
1969	China	1,062	44,849
	Zaire	7,314	328,933
1970	-	60	-
1971	Belgium	153	4,285
	Zaire	8,445	172,280
1972	Zaire	1,895	100,128
1973	Tanzania	3	266
	Zaire	50,082	2,642,655
1974	Tanzania	69,133	4,959,268
	Zaire	42,079	2,672,695
1975	Zaire	16,621	1,433,781
1976	Mozambique	8,507	495,715
	Malawi	302	17,186
1977	Angola	22,007	3,136,225
	Tanzania	31	4,318
	Zaire	3,568	376,868
1978	Angola	21,903	322,515
	Rwanda	50	7,367
	Zaire	39,332	4,633,510

[a]ZCSO (30).

[b]Chella, S. S. V. (3).

Table 6. Estimated maize demand[a]

Year	Population consuming (in millions) Urban	Total	Demand ('000 x 90 K bags) Total food	Market food	Feed	Industrial usage	Total demand	Market demand
1975	1.758	3.9	10,756	4,850	340	485	11,581	5,675
1976	1.876	4.0	11,037	5,176	362	518	11,917	6,056
1977	2.002	4.1	11,312	5,523	387	552	12,251	6,462
1978	2.136	4.3	11,862	5,893	412	589	12,864	6,894
1979	2.279	4.5	12,415	6,288	440	629	13,484	7,357
1980	2.440	4.7	12,967	6,732	471	673	14,111	7,876
1981	2.603	4.8	13,502	7,181	503	718	14,723	8,402
1982	2.777	5.0	13,794	7,661	536	766	15,096	8,963
1983	2.960	5.3	14,662	8,174	572	817	16,011	9,563
1985	3.374	5.7	15,726	9,309	652	930	17,308	10,891
1990	4.666	7.1	19,588	12,873	901	1,287	21,776	15,061
1995	6.453	9.1	25,106	17,803	1,246	1,780	28,132	20,829
2000	8.923	11.7	32,279	24,618	1,723	2,462	36,425	28,803

[a]Chella, S. S. V. (3).

Table 7. Maize procurements, imports and stocks, 1976-85 (000 bags)[a,b]

Year	Procurement	Imports	Stocks at end of May
1976	8,332	0	2,966
1977	7,819	0	2,924
1978	6,462	0	3,339
1979	3,734	700	3,167
1980	4,193	3,200	405
1981	7,610	1,033	719
1982	5,671	756	1,201
1983	5,899	1,122	906
1984	6,348	1,400	682
1985	7,070	1,211	288

[a]NAMBOARD Grain Marketing Division.

[b]World Bank (28).

Table 8. Maize imports by source, 1985 (000 bags)[a,b]

Country of supply	Type	Quantity received	Financing arrangement
Zimbabwe	white	554	commercial
Zimbabwe	white	165	E.E.C. aid
Zimbabwe	white	37	F.A.O. aid
Malawi	white	415	commercial
Malawi	white	5	WFP to SWAPO
China	yellow	27	Chinese aid
E.E.C.	yellow	5	UNHCR
		1,208	

[a]NAMBOARD Grain Marketing Division.

[b]World Bank (28).

Table 9. Maize imports by month, 1985 (000 bags)[a,b]

Month	Quantity	Month	Quantity
January	16	July	298
February	19	August	181
March	67	September	56
April	35	October	4
May	180	November	0
June	362	December	0
		Total:	1,208

[a]NAMBOARD Grain Marketing Division.

[b]World Bank (28).

Table 10. Population projections by province and residence, 1980-2000 (000's)[a,b]

Province	Residence	1980	1985	1990	1995	2000
Central	Total	512	616	749	916	1,124
	Urban	147	216	309	434	600
	Rural	365	400	439	482	524
Copperbelt	Total	1,251	1,549	1,946	2,457	3,106
	Urban	1,131	1,417	1,802	2,299	2,934
	Rural	120	131	144	158	172
Eastern	Total	651	741	847	974	1,121
	Urban	54	87	129	187	264
	Rural	597	654	718	787	857
Luapula	Total	421	475	539	613	698
	Urban	38	56	79	109	149
	Rural	383	419	460	505	549
Lusaka	Total	691	910	1,212	1,608	2,124
	Urban	550	756	1,042	1,422	1,922
	Rural	141	154	169	186	202
Northern	Total	675	757	852	960	1,081
	Urban	95	122	154	195	248
	Rural	580	635	698	765	832
North-western	Total	303	351	407	476	557
	Urban	18	39	65	101	149
	Rural	285	312	342	376	409
Southern	Total	672	791	936	1,114	1,330
	Urban	167	238	328	448	606
	Rural	505	553	607	666	725
Western	Total	486	535	586	640	695
	Urban	58	66	71	75	81
	Rural	428	469	515	564	614
Total Zambia	Total	5,662	6,725	8,073	9,758	11,836
	Urban	2,259	2,998	3,979	5,269	6,953
	Rural	3,403	3,727	4,094	4,489	4,884

[a]ZCSO (31).

[b]World Bank (28).

Table 11. Per capita consumption (kilogram per year) of mealie meal, 1980[a]

Province	Residence	Per capita consumption Meal	Maize	% Marketed
Central	Total	150.4	172.1	79
	Urban	98.2	115.5	100
	Rural	171.4	194.8	70
Copperbelt	Total	98.3	115.2	99
	Urban	97.2	114.4	100
	Rural	108.4	123.2	90
Eastern	Total	139.8	159.2	50
	Urban	102.6	120.7	100
	Rural	143.2	162.7	45
Luasula	Total	37.6	43.0	73
	Urban	88.1	103.6	100
	Rural	32.5	36.9	70
Lusaka	Total	113.1	131.7	98
	Urban	98.2	115.5	100
	Rural	171.4	194.8	90
Northern	Total	42.3	48.6	27
	Urban	95.3	112.1	100
	Rural	33.6	38.2	15
North-western	Total	50.2	57.3	53
	Urban	104.2	122.6	100
	Rural	46.8	53.2	50
Southern	Total	146.8	168.0	70
	Urban	121.7	143.2	100
	Rural	155.1	176.3	60
Western	Total	90.9	103.8	47
	Urban	95.4	112.2	100
	Rural	90.3	102.6	40
Total Zambia	Total	100.9	116.3	70
	Urban	99.2	116.7	100
	Rural	102.1	116.0	51

[a]World Bank (28).

Table 12. Marketed maize consumption (in 000 tonnes)[a]

Province	Residence	1980	1985	1990	1995	2000
Central	Total	58	69	83	100	122
	Urban	14	21	30	43	59
	Rural	44	48	53	58	63
Copperbelt	Total	122	151	189	239	302
	Urban	110	138	175	223	285
	Rural	12	13	14	15	17
Eastern	Total	50	58	68	80	95
	Urban	7	10	16	23	32
	Rural	44	48	53	58	63
Luasula	Total	14	17	20	24	30
	Urban	4	6	8	11	15
	Rural	10	11	12	13	14
Lusaka	Total	88	114	150	197	257
	Urban	64	87	120	164	222
	Rural	25	27	30	33	35
Northern	Total	14	17	21	26	33
	Urban	11	14	17	22	28
	Rural	3	4	4	4	5
North-western	Total	10	13	17	22	29
	Urban	2	5	8	12	18
	Rural	8	8	9	10	11
Southern	Total	77	93	111	135	163
	Urban	24	34	47	64	87
	Rural	53	58	64	70	77
Western	Total	24	27	29	32	34
	Urban	7	7	8	8	9
	Rural	18	19	21	23	25
Total Zambia	Total	464	570	706	880	1,100
	Urban	264	350	465	615	812
	Rural	201	220	241	265	288
Total Zambia		Total Marketed Maize (+ beer, stockfeed use)				
	Total	6,450	7,475	8,799	10,489	12,626
	Urban	3,662	4,501	5,615	7,078	8,989
	Rural	2,788	2,974	3,184	3,411	3,637

[a]World Bank (28).

Table 13. White maize intake by official marketing organizations by province, 1973-1985 (in thousands of 90 kg bags)[a,b,c]

Harvest Year	Central	Copper belt	Eastern	Luapula	Lusaka	Northern	North Western	Southern	Western	Zambia Total
1973	2,510	132	501	16	*	99	26	1,171	15	4,470
1974	3,784	25	622	16	*	67	29	1,970	30	6,543
1975	2,844	33	790	18	*	113	29	2,336	74	6,237
1976	3,948	72	912	25	*	184	38	3,073	80	8,332
1977	2,965	70	924	32	413	212	40	3,077	86	7,819
1978	2,164	51	772	34	254	203	34	2,911	39	6,462
1979	1,234	42	517	18	181	121	32	1,555	34	3,734
1980	1,524	35	739	18	197	118	15	1,534	13	4,193
1981	2,591	38	1,182	29	323	328	41	3,036	42	7,610
1982	1.685	66	1,273	50	218	649	50	1,642	38	5,671
1983	2,238	90	1,598	40	217	644	51	970	51	5,899
1984	2,118	134	1,849	71	193	751	67	1,076	89	6,348
1985	2,232	242	1,780	59	267	740	75	1,584	91	7,070

[a]ZMAWD (32).

[b]NAMBOARD and Provincial Cooperative Unions.

[c]World Bank (28).

*Included in Central Provinces.

Table 14. NAMBOARD maize purchases by month, 1976-1985 (in thousands of 90 kg bags)[a,b]

Harvest Year	May	June	July	August	September	October	November	December	Total
1976	0	64	616	1,947	3,380	1,235	512	0	7,656
1977	0	124	804	1,540	2,913	1,886	389	0	7,656
1978	0	90	732	1,238	2,168	1,249	961	1	6,440
1979	0	23	861	1,752	906	159	5	1	3,707
1980	30	240	569	959	1,554	795	53	0	4,200
1981	0	201	960	1,618	1,010	1,441	237	47	5,513
1982	0	87	140	706	769	504	330	340	2,875
1983	0	143	305	522	467	421	382	254	2,493
1984	4	64	111	579	422	598	525	0	2,302
1985	13	217	965	2,374	2,121	1,318	142	0	7,151

[a]NAMBOARD Grain Marketing Department.

[b]World Bank (28).

Table 15. Maize sales by official marketing organizations by province, 1972-1985 (in thousands of 90 kg bags)[a,b,c]

Harvest Year	Central	Copper belt	Eastern	Luapula	Lusaka	Northern	North Western	Southern	Western	Zambia Total
1972	1,274	2,129	-	n.a.	*	-	n.a.	393	n.a.	3,796
1973	1,698	2,346	-	n.a.	*	-	n.a.	560	n.a.	4,604
1974	1,719	2,635	-	n.a.	*	-	n.a.	557	n.a.	4,911
1975	2,350	2,666	-	n.a.	*	-	n.a.	667	n.a.	5,683
1976	2,412	2,512	-	92	*	-	19	673	35	5,743
1977	2,472	2,651	-	197	*	-	98	612	69	6,099
1978	964	3,004	89	269	1,854	63	92	718	123	7,176
1979	851	2,755	120	285	1,753	95	144	755	165	6,923
1980	817	2,483	180	271	1,462	110	124	886	209	6,542
1981	732	2,742	175	229	1,408	184	146	1,104	237	6,957
1982	746	3,036	366	191	1,378	165	120	903	254	7,159
1983	711	2,866	638	141	1,438	261	130	976	292	7,453
1984	736	3,122	312	118	1,581	240	111	971	274	7,465
1985	705	3,614	157	104	1,366	303	136	886	226	7,497

[a]ZMAWD (32).

[b]NAMBOARD and Provincial Cooperative Unions.

[c]World Bank (28).

*Included in Central Province.

Table 16. NAMBOARD maize stocks at month end 1975-1986 (in thousands of 90 kg bags)[a,b]

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1975	4,623	4,128	3,665	3,197	2,765	2,455	3,159	4,449	5,825	6,002	5,555	4,979
1976	4,401	4,358	3,902	3,419	2,966	2,966	2,765	4,218	7,053	7,512	6,805	5,862
1977	5,461	4,936	4,375	3,616	2,924	2,924	3,110	3,367	4,462	6,789	7,178	6,613
1978	5,826	5,318	4,687	3,869	3,339	3,339	2,389	3,195	4,128	5,414	5,588	5,059
1979	4,483	3,966	3,366	1,767	2,167	2,167	1,558	2,880	2,875	2,526	1,975	2,076
1980	1,547	1,021	764	700	405	905	1,684	2,435	3,447	3,768	3,427	2,862
1981	2,270	2,011	1,450	1,100	719	600	1,151	2,010	3,301	3,655	3,635	3,324
1982	2,663	2,222	1,705	1,321	1,201	942	1,098	1,187	1,640	1,915	1,824	1,638
1983	1,540	1,321	1,084	952	906	973	1,150	1,446	1,683	1,780	1,713	1,548
1984	1,420	1,272	1,009	824	682	541	435	606	787	1,085	1,152	1,015
1985	774	23	455	374	288	405	1,169	2,035	3,079	4,771	4,805	4,147
1986	3,470	2,755	2,010	1,454								

[a]NAMBOARD Grain Marketing Department.

[b]World Bank (28).

CHAPTER III. MODEL DEVELOPMENT

Literature Review

From the time of Zambia's independence in 1964, some empirical studies have been carried out on the maize sector in Zambia and particularly the marketing aspect of it. The most recent ones have been done in the past five years.

Dennis Pervis (22), in his study of the management of maize distribution in Zambia, used a linear programming transportation model to estimate optimum flows of maize from districts of production to districts of main storage, and from districts of main storage to districts of milling, and, finally, from districts of milling to districts of retailing. The model was run on microcomputers, and since microcomputers have very limited capacity for such large models, the model had to be broken down into sub models which were run separately. This type of optimization does not allow for the simultaneity effects in the optimization of maize movements. However, this does not pose a serious setback in the model since most of maize marketed in Zambia is restricted to follow the pattern of movement as indicated by the sub models.

In a study of the supply response of maize in Zambia, Suba (24) used the Nerlovian modeling technique, which is based on adaptive expectations theory, to investigate the variations in maize output. The study indicates that maize producer price and rainfall, among other variables, generally provide strong explanations for the variations in maize supply in Zambia.

Muntanga (17), in evaluating the uniform pricing system for maize in Zambia, used a transportation model to determine regional price differentials and maize optimum flows between regions. Optimization in this study was done under competitive conditions with exogenously given transportation costs per unit.

Mwanaumo (20), in a study on the evaluation of the marketing system for maize in Zambia, looked at ways of minimizing the processing, storage and transportation costs in the maize marketing system. The focus of the study was on minimizing the marketing costs covered by government subsidies using linear programming techniques. Pricing policy implications arising from these activities were also investigated, and the study indicated that substantial savings could be realized in the cost structure of the maize marketing system in Zambia.

The CEAP Project Report Number 4 (2) outlines a maize policy model for Zambia. The study itself does not draw any policy recommendations. Its intended purpose is for use by personnel in the agriculture sector of Zambia, especially those dealing with policy analysis. The model indicates expected levels of maize production, retention, marketings, import needs, producer revenues and government costs associated with producer and consumer subsidies as well as import costs.

Other studies of this nature have been applied to marketing systems elsewhere in the third world countries. Of major interest to this study are the economic modeling techniques utilized by Raj Krishna and Ajay Chhibber (15) of India in their study of the wheat marketing system in India. The study incorporates econometric modeling techniques to analyze the Indian wheat marketing structure and finally optimization techniques are utilized to derive least cost government decision variables. The study indicates that large savings can be introduced in the Indian wheat marketing system by pursuing rational policies. The general economic modeling techniques applied in the Krishna-Chhibber study form the background for this study,[2] and some comparisons between the two marketing systems in India and Zambia will be made in this study where necessary.

The Dynamic Optimization Model

In view of the high cost of maize marketing operations in Zambia, the research study will examine whether this cost can be reduced while allowing maize consumption to continue to grow over the projection period. To this effect, alternative projections under the four scenarios will be made using a dynamic optimization model with alternative assumptions, to obtain optimal least cost values of government policy variables for the same 16 year projection period. In this dynamic optimizing model, the sum of the present value of the annual cost of maize marketing operations over the projection period will be minimized subject to inequalities that reflect the concerns of policy makers.

The model developed in this study is dynamic in nature. The dynamic optimization model involves sequential transmission of situations. Each decision at present time takes into account future impacts and decisions. It provides an optimal policy strategy for maize marketing operations which gives us both the long term levels of policy decision variables and the optimal adjustment strategy to be pursued in order to achieve the stated goals. In this case, the model could be used to advise policy makers in which years to import or export maize and at what quantity levels. This strategy also involves building maize stock reserves at home, adjusted for size

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[2]Only the optimization part is simulated.

every other year. It also defines the optimal maize stock levels to aim for in each year.

The objective function being minimized is the sum of the net maize marketing operations costs incurred throughout the 16 year period under study. The objective function is minimized subject to the constraint structure imposed by the policy makers. The model can easily be altered to reflect changes in policy concerns as may be reflected from year to year.

The cost concept utilized in this study is quite different from that employed in many mathematical models done on the marketing system in Zambia. The cost concept here, denoted by C_t, is defined as the sum of three basic costs and three marketing costs (15). The net cost is derived by deducting sales revenue accruing from the sale of maize to millers and industrial processors. The three basic costs are:

1. the value of all the maize procured, i.e., the producer price of maize multiplied by the quantity of maize procured: $(P_{pt}PR_t)$
2. the value of all the imported maize, i.e., the import price of maize multiplied by the quantity of maize imported: $(P_{It}IM_t)$
3. total storage costs, i.e., per unit storage cost multiplied by the quantity of maize in storage: $0.5P_{st}(OS_t + CS_t)$

The three marketing costs are:

1. the cost of procuring maize: $\alpha P_{pt}PR_t$
2. the cost of distributing both domestic and imported maize: $\beta P_{pt}SL_t$
3. the cost of clearing imports at the port of entry: $\Theta P_{pt}IM_t$

This annual cost concept is similar to the one used by Krishna and Chhibber. The cost function is specified as follows:

(1) $$C_t = [P_{pt}PR_t + P_{It}IM_t + 0.5P_{st}(OS_t + CSt] + [\alpha P_{pt}PR_t + \beta P_{pt}SL_t + \Theta P_{pt}IM_t] - P_{SLt}SL_t$$

$$t = 1985, 1986, \ldots, 2000$$

where:

P_{pt} is the producer price of maize faced by farmers in year t.

PR_t is the quantity of maize marketed in year t.

P_{It} is the price of imported maize in year t.

IMt is the quantity of imports brought into the country in year t.

P_{st} is the cost of storing maize in year t.

OS_t is the level of maize opening stocks held by the marketing agents in a given year t.

CS_t is the level of maize closing stocks held by the marketing agents in year t.

αP_{pt} is the proportion of the producer price relating to the costs incurred in procuring maize in year t.

SL_t is the quantity of maize allocated to millers and industrial processors in year t.

βP_{pt} is the proportion of the producer price reflecting the average costs incurred in distributing both imported and domestic maize in year t.

ΘP_{pt} is the proportion of the producer price reflecting the costs incurred in clearing imported maize in year t.

P_{slt} is the price of maize offered to millers and industrial processors in year t.

After consolidating all the terms in the annual cost function, C_t becomes

$$C_t = (1+\alpha)P_{pt}PR_t + (P_{It} + \Theta P_{pt})IM_t + 0.5P_{st}(OS_t + CS_t) - (P_{slt} - \beta P_{pt})SL_t$$

The present value of this annual cost over the 16 year period under review is:

$$(2) \quad \sum_t C_t/(1+r)^{t-1985} \qquad t = 1985, 1986, \ldots, 2000$$

$$= \sum_{t=1985}^{2000} [(1+\alpha)P_{pt}PR_t]/[(1+r)^{t-1985}] + [(P_{It}+\Theta P_{pt})IM_t]/[(1+r)^{t-1985}] + [0.5P_{st}(OS_t+CS_t)]/(1+r)^{t-1985}] - [P_{slt}-\beta P_{pt})SL_t]/[(1+r)^{t-1985}]$$

where r, the discount rate, is assumed to be 15%. The dynamic optimization model to be minimized is the present value of the annual cost of maize marketing operations: The complete model specification is as follows:

$$\text{Minimize } \sum_t C_t/(1+r)^{t-1985} =$$

$$\text{Minimize } \sum_t [(1+\alpha)P_{pt}PR_t + (P_{It} + \Theta P_{pt})IM_t + 0.5\ P_{st}(CS_t + OS_t) - (P_{slt} - \beta P_{pt}]SL_t/(1 + r)^{t-1985} \qquad (3)$$

$$t = 1985, 1986, \ldots, 2000$$

subject to the following policy constraints:

$$PR_t \geq \underline{PR_t} \quad (3.1)$$

$$OS_t \geq \phi SL_t \quad (3.2)$$

$$CS_t = PR_t + IM_t + OS_t - SL_t \quad (3.3)$$

$$SL_t = \underline{SL_t} \quad (3.4)$$

$$IM_t \geq 0 \quad \text{or} \quad IM_t \leq \underline{IM_t} \quad (3.5)$$

$$OS_{t+1} = CS_t \quad (3.6)$$

$$PR_t, OS_t, CS_t, SL_t, \geq 0 \quad \text{for all } t. \quad (3.7)$$

The constraints are specified in order to reflect the concerns of the policy makers. Decisions over the entire sixteen year period are made regarding the interaction of the five basic variables under government control. The decisions to be made relate to questions of what quantities of maize to procure, import or export, or have in stock at the end or at the beginning of each crop year. Decisions also have to be made regarding the levels of maize sales to be made to millers and industrial processors over the seventeen year period.

However, the marketing operations cost as defined above is bound not to be substantially reduced if the variation of the five variables by policy makers is done nonoptimally. In Zambia, government policy with regard to maize purchases guarantees the buying of all the maize offered for sale by farmers. The producer price of maize is kept constant throughout the crop season and NAMBOARD is the government appointed agent with specific obligations as the buyer and seller of last resort. Over the years, marketed maize has constituted an average of about 70% of estimated total maize production. Therefore, maize procurements in the programming problem are not allowed to be less than 70% of estimated total maize production in each year. Opening maize stock levels at the beginning of May in each year are set at not less than 25% of the total maize sales to millers and the industrial processors. The official stated goal of the government is to maintain about 2.5 million 90 kg bags of maize as reserve stocks at any given time of the year.

In alternative model simulations, maize opening stock levels are set at a minimum of 50% of total sales to millers and industrial processors in each year. Sales to millers and industrial processors reduce the cost of maize marketing operations by increasing the maize sales revenue deducted from total cost. However, maize sales to millers and industrial processors are fixed each year in accordance with the government maize allocations which are determined on the basis of maize availability and the amount of maize demanded for consumption. This refers to market demand of maize for mealie-meal as well as for industrial processing uses. Increases in maize sales are supported by increases in maize procurements, opening maize stock levels and imports in the event of a shortfall in domestic maize supplies.

The maize opening stock level of minimum 50% of total maize sales as stipulated above ensures a greater measure of food security for the country, especially in the face of shortfalls in domestic maize supplies and the current critical shortage of foreign exchange needed to bring in imports expediently.

Thus imports are brought in on a very limited level only to fill the shortfall in domestic maize supplies for sale as well as to help maintain the 25 or 50% minimum levels set for maize opening stocks. In times of domestic maize surpluses, exports are allowed in the model after satisfying requirements for maize sales as well as for maintaining the stipulated minimum maize opening stock levels in each year.

The underlined quantities, $\underline{PR}_t$, $\underline{SL}_t$ and $\underline{IM}_t$ are constants reflecting the projected minimum, equality or maximum levels the policy variables are allowed to reach.

The Data Set for the Model

The initial aim of this research study was to develop two models. An econometric model was to be constructed to provide the quantity levels to which the policy decision variables in the dynamic optimization model were to be constrained. However, the difficulties encountered in obtaining enough data ruled out the possibility of building an appropriate econometric model. Therefore, alternative methods were used to obtain the model coefficients. Projected values of total maize purchases and maize sales from the World Bank Report (28) were used. These range from 1985 to the year 2000. Maize producer prices variations are administered by the government through annual adjustments that take into account the impacts on the farmers' welfare as well as the welfare of the consumer. During the 1980s, substantial increases in maize producer prices have been made. However, in view of government commitment to work towards reducing subsidies in the maize consumer market and their ultimate removal over the year, maize producer prices in the model are assumed to grow at a rate of 5% annually from 1988 through the year 2000. Marketing costs average out to about 40% of the producer price of maize. Of this cost, 21% of the maize producer price is spent on transportation (28). This is assumed to be the same proportion of the producer price that is used through the year 2000. This transportation cost covers the cost of distributing both imported and domestic maize. Total storage costs work out to about 43% of maize producer price (28). In this study, this situation is assumed to continue through the year 2000 by projecting storage costs as a fixed proportion (at 43%) of the maize procurement price in any given year (t). One-half of this cost constitutes the average carrying cost for opening and closing maize stocks, respectively.

Maize import prices grow at a rate of 3.5% per annum. The costs incurred in clearing maize imports at the ports of entry are assumed fixed at the 6% of maize procurement price level.

In the drought scenario and the drought and foreign exchange shortage scenario, droughts are assumed to occur in six of the sixteen projection years. The droughts occur in the years 1987, 1988, 1993, 1994, 1996 and 1998. The droughts are reflected by the inability of maize procurements to satisfy the required minimum maize sales in the assumed drought years.

The foreign exchange shortage situations affect the maize sector only in so far as they restrict the capacity to import. This reduces maize imports to between 80 and 90% of imports in situations with no foreign exchange restrictions.

Assumptions underlying the programming problem

Implicit assumptions have been made about the nature of the maize marketing operations and the decision variables as outlined in the mathematical formulation above.

1. Optimization: It is assumed that the present value of the net annual cost of maize marketing operations is minimized over the entire projection period.

2. Determinism: It is assumed that the coefficients in the objective function and in the constraint structure are all known constants.
3. Continuity: It is assumed that noninteger values, i.e., fractional units, can be used to reflect the levels of the government decision variables undertaken and the amount of resources utilized in carrying out maize marketing operations.
4. Finiteness: The government decision variables in maize marketing operations and the constraints imposed upon them are assumed to be finite in number. This makes it possible to arrive at a solution to the programming problem.
5. Proportionality: The gross margin and resource requirements per unit of government decision variable are assumed to be constant regardless of the level of the decision variable reached. A constant gross margin per unit of activity assumes a perfectly elastic demand curve for maize. Supplies of any variable inputs that may be used are also assumed to be perfectly elastic. Constant resource requirements per unit of activity are equivalent to a leontief production function, i.e., a linear ray through the origin (10).
6. Fixedness: It is assumed that at least one constraint has a right hand size whose coefficient is nonzero in value.
7. Additivity: Given the five policy decision variables specified in the model, their total product is the sum of the separate variable products. In other words, there are no interaction effects among the policy decision variables.
8. Homogeneity: Units of the same policy decision variable are assumed to be identical.

Conditions for optimality

The programming model specification (3) subject to policy concerns (3.1) to (3.7) has an optimal solution equivalent to one that would be derived from a Lagrangean function which has no constraints. The Lagrangean function for the maize marketing operations optimization problem is:

$$L = \sum_t [(1+\alpha)P_{pt}PR_t + (P_{It} + \Theta P_{pt})IM_t + 0.5P_{st}(CS_t + OS_t) \quad (4)$$

$$- (P_{slt} - \beta P_{pt})SL_t]/(1 + r)^{t-1985} + \mu_{1t}(\underline{PR_t} - PR_t)$$

$$+ \mu_{2t}(\phi SL_t - OS_t) + \mu_{3t}(-CS_t - SL_t + PR_t + IM_t + OS_t)$$

$$+ \mu_{4t}(SL_t - \underline{SL_t}) + \mu 5t(\underline{IM_t} - IM_t) + \mu 6t(CS_t - OS_{t+1})$$

where the variables, μ_{1t}, μ_{2t}, μ_{3t}, μ_{4t}, μ_{5t}, and μ_{6t}, are called Lagrangean multipliers. Their economic interpretation will be touched on below when the necessary conditions for an optimal solution to this problem to occur are outlined.

A numerical solution to this problem can be derived by using classical calculus. This requires taking partial derivatives of the stated Lagrangean function with respect to the specified policy variables which in this case are PR_t, OS_t, CS_t, SL_t, and IM_t, as well as with respect to the Lagrangean multipliers μ_{1t}, μ_{2t}, μ_{3t}, μ_{4t}, μ_{5t}, and μ_{6t}. These partial derivatives are then set equal to zero. The resulting system of equations would be as follows:

$$\eta L/\eta PR_t = [(1+\alpha)P_{pt}/(1+r)^{t-1985}] - \mu_{1t} + \mu_{3t} = 0 \quad (4.1)$$

$$\eta L/\eta OS_t = [0.5P_{st}/(1+r)_{t-1985}] - \mu_{2t} + \mu_{3t} = 0 \quad (4.2)$$

$$\eta L/\eta CS_t = [0.5P_{st}/(1+r)^{t-1985}] - \mu_{3t} + \mu 6t = 0 \quad (4.3)$$

$$\eta L/\eta SL_t = - [(P_{slt} - \beta P_{pt})/(1+r)^{t-1985}] - \mu_{3t} + \mu_{4t} = 0 \quad (4.4)$$

$$\eta L/\eta IM_t = [(P_{It} + \Theta P_{pt})/(1+r)^{t-1985}] + \mu 3t - \mu_{5t} = 0 \quad (4.5)$$

$$\eta L/\eta \mu 1t = \underline{PR_t} - PR_t = 0 \quad (4.6)$$

$$\eta L/\eta \mu_{2t} = \phi SL_t - OS_t = 0 \quad (4.7)$$

$$\eta L/\eta \mu_{3t} = -CS_t - SL_t + PR_t + IM_t - OS_t = 0 \quad (4.8)$$

$$\eta L/\eta \mu_{4t} = SL_t - \underline{SL_t} = 0 \quad (4.9)$$

$$\eta L/\eta \mu_{5t} = \underline{IM_t} - IM_t = 0 \quad (4.10)$$

$$\eta L/\eta \mu_{6t} = CS_t - OS_{t+1} = 0 \quad (4.11)$$

The solutions in the variables PR_t, OS_t, CS_t, SL_t, IM_t, μ_{1t}, μ_{2t}, μ_{3t}, μ_{4t}, μ_{5t} and μ_{6t} are derived by simultaneously solving the eleven linear equations (4.1) to (4.11). This procedure helps to reduce the minimization problem to a problem of simultaneous equations. For a unique solution to occur in this minimization problem, the number of constraints should equal the number of variables. At optimality, the variables μ_{1t}, μ_{2t}, μ_{3t}, μ_{4t}, μ_{5t} and μ_{6t} are the shadow prices associated with the resource constraints.

As stated earlier on, the classical optimization technique outlined above assumes equality constraints. However, the optimization model used in this study incorporates the use of inequality constraints as well. We, therefore, use the Kuhn-Tucker optimization techniques which generalize the Lagrangean method to include problems with inequality constraints. For the programming problem used in this study to have an optimal solution, the following Kuhn-Tucker conditions must be satisfied.

$$\eta L/\eta PR_t = [(1+\alpha)P_{pt}/(1+r)^{t-1985}] - \mu_{1t} + \mu_{3t} \geq 0 \quad (4.12)$$

$$\eta L/\eta OS_t = [0.5P_{st}/(1+r)^{t-1985}] - \mu_{2t} + \mu_{3t} \geq 0 \quad (4.13)$$

$$\eta L/\eta CS_t = [0.5P_{st}/(1+r)^{t-1985}] - \mu_{3t} + \mu_{6t} \geq 0 \quad (4.14)$$

$$\eta L/\eta SL_t = -[(P_{slt} - \beta P_{pt})/(1+r)^{t-1985}] - \mu_{3t} + \mu_{4t} \geq 0 \quad (4.15)$$

$$\eta L/\eta IM_t = [(P_{It} + \Theta P_{pt})/(1+r)^{t-1985}] + \mu_{3t} - \mu_{5t} \geq 0 \quad (4.16)$$

$$\eta L/\eta \mu_{1t} = \underline{PR_t} - PR_t \leq 0 \quad (4.17)$$

$$\eta L/\eta \mu_{2t} = \phi SL_t - OS_t \leq 0 \quad (4.18)$$

$$\eta L/\eta \mu 3t = -CS_t - SL_t + PR_t + IM_t - OS_t \leq 0 \quad (4.19)$$

$$\eta L/\eta \mu_{4t} = SL_t - \underline{SL_t} \leq 0 \quad (4.20)$$

$$\eta L/\eta \mu_{5t} = \underline{IM_t} - IM_t \leq 0 \quad (4.21)$$

$$\eta L/\eta \mu 6t = CS_t - OS_{t+1} \leq 0 \quad (4.22)$$

and the complementary slackness conditions are:

$$[[(1+\alpha)P_{pt}/(1+r)^{t-1985}] - \mu_{1t} + \mu_{3t}]\ PR_t = (\eta L/\eta PR_t)PR_t = 0 \quad (4.23)$$

$$[[0.5P_{st}/(1+r)^{t-1985}] - \mu_{2t} + \mu_{3t}]\ OS_t = (\eta L/\eta OS_t)OS_t = 0 \quad (4.24)$$

$$[[0.5P_{st}/(1+r)^{t-1985}] - \mu_{3t} + \mu_{6t}]\ CS_t = (\eta L/\eta CS_t)CS_t = 0 \quad (4.25)$$

$$[[-(P_{slt} - \beta P_{pt})/(1+r)^{t-1985}] - \mu_{3t} + \mu_{4t}]\ SL_t = (\eta L/\eta SL_t)SL_t = 0 \quad (4.26)$$

$$[[(P_{It} + \Theta P_{pt})/(1+r)^{t-1985}] + \mu_{3t} - \mu_{5t}]\ IM_t = (\eta L/\eta IM_t)IM_t = 0 \quad (4.27)$$

$$(\underline{PR}_t - PR_t)\ \mu_{1t} = (\eta L/\eta\mu_{1t})\ \mu_{1t} = 0 \quad (4.28)$$

$$(\phi SL_t - OS_t)\ \mu_{2t} = (\eta L/\eta\mu 2t)\ \mu_{2t} = 0 \quad (4.29)$$

$$(-CS_t - SL_t + PR_t + IM_t - OS_t)\ \mu_{3t} = (\eta L/\eta\mu_{3t})\ \mu_{3t} = 0 \quad (4.30)$$

$$(\underline{SL}_t - SL_t)\ \mu_{4t} = (\eta L/\eta\mu_{4t})\ \mu_{4t} = 0 \quad (4.31)$$

$$(\underline{IM}_t - IM_t)\ \mu_{5t} = (\eta L/\eta\mu_{5t})\ \mu_{5t} = 0 \quad (4.32)$$

$$(CS_t - OS_{t+1})\ \mu_{6t} = (\eta L/\eta\mu_{6t})\ \mu_{6t} = 0 \quad (4.33)$$

<u>The economic interpretation of the optimality conditions</u>

The Kuhn-Tucker conditions expressed in the equation system (4.12) to (4.33) cannot be used to solve for the policy decision variables, and the μ_{it}'s using simultaneous equation techniques. The Kuhn-Tucker conditions do not provide an analytical procedure for deriving the optimal solution, but they do, however, establish the conditions that the policy decision variables must satisfy if they are to be identified as the optimal solution (10).

In optimality, the μ_{it}'s are imputed values for the decision variable constraints, better known as the opportunity costs or shadow prices. Conditions (4.12) and (4.23) state that when a positive amount of maize is procured, in year t, then the total present value per unit cost of procured maize must equal the net imputed value of the procured maize. Similarly, conditions (4.13) and (4.24) state that the present value unit average cost of storing maize by the beginning of the crop year should equal the net imputed value of the stored maize in year t. This condition holds when a positive amount of maize is stored by the beginning of the crop year. The same interpretation is made with regard to conditions (4.14) to (4.16) in association with conditions (4.25) to (4.27). When we have positive amounts of maize stocks by the end of a crop year and also positive amounts of imports in any given year t, then the present value average unit cost of storing maize by the end of the crop season and the present value of the total cost of bringing in a unit of imported maize must equal their respective net imputed values. Conditions (4.15) and (4.26) state that for positive amounts of maize sales to millers and industrial processors, the net present value of a unit maize sale must equal the net imputed value of the maize sale.

Conditions (4.17) to (4.22) and (4.28) to (4.33) indicate the availability levels of the maize policy variables. Conditions (4.17) and (4.28) indicate that in any given year t, maize procurements will equal the projected minimum when the gross imputed value for the procured maize is positive. Conditions (4.18) and (4.29) indicate that when the imputed value of maize stored by the beginning of the crop year (t) is positive, then opening stock levels of maize in that year must equal the proportion of maize sales reflecting food security measures as required by policy makers. However, when the imputed value is zero, then opening maize stock levels can either be equal to the required proportion of maize sales as set by policy makers or they could be higher than the set proportion.

Conditions (4.19) and (4.30) state that when the imputed value of maize stored by the end of the crop year (t) is positive, then closing stock levels must equal the sum of maize procurements, imports or exports (i.e., $-IM_t$), and opening stock levels in that year less the amount of maize sold to millers and industrial processors. Similarly, conditions (4.20) and (4.31) indicate that when the imputed value of maize sales in a given year t is positive, then maize sales must be at the level allocated by policy makers. Conditions (4.21) and (4.32) indicate that for positive imputed values of exported/imported maize in a given year (t), the quantities exported/imported equal the levels set by policy makers in that particular year. The last two conditions (4.22) and (4.33) indicate that closing stock levels, in a given year t, must equal the opening stock levels in the following year when the imputed value, associated with constraining closing stocks in year t to the level of opening stocks in the following year, is positive.

CHAPTER IV. PROGRAMMING RESULTS

Analysis of Results

Before looking at the programming results, it is worth noting that during the entire sixteen year projection period, it is assumed that the government will continue to provide maize subsidies to consumers. This is reflected by the fact that maize procurement and import prices, in the programming model, are greater than the prices faced by millers and industrial processors. This means that the government marketing agents purchase a 90 kg bag of maize from a farmer at, for instance, K55 (in 1985) and sell it to the processors at K35, making a deficit of K20 per 90 kilogram bag. This deficit, however, is exclusive of other costs incurred during the procurement and distribution processes.

In the programming model, optimal government decision variables that minimize the cost of maize marketing operations are derived within the general context that takes into account specific constraints with regard to maize stock policies as well as maize trade policies. Government policy on maize procurements requires that every bag of maize offered for sale by farmers be bought at the government set price. Therefore, government flexibility on maize procurement decisions are very limited to seeing to it that all maize offered for sale by farmers is bought. On the other hand, the government has an obligation to ensure that at least minimum maize consumption levels are attained for the Zambian consumers. The government, therefore, can only vary the upper limit levels of quantities of maize to be made available for sale to millers and other industrial processors.

Cost saving adjustments in maize marketing operations are made mainly through changes in inventory and trade policies. The Zambian maize system has generally tended to be self-sufficient in maize production during years of good rains. This situation is postulated in the basic scenario where good rains are assumed throughout the projection period. No maize imports are made in this scenario and when exports are permitted, substantial reductions in the present value of the cost are achieved. The cost is reduced from K17.61 billion when no exports are allowed to K5.05 billion when exports are permitted in the basic scenario. The savings are mainly made through exports and the lower carryover stocks. No imports are made because of Zambia's self-sufficiency in maize production during normal rainfall situations. In fact, the self-sufficiency scenario, when minimum opening maize stocks are set at one-fourth of maize sales, renders this cost minimization approach to be of very limited value since all the government decision variables tend to come out at either their specified minimum or maximum levels.

However, the validity of this cost minimization approach for maize marketing operations in Zambia is much better observed in the scenarios that incorporate the two major external shocks, drought and foreign exchange shortages, that adversely affect maize marketing operations in Zambia. Nevertheless, foreign exchange shortfalls alone do not increase the cost of maize marketing operations when there is adequate rainfall throughout the entire projection period. This is because of the fact that no maize imports are allowed in throughout this entire self-sufficiency projection period. The cost of maize marketing operations when there is normal rainfall throughout is K5.05 billion when exports are permitted and opening stock levels are set to be at least one-fourth of the targeted maize sales. Banning exports in this situation would raise the operation costs to K17.60 billion in response to the enormous maize stock levels. In view of the limited adequate storage facilities in Zambia, such a situation would result in heavy maize losses due to lack of storage space. The cost penalties associated with banning exports are substantially high as reflected in the shadow prices for the excluded exports which range from K4,682.28 per metric tonne in 1985 to K346.33 per metric tonne in the year 2000. As expected, the shadow prices for all the other maize operation activities are zero since they are all allowed to be part of the solution and assume nonzero quantity levels.

On the other hand, the shadow prices associated with constraining the government decision variables suggest that relaxing the restriction on maize procurements would provide the biggest savings in the maize system over the projection period when self-sufficiency is accompanied by exports restrictions. This kind of ban on exports would not only be an irrational policy, it is also very unlikely to be pursued by the policy makers because the alternative policy of permitting exports not only reduces the present value cost of maize operations considerably by about 71%, it also satisfies the goals of food security minimum stock levels and at the same time accommodates increases in maize consumption.

In the scenario where there is a foreign exchange shortage but with normal rainfall throughout, the importance of permitting exports is as much a cost reduction concern as it is a great contributor towards foreign exchange replenishing, although the present values of the cost of maize marketing operations remain the same when compared to the normal rainfall scenario.

When drought occurs in six of the sixteen projection years and the foreign exchange situation is stable, the present value of the cost of maize marketing operations increases by about K130 million, i.e. from K5.05 billion to K5.18 billion when compared to the present value of the cost in the basic (normal rainfall) scenario with exports allowed. The increased cost is as a result of lost revenue from reduced exports in addition to the government's stringent measures to bring in imports in some of the drought years. Maize stock levels are also increased as a good security measure as well as a cushion against the high cost of importing maize during the years when there are maize supply shortfalls. The increased maize stock levels also contribute to the increased present value cost of maize operations.

The shadow prices associated with the constraints seem to suggest that marginally relaxing the constraint on maize sales would provide the biggest savings followed by relaxation of the minimum constraint on maize purchases in the initial stages of the projections. Over the years, the revenue loss from restricting exports takes on more prominence in raising the cost followed by costs incurred in maintaining maize stock levels at increased magnitudes. This situation may seem to suggest a more liberal policy on maize exports in the long run which in turn would require the maintenance of only moderate levels of maize stock in the long run.

With exports still permitted, the combination of drought and unstable foreign exchange levels would further increase the present value cost of maize marketing operations to K5.21 billion, an increase of K30 million over the drought scenario present value cost of maize operations. In the drought and foreign exchange scenario, maize imports and exports are further restricted while maize stocks are increased slightly in the middle term of the projection period. The combined effect of export revenue losses, as a result of reduced exports, and the increased cost of maintaining more maize stocks, override the savings made from reduced maize imports.

In all four scenarios, the banning of maize exports with minimum opening stocks at one-fourth of maize sales, drastically increases the present value cost of maize marketing operations. In the basic scenario, the cost increases from K5.05 billion when exports are permitted to K17.61 when exports are eliminated. Exact cost levels and changes are observed when a foreign exchange shortage situation arises while rainfall is assumed normal for the whole projection period.

In the drought scenario, the present value cost increases from K5.18 billion when exports are allowed to K10.44 billion when exports are not part of maize marketing operations. When there is a combination of drought and foreign exchange shortage, the present value cost increases from K5.21 billion, with exports, to K10.44 billion without exports. In all these situations, the present value cost more than doubles when exports are banned.

Introduction of a greater measure of food security by setting minimum opening stocks at one-half of maize sales increases the present value of the cost of maize marketing operations. When comparisons are made for the two different levels of food security (i.e., 25% and 50% minimum stocks), with exports allowed, the increase in cost in the 50% minimum stocks scenario results from reduced exports and increased maize stock levels.

In the basic scenario, increasing minimum opening stock levels from 25% of maize sales to 50% increases present value cost by about 15%, from K5.05 billion to K5.82 billion. In the first three years, opening stocks are in slack. As a result, the dual prices for opening stock levels for those three years are zero. This suggests that increasing the level of the minimum constraint on opening stock levels by the magnitude of the slack stock level would not increase the present value of the cost of maize marketing operations. Therefore, the government has more flexibility in the short term to maintain more than the minimum required opening maize stock levels. Exports on the other hand are not in slack during the first three years of the projection period and their imputed values indicate that further constraining exports on a marginal level would in fact increase the present value cost.

However, the middle and long term policy strategies seem to point in the direction of more stringent inventory controls and a more flexible export policy. Opening stock levels are no longer in slack and their shadow prices indicate that marginally relaxing the constraint on opening stock levels would in fact reduce the present value cost of marketing operations. For instance, in 1990, the shadow price associated with constraining opening stock levels to a minimum 25% of maize sales is K393.58. The marginal unit used in the programming model is one metric ton, therefore reducing the minimum constraint on opening stock levels by one metric ton in 1990 would reduce the present value cost of marketing operations by K393.58.

On the other hand, the long term cost penalties for restraining exports are reduced to zero as less is exported and exports actually get slack levels. In the short term (1985-1988) before exports exhibit some slack, their positive dual prices indicate that savings are possible with marginal relaxation of the restrictions on maize exports. However, in the long run this is no longer so as the contribution of exports to cost saving is reduced. Relaxing the maximum restraints on maize exports by the magnitude of their slack levels would actually not affect the amount spent on marketing operations. The maize opening stock levels fall to their minimum levels and the government would have more flexibility on maize export policy.

The basic and foreign exchange shortage scenarios, with exports allowed, follow the same kind of analysis dealt with above. Present value cost increases from K5.05 billion, with minimum opening stock levels 25% of maize sales, to K5.82 when opening stock levels are raised to minimum 50% of maize sales. However, holding opening stock levels at minimum 50% of maize sales in a drought scenario increases the present value cost of marketing operations by K20 million, from K5.82 in basic scenario to K5.84 in the drought scenario, an increase of 0.3%. Even though fewer maize procurements in the drought scenario have the effect of lowering the present value cost of maize marketing operations, this effect is offset by the loss in export revenues and also by the slight increase in the amount of opening stock levels held in the short term. Not only are exports drastically reduced, some imports are brought in during four of the six drought years. In the short term and middle term, the maize trade (export-import) strategy followed in the drought scenario and 50% minimum opening stock levels is the same as that pursued when maize opening stock levels are set at a minimum 25% of maize sales in a drought scenario. However, with a greater measure of food security, i.e., with 50% minimum opening stock levels, fewer exports and more imports are utilized in the long run than are used with 25% minimum opening stock levels under the same drought conditions.

When the drought scenario is beset with a foreign exchange situation, the present value cost of maize marketing operations, with

50% minimum opening stock levels, increases from K5.84 to K5.9 billion, an increase of K60 million over the projection period. The cost increases in response to some export revenue losses and the added cost of maintaining the slight increase in maize stock levels in the long run.

The banning of exports, when maize opening stock levels are held at a minimum of 50% of maize sales, more than triples the present value cost of maize marketing operations in the basic scenario. From the cost of K5.82 billion when exports are allowed, the present value cost increases to K18.12 billion. In the drought scenario the increase in cost is slightly moderate in comparison. The present value cost of marketing operations increases from K5.84 billion in Table 27 to K10.96 billion in Table 31, an increase of 87.7% as opposed to the 211.3% increase in cost in the basic scenario.

Another thing to note is that when exports are not permitted under all four scenarios, the present value cost of maize marketing operations is greater under the requirement of 50% of maize sales minimum maize opening stocks than it is under the 25% requirement condition. The differences in cost only reflect the degree of flexibility in inventory control under the two conditions. The greater the food security measure taken, the more rigid inventory control is and the greater the present value of maize marketing operations costs.

Table 17. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
<u>Basic</u>						
1985	636267	-59664	142447.5	149260.5	569790	5.05
1986	954401	-350546	149260.5	156073.5	597042	
1987	992577	-361470	156073.5	162886.5	651546	
1988	1032280	-373921	162886.5	169699.5	651546	
1989	1073571	-387960	169699.5	176512.5	678787	
1990	1116514	-401774.5	176512.5	185202	706050	
1991	1161175	-411677.5	185202	193891.5	740808	
1992	1207622	-423366.5	193891.5	202581	775566	
1993	1255927	-436913.5	202581	211270.5	810324	
1994	1306164	-452392.5	211270.5	219960	845082	
1995	1358410	-467581	219960	230949	879840	
1996	1412747	-477962	230949	241938	923796	
1997	1469256	-490515	241938	252927	967752	
1998	1528027	-505330	252927	263916	1011708	
1999	1589148	-522495	263916	274905	1055664	
2000	1652714	-542105	274905	285894	1099620	

Table 18. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Basic and Exchange <u>Shortage</u>						
1985	636267	-59664	142447.5	149260.5	569790	5.05
1986	954401	-350546	149260.5	156073.5	597042	
1987	992577	-361470	156073.5	162886.5	651546	
1988	1032280	-373921	162886.5	169699.5	651546	
1989	1073571	-387960	169699.5	176512.5	678787	
1990	1116514	-401774.5	176512.5	185202	706050	
1991	1161175	-411677.5	185202	193891.5	740808	
1992	1207622	-423366.5	193891.5	202581	775566	
1993	1255927	-436913.5	202581	211270.5	810324	
1994	1306164	-452392.5	211270.5	219960	845082	
1995	1358410	-467581	219960	230949	879840	
1996	1412747	-477962	230949	241938	923796	
1997	1469256	-490515	241938	252927	967752	
1998	1528027	-505330	252927	263916	1011708	
1999	1589148	-522495	263916	274905	1055664	
2000	1652714	-542105	274905	285894	1099620	

Table 19. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought						
1985	636267	0	142447.5	208924.5	569790	5.18
1986	954667	-331571	208924.5	234978.5	597042	
1987[a]	572641	0	234978.5	183325.5	624294	
1988[a]	637920	0	183325.5	169699.5	651546	
1989	1050124	-357710	169699.5	183325.5	678798	
1990	1071136	-347707	183325.5	200704.5	706050	
1991	1092139	-333952	200704.5	218083.5	740808	
1992	1135825	-342880	218083.5	235462.5	775566	
1993[a]	753556	32576	235462.5	211270.5	810324	
1994[a]	783698	70073.5	211270.	219960	845082	
1995	1181258	-290429	219960	230949	879840	
1996[a]	815046	119739	230949	241938	923796	
1997	1228508	-249767	241938	252927	967752	
1998[a]	847648	175049	252927	263916	1011708	
1999	1277649	-210996	263916	274905	1055664	
2000	1328755	-218146	274905	285894	1099620	

[a]A drought is assumed to occur in these years.

Table 20. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought and Exchange Shortage						
1985	636267	0	142447.5	208924.5	569790	5.21
1986	954667	-331571	208924.5	234978.5	597042	
1987[a]	572641	0	234978.5	183325.5	624294	
1988[a]	595546	42374	183325.5	169699.5	651546	
1989	1050134	-357710	169699.5	183325.5	678798	
1990	1071136	-347707	183325.5	200704.5	706050	
1991	1092139	-333952	200704.5	218083.5	740808	
1992	1135825	-329111.2	218083.5	249231.3	775566	
1993[a]	753556	29318.4	249231.3	221781.7	810324	
1994[a]	783698	59562.3	221781.7	219960	845082	
1995	1181258	-278455.1	219960	242922.9	879840	
1996[a]	815041	107765.1	242922.9	241938	923796	
1997	1228508	-214757.2	241938	287936.8	967752	
1998[a]	847648	140039.2	287936.8	263916	1011708	
1999	1277649	-210996	263916	274905	1055664	
2000	1328755	-218146	274905	285894	1099620	

[a]A drought is assumed to occur in these years.

Table 21. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Basic						
1985	636267	0	142447.5	208924.5	569790	17.61
1986	954401	0	208924.5	566283.5	597042	
1987	992577	0	566283.5	934566.5	624294	
1988	1032280	0	934566.5	1315301	651546	
1989	1073571	0	1315301	1710074	678798	
1990	1116514	0	1710074	2120538	706050	
1991	1161175	0	2120538	2540905	740808	
1992	1207622	0	2540905	2972961	775566	
1993	1255927	0	2972961	3418564	810324	
1994	1306164	0	3418564	3879646	845082	
1995	1358410	0	3879646	4358216	879840	
1996	1412747	0	4358216	4847167	923796	
1997	1469256	0	4847167	5348671	967752	
1998	1528027	0	5348671	5864990	1011708	
1999	1589148	0	5864990	6398474	1055664	
2000	1652714	0	6398474	6951568	1099620	

Table 22. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Basic and Exchange <u>Shortage</u>						
1985	636267	0	142447.5	208924.5	569790	17.61
1986	954401	0	208924.5	566283.5	597042	
1987	992577	0	566283.5	934566.5	624294	
1988	1032280	0	934566.5	1315301	651546	
1989	1073571	0	1315301	1710074	678798	
1990	1116514	0	1710074	2120538	706050	
1991	1161175	0	2120538	2540905	740808	
1992	1207622	0	2540905	2972961	775566	
1993	1255927	0	2972961	3418564	810324	
1994	1306164	0	3418564	3879646	845082	
1995	1358410	0	3879646	4358216	879840	
1996	1412747	0	4358216	4847167	923796	
1997	1469256	0	4847167	5348671	967752	
1998	1528027	0	5348671	5864990	1011708	
1999	1589148	0	5864990	6398474	1055664	
2000	1652714	0	6398474	6951568	1099620	

Table 23. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought						
1985	636267	0	142447.5	208924.5	569790	10.44
1986	954667	0	208924.5	566549.5	597042	
1987[a]	572641	0	566549.5	514896.5	624294	
1988[a]	595546	0	514896.5	458896.5	651546	
1989	1050134	0	458896.5	830232.5	678798	
1990	1071136	0	830232.5	1195319	706050	
1991	1092139	0	1195319	1546650	740808	
1992	1135825	0	1546650	1906909	775566	
1993[a]	753556	0	1906909	1850141	810324	
1994[a]	783698	0	1850141	1788757	845082	
1995	1181258	0	1788757	2090175	879840	
1996[a]	815046	0	2090175	1981425	923796	
1997	1228508	0	1981425	2242181	967752	
1998[a]	847648	0	2242181	2078121	1011708	
1999	1277649	0	2078121	2300106	1055664	
2000	1328755	0	2300106	2529241	1099620	

[a]A drought is assumed to occur in these years.

Table 24. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-fourth of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought and Exchange <u>Shortage</u>						
1985	636267	0	142447.5	208924.5	569790	10.44
1986	954667	0	208924.5	566549.5	597042	
1987[a]	572641	0	566549.5	514896.5	624294	
1988[a]	595546	0	514896.5	458896.5	651546	
1989	1050134	0	458896.5	830232.5	678798	
1990	1071136	0	830232.5	1195319	706050	
1991	1092139	0	1195319	1546650	740808	
1992	1135825	0	1546650	1906909	775566	
1993[a]	753556	0	1906909	1850141	810324	
1994[a]	783698	0	1850141	1788757	845082	
1995	1181258	0	1788757	2090175	879840	
1996[a]	815046	0	2090175	1981425	923796	
1997	1228508	0	1981425	2242181	967752	
1998[a]	847648	0	2242181	2078121	1011708	
1999	1277649	0	2078121	2300106	1055664	
2000	1328755	0	2300106	2529241	1099620	

[a]A drought is assumed to occur in these years.

Table 25. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS) Metric Tons	Closing Stocks (CS)	Sales (SL)	Present Value of Cost Billion Kwacha
Basic						
1985	636267	-59664	305334	312147	569790	5.82
1986	954401	-350546	312147	318960	597042	
1987	992577	-361470	318960	325773	624294	
1988	1032280	-367108	325773	339399	651546	
1989	1073571	-381147	339399	353025	678798	
1990	1116514	-393085	353025	370404	706050	
1991	1161175	-402988	370404	387783	740808	
1992	1207622	-414677	387783	405162	775566	
1993	1255927	-428224	405162	422541	810324	
1994	1306164	-443703	422541	439920	845082	
1995	1358410	-456592	439920	461898	879840	
1996	1412747	-466973	461898	483876	923796	
1997	1469256	-479526	483876	505854	967752	
1998	1528027	-494341	505854	527832	1011708	
1999	1589148	-511506	527832	549810	1055664	
2000	165214	-542105	549810	560799	1099620	

Table 26. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Basic and Exchange <u>Shortage</u>						
1985	636267	-59664	305334	312147	569790	5.82
1986	954401	-350546	312147	318960	597042	
1987	992577	-361470	318960	325773	624294	
1988	1032280	-367108	325773	339399	651546	
1989	1073571	-381147	339399	353025	678798	
1990	1116514	-393085	353025	370404	706050	
1991	1161175	-402988	370404	387783	740808	
1992	1207622	-414677	387783	405162	775566	
1993	1255927	-428224	405162	422541	810324	
1994	1306164	-443703	422541	439920	845082	
1995	1358410	-456592	439920	461898	879840	
1996	1412747	-466973	461898	483876	923796	
1997	1469256	-479526	483876	505854	967752	
1998	1528027	-494341	505854	527832	1011708	
1999	1589148	-511506	527832	549810	1055664	
2000	165214	-542105	549810	560799	1099620	

Table 27. Maize model programming projections (1985-1000) with exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought						
1985	636267	0	284895	351372	569790	5.84
1986	954667	-331571	351372	377426	597042	
1987[a]	572641	0	377426	325773	624294	
1988[a]	595546	0	325773	339399	651546	
1989	1050134	-357710	339399	353025	678798	
1990	1071136	-347707	353025	370404	706050	
1991	1092139	-333952	370404	387783	740808	
1992	1135825	-342880	387783	405162	775566	
1993[a]	753556	74147	405162	422541	810324	
1994[a]	783698	78763	422541	439920	845082	
1995	1181258	-279440	439920	461898	879840	
1996[a]	815046	130728	461898	483876	923796	
1997	1228508	-238778	483876	505854	967752	
1998[a]	847648	186038	505854	527832	1011708	
1999	1277649	-200007	527832	549810	1055664	
2000	1328755	-493051	549810	285894	1099620	

[a]A drought is assumed to occur in these years.

Table 28. Maize model programming projections (1985-2000) with exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought and Exchange Shortage						
1985	636267	0	284895	351372	569790	5.90
1986	954667	-331571	351372	377426	597042	
1987[a]	572641	0	377426	325773	624294	
1988[a]	595546	69626	325773	339399	651546	
1989	1050134	-357710	339399	353025	678798	
1990	1071136	-347707	353025	370404	706050	
1991	1092139	-333952	370404	387783	740808	
1992	1135825	-323650.8	387783	424391.2	775566	
1993[a]	753556	66732.3	424391.2	434355.4	810324	
1994[a]	783698	66948.55	434355.4	439920	845082	
1995	1181258	-266367.2	439920	474970.8	879840	
1996[a]	815046	117655.2	474970.8	483876	923796	
1997	1228508	-201570.4	483876	543061.6	967752	
1998[a]	847648	148830.4	543061.6	527832	1011708	
1999	1277649	-200007	527832	549810	1055664	
2000	1328755	-493051	549810	285894	1099620	

[a]A drought is assumed to occur in these years.

Table 29. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Basic						
1985	636267	0	284895	351372	569790	18.12
1986	954401	0	351372	708731	597042	
1987	992577	0	708731	1077014	624294	
1988	1032280	0	1077014	1457748	651546	
1989	1073571	0	1457748	1852521	678798	
1990	1116514	0	1852521	2262985	706050	
1991	1161175	0	2262985	2683352	740808	
1992	1207622	0	2683352	3115408	775566	
1993	1255927	0	3115408	3561011	810324	
1994	1306164	0	3561011	4022093	845082	
1995	1358410	0	4022093	4500663	879840	
1996	1412747	0	4500663	4989614	923796	
1997	1469256	0	4989614	5491118	967752	
1998	1528027	0	5491118	6007437	1011708	
1999	1589148	0	6007437	6540921	1055664	
2000	1652714	0	6540921	7094015	1099620	

Table 30. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS) Metric Tons	Closing Stocks (CS)	Sales (SL)	Present Value of Cost Billion Kwacha
Basic and Exchange <u>Shortage</u>						
1985	636267	0	284895	351372	569790	18.12
1986	954401	0	351372	708731	597042	
1987	992577	0	708731	1077014	624294	
1988	1032280	0	1077014	1457748	651546	
1989	1073571	0	1457748	1852521	678798	
1990	1116514	0	1852521	2262985	706050	
1991	1161175	0	2262985	2683352	740808	
1992	1207622	0	2683352	3115408	775566	
1993	1255927	0	3115408	3561011	810324	
1994	1306164	0	3561011	4022093	845082	
1995	1358410	0	4022093	4500663	879840	
1996	1412747	0	4500663	4989614	923796	
1997	1469256	0	4989614	5491118	967752	
1998	1528027	0	5491118	6007437	1011708	
1999	1589148	0	6007437	6540921	1055664	
2000	1652714	0	6540921	7094015	1099620	

Table 31. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought						
1985	636267	0	284895	351372	569790	10.96
1986	954667	0	351372	708997	597042	
1987[a]	572641	0	708997	657344	624294	
1988[a]	595546	0	657344	601344	651546	
1989	1050134	0	601344	972680	678798	
1990	1071136	0	972680	1337766	706050	
1991	1092139	0	1337766	1689097	740808	
1992	1135825	0	1689097	2049356	775566	
1993[a]	53556	0	2049356	1992588	810324	
1994[a]	83698	0	1992588	1931204	845082	
1995	1181258	0	1931204	2232622	879840	
1996[a]	815046	0	2232622	2123872	923796	
1997	1228508	0	2123872	2384628	967752	
1998[a]	847648	0	2384628	2220568	1011708	
1999	1277649	0	2220568	2442553	1055664	
2000	1328755	0	2442553	2671688	1099620	

[a]It is assumed that a drought occurs in these years.

Table 32. Maize model programming projections (1985-2000) with no exports allowed and minimum opening stocks one-half of maize sales

Scenario/ Year	Procurements (PR)	Imports (IM)	Opening Stocks (OS)	Closing Stocks (CS)	Sales (SL)	Present Value of Cost
			Metric Tons			Billion Kwacha
Drought and Exchange <u>Shortage</u>						
1985	636267	0	284895	351372	569790	10.96
1986	954667	0	351372	708997	597042	
1987[a]	572641	0	708997	657344	624294	
1988[a]	595546	0	657344	601344	651546	
1989	1050134	0	601344	972680	678798	
1990	1071136	0	972680	1337766	706050	
1991	1092139	0	1337766	1689097	740808	
1992	1135825	0	1689097	2049356	775566	
1993[a]	753556	0	2049356	1992588	810324	
1994[a]	783698	0	1992588	1931204	845082	
1995	1181258	0	1931204	2232622	879840	
1996[a]	815046	0	2232622	2123872	923796	
1997	1228508	0	2123872	2384628	967752	
1998[a]	847648	0	2384628	2220568	1011708	
1999	1277649	0	2220568	2442553	1055664	
2000	1328755	0	2442553	2671688	1099620	

[a]It is assumed that a drought occurs in these years.

Table 33. Summary table of the present value costs under the four scenarios

	Exports Allowed (in billion Kwacha)	Exports Not Allowed (in billion Kwacha)
25% OS		
Basic	5.05	17.61
Basic + Forex	5.05	17.61
Drought	5.18	10.44
Drought + Forex	5.21	10.44
50% OS		
Basic	5.82	18.12
Basic + Forex	5.82	18.12
Drought	5.84	10.96
Drought + Forex	5.90	10.96

CHAPTER V. SUMMARY AND CONCLUSION

Summary

Managing an efficient distribution system of food surpluses from farming communities to the nonfarming communities is a very important aspect of marketing operations. This is even more so in Zambia's context with a very high urban population that does not engage in direct food production. The government's role in the marketing system is that of ensuring that food supplies reach the consumers and that at least minimum food needs are satisfied even for the low income people. However, in managing such a distribution system, the government also tries to ensure that the system is run at the minimum possible cost. These cost minimization concerns are of great importance to Zambia in view of the current problems that have beset the economy.

Maize is by far the most important food crop grown in Zambia since it constitutes the staple food for over 95% of the population. Maize pricing and marketing have undergone a lot of review since the early times of colonialism.

Currently, maize producer prices are set by the government based on perceived maize production costs with an allowance for farmers' profit margins. In marketing operations, major policy reforms have been instituted, the most drastic one being the liberalization of marketing operations in 1986. Under this system, private traders within each province were invited to participate in marketing operations alongside NAMBOARD and the Provincial Cooperative Unions.

The Zambia maize sector tends to be self-sufficient when there is adequate rainfall and it is this heavy dependence on rainfed maize that results in maize supply shortfalls whenever a drought occurs. The present limited capacity of the Zambian economy to generate foreign exchange directly affects Zambia's capacity to quickly replenish food supplies whenever there is a shortfall in maize supplies.

The model used in the study is a dynamic optimization model where the present value of the cost of maize marketing operations is minimized over a sixteen year period. Four scenarios are used when making projections. In the basic scenario, it is assumed that there is adequate rainfall throughout the projection period. In the basic and foreign exchange scenario, rainfall is normal but a foreign exchange shortage situation is added. In the drought scenario, it is assumed that drought occurs in six of the sixteen projection years. In the drought and foreign exchange shortage scenario, foreign exchange limitations are coupled with drought problems besetting the maize sector.

Over the years, the issue of food security has received increased importance in maize policy in Zambia. The model, therefore, simulates two different food security measures under the four scenarios. In the first set of simulations, maize opening stocks are required to be a minimum 25% of maize sales. The second set of simulations involve a greater measure of food security by increasing minimum opening stock levels to 50% of maize sales. All these simulations are done either with exports permitted or with exports banned.

The results from the dynamic programming projections suggest that even with the current rigidities in maize procurements and sales, cost savings can be made through a rational blend of inventory and trade policies. Under the conditions used in the study, the

Zambian maize system is virtually self-sufficient. In the basic scenario and the basic and foreign exchange shortage scenario, the present value cost of maize marketing operations is reduced from K17.61 billion, when exports are not permitted and minimum opening stock level is 25% of maize sales, to K5.05 billion. In the drought scenario, the present value of the cost increases from K5.05 billion to K5.18 billion when exports are allowed.

Increasing the minimum maize opening stock levels to 50% of maize sales increases the present value of the cost from K5.05 billion in the basic scenario to K5.82 billion. Similarly, the cost increases from K5.18 billion to K5.84 billion under drought conditions with exports allowed and from K5.21 billion to K5.90 billion under the drought and foreign exchange shortage scenario with exports allowed.

When exports are not permitted, the cost structure depends mainly on the level of minimum maize opening stocks decided on and also on whether there is a drought or not. A greater level of minimum maize opening stocks increases inventory costs but drought has the effect of reducing procurement costs through the fewer maize purchases in the drought years. However, the imports brought in offset the cost reductions resulting from fewer procurements.

The model developed in this study may not be directly used for policy advice in its current form. Great improvement to the analysis can be made by incorporating econometric analysis to look into the effects of environmental and policy factors that affect government decision variables in the maize sector and to also provide more refined data for use in the programming model. This was the initial direction of this study, but time constraints and the difficulty in acquiring critical time series data in Zambia made it an impossible task to develop the econometric model part of the analysis.

However, this does not mean that the model is not useful the way it is. It provides direction on how cost savings can be introduced in maize marketing operations through the blending of rational inventory and trade policies. It could also be used on a yearly basis to determine optimal policy variable quantities for each particular marketing year.

Conclusion

The maize marketing operations as modeled in this study reflect rigidities in the areas of maize procurement and sales despite the efforts made to liberalize the marketing system starting from 1986. This is in line with government policy to purchase all maize offered for sale by farmers and to sell only allocated maize quantities to millers and industrial processors. On the other hand, flexibility is exercised in inventory and trade strategies.

However, the efforts of making maize marketing operations more cost effective will require socially profitable investments, opportunities for which significantly exist in Zambia's agricultural marketing system. Investments towards the development of rural infrastructure, especially communications and feeder roads for easy access to markets, should continue as priority activities in government plans. Even though Zambia's transport infrastructure is well developed by African standards, some rural areas still remain isolated and hard to reach and in most cases completely inaccessible in the rainy season when most rural roads become impassable. The current transport network situation better serves the urban areas and the import-export needs of the urban industrial sectors while leaving rural areas relatively inaccessible. This situation adds to the high marketing costs.

The movement towards greater food security would also require vast investments in storage facilities so as to provide even greater flexibility in inventory policy strategies. Proper and adequate storage facilities located in the right places can help to minimize storage losses and transport costs in the marketing process.

The role of credit in facilitating the flow of maize from farmers to consumers is very important and deserves a lot of government attention in so far as providing adequate and more accessible credit to all participants in maize marketing operations is concerned. The credit system should be streamlined towards providing more and adequate credit to all participants in maize marketing operations. The system should also be tailored towards maintaining equitable credit cost and access for all marketing agents. This is particularly important for private traders if they are to compete effectively in the maize marketing system, especially in view of the current conditions of maize subsidy payments.

The present financial institution setup seems adequate in meeting the credit requirements in the marketing system. However, since private participation in maize marketing was only introduced in 1986, private banks have not been very willing to lend money to private traders in the absence of credit ratings for these traders by the bankers. To minimize risks, the private banks will have to establish certain standards of risk for these traders before they provide credit allowances to them. In the meantime, the government could step in to fill the shortage of credit for licensed private traders by giving them more access to credit from the government financial institutions.

However, redressing issues of maize marketing inefficiencies will inevitably require government reforms in the pricing system. The current uniform pricing system for all regions may arguably result in inefficient allocation of resources since regional comparative advantages in maize production are not taken into consideration. The result may be a situation where maize is grown everywhere in the country at the expense of more agronomically and economically suited crops for those regions. Marketing efforts to collect all maize from all over the country would just compound the problem of high transportation costs faced at the moment.

It has been argued that a regionally differentiated pricing system, based on differences in transportation, marketing and production costs in general, for each region would encourage farmers to allocate their resources towards crops in which they face comparative advantages. Production of maize would, therefore, be concentrated in only those regions with comparative advantages in maize production and this would help to lower marketing costs as maize marketing activities get concentrated mainly in those areas.

The maintenance of a constant price throughout the crop season provides no incentives to farmers for on-farm storage and when farmers sell all their crop at harvest time, a lot of pressure is exerted on the procurement, transportation and storage facilities during this peak period of the crop season. Private traders would also tend to buy only enough to sell immediately so that they incur very minimal storage costs. The continuation of such a situation would in fact greatly limit active private participation and the government agents would still continue to provide all the storage facilities and in effect, government agents, whose operations are tied to the government annual budget, would still remain the only principle buyers of maize from farmers. Consequently, the efficiencies sought from competition in the marketing system would not be realized.

The current differences in the producer and the consumer prices, where the producer price is higher than the consumer price, may also serve as a disincentive for more on-farm maize retention. A greater farm retention is critical for rural populations where retail outlets for mealie meal are very limited. The model incorporates these price differences by reflecting a lower maize sale price relative to the producer price.

Suggestions for further research

Revisions on the model could be made as more data becomes available. The policy concerns as portrayed in the constraint structure can be updated to reflect new directions and policy strategies. As was stated earlier, the analysis can be further improved with the addition of econometric modeling to analyze the effects of the environmental and policy factors that affect the maize system in Zambia. This is the part that was omitted in this study due to lack of adequate time series data. The general formulation of the model would involve estimating five equations and one identity to approximate maize marketing operations in Zambia. The equations to be estimated could be for:

1. Total maize output (Q)
2. Total maize absorption (D)
3. Imports (IM)
4. Maize purchases (MK)
5. Maize sales (SL)

The specific formulation could be as follows:

(1) OS + MK + IM = SL + CS

where

OS = Maize opening stocks

MK = Maize marketings

IM = Maize imports

SL = Maize sales by marketing agents

CS = Maize closing stocks

(2) Q = f(PPM1, PPS1, FP1, ASM, RIM)

where

Q = Total maize output

PPM1 = Deflated producer price of maize, lagged one year

PPS1 = Deflated producer prices of major production substitutes of maize, lagged one year

FP1 = Deflated fertilizer prices, lagged one year

ASM = Area sown with maize

RIM = Rainfall index for maize

(3) MK = f(Q)

where

MK = Maize marketings

Q = Total maize output

(4) SL = f(CPM, CPS, CEX, MWP)

where

SL = Total maize sales

CPM = Deflated consumer price of maize

CPS = Deflated consumer prices of major maize substitutes

CEX = Aggregate real consumption expenditure

MWP = Deflated maize wholesale price faced by millers

(5) IM = f(IPM, MSS, FE)

where

IM = Total maize imports

IPM = Deflated import price of maize

MSS = Maize supply shortfall

FE = Foreign exchange available for food imports or total foreign aid utilized in the year

(6) D = f(CPM, CPS, CEX)

where

D = Total maize absorption, i.e., net output (allowance for seed, feed and losses), net imports and government stock depletions

CPM = Deflated consumer price of maize

CPS = Deflated consumer prices of major maize substitutes

CEX = Aggregate real consumption expenditure

The reduced form of the model could then be used to make projections of maize output, purchases, imports, stocks, sales and the price of maize for the 16 projection years. The projections so obtained could then be incorporated in the dynamic optimization model to improve the quality of the coefficients.

This type of specification is a slight revision, in the procurement function, of the specification used by Krishna and Chhibber (15) in their modeling of the dual wheat market in India which has an open market alongside the government run concessional food market that caters to low income people.

The inclusion of stochastic specifications in the study would greatly improve the analysis, especially in dealing with long term strategies within the marketing system. However, more precision is achieved in this kind of study if simulations are done on a year by year basis.

Such yearly runs and analysis could prove useful for current government programs such as the early warning system which is used in part to institute advance export or import programs based on the perceived maize inventory situation in the following year.

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