Cost implications of alternative grain storage programs: the case of Kenya

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ABSTRACT

The main objective of this study was to estimate the costs associated with different storage levels of maize for the National Cereals and Produce Board (the NCPB), the grain marketing agency of the Kenyan government. Linear programming was used as the optimization technique.

Four storage level scenarios were considered. The first involved a zero-supply security scenario, where the model was required to simply satisfy the demand in each period. The second, third and fourth respectively, involved two, three and four months supply security scenarios, where the model was required to purchase grain equivalent to the demand for those periods. Scenario two, providing two months supply security was not discussed because it posted results similar to scenario one. The hypothesis that a stocks management model can be developed to be used by the NCPB in order to determine the optimal quantities of maize that it handles every year, while minimizing costs, was partly supported under scenarios one and three. However, despite the reduction in costs under scenario one, the lack of inventory and foreign trade was seen to increase the risks and uncertainties associated with variations in production, especially under cases of short supply. Similarly, the lack of foreign trade under scenario three was postulated to increase risks and uncertainties in periods of low production. Under scenario four, the results involved foreign trade, and inventory was positive for most years. However, these results were suboptimal and thus unreliable for policy decisions. Nevertheless, results under this scenario were very similar to the actual performance of NCPB for the period 1980 to 1990.

The results of this study show that external trade may not be the solution to a strategy of cost minimization, given the existing objectives of the Kenyan government concerning maize. It was concluded, therefore, that the present strategy of self-sufficiency may be the better alternative, and foreign trade may only be undertaken at a loss, at least under current domestic pricing arrangements.

RÈSUMÈ

Le but de cette étude était d'évaluer les coûts associés aux différents plans d'entreposage de maïs proposés à l'Office Nationale des Produits et Céréales (ONPC), l'agence gouvernementale responsable de la mise en marché des grains au Kenya. La méthode de programmation linéaire a été choisie comme technique d'optimisation.

Quatre types de plan d'entreposage, ont été examinés. Le premier ne ne prévoyait pas d'approvisionnement en grains supplémentaire, le modèle servait simplement à satisfaire la demande périodique. Le deuxième plan incluait une strategie de réserve en grains de deux mois, le troisième de trois mois et le quatrième de quatre mois. Dans les trios cas, le modèle servait à déterminer la quantité de grains à acheter pour chacune de ces périodes. Les résultats du deuxième plan d'entreposage n'ont pas été présentés, ceux-ci etant à ceux du premier plan d'entreposage. L'hypothèse qu'un modèle de gestion de stock puisse être utilisé dans le but de déterminer le niveau de réserve de maïs à gérer annuellement, tout en minimisant les coûts a été partiellement supporté dans les modèles un et trois. Cependant, malgrè la réduction en coûts offerte par le premier modèle, le manque de réserve en grains et et l'abscence du commerce extérieur peuvent accroître les facteurs risques et incertitudes associes aux variations de production particulièrement dans le cas ou celle-ci serait trop faible. De la même facon, on peut prévoir que l'abscence du commerce extérieur dans le troisieme modèle peuvent donner lieu à un accroissement des risques et incertitudes dans des périodes de production insuffisante. Dans le quatrième modèle incluant le commerce extérieur et une réserve en grains, les résultats étaient positives pour la plupart des années. Cependant ces résultats étaient suboptimal et de fait ne devraient pas être considérés comme référence pour des décisions stratégiques. Néanmoins, les résultats de ce modèle ont été très similaire à la performance actuelle du ONCP pour la période 1980-1990.

Les résultats de cette étude ont démontré que le commerce extérieur ne serait peut être pas la solution à une stratégie de minimisation des coûts, étant donné les objectifs actuels du gouvernement du Kenya concernant le maïs. Alors, il a été conclus que la présente stratégie d'autosuffisance serait la meilleure alternative et le commerce extérieur pouvait être entrepris mais à risque.

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CHAPTER ONE: INTRODUCTION

1.1 AN OVERVIEW

Primary agriculture forms an important sector in the Kenyan economy, employing about 75% of the labour force (Sharma,1985), and providing food to Kenyans, the main food crop being white maize[1]. It is estimated that 80% of total maize production comes from small-scale farmers who retain their produce for subsistence consumption, for sale in the private market, or for sale to the National Cereals and Produce Board (NCPB), Kenya's official grain marketing board (World Bank, 1990).

Maize forms the main staple food crop of Kenyans, and is estimated to provide 50 to 70 per cent of the caloric intake of the population (Lofchie, 1989). Over eighty per cent of total maize production is consumed by rural dwellers, the vast majority of whom are small scale farmers (Bates, 1988). Lofchie (1989) argues that if the value of maize grown for home consumption is added to that purchased in the marketplace, it is the country's most valuable crop. He points out, however, that it may be difficult to estimate the value of this crop, because very little is known about what proportion is consumed directly by farm households or what percentage is marketed informally rather than through the NCPB. Nevertheless, in a study to determine the pattern and trends of maize consumption in Kenya, Ephanto (1992) estimates that maize in rural households comprises 24 per cent of the total value of food consumed, with milk and meat making up 14 and 10 per cent respectively, while beans take up 9 per cent.

There have been significant fluctuations in the production of maize from time to time. The way the government has responded to such fluctuations in the

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[1]All maize references in this study refer to white maize.

past has had far reaching implications, both for the government budget and political support. Government policy concerning maize production and marketing since independence in 1963 has been simple: all maize not sold directly from the producer to the consumer must be sold to the government, through the official grain marketing board, the NCPB, at a price set by the government (Pinckney, 1988). This maize is then resold by the NCPB at a higher price, again set by the government. The NCPB on the other hand is instructed to purchase and sell all maize offered for sale and demanded, respectively, at the set prices. It is also expected to maintain a certain volume of stocks in case of short supplies.

The government sets the prices for the sale and purchase of maize to and from the NCPB depots. Producer prices are determined by the Ministry of Agriculture in conjunction with the Ministry of Supplies and Marketing, Ministry of Planning and National Development and the Office of the President, and is based upon, among other factors, the cost of maize production (Ministry of Agriculture, 1992). The recommended price is announced before the beginning of the planting period each year and becomes effective at the beginning of the harvest period. Corresponding selling prices at each level of the marketing chain, including that of sifted maize meal, are also set by the government, again becoming effective after the first harvest of that year.

With prices set by the government long before the harvest, one might expect little fluctuation in producer prices. In reality, this is not the case. There exists an informal market that parallels the official market, and where prices tend to fluctuate according to supply and demand. This led Lofchie (1989) to conclude that important variables such as the rate of utilization of carryover stocks can only be roughly estimated, since an undetermined proportion of the country's maize transactions are conducted on the informal market. This market has thrived because of shortcomings of the NCPB, which as Duncan and Jones (1993) report, has failed to deliver cost-effective services to either producers or consumers. They go on to show that the failure of the marketing agencies in sub-saharan Africa have been as much the result of their infeasible mandates as of in-efficiency and bad management. The problem has been compounded because the government has asked the NCPB to perform a complex mix of commercial and non-commercial functions, with inadequate financial and skilled manpower resources to perform these functions effectively; yet it has paid little attention to costing the responsibilities allocated to the NCPB.

1.2 MAIZE MANAGEMENT: PRESENT AND FUTURE

Periods of bumper harvests create just as many problems for the NCPB as those of shortages. These include resources tied up in inventory, which results in cash flow problems and lack of storage capacity. Farmers on the other hand, due to frustrations over delays in payment and rejected deliveries, respond by changing their production plans for the following year, substituting other crops for maize (Bates,1989). By the time the NCPB decides to export the crop and generate cash flow, farmers will have cut back the hectares under maize, and by the time exports are made to honour contracts drawn during periods of increased production, the volume of maize delivered to the NCPB will be at its lowest. This implies that should there be a crop failure at this point in time, the NCPB would lack sufficient stocks to cover the demand that would result from the shortage, and a food crisis would be imminent (Bates, 1988).

One reason for slow decision making by the NCPB to export when there is a surplus, or to import when there is a shortage, is because the mandate to engage in foreign trade where maize is concerned rests with the cabinet. This means the NCPB has to submit proposals to either import or export maize to the cabinet, who in turn deliberate on it, make a ruling and communicate their decision to the NCPB. This takes time because trade may jeopardize supply security, and in turn threaten political stability in Kenya.

Since the maize marketing cost has been increasing steadily in the government budget since the 1980s, the government is now determined to find a lasting solution to the problem (Pearson, 1992). Government deficits have also been increasing, hence there have been recommendations that the government must allocate its expenditure according to orderly priorities (Pinckney, 1988). Maize production and marketing is now a priority for the government, with the main objective being to alleviate production instabilities. In mid-1992, the Kenyan Government was re-evaluating its efforts to stabilize maize prices in the context of the Cereals Sector Grain Reform Program (Pearson, 1992). Liberalization of the maize market was an important component of this reform program. Research activities that were conducted to find out the impact of liberating the maize market on maize supply and marketing issues showed that it would be beneficial for the government to liberalize the maize market (Monke, 1992). Based on these results and on recommendations from the World Bank, the Kenyan maize market was liberalized towards the end of 1993[2].

1.3 THE PROBLEM

Grain stocks become inappropriate when they are:

a) so large that they represent:

i. an unsaleable surplus,

ii. an inordinate burden of storage expenses, and

iii. mis-allocation of productive resources; or,

b) so small that they cannot:

i. service expected domestic and overseas demand, and

ii.provide a food buffer for human and livestock emergency (Winter and Iga, 1973).

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[2]The Weekly Review, January 15th, 1994.

Logistics of grain mobilization require a certain volume of stock and flow throughout the system for efficiency. Efficiency in commodity storage means least-cost storage, and this can be achieved by considering, one, the cost of resources used in the physical activity of storage, and two, the optimal management of quantities held in storage, so that expected benefits of the stored grain are maximized given the costs of storage (Gardner, 1987). Since Kenya's storage system is already established, this research will concentrate on the second factor, that is, optimal management of stocks in storage, and assume that whatever quantity of maize is stored, it will be at least-cost in the first factor, that is, cost of resources used in the physical activity of storage.

Optimal management of grain through storage leads to stable prices over time, provided that demand is also stable. This, in turn, leads to a reduction in the costs associated with risks and uncertainties of production instability.

Gislason (1960) argues that the implementation of a policy for lower or higher levels of storage must involve a storage program which stipulates the level of storage stocks under any set of given conditions. He defines a storage rule as a statistical decision function such that when the values of the relevant economic variables are known, the level of storage stocks is determined. Such a rule must involve a constant which the total quantity available must exceed before storage begins and a schedule that relates the quantity to be stored to the total quantity available when this constant is exceeded.

1.4 HYPOTHESIS

A maize storage program less costly than the one currently pursued by the NCPB can be developed. Such a program would enable the NCPB to reduce its costs while maintaining a specified level of maize supplies in the country from year to year, thereby reducing the risks and uncertainties associated with variations in production.

1.5 OBJECTIVES OF THE STUDY

The objectives of this study will be to:

i. Provide a descriptive analysis of the maize production, storage and marketing systems in Kenya.

ii. Develop a decision model for optimal stock management that can be used by the NCPB.

iii. Estimate costs associated with the optimal stock management program.

1.6 ORGANIZATION OF THE STUDY

The study is organized as follows:

Chapter 2 covers a descriptive analysis of the maize market in Kenya, with details on the maize marketing system, the pricing policies and production trends. Some of the short comings of the current system are also discussed under this section.

Chapter 3 presents a review of the literature relevant to the study and the research design. First, the review focuses on the objectives of grain storage. Second, a discussion of the different grain storage models follows, and third, the methodology used in this study and the model specification are discussed, which includes data requirements and sources, limitation of data collection and solution procedures.

Chapter 4 comprises the results and the analyses of these results, with discussions on whether such a model will be able to ease the NCPB storage problem and estimate storage costs efficiently. The shortcomings of such a model are also discussed under this section.

Chapter 5 summarizes the discussion, outlines the limitations of the study and makes suggestions on further areas of research concerning this issue.

CHAPTER TWO: BACKGROUND INFORMATION

2.1 THE GRAIN MARKETING SYSTEM IN KENYA

2.1.1 Policy and Institutions

Government policy objectives with regard to maize marketing in Kenya since independence can be summarised as the maintenance of an orderly and efficient market with a reasonable degree of price stability at an acceptable cost to the government[3] (Gordon and Spooner, 1992). Gordon and Spooner point out that the emphasis has been on maintaining national food self sufficiency and ensuring that producers and consumers have access to cereals markets at prices which serve as an incentive to producers and which are reasonable for consumers. This has been the reason why for many years the government has followed a policy of maintaining a reserve stock to ensure food security and stable prices both to consumers and producers in times of drought and over-production (NCPB, 1991).

The government adopted a strategy of controlling the market in order to pursue its objectives. This started at independence[4], when the operations of the Maize and Produce Board (MPB), which was the grain marketing body at the time, were modified in order to embrace food security objectives. This was done through a combination of one, a monopoly trading status and two, administrative controls over prices, commodity flows and private sector activity (Gordon and Spooner, 1992).

The MPB recognized the need to ensure market access at reasonable and

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[3]This includes the costs of the reports of the 1966 and 1973 maize sector commission of enquiries, Development Plans and the Sessional Paper no 4 of 1981 on National Food Policy.

[4]Kenya attained independence from Great Britain in 1963

stable prices, hence they invested in the development of a network of intervention points known as MPB depots, where farmers could deliver their produce at pre-announced producer prices. Through a similar network of depots in deficit areas, the MPB also ensured the access by consumers to reasonably priced food staples (maize included) at officially announced ex-depot prices. There were additional controls over wholesale and retail margins which completed the system of price control (Gordon and Spooner, 1992)

The depot network facilitated the accomplishment of the market stabilization activity by the public sector, without which it was argued that prices would be highly unstable as a result of weather induced variations in supply. Hence, by giving the MPB a monopoly status in the marketing of cereals, it was assured of the ability to secure supplies from surplus regions and make these available in deficit regions. The essence of the market control concept was physical control over maize supplies (Gordon and Spooner, 1992). There were restrictions imposed on the private sector which served to guarantee the monopoly position of the MPB, y 't its purpose was that of preventing the possibility of exploitation of producers and consumers by private traders.

The MPB was further charged with the responsibility of building up strategic grain reserves, with the objective of promoting national food self sufficiency, and which could be drawn upon in times of shortages. The massive costs involved in maintaining these strategic reserves, together with the remoteness of some of the maize depots used to hold the strategic reserves, served to strengthen the government's resolve to restrict competition from the private sector.

Other controls such as restrictions on the intake of grain by maize millers from private traders guaranteed a ready market for MPB maize, whereas restrictions on grain movement served to reinforce the parastatal's ability to procure grains from surplus regions and prevent unofficial movements to consumers. One other reason often cited to justify maize controls is the fear of movement of the grain out of deficit areas or over national boundaries (Maritim, 1982).

The system of market control evolved out of a priority for ensuring national food security and safe guarding of producer and consumer interests. However, as Gordon and Spooner argue, the government has long been aware of the potential inefficiencies of the system, but these have been regarded as of secondary importance since market control appeared to effectively advance the aims of direct control over food supplies and support for producer incomes.

2.1.2 Pressures for Reform

Pressure for changes in the structure and handling of grains, specifically that of maize, started as early as 1966, only 3 years after independence. The publication of the recommendations of the 1966 Maize Commission of Inquiry highlighted the difficulty that arises with planning production to meet domestic demand (Kenya, 1966). They cited the sharp fluctuations in annual supply of maize, and an inflexible consumer demand as being a major setback to this structure. They also argued that despite an allowance being made for the holding of an unduly large and costly domestic stock, there would be need to import or export at a loss from time to time. Gordon and Spooner summarised some of the problems that critics of the system have pinpointed as:

i. That parastatals are inherently inefficient and tend to operate at high cost, whereas marketing activity is operationally more efficient when carried out by the private sector. The critics have even suggested that increased private sector involvement in grain marketing will result in increased producer prices and lower consumer prices.

ii. That controls on prices and flows such as is done by the Kenya government create distortions, whereas allocative efficiency is best pursued through greater reliance on market forces, and this inevitably involves a greater role for the private sector.

iii. That there are multitudinous inefficiencies associated with large scale public sector intervention in grain markets, which inevitably leads to an unsustainable drain on government funds.

iv. That the role of the public sector in grain marketing should not be the control of the market, but rather should be confined to that of market stabilisation. This is because instability would be expected to exist in a liberated system, and this role would enable the government to stabilize prices from time to time.

As Gordon and Spooner point out, these criticisms focus heavily on the inefficiencies of the market control regime, and most of the recommendations are broad, providing little in the way of operational guidelines for implementation. They also observe that the government's response to these early pronouncements was limited because they amounted to a relinquishment of market control and an increased risk of food insecurity for producers and consumers. The government was concerned that the private sector was underdeveloped and as a result, moves towards market orientation would lead to exploitation. The government's move towards implementation of these recommendations may have been further hampered by the lack of a detailed guideline by the critics as to how the policy objective of food security would be met once the government relinquished their control.

2.2 MAIZE PRICING POLICY

2.2.1 Justification for Government Intervention

Pricing policy plays an important role in any scheme of public sector intervention in the marketing system. In Kenya, the government sets both producer and consumer prices of maize. This affects almost all Kenyans and influences the effects and magnitude of operation of the NCPB (Development Support Group). It is also crucial in determining the viability of different elements in the private sector. Appropriate pricing policies must be based closely on the government's objectives in intervening in the market and must take account of the existing international markets (Kenya, 1989).

The Kenyan government has justified its intervention in the maize market by arguing that without such an intervention, the market would be characterised by massive domestic price instability (Development Support Group). The source of instabilities have over the years been attributed to one, extreme variability in domestic weather conditions which make production vary from year to year (Fig. 2.1); two, more modest instability in world prices for white and yellow maize; and three, the long transport hauls to and from the port of Mombasa for exports and imports, which have the effect of widening the scope for price movement, especially in the countryside (Gordon and Spooner, Development Support Group, Pinckney).

The Development Support Group used parity (border) prices adjusted for location within the country to investigate the extent of the Kenyan maize market instability. They identified two types of parity prices as relevant for their study, import parity prices (IPP) and export parity prices (EPP) (Fig. 2.2). The IPP, they argued, was an indicator of the price in domestic currency, at which imports would be available at different locations in the country. It is calculated from the world market price (expressed as Mombasa cost, insurance and freight (CIF), at port of entry), and adjusted upwards for the transport, processing and marketing margins incurred in making the imports available at a given location in the country. It is an indicator of the level at which domestic prices for the commodity should stabilize if imports are permitted to flow freely during periods of shortages. They also argued that the EPP was an indicator to the local maize producer of the value of a unit of export sales. It is calculated from the export free on board (fob) price by deducting all storage, marketing and processing costs and margins from the farm gate to fob at the port of export (Mombasa). The results showed that under a fully liberalised trade regime, domestic prices could be expected to be volatile within the IPP and the EPP band at each location within the country. The Development Support Group concluded that in spite of improvements to the parity band (calculated as IPP less EPP) in years when Kenya would be able to export maize to neighbouring countries, the stabilising role of international trade on domestic prices would be rather limited. They noted especially that in the hinterland, (Eldoret and Kitale), the parity band widened dramatically, with the IPP being approximately twice as much as the local producer price, and the EPP being negative (Fig. 2.2). Considering that these locations are the principal maize growing areas in the country, the Development Support Group noted that external trade would not be profitable. Hence, they ascertained that it was justifiable for the government to intervene in the maize market.

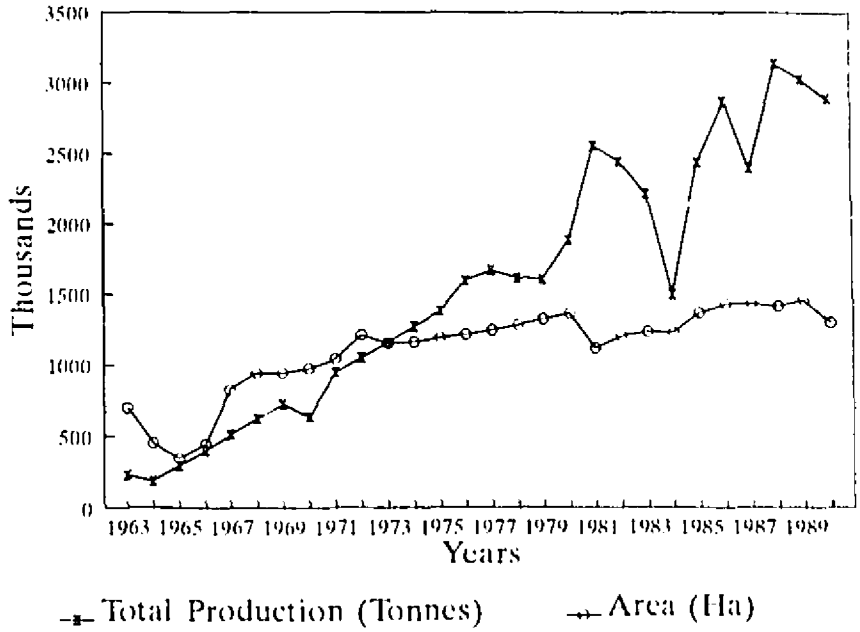

Fig. 2.1 Maize Production and Area

Source: MoA, DPD, Nairobi, Kenya

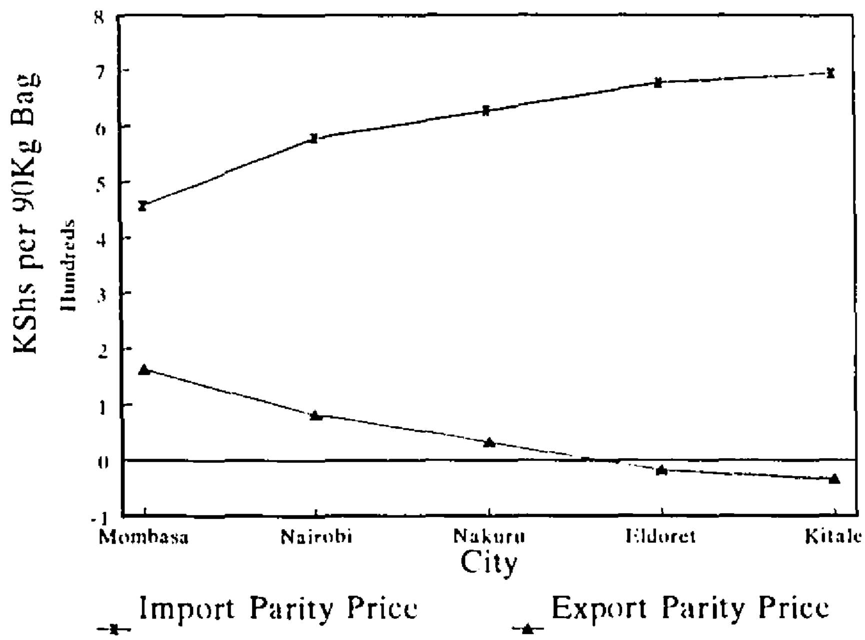

Fig. 2.2 Maize Parity Price (1990)

Source: Development Support Group, 1992

2.2.2 A Historical Review of Maize Price Formation

Official prices, both producer and NCPB selling price have fallen broadly in line with the band formed by import and export parities (Figs 2.3 and 2.4)[5]. However, as observed by the Development Support Group, Kenya's official prices have tended to be more stable in real terms compared to world market prices. Secondly, there have been considerable variations in the width of the NCPB's margin between the producer price and the ex-depot (selling) price (Fig. 2.5). In the 1970's, this margin seems to have been considerably constrained, but widened again in the mid 1980's. Domestic market prices (in the parallel market) on the other hand, were at levels above NCPB selling prices in the early 1980's, but fell below these prices after 1985 (Fig. 2.6). This could be attributed to the fact that after the drought period of 1984, Kenya's maize production was higher than consumption (Fig. 2.7), and therefore the parallel market prices remained below those of NCPB. According to the Development Support Group, in drought years market prices have moved substantially out of line with import parities, reflecting domestic scarcity during such periods (for example the scarcity periods of 1980 and 1984). In such periods, the domestic consumer market was not successfully stabilised when measured in terms of market prices. Consequently, it can be concluded that despite the apparent success of the government's price stabilisation program, it works only for normal years. The Development Support Group report, however, that in spite of Kenya's official prices being rather stable in real terms compared to world market prices, there have in fact been substantial movements in real producer prices. They note that there has been a tendency for real producer prices to be eroded during periods of high production and high NCPB stocks as prices are held constant in nominal terms, only to be adjusted sharply upwards during scarce periods.

[5]The import and export parity prices used are for Nairobi. This represents the principal location at which domestic production competes with imports.

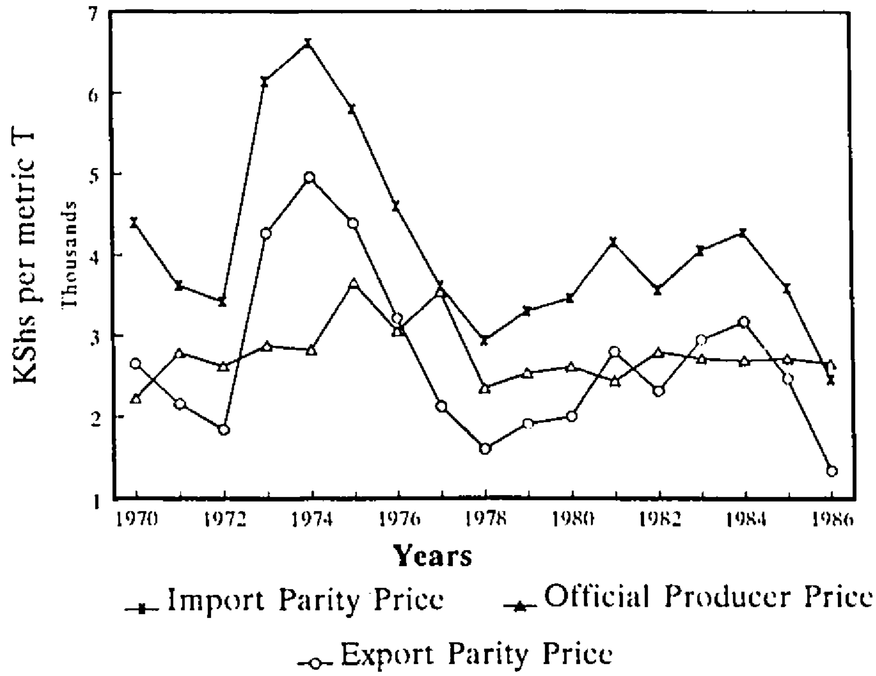

Fig. 2.3 Parity and Official Producer Price

Source: NCPB, Development Support Group

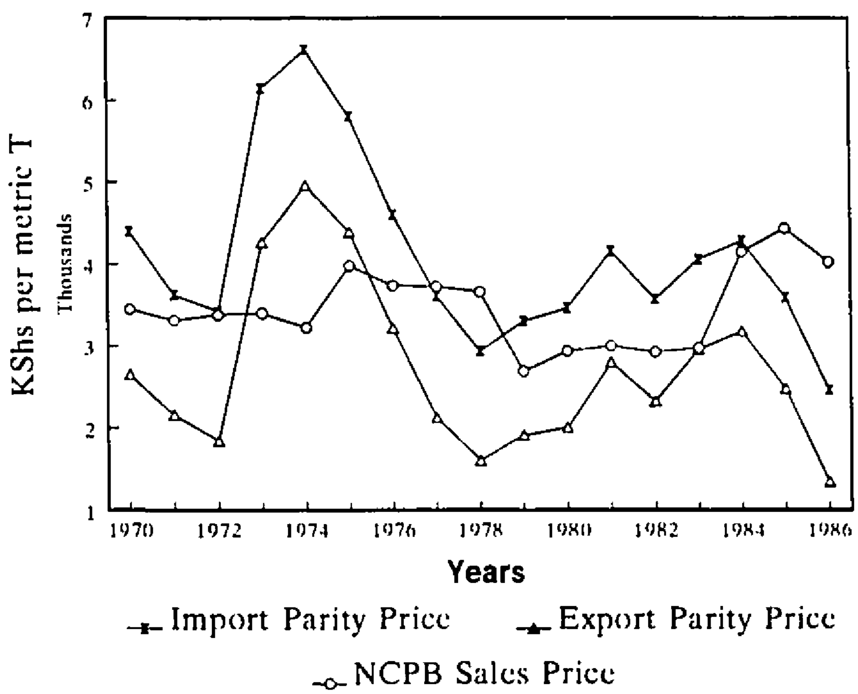

Fig. 2.4 Parity and NCPB Selling Price

Source: NCPB, Development Support Group

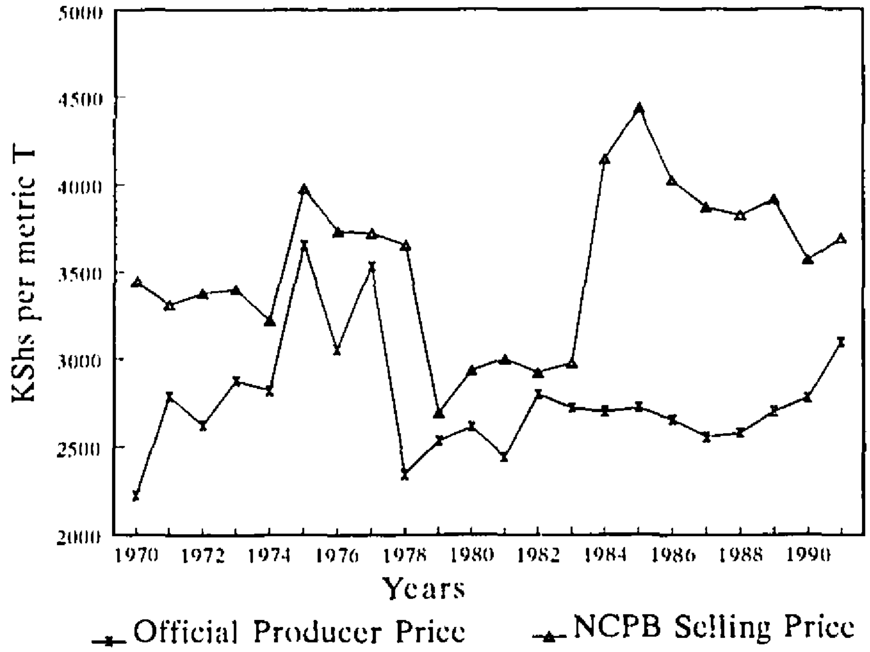

Fig. 2.5 Official Producer and Ex-depot Prices

Source: NCPB, Nairobi

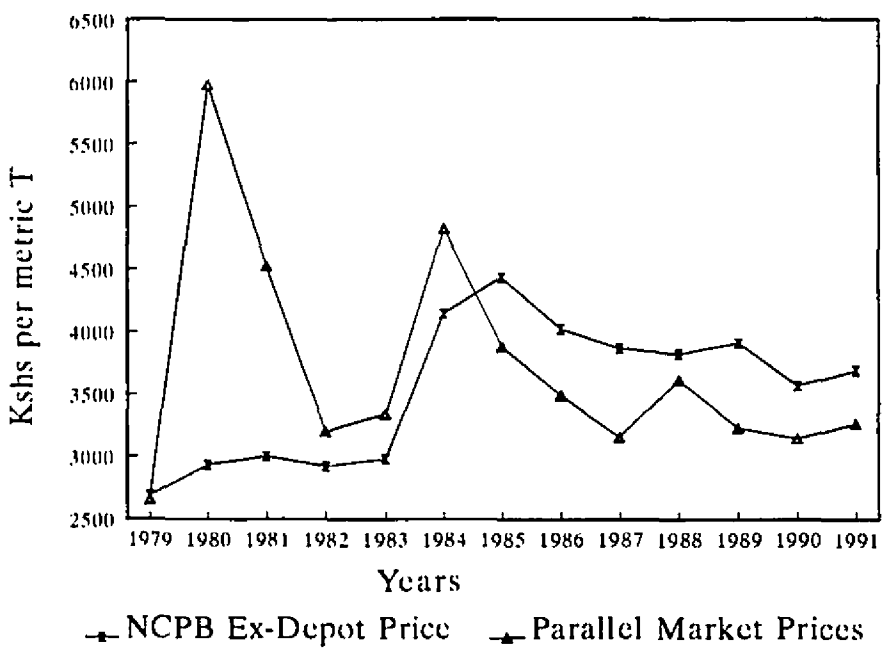

Fig. 2.6 NCPB Selling Prices and Market Prices

Source: NCPB, MoA, Nairobi, Kenya

2.2.3 The Current System for Setting Maize Prices

Under the current system, the official maize prices are set by the Cabinet on the basis of recommendations generated through the inter-ministerial price review committee. The basis for the review is the technical analysis carried out by the Planning Division in the Ministry of Agriculture. The main factors considered in the technical analysis that are deemed important for the price review are import and export parities for white maize and the costs of production.

As noted above, import and export parities are calculated from estimated maize border prices (at Mombasa port) plus/minus the full transfer costs to/from the principal locations of production and consumption (Development Support Group, 1992). In this analysis, the import and export parities are treated as the limit prices within which officially set prices should fall (Kenya, 1989). It is argued that the rationale for this approach is that as long as Kenya is assumed to be in a maize commodity balance in most years, the domestic price structure should be set on the basis of having domestic supply and demand in equilibrium within the IPP - EPP band.

A cost of production analysis is usually undertaken for a representative maize farm, with particular attention given to the cost increases of key inputs, such as fertiliser, seed, diesel fuel and the cost of transport (Development Support Group, 1992). Other considerations in such an analysis may include the trends in domestic inflation, and the level of officially held maize stocks (i.e NCPB stocks).

The Development Support Group, however, observed that in spite of such a formal analysis, the establishment of a recommended producer price by the Cabinet is essentially judgemental under the current pricing system. They recognised that in practice, the parity band is wide especially for locations that are furthest from the port of entry. Consequently, the calculated external parity prices may provide little or no guidance to the actual recommended producer price level except in periods of extreme price movements in world markets. They also contend that Kenya's maize sector includes a wide range of farm types operating in widely differing agro-ecological conditions across a wide geographical area. Consequently, there is a large element of subjectivity in the selection of one or a few farm types as representatives. They conclude that the problem with the technical analysis as currently practised is that it leaves a wide margin for judgemental and political factors to influence the pricing process. They also observe that the pattern which has emerged in this situation is of periods of relatively stagnant nominal prices when supply and stocks are abundant, followed by sharp upward readjustment during periods of drought and stock reduction.

The maize consumer price and related prices higher up the marketing chain, such as the ex-depot and the ex-mill prices are, in principle, set on the basis of a cost-plus approach which incorporates the full marketing costs of the NCPB, the miller, the wholesaler and the retailer (Kenya, 1989). The Prices and Incomes Commission in the Ministry of Finance is responsible for the preparation of these cost-plus calculations to establish the appropriate margins for NCPB, the millers and the wholesale and retail trade. The Development Support Group again recognised that, in practice, this consumer price is affected by judgemental and political factors, reflecting the social importance of the maize meal price, especially for low income urban consumers.

2.2.4 Shortcomings of the Current Maize Pricing System

Some problems have been identified by previous studies concerning the current maize pricing system in Kenya (Maritim; Pinckney; Kenya, (1989); Development Support Group). These include the following:

i. That there is inadequate precision in defining an efficient producer price. The fact that a producer price may fall within the import and export parity does not necessarily mean it is efficient, especially for a country which fluctuates between imports and exports such as Kenya. The current price review fails to address the important issue of defining economically efficient prices within the import-export parity band.

ii. That there is lack of a spatial and temporal price structure. The current pan-territorial official pricing system tends to preclude the setting of appropriate incentives for an efficient spatial pattern of production, in order to reflect the availability of maize in different locations within the country.

iii. That there is inadequate inter-commodity price analysis, which has led to significant year-to-year shifts in the relative incentives for competing major land uses, and which may have induced short-term shifts in production that did not reflect underlying economic conditions.

iv. That there is poor forecasting of the financial implications of the pricing policy. This has arisen partly because of lack of an appropriate analytical framework for assessing the budgetary impact; and partly because the analysis for the producer and the consumer ends of the market are not undertaken on an integrated basis.

v. That there is poor stabilisation of consumer price markets. This is reflected in the significant differences in prices in the parallel market and the official marketing channel.

2.3 MAIZE PRODUCTION INSTABILITY IN KENYA

Maize, like any other crop, is prone to fluctuations in production, because of its dependence on weather conditions. Due to the importance of maize in Kenya as the staple food crop, the fluctuations in production cause multiple problems for the country. According to Acland, maize in Kenya requires approximately 200 millimetres of rainfall in the growing season. Amounts less than this cause yields to decline, and sometimes a total crop failure may occur. Maize production in Kenya has not escaped these fluctuations and there have been shortages reported in the country from time to time (Pinckney). All shortages reported so far have been attributed to unfavourable weather conditions. As Casley et al (1978) report, efforts to deal with the problems caused by extensive crop failures lead to a major diversion of resources from development needs to emergency relief work and thus compromise economic growth and creation of employment.

Pinckney reports that in most of the 1980s, the country produced about the same amount of white maize as it consumed (Fig. 2.7). He argues that in years with normal weather conditions, private markets cleared at prices that were between import parity and export parity, yet the country faced severe shortages in 1984, and in some years (like 1981, early 1987 and 1988), was faced with the opposite problem of excess supply.

Maize crises in Kenya are not new. In 1966, a Maize Commission of Inquiry (Kenya, 1966) reported that it was impossible to plan production exactly to meet domestic demand because of the sharp fluctuations in annual supply of maize, and an inflexible consumer demand. The report went on to say that even if an allowance was made for the holding of an unduly large and costly domestic stock, there would be need to import or export at a loss from time to time; hence, it recognized the problem of fluctuations in production and the costs associated with depending on storage or trade alone to deal with the intricacies that arise thereafter. Many years later, the government has not developed a long term solution and still continues to make ad hoc decisions as each problem comes along (Pinckney). Maritim also recognizes the problem of fluctuations and reports that since the first documented maize crisis in Kenya of 1918, periodic maize shortcomings have provoked thirteen commissions of inquiry, working parties and/or select committees to investigate and make recommendations on the pricing and marketing of maize in the country. He laments that despite most of these investigations having conducted expert analysis, with responsible recommendations made, it has been disappointing to see maize policy continue on an ad hoc basis, with the authorities acting too late to avert the immediate crisis, and then taking little remedial action until the next crisis.

CHAPTER THREE: LITERATURE REVIEW AND RESEARCH DESIGN

3.1 INTRODUCTION

The theory of grain storage dates back to the ancient times of the Pharaoh and Joseph, when they planned for seven lean years, by storing stock harvested in the seven good years. But unlike Joseph who was certain of the future, governments are faced with uncertainty. There are weighty institutional, political and economic obstacles arrayed against any attempt to further the public good by establishing food reserves (Taylor et al, 1977). As Reutlinger et al (1977) point out, if it were true that a certain profit could be earned by buying grain in years of plenty and selling it in years of want, there would be no reason for international concern for buffer stocks, because individuals or companies would gladly come into the grain reserve business. They concluded however, that because this is not so, it should be apparent a priori that a reserve might not be a profitable investment.

Gardner (1979) defines stockpiling as the activity of holding back grain from consumption on the current crop year for use in the future, and optimal stockpiling as the holding back of quantities from current consumption, such that expected welfare, as measured by an objective function, is maximized given the current state of the world. On the other hand, Gustafson defined an optimal grain storage policy as a set of rules which specifies optimal stocks for every possible state of nature. That is, the storage rules state how much grain should be carried into the following period given the initial supply for the current year. Grain reserves have an important element to play in encouraging efficient production, in contributing to a healthier and perhaps less rapidly growing population, and most important to the avoidance of economic, social, and political disaster (Hathaway).

According to Casley et al, the stock policy of a country depends on a number of factors and the inter-relationships between these factors. They list among these factors, foreign trade prospects such as the availability of imports, foreign exchange considerations, the transport network, dock loading and unloading capacities, the availability of substitute foods, the marketing channels, and price considerations. They go on to argue that in determining such a policy, each government has to assess the risk it is prepared to take and to know the chance of success of such a scheme with a given opening stock. The kind of risks a government is willing to take will depend on the political circumstances, such that in a politically volatile situation a government may hesitate to risk a major price rise of essential commodities. On the contrary, freezing prices in years of shortage may have a dampening effect on the incentive to farmers to produce or invest in agricultural development, particularly if non-agricultural prices and prices of agricultural inputs are rising. Thus, it can be concluded that when all factors have been considered, any policy measure to eliminate or reduce the impact of fluctuations in domestic production must aim at buying up surpluses in a favourable year and storing them for release in a deficit year (Casley et al). The stocking problem therefore, concerns the allocation of a given supply between current consumption, and carry over to the following year. Gislason notes that the decision dividing the total quantity of grain between consumption and storage is assumed to be made as soon as the new harvest is in and the total quantity of grain available is known.

There are problems in attaining socially optimal grain storage programs by means of public stocks. Gardner (1979) gives two reasons why there is a tendency for public storage to generate stocks which are on average too large:

i. The political pressure to use stocks as a tool to increase mean price, and thereby to support farm incomes as opposed to merely stabilising them.

ii. Public stock managers' reaction to the risk of running out of stocks.

3.2 OBJECTIVES OF GRAIN STORAGE

There are several reasons why grain storage may be undertaken: a farm program agency may undertake storage to support current prices; individual farmers in the hope of a rise in price; livestock feeders or millers in fear of a price rise; a food agency in order to ensure against famine; an importer in order to guarantee supplies against interruptions of trade; and by a buffer-stock authority as a part of a price stabilization scheme (Gardner, 1979). Consequently, an optimum storage rule is one which best fulfils the given objective so as to maximize the net benefits.

The following literature will expound on some of the objectives of governments in holding stocks.

3.2.1 Price Stabilization and Storage

Governments may undertake organized stock piling of grain with the stocks being largely a by-product of government programs to support the price of grain. In this approach, a floor price is guaranteed by the government removal of sufficient grain from the market to maintain the set price. This is one of the reasons for the maize stocking policy in Kenya (Kenya,1986). The producer price of maize is set by the government prior to the planting season, and is used as an incentive to increase maize production. As Pinckney reports, despite large losses on every tonne of maize that was imported and sold domestically in 1980/81 and 1984/85, the government's official price remained firm. Similarly, in 1981/82 when buying the bumper crop that had been harvested that year caused the NCPB to run out of cash, official prices did not decrease.

The government sets not only maize producer prices, but also consumer prices. This is because one of the policies of the government is increased consumer welfare (Kenya, 1986). There have been considerable discussions in welfare economics concerning whether or not price stability should be a goal of the government. Waugh (1944) argues that price stability may hurt consumers more than benefit them if the instability occurs from the supply side. He concludes that consumers do benefit from price instability in such a case. Oi (1961)[6] concludedthat producers prefer price instability when it occurs from the demand side. However, the conclusion reached by Massel (1969), when he considered producers and consumers together, was that, overall, society benefits from price stabilization of storable products through a reserve policy if storage costs are not excessive (Fig. 3.1a and b). The Massel approach is presented in Fig. 3.1a for stochastic supply and 3.1b for stochastic demand (Schmitz, 1984). In Fig. 3.1a, consumer demand is represented by D, and stochastic supply is represented by S1 and S2, each of which occurs in alternating periods. Equilibrium prices are p1 and p2, respectively. Assuming that prices are stabilized at μp, could be by means of a buffer stock authority which buys q1' less q0 when S1 occurs, and sells q0 less q2 when S2 occurs. When S1 occurs, consumers lose area c + d while producers gain area c + d + e, for a net gain of area e. With S2, producers lose area a but consumers gain area a + b, for a net gain of area b. Schmitz concludes that the average overall effect of price stabilization with such a reserve policy is a gain of 1/2 * (area b + area e), implying that the loss from stabilization for consumers offsets some of the gain for producers, who are benefited by stability; however, the gain for producers more than offsets the consumer loss.

With fluctuations in demand (Fig 3.1 b), the prices vary between p1 and p2, respectively. Price stabilization at μp through a buffer stock leads to a gain of area e if D1 occurs or of area c if D2 occurs. On average, the producer loss of 1/2 * [area (a+b) - area (d+e)] is more than offset by a consumer gain of 1/2 * [area (a+b+c) - area d].

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[6]The Oi (1961) and Massel (1969) references are found in Schmitz (1984)

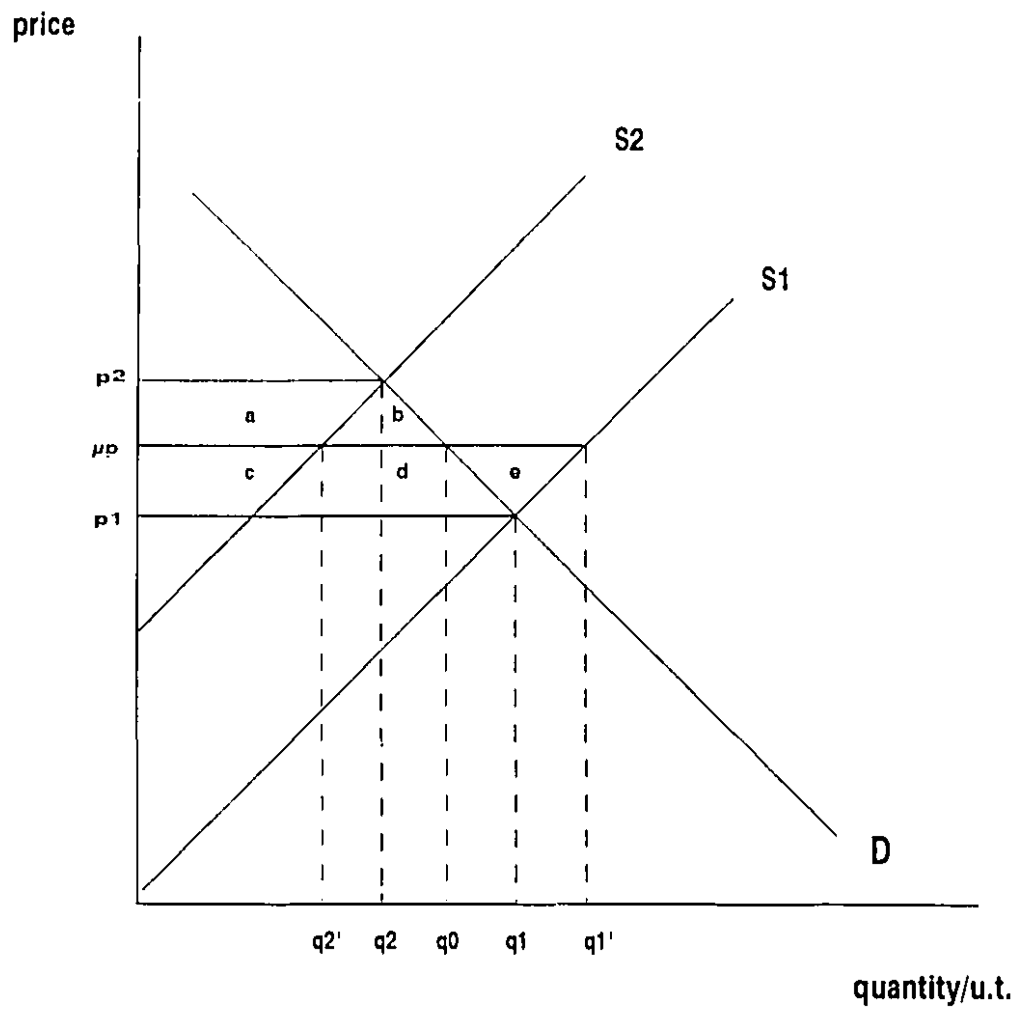

Fig. 3.1a The Massel Approach to welfare effects of price stabilization: Stochastic Supply

Source: Schimtz (1984)

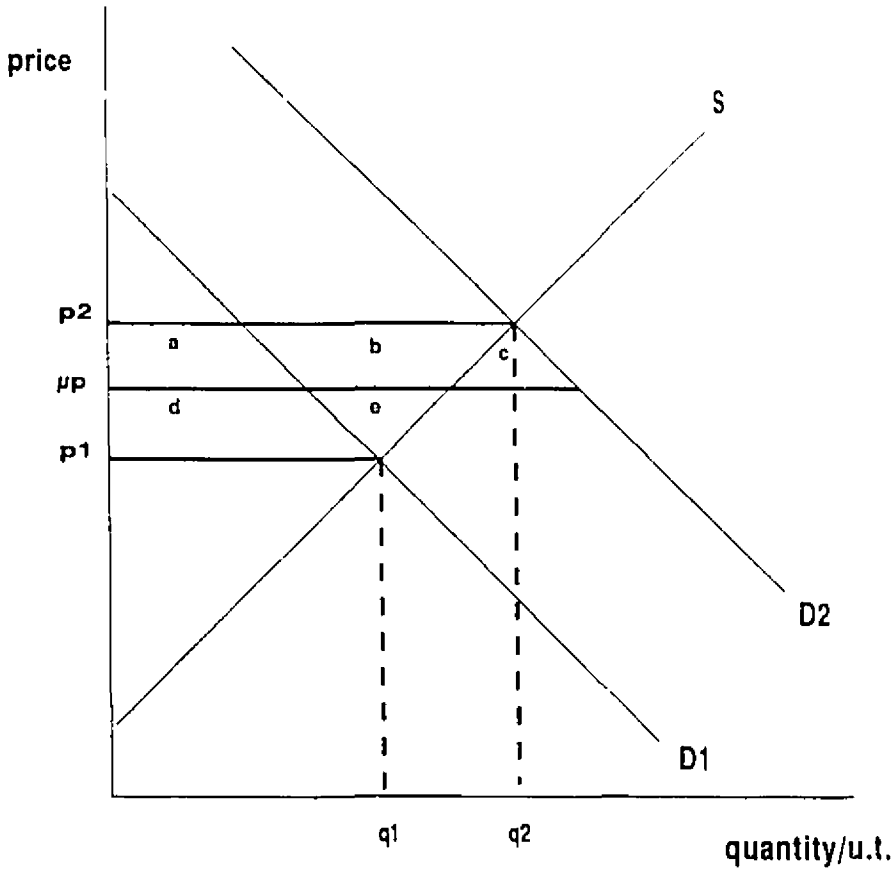

Fig. 3.1b The Massel Approach to welfare effects of price stabilization: Stochastic Demand

Source: Schimtz (1984)

The overall conclusion reached by Schmitz from the above results was that society benefits by stabilizing prices of storable commodities through a reserve policy if storage costs are not excessive. He points out, however, that even though society benefits, there are both gainers and losers from stabilization policies. When instability occurs from the supply side consumers lose from stabilization (Fig. 3.1a), whereas when instability occurs from the demand side producers lose from stabilization (Fig.3.1b). These conclusions are similar to those reached by Waugh (1944) and Oi (1961). Nevertheless, Schmitz (1984) argues further that one group gains more from stability than what the other group loses. Consequently, through some form of compensation, everyone can gain from price stabilization. He therefore concluded that a buffer stock scheme is Pareto superior to no buffer stock.

The above conclusion notwithstanding, Myers and Runge (1984) noted that the net gain in economic efficiency from intervention that successfully stabilizes prices, fails to account for risk responsive behaviour, existence of private speculative storage activity and budgetary costs of government stabilization policies.

3.2.2 Foreign Trade and Storage

The Kenyan government's official policy is to set prices at which maize will be bought and sold long before the size of the crop can be estimated. Yet Pinckney (1988) argues that simple accounting identities show that if prices are to remain constant in real terms while production is variable, either the foreign trade account or the stock level, or both must absorb the instability.

Kenya has been reluctant to enter into the foreign trade of maize. There are several reasons for this:

i. Kenyans prefer a policy of food self sufficiency (Kenya, 1986); therefore exports of the main staple crop in years of abundance when future supply is unknown, are seen as going against this policy.

ii. As Pinckney reports, imports present Kenya with a threefold problem:

- since the selling price of maize is determined in advance, is usually below the import price, and is officially not expected to fluctuate, the government suffers losses on every tonne of imported maize sold domestically.
- imports are interpreted by the public as a food self sufficiency policy failure.
- Kenyans produce and consume white maize, and virtually all the maize on the international market is yellow.

In his study of four East African countries, Kenya included, Gerrard (1983, 112) notes:

> `..... all four countries have been pursuing a policy of relative self sufficiency that has insulated domestic food grain markets from international markets. This explains why none of the countries has historically been a major exporter or importer of food grains that can be produced domestically, although net imports have fluctuated, sometimes dramatically, from year to year ......'

However, Gardner (1987) has shown that with optimal storage systems, countries could export during periods of abundance in local production. He argues that for commodities produced in many countries, the gains from transitory trade are likely to be even greater than gains from trade based on static comparative advantage. He goes on to say that each country could establish an optimal price stabilization rule given its domestic price history and prospects, such that an importing country would rationally plan for export embargoes under the contingency of worldwide crop shortfalls by acquiring their own stocks in times of abundance. He notes that there is no inefficiency in this since all countries have the same storage costs, and random supply and demand shocks are perfectly synchronized across countries. He further recognizes that the opportunity for improved efficiency arises when some countries have transitory excess supply of grain in the same years other countries have transitory excess demand.

In support of this argument by Gardner (1987), is Johnson and Sumner's (1976) study of empirical simulation on optimal storage. They compared self sufficiency with free trade, and established that the mean optimal stock level is about eight times higher for regions with self sufficiency, as for the world as a whole under free trade. Thus, the efficiency gains achievable in storage under free trade could be quite considerable for a country like Kenya, especially considering that the average quantities in storage under the current policy (self sufficiency), in exceptionally good harvest years are in excess of 540 thousand tonnes (Appendix 1, Table 1-C). This represents an average of 23 per cent of total disappearance annually for the period 1980 to 1990.

Gains arise primarily because reliance on trade to meet shortfalls in production is cheaper than stockpiling (Taylor et al, 1977). However, Donaldson (1984) advises against over reliance on international grain markets as a residual source of supplies, and warns that a grain trading strategy is no substitute for a sensible domestic production policy, nor is a grain import strategy a substitute for a sensible stock holding policy. He argues that internal distribution problems in importing countries make grain imports an expensive and hazardous source of supply for all except those in major cities. Further, he notes that since the vast majority of the population in developing countries live in rural areas, with incomes dependent on farm production, imports cannot provide a long term solution to their food security. He justifies a sensible stock policy on the grounds that domestic political factors may call for holding of additional reserves of grain over and above operational stocks. He observes, nonetheless, that such a storage program is expensive and the benefits may be psychological rather than economic. He concludes accordingly that, such a program should be backed by an effective trading policy.

The Maize Commission of Inquiry (Kenya, 1966), commenting on the cost of maize reserves, observed that the costs of storage have to be balanced against importing maize from overseas, and the cheaper alternative pursued. However, they observed that it is easier to make calculations posteriori rather than a priori in a case like Kenya. They warned that even though reserves may appear to be a money-saver when the calculations are done, they are only feasible if they can be utilised within three years. They recognized that the average length of the rainfall cycle in Kenya is such that it is reasonable to expect that reserves will be utilised once every four to five years. Consequently, they concluded that it seemed unlikely that the holding of reserves would be cheaper than importation. They also observed that the additional cost of holding reserves would be increased when storage costs increased or import prices decreased, and reduced when the reverse process occurred.

This study uses optimization techniques which take into consideration problems of decision making that concern imports and exports of maize. However, it incorporates the objective of gaining from foreign trade, without having to compromise the availability of stocks domestically. As Gustafson (1958) points out, storage rules specify how much grain will be carried over to the next period, given supply for the current year. As soon as this amount is determined, if there is a surplus it will be exported and if there is a deficit it will be imported. Exported surpluses will earn the country the much needed foreign exchange. Despite the fact that the maize exported may be in small quantities, part of it is exported at a white maize premium since white maize is usually a preferred commodity on the world market (Pinckney, 1988).

3.2.3 Food Self Sufficiency and Storage

A food policy should include two basic elements, the provision of an adequate and improving food supply to consumers, and, the avoidance of economic, social and eventually political disasters (Hathaway, 1977). In the face of uncertainty, social risks associated with shortages are increased in poor, low-income agricultural based economies, because as argued by Hathaway, in such economies the marketable surplus is a function of the quantity above that which the farmer holds for his own family consumption and payment in kind to his various creditors. This means that production variations result in much greater variation in market supplies and prices.

Ruppel (1991) points out that food policy goals require commitment to a storage capacity, since in the face of harvest uncertainty, complete food self sufficiency necessarily requires the accumulation of stocks. The World Bank Survey of 1962 (World Bank, 1962)[7] also noted that it is a nation's responsibility to ensure sufficient supplies of its staple food crop at reasonable prices. It called for an efficient system of distribution, including the holding of reserves to cover shortage periods. However, in discussing the subject of reserves and storage policy, the 1966 Commission of Inquiry (Kenya, 1966) noted that it is not only the size of the reserve stocks that is of importance, but also the location of these reserves, the linked transportation problems, what kind of storage accommodation is appropriate, the cost of holding these reserves and who should meet these costs. They suggested that the reasons which determine the size of the reserve stocks to be held should be the amount needed to assure continuity of supplies, the comparative costs of holding reserve stocks compared to importing, the saving of foreign exchange and the balance of payments position, and the value of reserve stock in generating local employment and income. Notwithstanding, the necessity of potentially accumulating stocks in years of abundance in the quest for self sufficiency in years of short production, may increase costs to the government since:

i. there will be increased supply due to increased or subsidised producer

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[7]Referenced in Kenya (1966)

prices, which may lead to the problem of increased consumer prices arising due to increased inventory costs; otherwise governments must subsidise consumption,

ii. increased production will lead to increased stocks, which can be expensive to maintain, and

iii. a large volume of government stocks may affect commodity prices, as in the case of buffer stocks, when governments choose to use them.

These reasons necessitate finding a way of determining how much stocks will be carried over from one period to another. This can be done as reported by de Janvry and Sadoulet (1991) through proper management of stocks which stabilises the availability of grains for food.

Yearly maize producer and consumer price adjustments before the planting season is hoped to bring about price stabilisation in the official market. Yet, as Pinckney (1988) reports, the existence of a parallel informal market makes it difficult to achieve this goal, especially when it is precipitated by the shortcomings of the formal market (selling through the NCPB). The NCPB is supposed to be the sole buyer and seller of all maize, but in times of surplus production the NCPB has not been able to buy all maize that has been offered for sale, and in times of shortages it has also not been able to meet demand. As Hathaway (1977) points out, when total supplies are short, there is a tendency for individuals throughout the system to increase private stocks and reduce market supplies. These actions amplify the magnitude of market price swings, and for the NCPB, reduce its market share in terms of purchases, while increasing the pressure on its stocks. This fact was also noted by Bates (1989) who observed that sales by the NCPB increased dramatically during years of low rainfall (shortages), indicating that stocks held by the NCPB can play a major role in stabilising prices. Despite the controlled prices in the formal market, lack of stocks by the NCPB that can be offered for sale during periods of shortages do play a major role in regulating the prices in the informal market.

With all these problems faced by the NCPB, buyers and sellers have tended to resort to the informal market which meets their need, even though it is illegal and has lower prices for producers during periods of abundance, and higher prices for consumers during periods of scarcity. This market is faced with high price instability, thus, the only tools that successfully control price stability for all market participants are trade and storage policies (Pinckney, 1988).

Cyclical domestic over-production of maize is as much of a problem in Kenya as is under-production. This type of instability and institutional uncertainty invites, but cannot be solved through, simple increases or decreases in state intervention (Haugerud,1988). There is need for research in the area that concerns marketing, storage and trade of such crops. In addition, the introduction of structural adjustment programs in many Eastern and Southern African countries is encouraging governments to trim parastatal losses and re-examine the wisdom of carrying over large stocks of grain (Rukuni and Eicher, 1991). The rural storage facilities in Kenya are poor, hence rural farm reserves form a small percentage of total stocks in the country, and cannot be relied on to cover shortages in periods of scarcity. Consequently, with rural storage facilities so poor that the supply of locally produced food staples experience an extreme cycle, ranging from high availability to severe scarcity, there is need for increased research in the area of storage (Lofchie, 1989).

3.3 RESEARCH DESIGN

3.3.1 Methodology

Many studies have been done on grain storage using various methods. The most notable are the buffer stock system, which is also called the price band scheme, optimization techniques, stochastic simulation models and stock and allocation models. The first three techniques make use of simulation analysis; the buffer stock method and the stochastic simulation models explicitly, and the optimization approach only after a desired policy has been achieved by use of dynamic programming. The stock and allocation models utilize econometric analyses and probability models.

3.3.1.1 Buffer Stock Method

This is the traditional form of public storage to stabilize inter-year supplies of grain. Grain is saved during periods of excellent domestic harvests or low international market prices for use in years of poor production (Reutlinger et al, 1977). In this method, there exists a floor price at which produce may be purchased, and a ceiling price at which produce may be sold. The buffer stock scheme has a pre-established release-price trigger, so that those dealing in the product know the principles on which the public stock authority intervenes. Since it is undesirable to accumulate stock indefinitely, the release price is usually set appropriately, with reference to the floor price and mean expected price, usually slightly above mean expected price. The quantity held in stocks between floor price and ceiling price is a function of past market conditions, so that the resulting total demand function for grain is of the form shown in Figure 3.2[8].

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[8]Example given is from Gardner (1979).

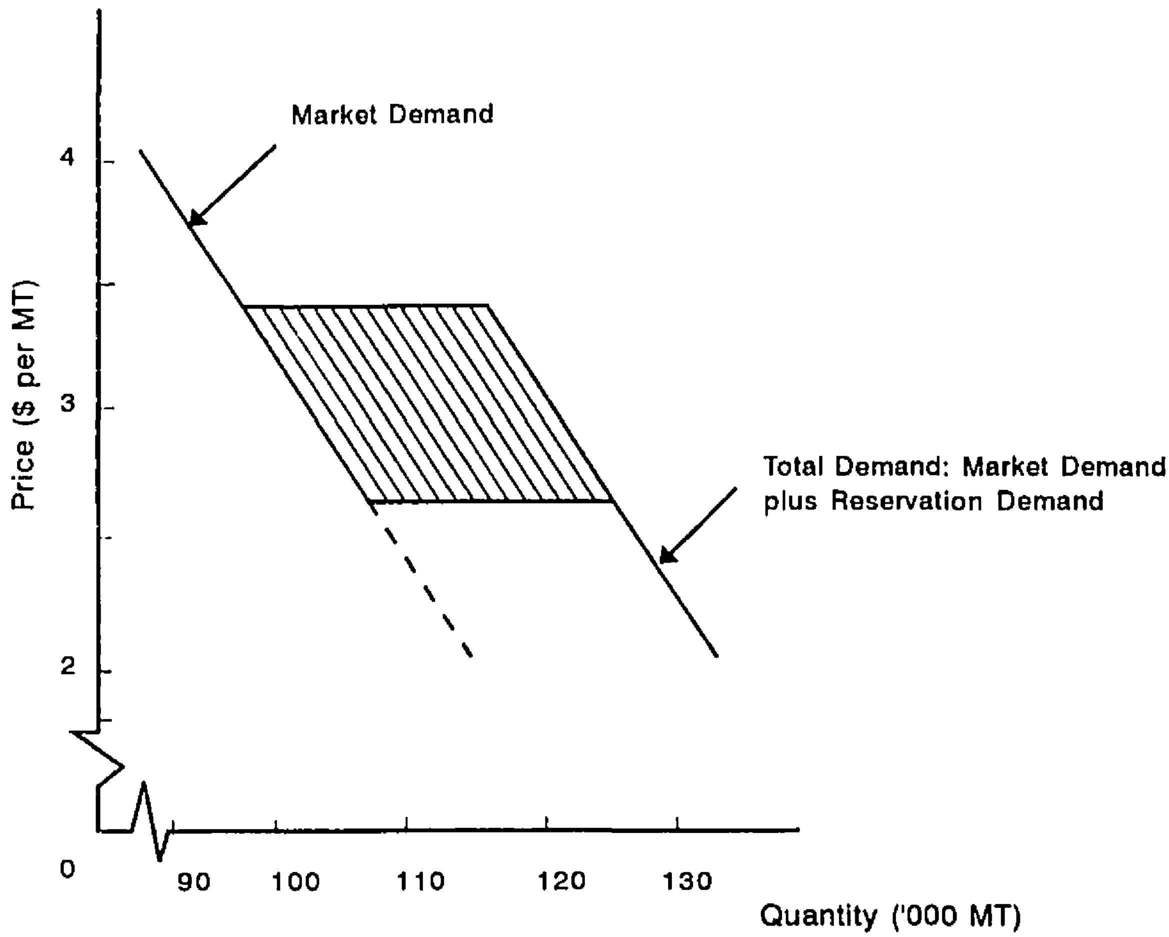

Fig. 3.2 Total Demand with Buffer Stock

Source: Gardner (1979)

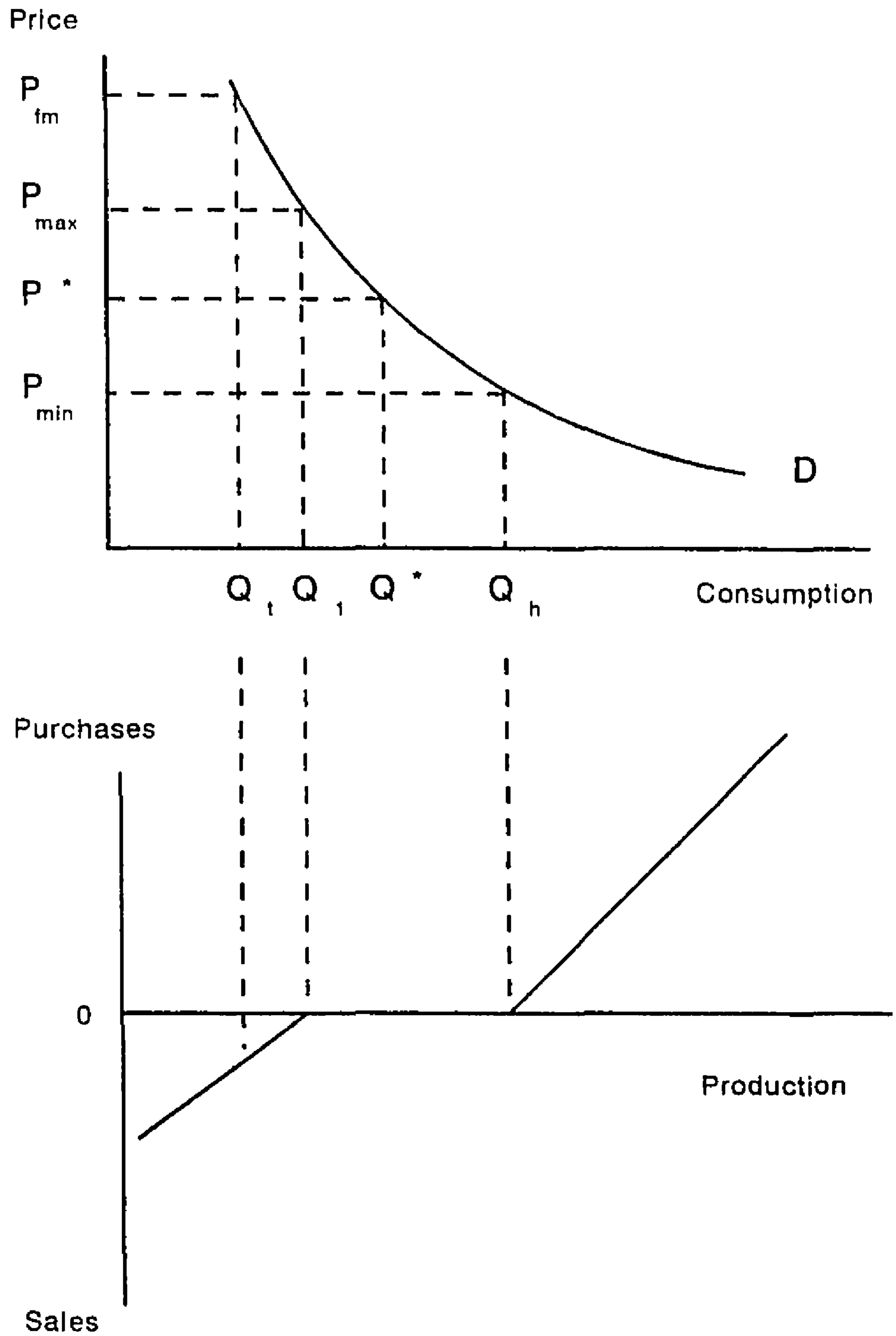

Fig. 3.3 Net Purchases with Price Band/Buffer Stock Policy

Source: Pinckney (1988)

Buffer stocks reservation demand is zero at prices above \$3.40, constant at some value say 20 (upper limit set in terms of size of stock) at prices below \$2.60 and between 0-20 at prices \$2.60 and \$3.40. The problem with this method in practice is that purchase and release rules are sub-optimal, that is, the buffer stock authority does not intervene to support prices soon enough, and when it intervenes, it tends to hold prices too high for too long (Gardner, 1979).

The Inter-Ministerial Working Group (Kenya, 1983) utilised this method with a simulation approach to measure the costs of different policy options. They assumed that the government had a target price p^*, and set a maximum price, p_{max}, at which the government would promise to sell sufficient quantities of maize to meet demand (Fig. 3.3). A price P_{min}, would be set at which the government would buy all the maize offered for sale. Prices would then be allowed to fluctuate freely between P_{min} and P_{max}. This is best illustrated in Fig. 3.3. If production in a certain year, say t, is Q_t which corresponds to a free market price, P_{fm} greater than P_{max}, the government would have to sell Q_1 less Q_t, to keep the price at or below P_{max}.

The lower graph explains the relation between production and government purchases under this system, where the NCPB purchases all that is produced above Q_h, which makes up the difference between Q_1 and actual production. The Working Group (Kenya, 1983) chose P^* as the free market price during a normal weather production year, and the logarithms of P_{min} and P_{max} to be symmetrically distributed around the logarithm of P^*. Under this system, the rules for exporting and importing are difficult to choose, but the working group simulations followed past government practices and allowed stocks alone to trigger trade, so that they had S_{min} and S_{max} as the level of stocks that would trigger imports and exports, respectively. S_{min} was set greater than zero because it takes at least three months for imports to arrive in Kenya. But as Pinckney (1988) reports, the important parameter for purposes of dealing with production instability is (S_{max} - S_{min}), the difference between maximum and minimum stocks, not S_{min} or S_{max}, per se. The purpose of stocks is to act as a shock absorber, to move grain from a surplus production period to a deficit period.

Such price band/buffer stock schemes have been suspected to be inefficient. Newbery and Stiglitz (1981) have shown that since the government's tools in the buffer stock scheme do not respond to changes in the world price, it would seem that these policies may be even less efficient in an open economy.

3.3.1.2 Optimization Methods

Pinckney (1988) has listed four reasons for using optimization methods rather than simply simulating chosen policies as is done in the buffer stock method. First, he says there is a potentially infinite number of possible policies, and the choice of which to simulate will be to some extent an ad hoc activity. As Eaton (1980) points out, optimization is the preferred mode of analysis for screening many alternatives. Secondly, that optimization ensures the trade-offs between objectives are measured accurately. Thirdly, finding the optimal policy allows for measurement of the degree of sub-optimality of alternative policies, and then simulating it in the same way as a buffer stock scheme. He says this is important for policy recommendations, since administrative rules are generally easier to understand and implement, than those that are a result of optimization routines. Fourthly, that differences between the way the optimal policies and the administrative rules respond to the state of nature can be studied, and administrative rules adjusted in ways suggested by the optimal policies.

This method has its own limitations, since costs in terms of program development and analysis are considerably larger for simulation of administrative rules. But Pinckney argues that, the benefits gained from using this method should be weighed against the costs, and recommendations made thereafter.

At least two optimization techniques have been utilised to analyze storage problems: Quadratic Programming utilised by Bigman, (1985) (Bigman's Method), and Eaton (1980) (Eaton's Programming Method); and Stochastic Control Methods (also known as Dynamic Programming) utilised by Reutlinger, (1976); Rausser and Hochman, (1979), and Kendrick, (1981).

Bigman's method is used to find the optimal price band/buffer stock policy, hence, is useful when the government has already decided that a policy of this type is to be implemented (Pinckney, 1988).

Eaton's method requires that the problem be formulated with a quadratic or linear objective function, with linear constraints. Pinckney (1988) cites the shortcoming of this method as the unknown best specification of regression equations, so that given the results of the quadratic programming problems, it may be difficult to move ahead. He concludes that Eaton's method is not a true optimization technique, since there is no way to guarantee that the optimal specification for policy structure has been tested in the regression analysis.

Stochastic control methods, under certain specified conditions, are true optimization techniques, but they are difficult to apply since they involve solving continuous optimization problems by applying calculus techniques (Pinckney, 1988). These control methods are advocated for quantifying the impact of alternative buffer stock levels and storage policies on stabilising grain supplies and for estimating the corresponding benefits and losses to the concerned parties (Reutlinger, 1976). In his study on simulating the fluctuations in the consumption and price of wheat under various levels of storage, Reutlinger (1976) utilised stochastic simulation, and concluded that while the model is static, it can be used to analyze the projected impact of alternative levels of storage activity, as long as the appropriate assumptions are specified.

Given the estimated quantities and prices which obtain with and without storage, the model estimates the economic and financial benefits or losses attributable to storage and gains or losses experienced by producers and consumers each year. The calculation of annual gains or losses attributable to storage is illustrated in Fig. 3.4 (Reutlinger, 1976). The demand curve for grain is represented by D; Q_2 is the level of production in a year of plenty. A quantity, Q_2 - Q^*_2, is placed in storage; Q_1 represents the level of production in a year of poor harvests; Q^*_1 - Q_1 is released from storage. In a year of plenty, the prices are P_2 without, and P^*_2 with storage. In a year of poor harvests, the prices are P_1 without and P^*_1 with storage.

Assuming the purchases or sales from storage are valued at the market price, the cost of grain put into storage is $P^*_2(Q_2 - Q^*_2)$, areas F + D + E in Fig. 3.4. Similarly, the revenue from the grain taken out of storage is $P^*_1(Q^*_1 - Q_1)$, areas G + B + H in Fig. 3.4. As for producers gains and losses, when grain is put into storage, producers sell the same amount of grain but at a higher price. Their gain is $(P^*_2 - P_2)Q_2$, areas A + B + C + D + E in Fig. 3.4. Similarly, when grain is taken out of storage, producers receive a lower price; their loss is (P1 - P*1)Q, area K in Fig 3.4.

Reutlinger argues that consumer gains or losses can be measured in terms of consumer surplus. He points out that consumer's losses are of two kinds when grain is withdrawn from the market. With storage, they pay a higher price for the grain which they do consume (areas A + B + C in Fig. 3.4), and they are deprived of the amount of grain which is stored. Applying the consumer-surplus concept, the consumer loss due to the decline in consumption is measured by area D in Fig. 3.4. Using a similar argument, when grain is withdrawn from storage, consumers experience a cost saving on the grain which they consume (area K in Fig. 3.4). The additional grain consumed as a consequence of storage is measured by area I in Fig. 3.4.

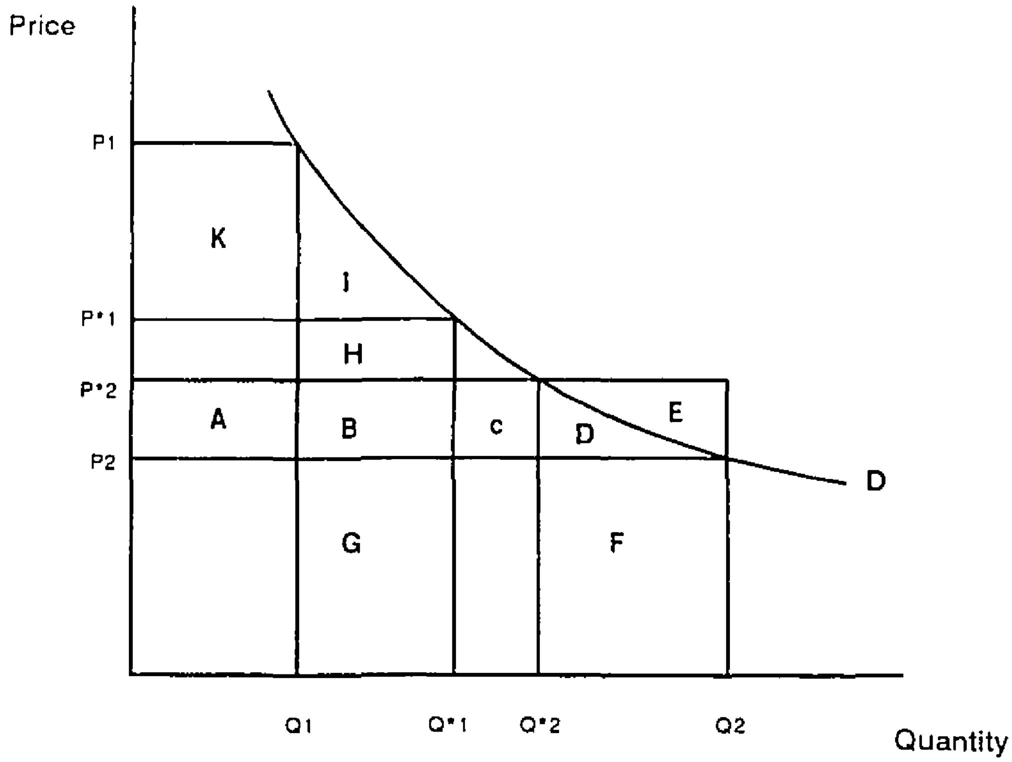

Fig. 3.4 Storage Benefits and Losses

Source: Reutlinger (1976)

Reutlinger also notes several limitations associated with these models: that the storage rules are crude, and more refined storage rules could increase the benefits (or reduce the costs) of operating storage schemes at any level; that production is assumed to be a random independent variable, whereas if production is characterized by systematic cycles the stabilization effect of a given level of storage capacity will be less than if year-to-year production is not correlated; that the model is static and abstracts from changes over time in demand and supply conditions which are relevant to projections in a dynamic world, but only under certain restrictive assumptions. Thus, because of the level of abstraction from reality, and because of its difficulty in the computations, Kim, Goreux and Kendrick, (1975), conclude that one cannot be certain the computations are correct when using this method.

However, to be useful, Pinckney (1988) notes that stochastic control methods have to be simplified, and at least two ways have been previously utilised: Certainty equivalence methods (Theil, 1957) and Dynamic programming (Bellman, 1957; Gustafson, 1958; Johnson and Sumner, 1976; Gardner, 1979)

Pinckney (1988), however, argues that the better method is dynamic programming. He points out that the derivation of the certainty equivalence theorem assumes that there are no inequality constraints, but that stocks, imports and exports are all strictly non-negative variables. He concludes that this non-negativity condition renders the certainty equivalence formulation unworkable. In addition, he goes on to show that from past studies (Arzac and Wilkison, 1980)[9], this method seems to overlook differences in production variability, whereas Gustafson (1958) showed that different results are obtained when variability in production is taken into account.

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[9]This reference is cited in Pinckney, (1988)

Dynamic programming involves making the problem discrete rather than continuous, and solving by means of backward recursion. It begins with a final year, t, in which there is no carry over of stocks, and according to Gardner (1979), this is usually the trick that makes the problem solvable, because in this final year, consumption equals supply, so that no allocation problem arises. This method can solve dynamic, stochastic problems which are similar to Kenya's problem of maize storage. This method also has an added advantage in that it allows inequality constraints on the variables, which do not have to be linear (Pinckney, 1988).

The limitations of this approach are, one, as a discrete system, inequality constraints are required on every variable (Pinckney, 1988); two, the objective function is complicated, since it is usually a single valued social welfare function, generally the sum of the present and the expected future consumers' and producers' surplus (Bigman and Yitzhaki, 1983), an objective function which Cochrane has criticised; and three, the curse of dimensionality (Bellman, 1957), which multiplies in difficulty with the number of possible states of nature in the model.

Other optimization techniques that utilize linear programming (LP) can be used to analyze storage problems. Multiperiod LP inventory models are dynamic, reflecting the fact that decisions made in one period affect not only that period's returns (costs), but also the allowable decisions and returns in future periods as well (Eppen et al, 1988). Multiperiod inventory models can either be deterministic or non-deterministic. Deterministic models are those where demand in each future period is assumed known a priori, whereas non-deterministic models are those in which demand in each future period is not known a priori. In general, the structure of such models is complex; because interactions are occurring between large numbers of variables (Eppen, et al, 1988). For example, inventory at the end of the period, say t, is determined by all production decisions in periods one through t .

Fig 3.5 adapted from Eppen et al (1988) illustrates a multiperiod inventory control model similar to the one used in this study. From the figure, the stocks at the beginning of period i are (I_{i-1} + X_i), where I_{i-1} represents the carry-in stocks from the previous period, and X_i represents the total production in period i. K_i represents a constraint on total production, for example, a capacity constraint. I_i represents the carry-over stocks from period i to period i+1 (i.e, the next period), whereas di represents the total demand in period i.

In this model, the total stocks available for saie in period one are the carry - in stocks, I_{i-1} , plus the total production in that period, X_i. With demand at d_i, the available stocks are then run down from (I_{i-1} + X_i) to I_i, which becomes the carry - over stocks to the next period. The capacity constraint is not limiting in this case as is shown by K_i - X_i, which is the excess capacity.

This type of model is utilised in this study to analyze the costs of the storage program for maize in Kenya. The advantages of these types of models are that they are easy to use, and utilize linear programming techniques, which are straight forward and easily available. However, as noted by Hazell and Norton (1986), in solving linear programs, all the objective function and constraint coefficients, and the right hand side values of the constraints are assumed to be known constants. This is a shortcoming since the user may not always be sure of the data, particularly the forecasts of activity incomes. They also note that the variability in some of the coefficients such as prices and yields may vary from year to year because of weather or economic changes. Nevertheless, they propose that one way of dealing with uncertainties in the data is to solve the model for realistic sets of assumptions in order to determine the stability and/or robustness of the optimal plan.

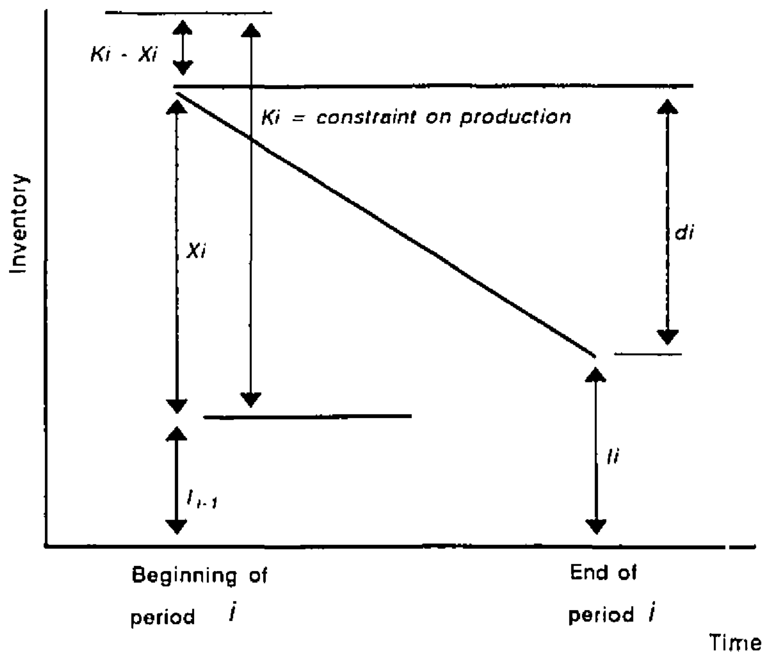

Fig 3.5 Multiperiod Inventory Control Models:

An example

Source: Eppen et al, 1988

3.4 MODEL SPECIFICATION

This section presents the methodology used to analyze the problem identified in the study. A general overview of the model with the assumptions, will first be discussed, and then the specific model relevant to this study will be developed, together with a detailed description of the objective function, activities and constraints.

3.4.1 The Model: A General Overview

The model used in this study is a multiperiod inventory model, using linear programming as the optimization technique. Multiperiod models have sometimes been applied to dynamic problems, because they reflect the fact that decisions made in one period affect not only that period's returns (and/or costs), but also the returns and costs in future periods (Eppen et al, 1988). This multiperiod inventory model is described as a classical deterministic single-product inventory problem, and is noted as deterministic because it is assumed that demand[10] in each future period is known at the beginning of period one. The model works at minimizing the costs associated with satisfying this known future demand.

The objective function of the model in this study is to minimize the costs, expressed in real 1990 values, associated with carrying maize from one year to another over a period of eleven years. The major activities within the model include maize purchases and sales, both in the local and international markets, and inventory holding. Four scenarios are utilised to analyze the effect of changes in inventory on total costs. The scenarios are characterised by the introduction of constraints that require the NCPB to purchase a given percentage of maize as

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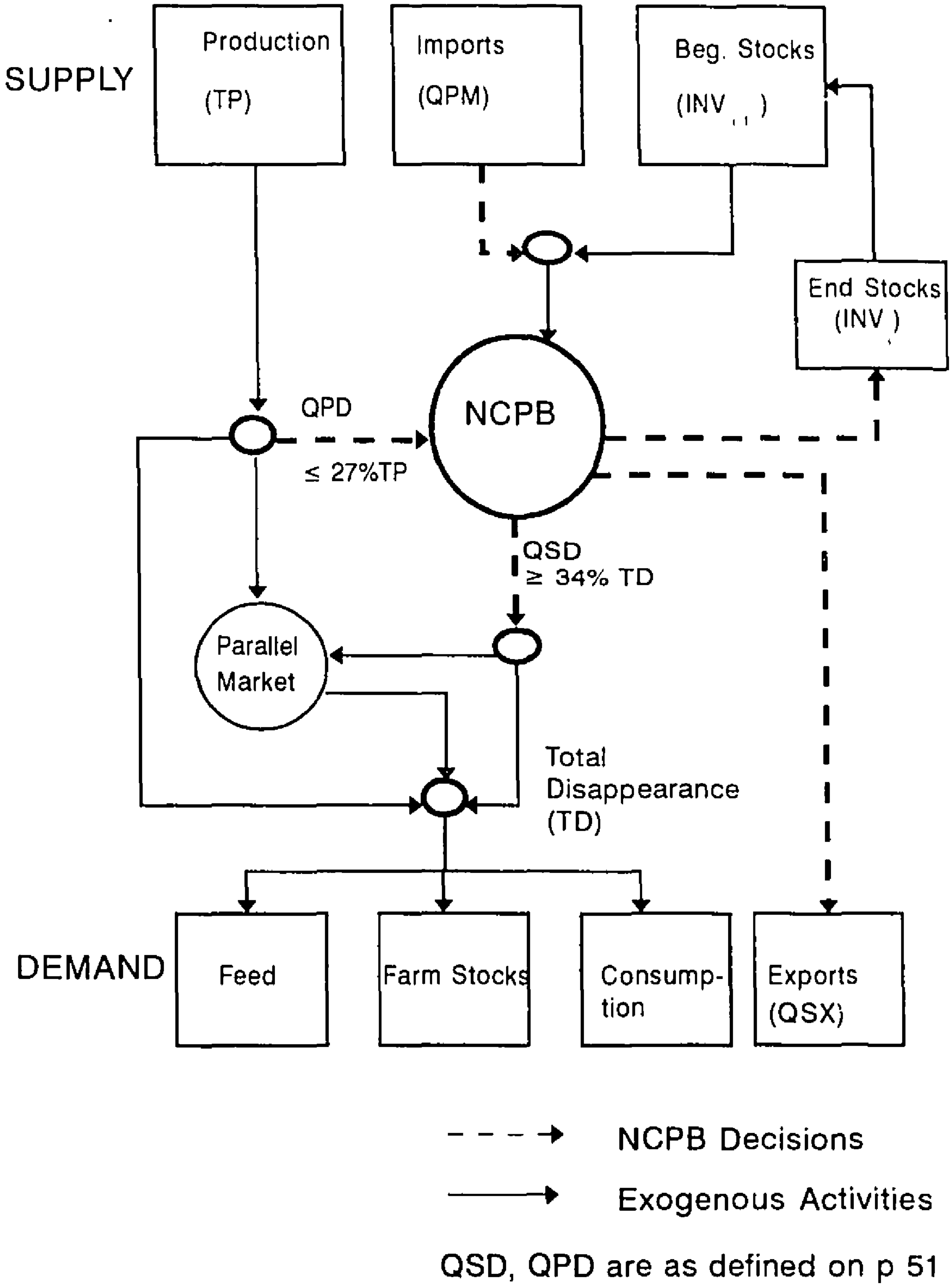
[10]For the purposes of this study, demand and disappearance will be used interchangeably; but it is understood to denote disappearance

supply security (0, 17, 25 and 33 per cent), based on known disappearance.

The flow chart in Fig. 3.6 illustrates the activities within the model. On the supply side, maize flows into the NCPB are drawn from three basic sources, local production, imports and beginning stocks. Based on past performance, the NCPB can purchase at most 27 per cent of local production, the rest is either used for home consumption, as livestock feed, stored on the farm, or channelled into the parallel market, and ends up in the same end use. On the demand side, the NCPB services at least 34 per cent of domestic disappearance, which may end up as final consumption, as livestock feed or stored on the farm; or in the parallel market. It is important to note that under normal circumstances, total production (TP) is higher than total disappearence (TD). This means that 27 per cent of local production available to the NCPB is able to cover the requirements for 34 per cent of domestic disappearence, unless it is a short crop year. The model also makes decisions on exports by the NCPB, and inventory at the end of the year.

The activities in the model are summarised as: on the supply side, how much maize to purchase from the local market and how much to import; and on the demand side, how much maize to sell to the local market (at least 34 per cent), how much to export and how much to put in inventory at the end of the year.

The major constraints include storage capacity; the requirement for the NCPB at least to break-even each year; the inventory equation; the requirement to satisfy known demand faced by NCPB during the year; supply security constraints; a constraint that defines the availability of domestic maize supply; and, a constraint to define the market share of the NCPB. The inventory equation is an expression that shows the inventory on hand at the end of each period. This is important because there is an inventory charge that contributes to total costs in the objective function.



QSD, QPD are as defined on p 51

Fig.3.6 The Model: An Overview

3.4.2 Assumptions

i. It is assumed that total production and disappearance are known at the beginning of each period, and are exogenous to the model. It is also assumed that the demand for maize is perfectly inelastic during the entire period of study.

ii. NCPB domestic prices are controlled by the government, and are set annually, at the beginning of each year, before the planting season, whereas in the parallel market, free market prices, exogenous to the model, are assumed. Import and export prices used are free market prices quoted at US Gulf Ports for no. 2 yellow maize, with freight, insurance and handling costs added (in the case of imports), and subtracted (in the case of exports), up to and including Nairobi NCPB depot.

iii. The NCPB does not have to buy all maize offered for sale, or sell all maize demanded, any requirement beyond that which the NCPB is able to provide is assumed to be provided by the parallel market. Because of this, the NCPB does not have to carry inventory from one period to another.

iv. The NCPB has to at least break-even on an annual basis. This is unlike past experience where the government has had to subsidise the NCPB from time to time.

v. The capacity for storage is assumed fixed within the period of study.

vi. One third of the stocks in inventory are renewed every year (MoSM, 1989).

vii. There is a white maize preference by the Kenyan consumers, but the model does not take into consideration this preference, and treats white maize as a perfect substitute for yellow maize.

The notation in this section will be as follows:

CC_i = Carrying Costs

i = Time period in years

INV_{i-1} = Inventory carried in from the previous year

INV_i = Inventory carried over at the end of the year

K_i = the maximum amount of maize that can be stored because of capacity limitations.

P_{Di} = Domestic buying price of maize

P_{Mi} = Import price of maize

P_{SDi} = Domestic sales price of maize

P_{Xi} = Export price of maize

QPD_i = Quantity of maize purchased domestically

QPM_i =Quantity of maize purchased internationally (imports)

QSD_i = Quantities of maize sold domestically

QSX_i = Quantities of maize sold internationally (exports)

TD_i = Total disappearance (demand) in year i

TP_i = Total production of maize in year i

3.4.3 The Objective Function

The objective function minimizes the costs associated with maize purchasing and holding inventory for the years 1980 to 1990. The results show the costs associated with each year, the quantities purchased domestically and imports in each of those years.

The objective function was formulated as:

$$\mathbf{Min\ C = \Sigma^{11}_{i=1}\ COSTS_i} \quad \text{Exp 3.1}$$

where:

C = total costs for the years 1980-1990, expressed in real 1990 values; and

$$COSTS_i = P_{Di} * QPD_i + P_{Mi} *QPM_i + INV_i * CC_i \quad \text{Exp 3.2}$$

The model also determines the quantities carried over from one period to another, given the costs associated with carrying these quantities. The carrying costs include interest charges and storage losses (estimated at 2 to 3 per cent per year).[11]

3.4.4 The Constraints

1. Capacity Constraints

There is need to specify a contraint that limits the quantity of maize that will be put in storage (because of capacity limitations). Kenya does have an extensive capacity for maize storage which has been suspected of being too large. The inclusion of this constraint not only acts as a capacity limitation, but also serves to test whether the storage capacity in Kenya is, in fact, too large, thereby increasing the unit carrying costs due to under utilization.

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[11]Some of the carrying charges, namely, fumigating and handling charges are not included in the CC because of lack of data.

Ki denotes the maximum amount of maize that can be stored. The constraint was expressed as:

$$\mathbf{QPD_i + QPM_i + INV_{i-1} \leq K_i} \text{ .... Exp. 3.3}$$

2. Break-even Constraints

This constraint enables the model to ensure that the NCPB operates at least at break-even point each year, that is, no losses being allowed. This constraint was included specifically to give the model an incentive to sell maize, either to the domestic market or to the international market. It is desirable for the NCPB to break-even at the lowest possible cost, therefore enabling it to sell maize to consumers at the lowest possible price. Again, as discussed earlier, domestic prices, both NCPB buying and selling, are set by the government. However, the international price is the free market price, quoted at Gulf Ports, US no. 2 yellow maize, that is adjusted for freight, transport and handling charges at Nairobi NCPB depot. The export price[12] is the international price less transport, freight and handling costs, whereas the import price has these costs added to it (Appendix 1, Table.1-A).

The break-even constraints are therefore expressed as:

$$\mathbf{\{ (P_{SDi} * QSD_i) + (P_{Xi} * QSX_i) - (P_{Di} * QPD_i) - (P_{Mi} * QPM_i) - (CC_i * INV_i) \} \geq 0} \text{ .... Exp. 3.4}$$

3. Inventory on Hand

A constraint to determine the inventory on hand at the end of each period

[12]Pinckney (1988) reports that the first 100 000 tonnes of white maize, such as that produced in Kenya, usually fetch a premium price on the world market because it is a preferred commodity, but the model used in this study does not take into account this premium.

was developed. Since there is an inventory carrying charge, this quantity will clearly play a role in the objective function. Suppose that I_i is the inventory on hand at the end of year i. Purchases_i and Sales_i represent the quantities of maize bought and sold in year i, respectively. Then:

$$I_1 = I_0 + \text{Purchases}_1 - \text{Sales}_1 \quad \text{Exp. 3.5}$$

That is to say, the inventory on hand at the end of year 1 is equal to the inventory on hand at the end of year 0 (for which no carrying charge is calculated), plus purchases less sales in year 1. It is assumed that all demand faced by the NCPB must be satisfied, therefore the Sales_i represents total demand for maize from NCPB, both locally and internationally in year i. Using a similar argument, in general, we can derive the same equation for any period t as:

$$\mathbf{I_t = I_{t-1} + Purchases_t - Sales_t} \quad \text{Exp. 3.6}$$

from which one may derive the general expression:

$$\mathbf{I_t = I_0 + \Sigma^{t}_{i=1} \left(Purchases_i - Sales_i \right)} \quad \text{Exp. 3.7}$$

for any period t.

Exp. 3.7 relates the inventory at the end of period t to all previous purchases.

The specific constraint was specified as:

$$\mathbf{INV_i - QPD_i - QPM_i - INV_{i-1} + QSD_i + QSX_i \geq 0} \quad \text{Exp. 3.8}$$

4. Constraints that reflect satisfaction of total demand faced by NCPB

The quantity purchased in each period, together with the inventory carried in from the previous period, must be at least great enough to meet the demand in that period. In order to satisfy this condition in period one,

$\mathbf{INV_1 \geq 0}$;

This shows that for demand to be satisfied in period 1, inventory at the end of period 1 must be non-negative. Following a similar argument, in order to fulfil the condition that demand in any period i must be satisfied, it can be concluded that:

$$\mathbf{INV_i \geq 0} \quad \text{Ep 39}$$

That is, inventory at the end of period i must be non-negative.

5. Supply Security Constraints

Scenarios two, three and four require a prescribed proportion of total demand to be supplied by the NCPB, which is referred to as supply security in this study. Constraints that specify this amount were included. The main reason for including supply security constraints was to determine the trade-off between supply security and costs. The higher the supply security, the higher are the costs incurred in terms of holding inventory, and in some cases importation of the product. A minimum supply security quantity is needed to enable the NCPB to call for imports in case of a shortage, and have enough maize supplies to last until the imports arrive in the country[13].

The expressions for these constraints were:

$$\mathbf{QPD_i + QPM_i + INV_{i-t} \geq ß * TD_i} \quad \text{Ep 310}$$

where: ß represents the proportion of total demand required as supply security. For this study, the scenarios were represented by ß = 0 for scenario one, .17 for scenario two, .25 for scenario three and .33 for scenario four.

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[13]Imports take three months to arrive into the country from the time of placing an order to the time of reception.

6. Total Domestic Supply Constraints

A constraint is required to define the availability of domestic maize supply to the NCPB. The model can purchase maize from the domestic and international markets, but it will tend to purchase from the domestic market because of the relatively lower price at which the NCPB buys in this market compared to the international market. Although this may be beneficial in terms of cost reduction, in reality, only a fraction of the maize produced in the country is sold to the NCPB. The rest is either sold in the parallel market, or stored on the farm for home consumption. This constraint therefore aims at portraying the total quantities of maize available to the NCPB to purchase from the domestic market.

To arrive at a percentage of production that is available to the NCPB, the ratio of NCPB purchases to total production was calculated for each year over the period 1980 to 1990 (Appendix 2, Table 2-A). As explained in chapter one, the NCPB was mandated to buy all maize offered for sale, and to sell all maize demanded. Other than 1985, when the NCPB purchased 34 per cent of total production because of a special price incentive which followed the 1984 short year, the highest proportion purchased by the NCPB over the entire period was 27 per cent of total production. This is the percentage used as an indicator of the maximum share of total production available to the NCPB for the period 1980 to 1990. This constraint is therefore expressed as:

$$\mathbf{QPD_t \leq 27\% * TP_t} \quad \text{.......... Eq 311}$$

7. Domestic Sales Constraints

In a normal year, domestic sales by the NCPB do not exceed 20 to 25 per cent of total disappearance. In fact, the average market share serviced by the NCPB in normal years is about 21 per cent (Appendix 2, Table 2-B). In years of short crops, the share of the domestic market serviced by the NCPB rises to one third or more. A constraint is therefore required to define the market share of the NCPB.

The argument for the inclusion of such a constraint is that domestic sales should be at least large enough to meet domestic demand, or in this case, total disappearance. The explanation for such a variation is that during periods of abundance, the parallel market is able to meet most of the demand at lower prices than the NCPB where the prices are fixed and do not reflect market conditions. In periods of scarcity, prices in the parallel market increase and may be higher than NCPB prices, again because of price controls in the NCPB. This means it becomes the responsibility of the NCPB to satisfy the demand that would otherwise be satisfied by the parallel market under normal conditions. For this reason, this constraint defines NCPB's minimum market share, but uses the maximum ratio of sales to disappearance previously recorded. The use of percentage market share was to allow for the increase in volume of production during this period.

This constraint is therefore expressed as:

$$\mathbf{QSD_i \geq 34\% * TD_i}\text{[14]} \quad \text{.......} \quad \text{Eq 3.12}$$

8. Non-negativity constraints

These constraints are to satisfy the linear programming requirement of non-negativity.

[14] 34 per cent is used because this reflects NCPB's market share in periods of shortages.

3.5 DATA

3.5.1 Food Production and Consumption Data

The quality of data on both food production and consumption in Kenya may be unreliable (Pinckney, 1988). Lele and Chandler (1981), in reviewing the problems associated with formal analyses of food security issues in East Africa point out that it is important not to assume that all the data required are readily available and that the system is totally commercial. They conclude that one of the realistic approaches to national food security policies must be:

> '.........a combined exercise in "planning without facts," within the context of a complex marketing system and particular national policies.........',

(Lele and Chandler, 1981, 105). They also suggest a study to link the known hard data available, to the government estimates.

Pinckney (1988) points out that the only hard data available in Kenya are the purchases and sales by the NCPB, but that these series are not appropriate for use as proxies for total production. He reasons that since there exists a parallel informal market, the purchases and sales by the NCPB may not reflect total production and consumption of maize in the country. This is because they are forced to take a larger proportion of the crop during periods of good production and less during periods of glut, due to the differential prices offered in the two markets. Consequently, he concludes that NCPB purchases and sales may fluctuate much more dramatically than actual production.

Data series on production and consumption are available from several sources in Kenya, the main ones being the Kenyan government, and international organizations such as the U. S. Department of Agriculture (USDA) and Food and Agriculture Organization of the United Nations (FAO). Table 3.1 presents the series used by the Development Planning Division of the Ministry of Agriculture (DPD, MOA), together with the series used by USDA and FAO.

Table 3.1 Different Series of Maize Production in Kenya

Year	DPD, MOA '000 T	USDA '000 T	FAO '000 T
1980	1888.3	1750.0	1620.0
1981	2560.0	2200.0	1980.0
1982	2450.1	2340.0	2349.0
1983	2214.8	2000.0	2178.0
1984	1500.0	1700.0	1440.0
1985	2440.3	2700.0	2520.0
1986	2870.0	2730.0	2898.0
1987	2400.0	2416.0	2250.0
1988	3140.0	2761.0	2761.0
1989	3030.0	2925.0	2925.0
1990	2890.0	2700.0	2700.0

Sources: Based on data from Food and Agricultural Organization of the United Nations, *FAO Production Yearbook*, various issues (Rome: FAO, various years); U. S. Department of Agriculture, Economic Research Service, *World Indices of Agriculture and Food Production 1977 - 86*, Statistical Bulletin Number 759 (Washington D.C.: USDA 1988); U. S. Department of Agriculture, Economic Research Service, *World Agriculture Trends and Indicators, 1970 - 89*, Agriculture and Trade Analysis Division, Statistical Bulletin No. 815 (Washington D.C.: 1990); and Unpublished data from the Development Planning Division, Ministry of Agriculture, Nairobi.

Notes: DPD, MOA = Development Planning Division, Ministry of Agriculture; USDA = U.S. Department of Agriculture; FAO = Food and Agricultural Organization of the United Nations.

The fiscal year begins July 1st of every year, and ends June 30th of the following year.

The series are conflicting as one moves from one source to the other. For example, the FAO's time series data on maize produced differs from USDA's for most of the years, which in turn differ from DPD, MOA (Table 3.1).

The DPD, MOA series is built from the district and provincial estimates of maize made by Ministry of Agriculture officers in the districts. Pinckney (1988) reports that Goldman (1988)[15] used the provincial estimates to test for links between the NCPB sales and purchases series and the production series. The equations estimated had high R^2 - values, and all the t-statistics were significant at the 2.5 per cent level. He concluded therefore that the equations gave strong support to the DPD, MOA production series since they related the building blocks of that series to the only hard data available. He notes, however, that it is not possible to compare the competing series of USDA and FAO by comparable tests as they are not reported by province. Nevertheless, because the DPD, MOA is supported by Goldman's study, it was used in this study.

On consumption, Pinckney (1988) reports that there are no series linked to hard data, and that the best consumption series is a derived series that leaves out the critical variable of changes in private stocks. He also recognises that the series is more appropriately called disappearance as opposed to consumption, because important variables that make up consumption are unavailable, such as the magnitude of private stocks.

This study utilises disappearance data from U. S. Agency for International Development (USAID), Nairobi, because it was readily available. The data are derived by assuming per capita consumption of maize at 105 Kg, and 14 per cent of total production as non-food use, which includes livestock feed, pilferage and storage losses. The per capita disappearance is then multiplied by the population

[15]This reference is in Pinckney (1988).

figures for the year, and the end result is the total disappearance. Table 3.2 shows these figures.

Pinckney (1988) reports that there is virtually no evidence on the magnitude of private stocks in the country. However, he cites a survey held by the Integrated Rural Surveys of the 1970's having reported figures for private stocks held by small holders, but points out that the figures were derived from production and consumption numbers, and not from stocks.

Table 3.2 Derivation of Maize Disappearance series ('000 MT)

Year	Food Use (Disappearance)	Non-Food Use (14% of Production)	Total Disappearance
1980	1750.0	264.36	2014.4
1981	1818.8	358.40	2177.21
1982	1888.6	343.01	2231.65
1983	1990.8	310.07	2300.87
1984	2074.9	210.00	2284.91
1985	2110.1	341.64	2451.72
1986	2255.7	401.8	2657.52
1987	2262.6	336.00	2598.65
1988	2349.4	439.60	2788.98
1989	2434.4	424.20	2858.63
1990	2523.3	404.60	2927.86

Sources: USAID, *Comparison of FAO and USAID analyses of 1991/92 Maize Balance*, (USAID, 1992) Nairobi, Kenya, Unpublished; *The Family Planning Programme in Kenya Demographic Impacts and Expenditure Implications*, (Kenya, March, 1992), National Council for Population and Development, Ministry of Home Affairs and National Heritage;and Unpublished data from the Development Planning Division, Ministry of Agriculture, Nairobi.

Notes: Food use refers to the maize used for human consumption, and is derived by multiplying total population by 105 Kg of maize, because is assumed that each person consumes 105 Kg of maize per year; whereas the non-food use is assumed to be 14 % of total production. USAID = U. S. Agency for International Development, FAO = Food and Agriculture Organization of the United Nations, .

3.5.2 Data on Prices, Carrying Costs, Exchange Rates, the Consumer Price Indices and Interest Rates

The data on prices are presented in detail in Appendix 1, Table 1-A. It is important to note that all prices are adjusted for inflation using the consumer price index, with 1990 as the base year. The exchange rates are also included under this section.

In order to arrive at these prices, import and export prices were converted to Kenya shillings using the average exchange rate for each year. All the nominal prices (NCPB's purchase and sales prices, import and export prices and the carrying costs) were then adjusted for inflation using the consumer price index, with 1990 as the base year.

The Carrying Costs were arrived at by converting the inventory at the end of the year into values (that is, Inventory multiplied by the prevailing sales price). The value of inventory was then multiplied by the average deposit interest rates, in order to arrive at the opportunity cost of holding inventory. According to the NCPB's Planning Unit (NCPB, 1990), losses are estimated at 2 to 3 per cent of inventory. This study used the upper limit of 3 per cent. It is noteworthy that other important carrying costs such as handling and fumigation charges were not included in the carrying costs. This was due to the unavailability of the data.

Export and import parity prices were utilised in this study for the international maize trade in Kenya. Chapter Two gives a detailed discussion on how parity prices are arrived at; however, it is important to note that import parity prices are those which the farmers would receive if there was a national deficit of maize and prices for domestic maize were determined with no import or price controls. Similarly, export parity prices are those which would be received by farmers if there was a national surplus of maize and no government controls of exports and\or domestic prices. World prices for U.S. No. 2 yellow maize (fob U.S. Gulf ports) specified in current U.S. dollars are used as the import and export prices for each year.

In the case of the import price, freight charges are added to the world price of maize up to and including into-Nairobi depot[16], whereas for exports, the freight charges are deducted from Nairobi depot to fob, Mombasa.

The exchange rates used to convert the world prices (U.S dollars) to Kenya shillings, the Consumer Price Indices and the interest rates are from the International Monetary Fund Statistics Department (IMF, 1993).

3.5.3 NCPB Data

NCPB maize purchases, sales and inventory are the only hard data available on maize trade in Kenya. Hence, there was no problem associated with the procurement of these data. The data were from the NCPB's Forward Planning Division, and are given in Appendix 2, Table 2-C. The quantities given cover the period between July, 1st and June, 30th every year, which is the fiscal year for the NCPB.

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[16]Imported maize is expected to compete with domestically produced maize in Nairobi, a distance of about 600 Km from the main port of entry (Mombasa).

CHAPTER FOUR: ANALYSIS OF RESULTS AND DISCUSSION

4.1 INTRODUCTION

The model was run under four different scenarios; namely no supply security (Scenario One), two months (Scenario Two), three months (Scenario Three) and four months (Scenario Four), respectively. This was done to analyze the effect of changes in inventory on the total costs.

This chapter presents the results of the analysis in four sections. First, the constrained optimal quantities and costs suggested by the model for NCPB will be presented, with brief descriptions of each. Second, a comparison of the optimal quantities suggested by the model and the actual NCPB performance during the same period will be presented, again with a brief description of each. Third, the LINDO[17] output and a sensitivity analysis will be presented. Finally, a general discussion will follow, with details concerning the differences between actual performance and optimal quantities.

Scenario two involved the requirement to purchase two months worth of supply security. The results under this scenario showed no difference from the results under scenario one, because the optimal purchases under scenario one exceed the quantities required to provide two months of supply security. Hence, the constraint requiring two months of supply security is redundant and will not be discussed further (See Appendix Table 4 for quantities).

4.1.1 The notation in this section is as follows:

In Figures 4.1a through 4.3c, QPD represents the quantities of maize

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[17]Linear, Interactive, aNd Discrete Optimizer

purchased from the domestic market; QPM represents the quantities of maize imported; QSD represents the quantities of maize sold by NCPB on the domestic market; QSX represents the quantities of maize exported; INV represents carryover of maize from one year to another, and COSTS represents the total costs incurred by the NCPB in carrying out the maize transactions.

In Figures 4.4a through 4.4d, QPD-0, QPD-3 and QPD-4 represent quantities of maize purchased from the domestic market under scenarios one, three and four respectively, and QPD-Actual represents actual quantities of maize purchased by NCPB from the domestic market; QPM-3 and QPM-4 represent quantities of maize imported, and QPM-Actual represent actual quantities of maize imported by the NCPB; QSD-0, QSD-3 and QSD-4 represent quantities of maize sold on the domestic market under scenarios one, three and four respectively, and QSD-Actual represents actual quantities of maize sold on the domestic market by NCPB; QSX-3 and QSX-4 represent the quantities of maize exported under scenarios three and four respectively, and QSX-Actual represents actual quantities of maize exported by NCPB; INV-0, INV-3 and INV-4 represent inventory carried over from one period to another under scenarios one, three and four; and INV-Actual represents actual inventory carried over by the NCPB from one period to another.

In Figure 4.4e, 0-month SS, 3-month SS and 4-month SS represent the total costs incurred by the NCPB under scenarios one, three and four respectively, whereas Actual represents the actual total costs incurred by the NCPB.

The monetary values in this section are given in the Kenyan local currency, the Kenya Shilling (KShs).

4.2 OPTIMAL QUANTITIES AND COSTS

4.2.1 Scenario One

Scenario one involved minimizing the costs for NCPB, without requiring any supply security stock to be bought. This means that the model was not required to purchase a minimum amount of stock for use as supply security, instead it was allowed to purchase the minimum amount required to satisfy demand in each period.

The results are presented in Fig. 4.1a for optimal quantities traded during the 1980 to 1990[18] period, whereas the costs associated with these quantities are presented in Fig. 4.1b. From Fig. 4.1a, it is observed that, except for 1982, 1983 and 1984 the quantities purchased domestically as suggested by the model are just enough to meet demand, (i.e, the quantities sold domestically). The 1982 crop was an exceptionally good one, and the model responded by purchasing a large amount of maize from the domestic market and storing it in form of inventory. Demand in 1983 was satisfied by purchases during the year plus inventory carried from the previous year. However, it is important to note that there was inventory carried over at the end of this period into the following year (1984). This inventory was then added to the quantities purchased domestically that year in order to meet demand. This is because 1984 was a drought year, and the total quantities available for sale to the NCPB were below the average for a normal year, consequently, the model called for inventory to be carried from the previous two years in order to meet this shortage.

Except for 1982 and 1983, the model suggests no inventory in the basic solution. There is also no external trade suggested, that is, there are no imports

[18]The 1990 figures cover only up to June 30th, 1990; the end of the fiscal year for the NCPB.

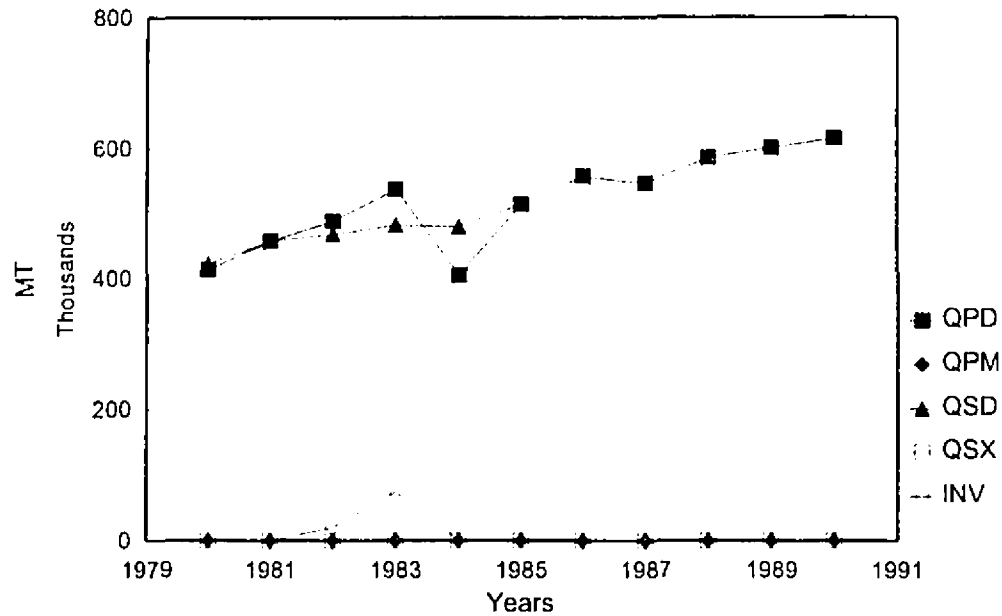

Fig. 4.1a Optimal Quantities
Under no Supply Security

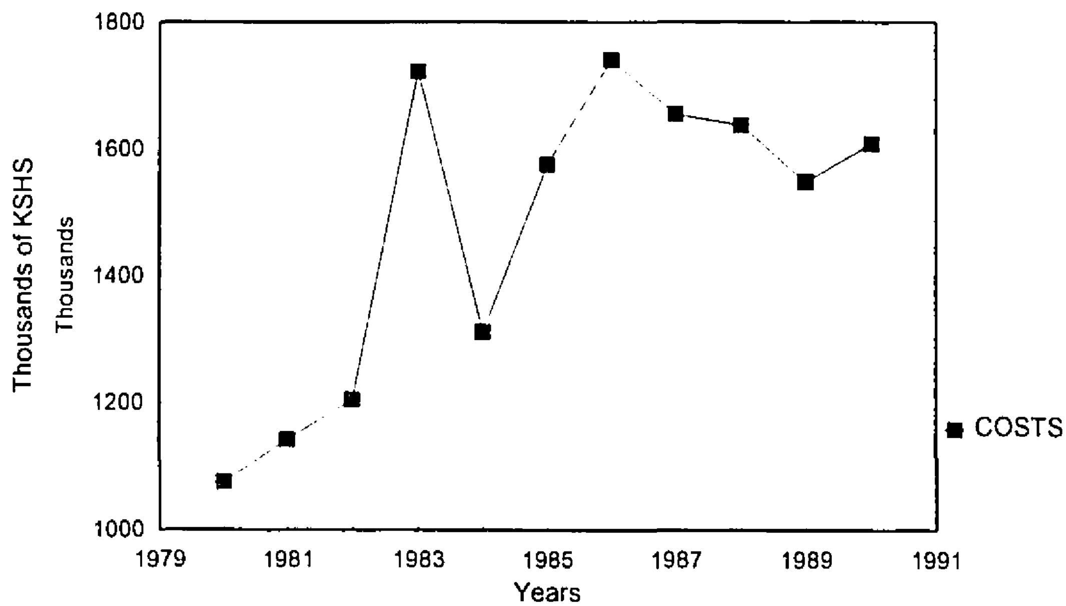

Fig. 4.1b Total Costs
Under no Supply Security

and exports for the entire period of study under this scenario.

The costs under this scenario are as shown in Fig. 4.1b. These are real 1990 values. Note that the cost graph reflects the quantities traded during the same period. There was a sharp increase in costs in 1983 because of the inventory that was carried in from the previous year, and that carried over to 1984, during this period. These increased costs in inventory helped reduce the costs that would have been incurred by importing in the short year of 1984. The general trend of the cost curve increases over time despite the quantities traded remaining relatively constant. This is because the prices of maize have generally tended to increase from the early 1980s to the 1990s, which contributes to an upward sloping cost curve for the NCPB.

4.2.2 Scenario Three

Scenario three required that at least three months worth of supply be purchased. The results under this scenario are presented in Fig. 4.2a and 4.2b. The optimal solution is different from that under scenario one, because the supply security under this scenario exceeds the optimal purchases under scenario one. Except for 1981, the period between 1980 and 1984 experienced higher purchases than sales. However, there was a production shortage in 1984, and the sales were higher than purchases during this period. Inventory carried in from the previous year was released to cover for the short crop. The short crop is evidenced by the NCPB purchasing all the maize offered for sale in 1984, which however, was not enough to meet the demand. In 1985 and 1986, the purchases suggested are just enough to cover sales, but after 1986, the purchases increase while the sales remain relatively constant. This increase is absorbed into the inventory.

Inventory in this scenario is an integral part of the optimal solution for each year, because of the supply security requirement. The inventory quantities increase

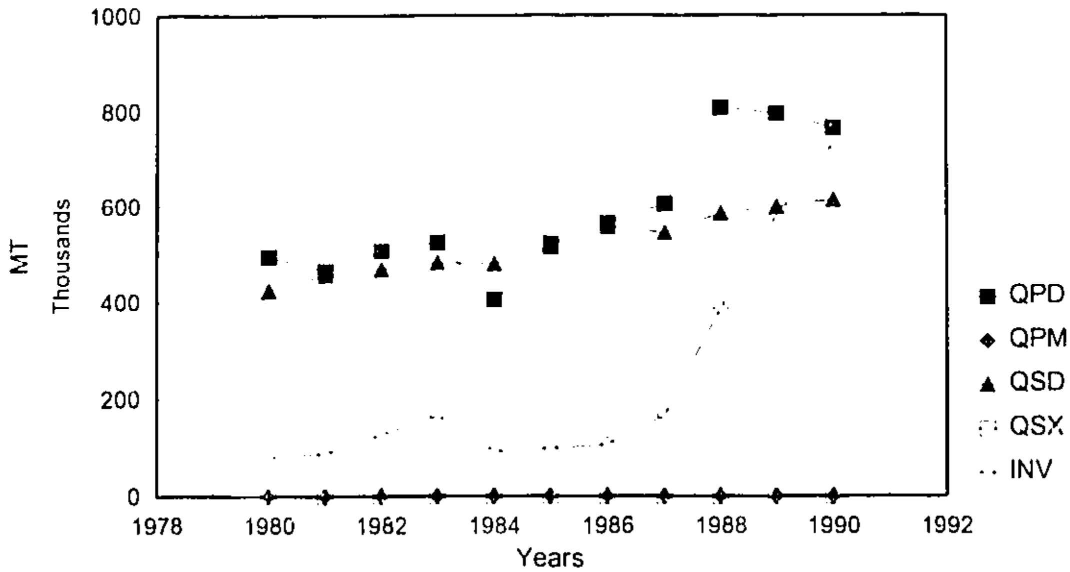

**Fig. 4.2a Optimal Quantities
Under a 3-Month Security Level**

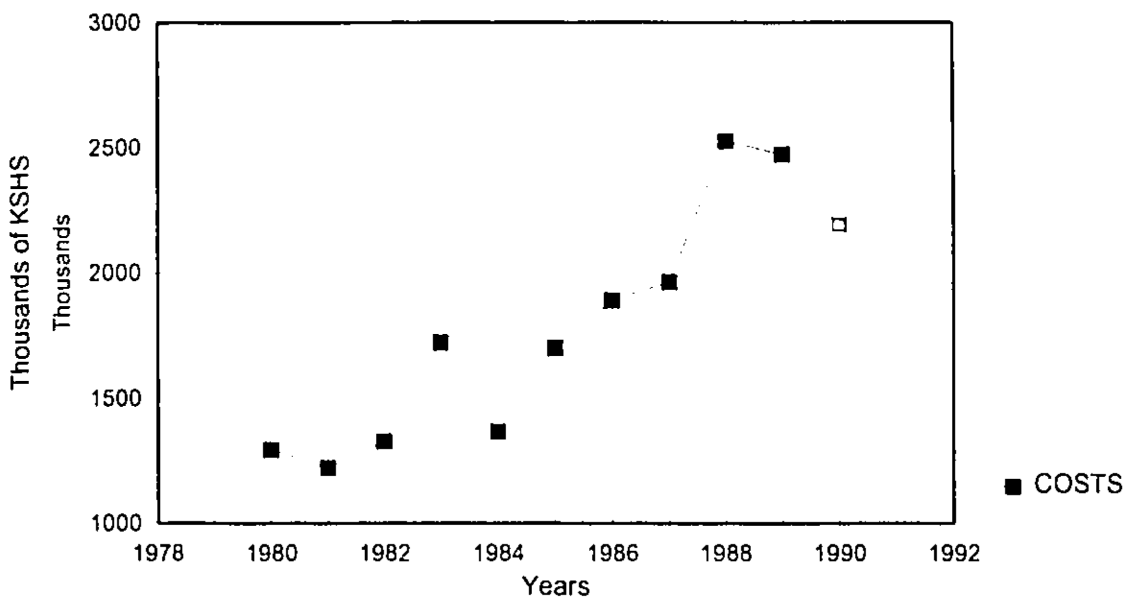

**Fig. 4.2b Total Costs
Under a 3-Month Supply Security**

slightly in 1982 and 1983, because of the short crop in 1984. It is noted that except for 1983 and the period after 1987 to the end, when the inventory shows a marked increase, the inventory in the other years remains relatively constant. This reflects the supply security requirement of three months. As explained, inventory increase in 1983 was due to the sensitivity of the model to the short crop of 1984. However, the increases in inventory from 1987 to 1990 were due to the constraint imposed on the model under this scenario in the last year of 1990. It was required to carry inventory worth at least three-months of supply security. This was in order to stop the model from selling all the stock in the last period. The model responded by stocking up on inventory from 1987 to 1990, hence the increase in inventory during this time. A three month-supply security was utilised because it takes two months for imports to arrive into the port of Mombasa, and due to other delays in handling and distribution, it could take another one month for these imports to reach the consumer.

As in scenario one, foreign trade is not included in the optimal solution. This is because of the prohibitive import costs when compared to the cost of local purchases. On the other hand, exports are excluded because the world market sales price of maize, after deducting freight charges is below the local sales price (that set by the government and utilised by the NCPB). It is also lower than the local purchase price, which implies that by exporting, the NCPB would be losing money. Consequently, the model excludes exports from the basic solution (refer to section 3.5.2, p 61, for an explanation on the derivation of import and export prices).

The costs under scenario three are obviously higher than in scenario one, but the trend of the cost curve is generally the same under both scenarios. The increase in costs is ascribed to two main factors. One, the inventory lacking in scenario one is part of the optimal solution under this scenario. Since there is an inventory carrying charge, the costs increase to accommodate the carrying costs associated with the increase in inventory. A second source of increased costs are the increased purchases under this scenario. Appendix Table 5 shows the optimal quantities purchased under all three scenarios. In all the years except 1983, when the quantities purchased under scenario three are lower than those purchased under scenario one, and in 1984 when they are equal, purchases under scenario three are higher than under those under scenario one.

4.2.3 Scenario Four

The results for scenario four which required the carrying of four months worth of supply security are as shown in Fig. 4.3a for the quantities purchased and the inventory carried. Fig. 4.3b presents the quantities sold and 4.3c shows the costs associated with the activities under this scenario. The quantities include not only the carrying of inventory, but also external trade, that is, both imports and exports which are part of the basic solution.

However, the results under this scenario were infeasable. The reason for the infeasibility is attributed to the quantities of supply security being greater than the quantities available for purchase by the NCPB on the domestic market (Appendix Table 4). When the quantities available for purchase by the NCPB were increased for some of the years to at least equal to the supply security constraint under this scenario, the results were no longer infeasible. This seems to support the argument that international trade may not be a profitable substitute to self sufficiency in maize production. As shown in Appendix 1 Table 1-A, the purchase price for locally produced maize is lower than the import price, and the local sales price for maize is higher than the export price, hence the infeasibility.

Nevertheless, purchases from the domestic market as expected, are positive for every year, whereas, imports are positive for all years except 1983, 1986, 1988, 1989 and 1990. Inventory too, is positive for every year except 1980, when the model suggested no inventory. It was expected that the model would carry inventory every year because oı the requirement of a four month supply security, but the lack of inventory in 1980 does not conform to this expectation. The explanation for this is the infeasible results under this scenario. Since the model does not stabilize, meaning it does not complete the number of iterations necessary to arrive at an optimal solution, such results are expected. It is interesting to note that the general trend of inventory increases over time under this scenario, peaking in 1990, due to a constraint that required it to hold inventory worth at least three months supply (to constrain the model from selling all the stock at the end of the eleven-year study period).

Fig. 4.3b shows the quantities sold during this period, both in the domestic and the international markets (QSD and QSX, respectively). Except for 1980 and 1987, the domestic sales are relatively constant, with slight variations over the years. This reflects the stable demand for maize in the domestic market, at fixed prices. Except for the first two years and 1987, the local sales under this scenario are not very different from the sales under scenarios one and three (Fig. 4.1a and 4.2a respectively). The local sales increase in 1987 because of the increased imports during that year. There are exports (QSX) only in two years, 1981 and 1982, out of the entire eleven year study period. As noted earlier, the export price is lower than the local sales price of maize (section 3.5.2, p 61 and Appendix 1, Table 1-A). Hence, exports may actually be a loss to NCPB rather than a gain. This is because of the method used to calculate the parity prices.

The costs under this scenario are presented in Fig. 4.3c. They are higher than the costs under both scenario one and three because of the presence of foreign trade and a higher level of inventory due to the higher supply security. The highest costs occur in a year when there are imports (1987).

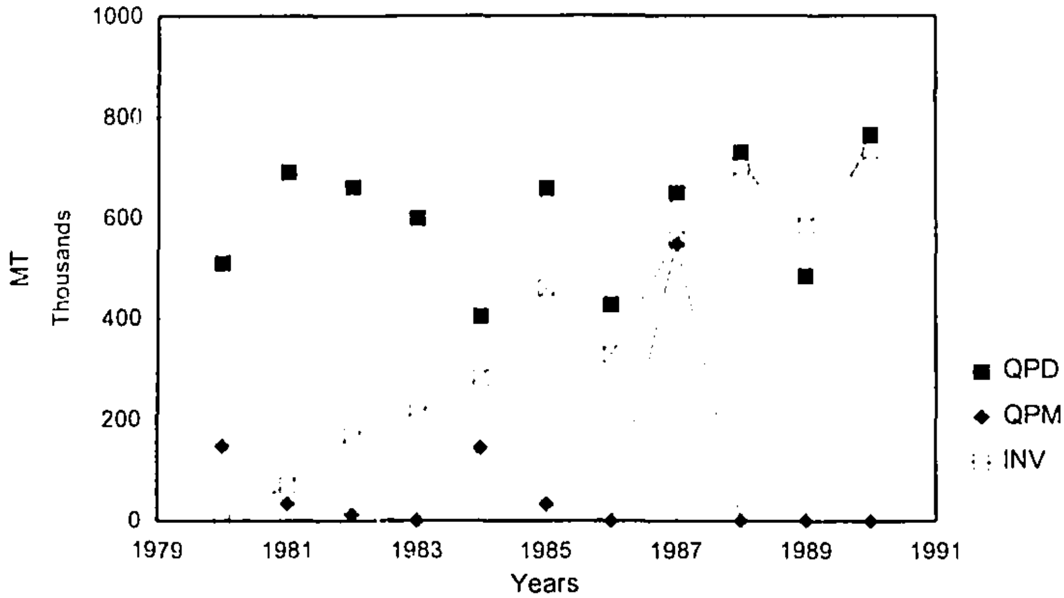

Fig. 4.3a Optimal Purchases & Inventory Under a 4-Month Supply Security

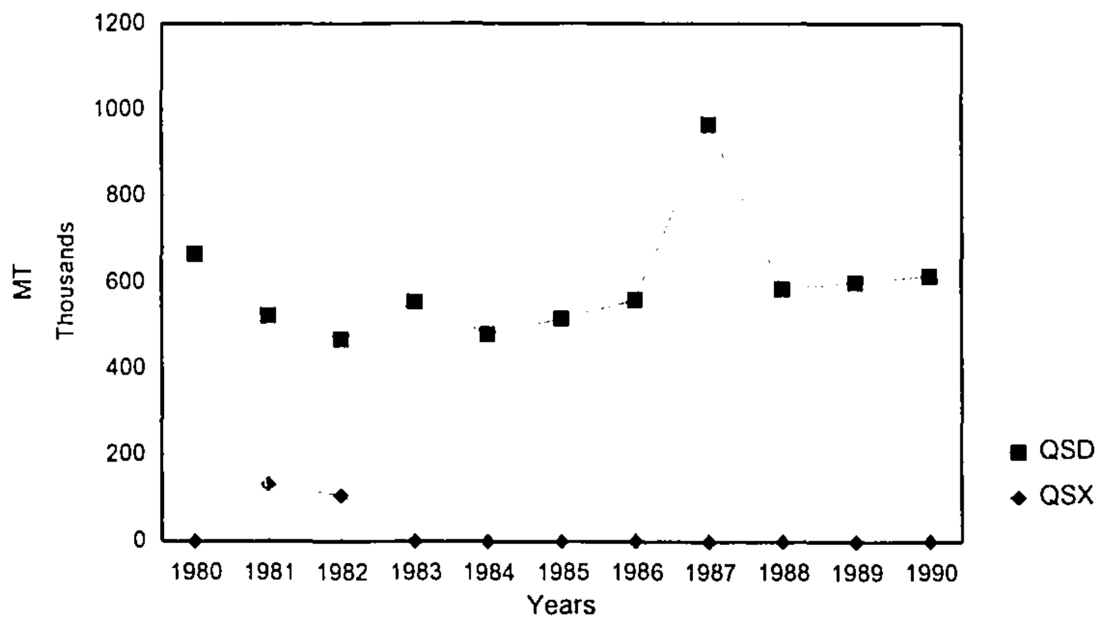

Fig. 4.3b Optimal Sales Under a 4-Month Supply Security

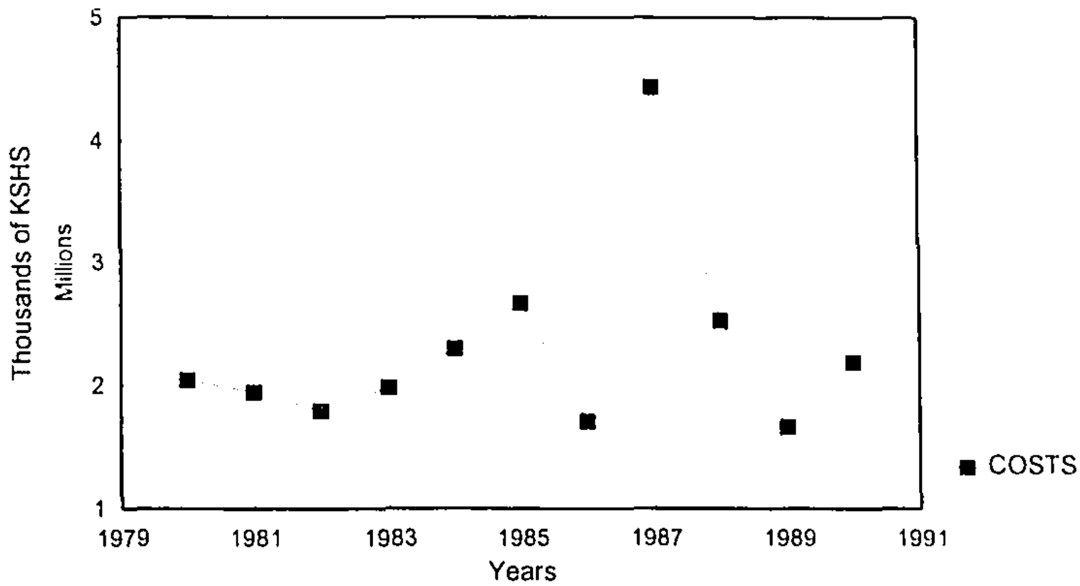

Fig. 4.3c Total Costs
Under a 4-Month Supply Security

4.3 OPTIMAL QUANTITIES VERSUS NCPB PERFORMANCE IN THE 1980s

4.3.1 Introduction

In this section, a historical analysis is presented, where the optimal quantities and costs suggested by the LP model are compared to the actual operations of NCPB for the 1980 to 1990 period. The disparities will be explained in brief, but a detailed explanation will be given under the general discussion (Section 4.5). The historical analysis allows for comparisons between the observed data and the optimal quantities generated by the model.

4.3.2 Domestic Purchases and Sales

A comparison was made between the quantities purchased under the LP model and the actual purchases by the NCPB. Similarly, quantities sold under optimal conditions were compared with actual sales by NCPB. Fig. 4.4a and b show these comparisons under the three scenarios throughout the 1980s.

It is noted from Fig. 4.4a that the optimal quantities purchased under scenarios one and three were generally higher than the actual NCPB purchases for at least six out of the eleven-year period of study. Furthermore, the purchases under these scenarios were relatively constant between years as opposed to NCPB purchases which show a wide variation from one year to another. This is due to the requirement by government policy that NCPB purchase all that is offered for sale and satisfy all demand. With such a policy, the quantity purchased by the NCPB would tend to move with the total production in the country; that is, as production increased, so did the quantity purchased and vice versa. This would mean that in years of abundant production, the NCPB was obliged to purchase more than it could easilv handle in terms of financial resources, whereas in periods of scarcity, the quantity purchased was greatly reduced (Fig 4.4a).

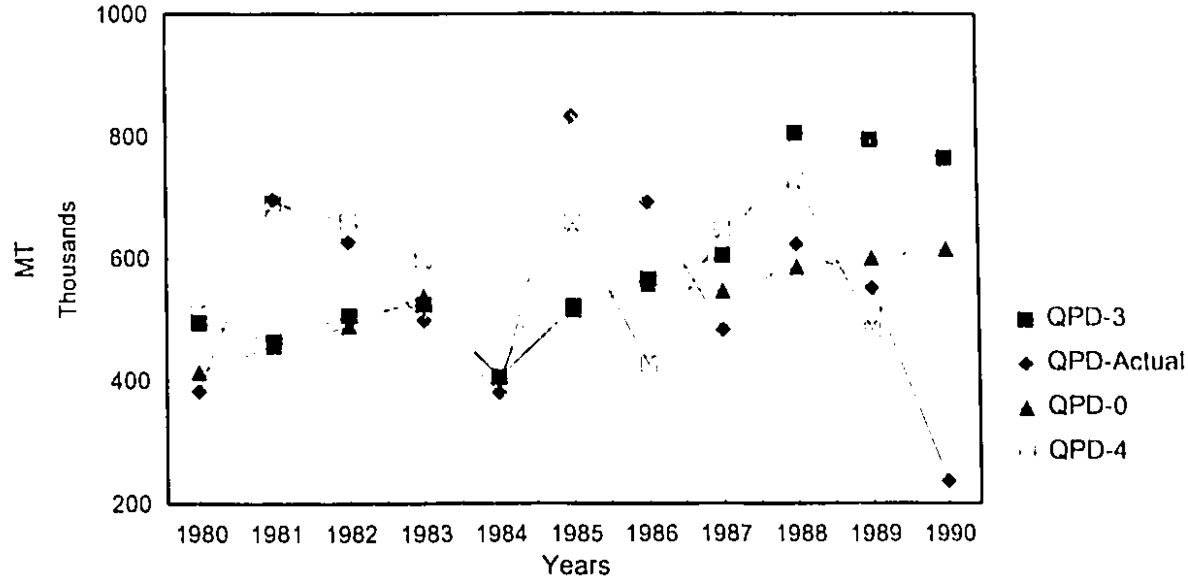

Fig. 4.4a Actual vs Optimal Quantities
NCPB Domestic Purchases

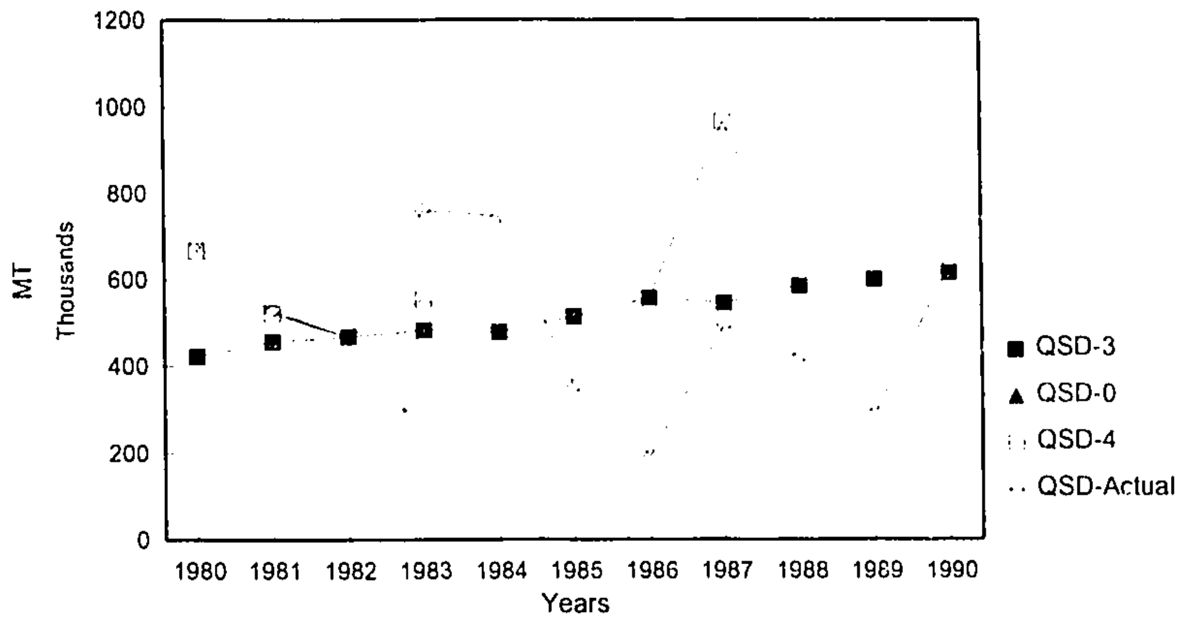

Fig 4.4b Actual vs Optimal Quantities
NCPB Domestic Sales

As discussed in an earlier section, in periods of scarcity, most of the maize is channelled to the parallel market where the prices are higher because they reflect free market prices. In the optimal solutions under scenarios one and three, the requirement for minimum costs limits the quantities purchased, and evens out maize purchases throughout the 1980s. It is noted, however, that the optimal purchases under scenario three increased for the period between 1988 and 1990. This was in order to meet the supply security requirement of three months.

While the variation in purchases is evened out under scenario one and three, scenario four does show a similar variation of purchases to that of the NCPB. As explained earlier, the results under this scenario were suboptimal, therefore it is not possible to make concrete conclusions on the movement of stocks based on these results.

Except for the years 1980, 1981 and 1987 of scenario four, optimal quantities for domestic sales under the three scenarios suggest that the NCPB sales for the early 1980s were too high, whereas for the latter part, they were too low (Fig. 4.4b). The actual sales for the early part of the 1980s were too high given that there were shortages in 1980 and 1984 which increased the demand for NCPB maize. This increase in demand is due to the price differentials between the official and parallel markets, the parallel market reflecting market determined prices, while the official market maintained fixed prices (Lofchie, 1988). On the contrary, the latter part of the 1980s were good crop years, hence the demand for NCPB maize was low. It is important to note that this model is not sensitive to the activities in the parallel market, which handles a significant amount of maize trade. The low NCPB sales after 1985 are attributed to lower prices in the parallel ıarket, which made NCPB maize relatively expensive.

The model worked to even out sales throughout the 1980 to 1990 period. This is because the constraint for quantities sold domestically requires the NCPB to meet at least 34 per cent of total disappearance. Consequently, all the sales reflect this disappearance, and because the disappearance is fixed, changing only from year to year as a function of the population, then optimal sales are evened out. It is important to note that 34 per cent is the highest percentage of total disappearance which the NCPB handled in the period between 1980 and 1990. This occurred when there was a domestic shortage in 1980 and 1984.

4.3.3 Inventory and External Trade

Fig 4.4c shows the inventory levels for NCPB under the different scenarios compared with actual performance. The results indicate that the actual inventory levels of NCPB were above those generated by the model under cost minimization in all the scenarios, except 1990. The optimal results for scenario one suggest that NCPB should not carry inventory, but rather purchase enough stocks to meet demand. This is expected since the supply security under this scenario is zero, and stocks would only serve to increase costs, hence, are not included in the basis. However, inventory was positive in 1982 and 1983. This is attributed mainly to the drought that occurred in 1984, which may have forced inventories to be carried in order to satisfy the demand in this period of low production.

The LINDO output suggests that the capacity level for the NCPB is too high, at least in relation to the levels of supply security considered here. This is evident from Table 4.1 (p 87), which shows the slack/surplus variables on the capacity constraints under the three scenarios. In all the scenarios, the capacity is not fully utilized, implying that the NCPB has too much capacity. The surplus could be utilized in other ways, such as leasing to private traders or millers.

Under scenario three, inventory was positive for all the years, but was much less than the actual quantities that were carried over by NCPB, except in the last year. As noted earlier, the model was constrained to hold inventory worth three months supply, in order to constrain it from going to zero in the last year. The main reason for carrying inventory under this scenario is in order to satisfy the supply security requirement of three months. Despite carrying inventory, the capacity constraint is not a limiting factor under this scenario. Note that the general trend of inventory under scenario three and four is increasing.

Under scenario four, as discussed earlier, supply security to cover four months was one of the constraints. The results, despite sub-optimal, show that inventory in all the years was positive, except in 1980, when the inventory was zero. The inventory carried under scenario four was less than actual NCPB inventory. Since the results under this scenario were sub-optimal due to the level of supply security required, and the share of domestic supply available, any supply security that is greater than four months will tend to be sub-optimal for the same reason. Under such a policy, the NCPB would be required to import maize in all the years to satisfy the supply security requirement, unless it is able to acquire more than 27 per cent of domestic supply (Appendix Table 4).

Under scenario three, the optimal solution suggested no external trade. This is attributed to the fact that the selling prices in the domestic market are higher and buying prices lower than freight-adjusted prices in the international market. Since the prices used in this study for international trade are adjusted for freight and handling charges, the import price is increased and the export price is reduced accordingly, making it unprofitable for the NCPB to participate in international trade. The NCPB utilizes government-set prices which may not reflect actual market prices, but fall within the band of adjusted export and import prices. It is possible that if market forces were the only determinant of maize prices, foreign trade may indeed become an integral part of NCPB's activities, without necessarily having to make losses. However, this would mean less price stability within the country with prices being much lower in surplus periods and much higher in periods of short supply.

Fig. 4.4d shows the actual external trade by NCPB compared to the optimal trade. It has been argued in the literature that imports cost the NCPB more than it receives for its sales (Pinckney (1988), Maritim (1982)), because the quantities imported are sold in the domestic market at the domestic price. The optimal solution of no trade under scenarios one and three support this argument. Further, the low international price of maize has been used as an argument against exports, and the optimal results under scenarios one and three which suggest no exports tend to support this argument. However, it is important to note that a given quantity of white maize fetches a premium price on the international market[19], but this was not incorporated into the export price in this study. Instead, the white maize was assumed to be a perfect substitute for yellow maize, resulting in a lower price than would normally be the case. It is important to also note that since the export price is adjusted for freight and handling costs, it is lower than the international price and even lower than the domestic price set by the government, hence, its exclusion from the optimal solution under the two scenarios. Even in the shortage periods of 1980 and 1984, the model under scenario one and three did not call for imports to cover the shortages, but instead increased inventory from the previous years to cover these shortages. It is important to realize that this works only in the case of perfect knowledge as assumed in this study. In real situations, unexpected shortages do occur from time to time, and a stochastic programming model would be more helpful in such cases.

Scenario four results had both imports and exports in the basic solution. Imports were positive in the early part of the 1980s, except in 1983. The positive imports in the early 1980s may be due to a reaction of the model to the short-supply years of 1980 and 1984. In comparing actual imports to those suggested in the model under this scenario, note that actual NCPB imports were positive and

[19]According to Pinckney, the first 100,000 tons of white maize fetches a premium price on the international market. This study does not reflect this difference.

absent in the same years as the model's imports were positive and absent, respectively, except 1982 and 1985, and 1987, when the imports were positive under scenario four and absent in actual NCPB performance. The exports under this scenario were positive in 1981 and 1982, while in actual performance, the NCPB exported maize in all the years except in 1980, 1981 and 1984.

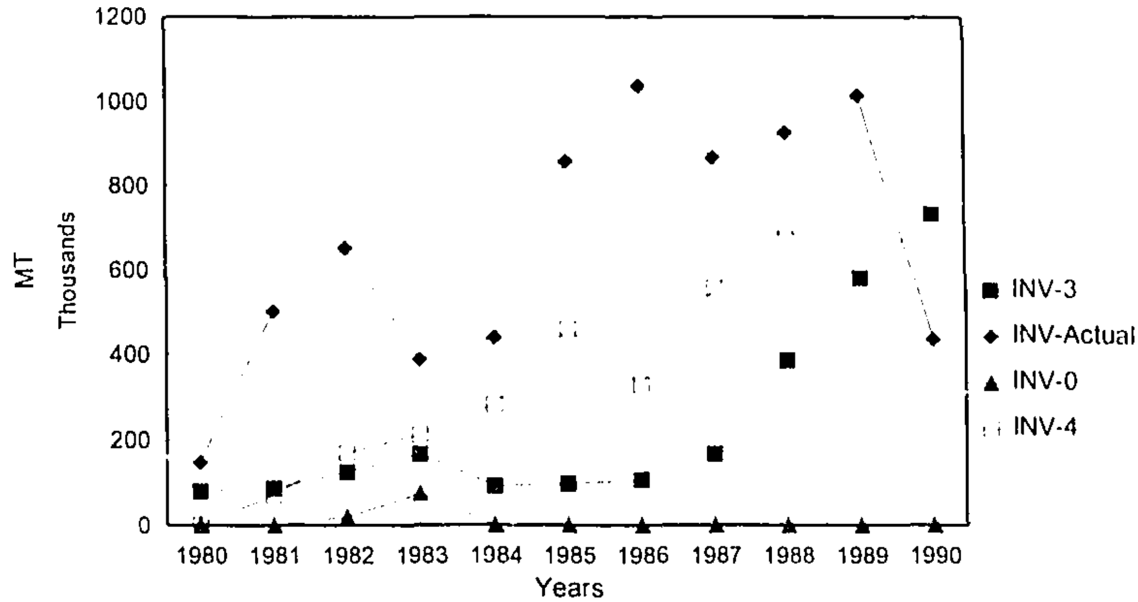

Fig. 4.4c Actual vs Optimal Quantities NCPB Inventory

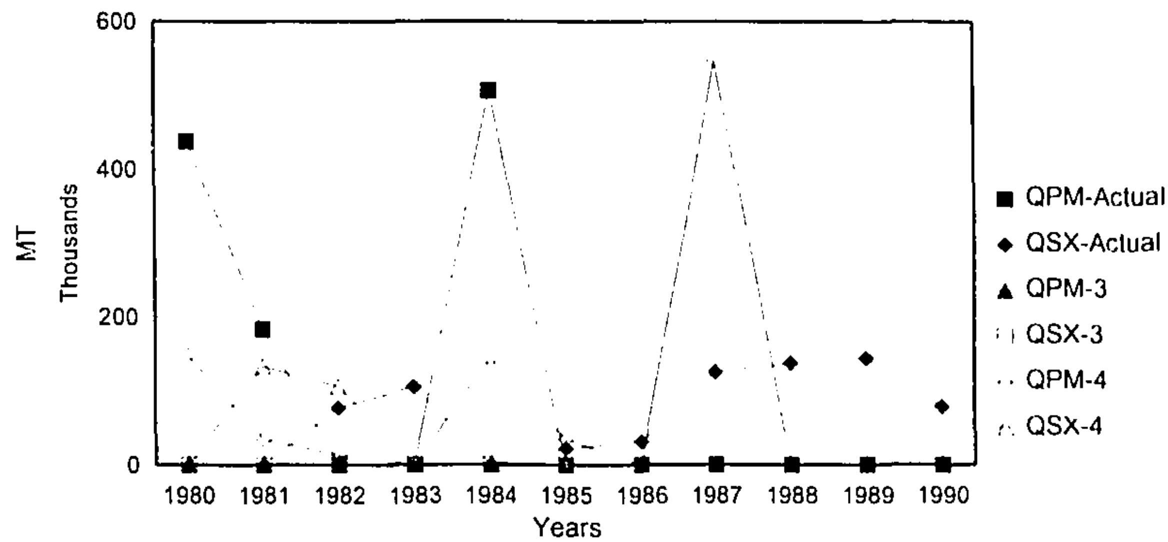

Fig. 4.4d Actual vs Optimal Quantities Imports and Exports

4.3.4 Costs

The costs incurred by the NCPB as defined in this study consist of the costs of procurement of stocks, both from the local market and internationally; and the carrying costs. As explained earlier, the carrying costs include interest charges and storage losses. Thus, the total cost for the NCPB is calculated per tonne per year.

Fig 4.4e shows the estimated costs under the three scenarios compared to actual costs incurred by NCPB for the period under study. For the period between 1980 and 1987, except for 1983, it is obvious that the actual costs incurred by NCPB are much higher than the costs generated by the model, as a result of the large quantities of maize transacted and stored during this period. As explained earlier, 1984 was a short crop year, and this forced the NCPB to import, which contributed to the high cost during this year. Apart from that, the inventory factor contributes to the cost differences, since the model included no carryover in scenario one, and carried less inventory than the NCPB under scenarios three and four.

Another factor that contributed to the increased costs was the external trade undertaken by the NCPB at an apparent loss (Fig. 4.4d). Maize was imported to cover the shortages that occurred in 1980 and 1984, and exported during some of the abundant supply years. However, according to the optimal results, external trade is totally excluded from the basic solution under scenarios one and three. It does occur under scenario four where its presence yields sub-optimal results. It may be suspected, therefore, that external trade must have been at a loss to the NCPB. This may occur because of the policy that governs the operations of NCPB: buying all that is offered for sale and satisfying all the demand. Farmers are not turned away even when it is apparent that enough stocks have been purchased during years of plenty. Increased quantities of maize are sold to the NCPB because of depressed prices in the parallel market at such times, and since the

NCPB price is the official price set by the government, it is held constant under all market conditions within the year.

The actual NCPB costs compare fairly closely with the model results after 1987, despite the constraints facing the NCPB, and the higher quantities of inventory. The difference between the operations of the NCPB and the model results during this period is the presence of exports under the former. The exports, although not fetching the same price as local sales, seem to reduce the overall costs, and therefore contribute to a reduction in total costs. Inventory costs increase too, under scenario three and four, therefore increasing the costs of these options during this period. According to Fig. 4.4f, the per unit cost of grain handled by NCPB is lower than the model's results under all the scenarios for every year between 1980 and 1990. This shows that despite the apparent high costs for the NCPB during the study period, on a per unit basis, they were the lowest. The NCPB's stock policy during the study period was to carry a minimum of 270 thousand tonnes of maize in inventory at all times, and to import every time the stocks fell below this level.

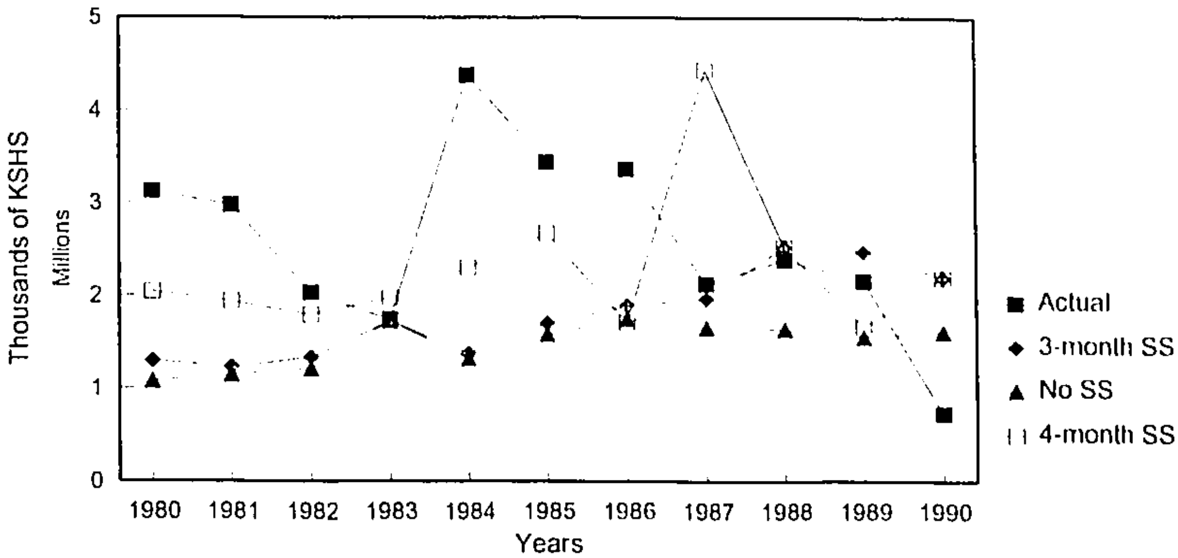

Fig. 4.4e Actual vs Optimal Costs

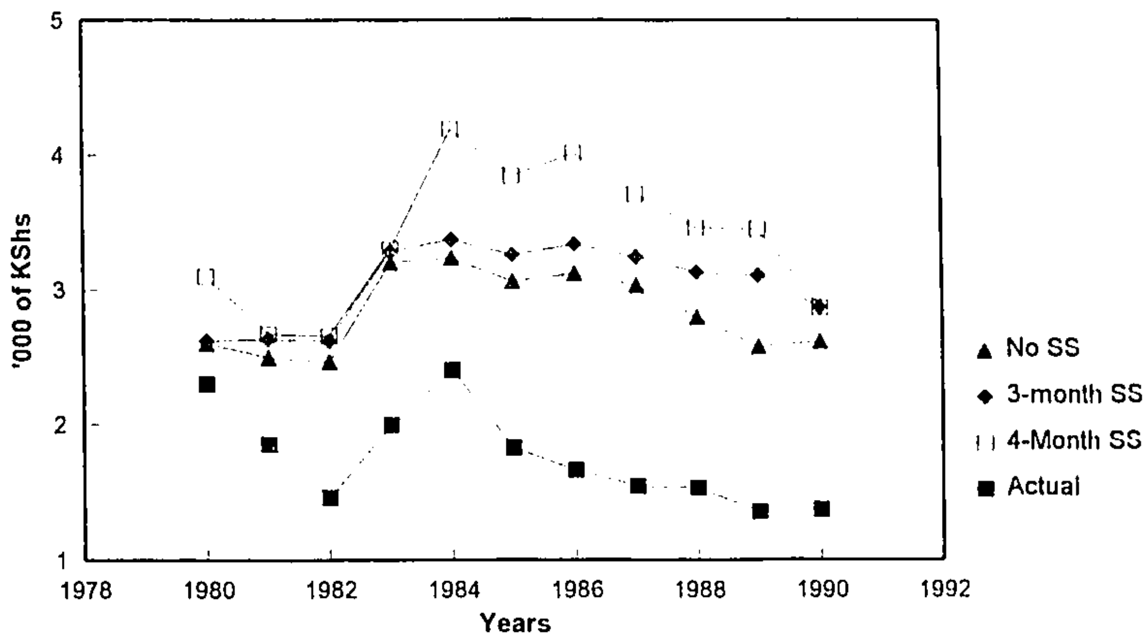

Fig. 4.4f Costs per Tonne of Grain Handled
NCPB vs Model Results

4.4 LINEAR PROGRAMMING SOLUTIONS

4.4.1 Introduction

LINDO not only provides information on the optimal decision variables and the objective function, but also furnishes useful data on other important economic decision variables. This section will present and discuss this data.

4.4.2 Slack/Surplus Variable Values

Knowledge of the slack/surplus values help in the deduction of the values of the constraint functions (the amount of resource used, the levels of requirements satisfied, etc) at an optimal solution. Constraints with zero slack are considered to be binding or active, whereas those with positive slack are considered to be inactive, meaning the resource is not fully utilised under the current optimal solution.

The slack/surplus variable values represent the optimal values of the surplus variable associated with each constraint. Table 4.1 shows the slack/surplus variable values under scenarios one, three and four for the profit, capacity and total purchases constraints in the model[20].

[20]Note that equality constraints do not have slack/surplus variable values.

Table 4.1 Slack/Surplus variables under Scenarios One, Three and Four

4.1-a) Profit Constraints (Thousands of KSHS)

Year	Scenario One	Scenario Three	Scenario Four	NCPB Actual
1980	216811	0	0	-1031580
1981	340278	259228	0	-1253326
1982	402832	279004	0	-290637
1983	0	0	0	1194075
1984	1051867	997850	65010	-705446
1985	1090053	968034	0	-1572651
1986	1040482	891523	1073282	-2075644
1987	850042	542040	0	183080
1988	886899	0	0	-443352
1989	923148	0	808164	-744499
1990	582737	0	0	1612340
Total	7385149	3937679	1946456	-5127638

The slack/surplus variables on the profit constraints represent the estimated total profit that would have been made by the NCPB under the current optimal solutions in the different scenarios. It is notable that no profits would have been made in the 1983 period under all the scenarios. This is attributed to the high inventory during this period (Fig. 4.4c), thus increased costs and the absence of profit. This was the period before the short crop year of 1984, and therefore the carrying of inventory to cover for the shortages. It is noted however, that profits would have been positive under all the scenarios in 1984. In the case of perfect knowledge of a short crop year in advance, this is possible, but under normal circumstances, this is not the case. NCPB's unplanned imports increased NCPB's costs during this year (Fig. 4.4d and e).

Scenario one, with no supply security and minimal inventory would have been the most profitable, as can be seen by the total profit for the period of about KShs 7.4 billion. In this scenario, only one year, 1984, would have recorded zero profits. However, this scenario is only possible because of the assumptions of perfect knowledge imposed on the model. In reality, a situation like scenario four would be likely to happen, where most of the years record zero profits, with only a few recording positive profits. The high inventory and high level of activity (higher purchases, imports and exports) increase the costs under this scenario, rendering it low in profits. Scenario three shows clearly that the higher the inventory carried, the less the profits made, as can be noted in Fig. 4.4c and e. The latter years of scenario three were characterised by high inventory, hence the absence of profit.

The last column represents the actual profits made by the NCPB during this period. It is notable that the NCPB made negative profits in most of the years except in 1983, 1987 and 1990, when there were positive profits. The increased demand that arose due to the drought of 1984 caused the quantities sold domestically to increase, and the inventory to decrease in 1983, hence the profits made during this year[21]. The high volume of maize handled by the NCPB, in terms of local purchases, imports and inventory, when compared to the model during this period contributed to the increased costs, hence the negative profits.

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[21] As discussed, the NCPB's fiscal year begins in July and ends in June of every year.

4.1-b) Capacity Constraints (Metric Tonnes)

Year	Scenario One	Scenario Three	Scenario Four
1980	1100046	1019470	856127
1981	1065856	978767	797330
1982	1034197	929442	779190
1983	965056	873659	756110
1984	1043239	951842	761430
1985	1008209	910140	548088
1986	964991	858690	637230
1987	977353	811489	0
1988	937384	550419	237186
1989	922758	341075	341075
1990	908219	176254	176254

The surplus/slack variables on the capacity constraints represent how much capacity is not utilised by the model. Except in 1987 under scenario four, all the scenarios show that there is a positive value for the surplus/slack variable on these constraints, and as already noted in an earlier section, this supports the argument that the NCPB does have more capacity than it actually requires. Despite showing a limitation on capacity in 1987, it is noted that scenario four recorded sub-optimal results. Despite this occurrence of a limitation on capacity, the argument that the NCPB does have a higher capacity than it requires still holds.

4.1-c) Total Purchases Constraints (Metric Tonnes)

Year	Scenario One	Scenario Three	Scenario Four
1980	96217	15641	0
1981	233986	227024	0
1982	172653	154988	0
1983	60208	73566	0
1984	0	0	0
1985	144020	137348	0
1986	216821	208589	349181
1987	102283	42720	0
1988	262114	41013	118759
1989	217788	23069	336302
1990	165449	15167	15167

The slack/surplus variables on the total purchases constraints indicate the total quantities offered for sale (pre-determined percentage of production), but not purchased. As noted, the NCPB was not required to buy all that was offered for sale in this study, unlike what happens in reality, when the NCPB has been required by government policy to purchase all produce offered for sale. This policy implies that no other market exists to absorb produce not sold to the NCPB. In this study, a parallel maize market is assumed present, therefore all demand and supply not met by the NCPB will be met by the parallel market. The quantities of the slack/surplus variables under this constraint are an indication of how much of the total supply the NCPB cannot purchase, and therefore must be channelled to the parallel market.

In 1984, according to the current optimal solution under all the scenarios, the NCPB would have purchased all maize offered for sale, reflecting the scarcity during that year. Further, the NCPB would have purchased all offered for sale under scenario four in the first six years of the study, and in 1987, showing that the higher the supply security required, the higher the demand for maize by NCPB. This suggests that in order to satisfy the demand in these periods, the NCPB would probably have had to resort to imports, as the model did under scenario four.

The surplus/slack variables on the total supply constraint requirement shows how much more sales would have been made by the NCPB, more than the minimum requirement in order to meet demand. It is only in 1980 (under scenario three); and 1980-1981, 1983 and 1987 under scenario four that a positive surplus/slack value is recorded. This implies that in these years, the NCPB's market share would have increased. Under scenarios one and the rest of the years in scenario three, the slack/surplus for this constraint was zero, meaning that the model supplied just enough maize to meet demand in those years.

The surplus/slack variables on the supply security constraints in scenario three and four indicate how much more would have been purchased by the NCPB over and above the supply security requirement. The results show that in all years, the NCPB would have purchased the equivalent of the supply security under scenario three, except in 1982, 1983 and 1987-1990, when it would have been required to purchase more than the supply security. As explained earlier, the 1982 and 1983 increase in purchases was as a result of the drought of 1984 which would have required the NCPB to carry inventory in order to meet the minimum requirements for the following year. Similarly, the constraint that required inventory equivalent to three months supply security to be carried in 1990, caused the purchases for the previous three years to increase. In scenario four, quantities that would have been actually purchased by the NCPB would have been equal to those required to meet supply security, except in 1980, 1985 and 1987-1990. The argument for the increase in purchases in 1987 through 1990, is similar to that under scenario three, the requirement to satisfy the constraint imposed upon it of carrying inventory worth three months supply security.

4.4.3 Dual prices and Right Hand Side (RHS) ranges

The dual price (also called shadow price) on a constraint shows the rate of improvement (impairment) in the optimal value of the objective function as the RHS of that constraint increases (decreases), with all the other data held constant. For the purposes of this study, improvement (impairment) will mean a decrease (increase) in the optimal value of the objective function.

The RHS ranges give an allowable range over which the dual price is valid; beyond these ranges, the dual price of a constraint may change.

The dual (shadow) prices on the total domestic supply constraints under all the scenarios indicate that there would be a positive improvement in the optimal value of the objective function, that is, a reduction in costs, if the RHS requirement on QPD was increased for the 1984 year. Thus, instead of carrying inventory from the previous year (Fig. 4.4c), and importing under scenario four, the model suggests buying maize from the domestic market to meet demand. The dual price is KShs 435.92 under both scenarios one and three, and zero under scenario four. This means that an increase of one tonne of maize purchased on the local market under scenarios one and three would decrease the total costs by KShs 435.92, whereas under scenario four, there would be no change in the objective function despite an increase in the RHS by one tonne of maize. However, 1984 was a short crop year, hence the slack/surplus value of zero.

The dual price on the total domestic sales suggests that for each tonne of reduction on this requirement, the total cost would reduce by the price per tonne of local purchases under scenario one. This is because the total domestic sales constraints require the model to sell maize quantities equal to at least market demand. In order to meet this requirement, the model must purchase stock either from the local or the international market, and/or carry inventory. The dual prices under these constraints suggest that, for the current optimal solution under scenario one, the costs would decrease by the price per tonne of local purchases, if these constraints were relaxed.

However, the dual price is reduced under scenario three, where the 1980 dual price on total domestic sales show that these constraints are not binding, while all the other years have a lower dual price than under scenario one. This is because, with the supply security requirement imposed under scenario three, the total requirements of maize increase, and the model begins to explore other options available as maize supply sources. For this reason, the dual prices under scenario four indicate that the total domestic sales constraints are not limiting, because they have dual prices of zero.

The dual price on the supply security constraints in scenario three indicate that except for 1982, 1983, and 1987-1990, when the constraints were inactive, all the other years were limiting, with negative dual prices. Relaxing these constraints would therefore mean an improvement in the optimal value of the objective function by the value of the dual (shadow) price in each year. In scenario four, the dual prices are zero, with RHS ranges of zero. Since the solution in this study is degenerate[22], this is expected. For that reason, we obtain limited information under

[22]Degeneracy exists in a problem if the value of the objective function does not change when moving from one iteration to the next, this may be because the best incoming activity can only enter at the zero level or there are more than one incoming activities at a given iteration that are equally good in terms of the resultant increase in the objective function (Hazell and Norton, 1986). Degeneracy can be detected on the computer output when the number of variables with a positive optimal value, including both decision and slack or surplus variables are less than the constraints at optimality (Eppen et al, 1988). The results in all the scenarios in this study are degenerate. This is important in the way the results are interpreted.

this scenario (refer to Appendix Table 6 for the dual prices and their RHS ranges).

4.4.4 Objective Coefficient Ranges

These ranges show the allowable changes that can be made in the objective function coefficients without changing the optimal solution. Within the range, the optimal value of the objective function may or may not change, depending on whether or not the objective function value is positive. If it is not positive, then the optimal value will remain unchanged, but if it is positive, then the optimal value will change as the coefficients change within the range (Eppen, et al).

The objective function in this study was to minimize costs, where costs were defined in the constraint section as total purchase and inventory costs. Since the coefficients for these costs did not appear in the objective function, these ranges will not be discussed.

4.4.5 The Reduced Costs

These show the amount the coefficient of that variable in the objective function would have to change in order to have a positive optimal value for that variable, that is, to have that variable included in the basis. This means if a variable is already in the basis, its reduced cost is zero. The reduced cost is the same as the allowable decrease for the objective function of the given variable, the allowable increase being infinite. This means that an increase in the coefficient of this variable would make the variable more expensive, therefore not likely for it to enter into the basis.

The reduced cost of a decision variable (whose current optimal value is zero) is also the rate at which the objective value is hurt as that variable is forced into the optimal solution. Since the solution in this study is degenerate, the coefficient of the variable in the objective function must be changed by at least as much as, and possibly more than, the reduced cost in order for there to be an optimal solution with that variable appearing at a positive level.

According to the results, the quantities imported and those exported in scenarios one and three, and in some years in scenario four, and inventory (in scenario one) have an optimal value of zero. The reduced cost is an indication of at least how much the coefficients of these variables, that is the prices of imports, exports and the cost of carrying inventory (in those years without inventory) have to be reduced (increased in the case of exports) in order for them to become part of the optimal solution given the government-set domestic prices (for the reduced cost values, refer to Appendix Table 7).

On imports, the reduced costs under scenario one indicate that the cost of imports have to be reduced to at least the price of domestic purchases in order for this variable to be included in the basis. Under scenario three, the reduced cost is lower because of the increased costs caused by the introduction of the supply security constraints. Years with positive imports under scenario four have reduced cost values of zero. However, years without imports under this scenario show a zero value for reduced costs. This is attributed to the fact that the results under this scenario were sub-optimal.

For exports to form part of the basic solution under scenario one, the reduced costs suggest that the export prices have to increase by at least the cost of purchasing grain from the domestic market. Under scenario three, the reduced costs are lower, implying that the costs increase considerably under this scenario. On the other hand, scenario four's reduced costs are zero, even for those years that have no exports. Again, this is attributed to the sub-optimality of the results under this scenario.

On the inventory side, the reduced costs under scenario one suggest the costs of inventory have to be reduced by the value of the reduced cost in each year, from 1984 to 1990. However, 1980 has a reduced cost value of zero, yet no inventory is recorded during these year, however inventory is positive in 1982 and 1983.

4.5 GENERAL DISCUSSION

The key results of this study are the optimal quantities suggested by the model, as presented in Figs 4.1a, 4.2a and 4.3a and b, with the costs associated with these levels of operation as shown in Figs. 4.1b, 4.2b and 4.3c, under scenarios one, three and four. The results under scenario one and three are similar to those recommended under the price band schemes (Pinckney, 1988). According to the price band schemes, domestic trading gains are determined by the difference between the buying price and selling price, and the degree of government intervention. With higher levels of price variability, the NCPB makes higher profits whenever it buys one year and sells the next, as long the following year is a short crop year. In this study however, prices were fixed and price variability within the year was absent. Despite this difference, it is obvious that domestic trading gains are determined by the difference between purchases and sales prices, with some allowance being given for government intervention[23].

In the case of storage costs, the price band scheme (Pinckney, 1988) noted that for stock variability levels above 200,000 tonnes, storage costs decrease with increasing price flexibility, but for higher levels of stock variability, the decrease is larger proportionately than the corresponding change in mean stock level. For stock variability levels of 150,000 tonnes and below, the price band scheme found that storage costs increase slightly with increasing price variability. According to this study, no analysis was done for storage costs per se, nevertheless, storage costs did contribute to the overall costs of the NCPB. The effect of price variability within the year was not analyzed since prices were assumed constant within the year for the entire study period. In this study, the storage costs are the sum of the average closing stock levels in each year multiplied by the storage cost per tonne.

[23]The government is responsible for setting both the sales and purchase price. Hence, their intervention is embedded in the prices.

However, storage costs differ from a straightforward multiplication of closing stock times inventory cost per tonne, because the mean stock level in each month during the year differs from the mean stock level at the end of the year. The level of inventory at any one time during the year depends on existing market conditions, with the harvest and glut seasons translating into higher stocks, while pre-harvest and short seasons mean lower stocks.

In scenario one, except for 1982 and 1983, there were no storage costs because there was no inventory recorded. This is not practical for a country like Kenya, which faces production instability. Lack of inventory means that in periods of shortages, the NCPB will be forced to import maize. As noted earlier, imports take at least two months to arrive at the port of Mombasa, about 500 Km away from the nation's capital, Nairobi. This means when ordering imports, the NCPB would need inventory worth at least two months of total disappearance to cover the period before imports arrive in the country. Consequently, a case such as scenario one that does not allow for inventory to be carried would not be an adequate policy for the Kenyan maize market.

In scenario three, storage costs did form part of the total costs in each year because inventory was part of the optimal solution. Nevertheless, it is important to note that the quantity of inventory advocated under this scenario was less than that which was carried by the NCPB for most of the same period. Normally, the NCPB stock policy during the study period was to carry 270 thousand tonnes of maize in inventory, and whenever the stocks fell below this level, imports were ordered. The highest quantity of inventory carried in scenario three was about 730 thousand tonnes in 1990. As explained earlier, this was because of the constraint on the model to carry inventory worth three months supply security in the last period of the model. This constraint caused inventory to be accumulated from 1987 to 1990, increasing tremendously the carrying costs associated with these years. However, carrying of inventory is expensive, and forcing it into the model in the form of supply security constraints increases the NCPB costs.

In scenario four, with the exceptions of 1980, 1981, 1989 and 1990, the inventory level is higher than that under scenario three, and thus higher costs. The general trend of the inventory under this scenario is similar to the NCPB policy, albeit much lower. From 1985 to the end of the period, the inventory level is in fact above the minimum NCPB level of 270 thousand tonnes.

In a discussion on carrying stocks from one year to another, it is important to note that in their study on whether developing countries should carry grain reserves, Reutlinger et al (1977) found that a decision by a less developed nation to carry grain reserves may find little justification on traditional economic grounds, such as profitability and economic efficiency, hence, the reason for lack of reserves under scenario one. However, they note that profitability or efficiency are not the only reasons for a reserve, but rather that the investment is made within a context of competing political interests. They point out that the strongest rationale for a reserve may rest on its effect on a government's financial ability to secure minimally adequate consumption of grain for the entire population at all times and its incremental stabilization effects for prices, supplies and the balance of trade, which are not priced by the market. Thus, despite the increase in costs as the model moves from scenario one to scenario three, as a result of the supply security constraints, it may be justifiable for the Kenya government to impose these constraints based on such an argument.

The foreign trade account is the most difficult to understand. This account reflects the cost of imports less the cost of exports. According to scenario one and three results, NCPB should not engage in foreign trade, but rather confine itself to a domestic self sufficiency policy in order to minimize costs. The results confirm NCPB's reluctance to engage in foreign trade, and its preference to limit maize imports only to those years in which maize shortages are experienced. As noted earlier, the import cost is higher than the domestic price of maize. Hence, it is expected that the model would first purchase maize from local sources rather than from the international market. The export price is lower than the domestic sales price set by the government, after adjusting for freight and handling costs. It is therefore expected that the optimal solution would exclude exports in the basis.

Under scenario four, the results include foreign trade in the basic solution. Nevertheless, it registered infeasible results, and hence not much can be concluded using these results.

NCPB did engage in external trade in the 1980s. There were imports only in periods of scarcity in the domestic market, and small quantities of exports were undertaken rather cautiously, considering the uncertainty of the harvest. Several authors (Pinckney, Bates, Maritim, Kenya (1966)) pointed out in their studies that foreign trade for the NCPB may be costly. In his study on measuring trade-offs between different government objectives, Pinckney recognizes that import parity is considerably higher than export parity. However, he goes on to point out that in every case, foreign exchange losses are larger for the lowest level of imports (in other words, the highest level of stock variability) than they are for the highest level of imports, therefore at some point for each level of price variability, reducing imports implies losing foreign exchange. Irrespective of the level of imports, losses are incurred.

The foreign trade that Kenya does undertake periodically is justified only on the grounds of having no alternative. It has been pointed out that because of the variation in weather conditions, and a thriving parallel market within Kenya and along the Kenyan borders, maize shortages in the country have been a real problem, deserving a solution. This study hypothesized that an economical solution may lie in a constrained stocking policy, coupled with the judicious use of foreign trade, but the difference between domestic and international prices suggests that foreign trade may not be a clear solution. Nevertheless, the NCPB has to engage in foreign trade at a loss from time to time (Kenya, 1966), in order to manage its dual objective of supply security and price stability. The results of this study suggest that the NCPB has performed its mission reasonably well.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

In this study, a historical description of the maize production, storage and marketing systems was provided, and a decision model for optimal stock management by the NCPB was developed. Costs associated with alternative storage strategies for the NCPB were also estimated using the model developed. Finally, a historical analysis that compared optimal results estimated by the model with actual NCPB performance for the 1980 - 1990 period was done.

Under the section on maize production, storage and marketing systems, it was shown that the Kenyan government intervenes extensively in the maize market, and that the NCPB (previously known as the MPB) was established as a monopoly to carry out the maize marketing functions for the government. Pressures for reform outlined under this section focused on the shortcomings of the NCPB such as inefficiency and high cost operations, price controls by the government which, it was argued, tended to create distortions, and inefficiencies associated with large scale public sector intervention in grain markets. The development of the pricing policy and the current system for setting prices in Kenya was also described, with the shortcomings identified as inadequate precision in defining an efficient producer price; lack of a spatial and temporal price structure; inadequate inter-commodity price analysis; poor forecasting of financial implications of the pricing policy; and poor stabilisation of consumer price markets (Development Support Group, 1992).

It was hypothesized that by the use of optimization techniques, the NCPB would be able to regulate maize supplies in Kenya and at the same time reduce the costs associated with storage by relying not on storage alone to meet shortages, but also on external trade. A linear programming model was developed with the objective function being cost minimization. External trade was incorporated as an alternative to local purchases and sales of maize by the NCPB, an activity previously reserved only for short periods. The model was then run under three scenarios, no-, three- and four-months supply security. It was expected that the model under the different scenarios would reflect the changes in the costs associated with the movement from a no supply security scenario (no stocks held) to a four-month supply security scenario (stocks bought and held to cover at least four months worth of disappearance).

The results showed that as expected, the movement from scenario one to scenario three increased the costs associated with storage and trade, due to an increased level of activity to cover the supply security constraint. However, the expectation that the NCPB would utilize external trade, which was presumed cheaper, as an alternative to maize storage in order to decrease costs and even out maize supplies, was rejected. The model under scenario one and three called for no external trade, while under scenario four, external trade was an integral part of the solution albeit sub-optimal.

The prices used in the study were adjusted for freight, insurance and handling costs in the case of imports and exports, based on Nairobi depot prices. They rendered export prices lower than local sales prices, and import prices higher than local purchase prices. Accordingly, the results reflected these differences, through the dominance of internal trade, and for the most part, the absence of external trade. The trade-off between storage costs and external trade was expected to determine if, when and how much the NCPB should engage in external trade. However, despite the increase in costs and presence of external trade under scenario four, the local trade and storage strategy was still the preferred strategy, considering that the results under this scenario were sub-optimal. The infeasibility resulted because the supply security constraint called for stocks every year that were greater than the stocks presumed to be available to the NCPB on the domestic market. The implicit assumption of this constraint is that shortages were experienced every year, between 1980 and 1990. Nevertheless, it is unrealistic to have an assumption of this nature, and despite the NCPB previously not having allowed its stocks to fall below a given minimum (180 to 270 thousand tonnes), it has met most of its requirements through purchases in the domestic market.

This study showed that, in the case of a country like Kenya, external trade may not be the solution to a strategy of cost minimization under the current pricing system. Despite the use of optimization techniques in this case, external trade was absent from the optimal solution. Nevertheless, external trade cannot be avoided completely in the face of production instability, since an inflexible demand for maize does exist in the country, and the government is assumed responsible for any shortages. Thus, it is important to note that maize has to be imported at a loss from time to time.

5.2 LIMITATIONS OF THE STUDY

There were several limitations encountered in this study. The most notable ones will be described under this section.

First, as discussed in the data section, the quality of data on both food crop production and consumption in Kenya is relatively poor. The only reliable data are those on purchases and sales of grains by the NCPB, but these are inappropriate for use as proxies for total production since the presence of a parallel, informal market causes fluctuations in the NCPB total purchases of grain. While little is known about the quantities traded in the parallel market, the impact these have on the availability of grain in the domestic market is great. Assumptions that are made based on estimates by the Ministry of Agriculture, Development Planning Division

(DPD, MoA), the US Department of Agriculture (USDA) and Food and Agriculture Organization (FAO) on the total quantities of maize produced in the country may not reflect the actual magnitude of stocks held and traded in the parallel market.

This study utilized DPD, MoA total production estimates, because as discussed earlier, Goldman (1983)[24] did a study that tested the links between NCPB sales and purchases series and the production series, and the results showed a strong support to DPD, MoA series. However, the same study showed that no disappearance series was linked to any hard data and the choice of one series over another was of no advantage. This study therefore utilised estimates of disappearance by USAID.

The second limitation of the study was the type of model used in the analysis. The linear programming technique is static, and this makes it difficult for dynamic problems to be correctly analyzed. An appropriate model for a case like this would have been the use of dynamic programming techniques as outlined in Gardner (1979) and Gustafson (1958). This method is a form of stochastic programming which involves making the problem discrete rather than continous, and the solution is obtained by backward recursion. However, because of the limitations of this approach as having a complicated single valued social welfare objective function (Pinckney, 1988), and in terms of time and resources, it was not chosen for this study.

A third limitation concerns the prices used in the study. Except for international prices, the Kenyan prices though flexible between years, are fixed within the year. These prices may not be representative of what would actually happen in a free market situation. As noted by the Development Support Group (1992), there are several issues relating to the current maize pricing system that

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[24]This reference is cited in Pinckney (1988)

need to be reviewed. A poor pricing structure, which distorts the actual value of maize locally (lower prices in this case), may render foreign trade unprofitable. In contrast, a price that reflects the actual value of maize locally, may change the results of such a study considerably, and foreign trade may become the norm, rather than the exception. Free market prices would give a better picture of the grain situation in the country.

Fourthly, one particular set of data were analysed, and conclusions were drawn. Another set of data might have resulted in much heavier use of the international market. Therefore, the results depend on the type of data utilised in the study.

Fifth, it is important to note that the model does not embody the flexibility in producer and consumer behaviour that one would expect in a market in which there are periodic shortages and surpluses. The model simply forces the NCPB to service 34 per cent of demand, and purchase no more than 27 per cent of grain produced. On the demand side, this allows the NCPB to sell whatever suits it in order to at least break-even. On the supply side, the NCPB is able to purchase up to 27 per cent of the crop, regardless of whether or not farmers would want to sell. Further research should be done in this area.

Finally, white and yellow maize are assumed to be perfect substitutes. However, in the Kenyan market there is a consumer preference for white maize.

5.3 SUGGESTIONS FOR FURTHER RESEARCH

There are several variables that can be included in a study similar to this one, in order to improve on the results.

One notable area is a thorough and efficient study on the magnitude of maize quantities available in the parallel market and their prices, and the quantities that are retained for home consumption. A proxy should be used to value these quantities retained, and incorporated in the analyses. This means a compilation of adequate statistics for maize consumption, together with reasonable reliable estimates of production for the whole country. Knowledge of such statistics will greatly enhance the results of any research concerning maize trade in Kenya.

This study did not include the premium price offered for white maize such as is grown in Kenya in the world market. Further research should incorporate this, and analyze the impact on external trade.

The current pricing system in Kenya should be analyzed, and changes made accordingly. Competitive free market prices, if they existed, would be the efficient, and should be used in any research. The government intervenes because of lack of these efficient market prices. The pricing system under government intervention should be such that efficient prices are set for both producers and consumers. Kenyan prices have been suspected of being inefficient and lacking in terms of a spatial and temporal structure (Development Support Group, 1992; Gordon and Spooner, 1992; Maritim, 1982). The assumption of a unified maize market system during the year, and hence a common pricing system for the whole country is misleading, and thorough research on maize pricing should be done to eliminate these shortcomings.

It is recommended that research be done on the impact of government policy on the performance of the NCPB. It is suspected that because of the sensitivity of the maize crop in Kenya, tendencies are for the NCPB not to follow economically sound principles, such as authorising exports in years when it should not, and not ordering for imports on time in years of shortages, despite economic justification for such. Research should therefore be carried out and recommendations made thereafter.

Finally, a model that would take into consideration the spatial and temporal structure of the maize industry in Kenya is recommended. Maize is grown in the western area, but demand is highest in the central and eastern areas of the country. The port of Mombasa is also a case in point. It is located in the eastern part, and with imports called for by shortages, the freight costs to the shortage points are considerable. Thus, a model that would allow for these details to be built in would be desirable.

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APPENDICES

Appendix 1: DATA

Table 1-A: NCPB and International Maize prices, and Carrying Costs (KSHS per MT, Real 1990 prices)

Year	CPI 1990=100	Exchange Rate (Kshs to US $)	Interest Rates (Deposit)	P_{Dt}	P_{Mt}	P_{SDt}	P_{Xt}	CC_t
1980	36.65	7.4202	5.75	2601.00	4819.85	3055.73	342.16	107.38
1981	40.01	9.0475	14.94	2499.24	4708.23	3243.46	1847.49	730.76
1982	43.98	10.9223	12.20	2432.76	4197.99	3430.63	1734.92	771.82
1983	49.05	13.3115	13.27	3139.45	4734.32	3565.30	2164.83	458.83
1984	54.06	14.4139	11.77	3237.01	5710.09	4924.35	2478.17	591.01
1985	61.09	16.4321	11.25	3061.19	5030.74	5178.37	1809.12	1035.96
1986	63.47	16.2257	11.25	3119.60	4555.11	4984.00	1055.15	1159.72
1987	68.91	16.5150	10.31	3033.09	3732.35	4590.75	351.63	767.75
1988	76.60	18.5990	10.33	2796.50	4304.90	4310.79	933.93	694.10
1989	86.56	21.6010	12.00	2580.07	4982.27	4117.85	1486.13	723.35
1990	100.00	22.9150	13.67	2616.67	3921.03	3564.44	1112.80	258.89

Where:

P_{Dt} is NCPB's Domestic purchase price

P_{Mt} is the import price (Nairobi Depot)

P_{SDt} is NCPB's domestic sales price

P_{Xt} is the export price (Nairobi Depot)

CC_t is the carrying cost

Source: NCPB's Forward Planning Division, Nairobi; International Monetary Fund, 1993; Feed Situation & Outlook/ FDS - 328, Nov. 1993.

Table 1-B: MAIZE PRODUCTION AND CONSUMPTION (MT)

Year	Area* '000 Ha	Total Production '000 T	Total Disappearance '000 T
1980	1364.9	1888.3	2014.4
1981	1120.0	2560.0	2177.21
1982	1208.0	2450.1	2231.65
1983	1236.0	2214.8	2300.87
1984	1230.0	1500.0	2284.91
1985	1370.0	2440.3	2451.72
1986	1430.0	2870.0	2657.52
1987	1440.0	2400.0	2598.65
1988	1420.0	3140.0	2788.98
1989	1460.0	3030.0	2858.63
1990	1300.0	2890.0	2927.86

* This represents the total area under Maize.

Source: Development Planning Division, Ministry of Agriculture, Nairobi; United States Agency for International Development, Nairobi, Kenya.

Table 1-C: NCPB PURCHASES, SALES AND INVENTORY: 1980 - 1990 (MT)

Year	Purchases	Sales	Imports	Exports	Closing Stock
1980	382.6	684.16	438.03	0.00	147.2
1981	696.5	529.84	183.49	0.00	502.5
1982	627.1	467.66	0.00	76.68	651.0
1983	498.4	759.72	0.00	105.40	388.0
1984	379.7	746.45	506.56	0.00	439.3
1985	833.7	353.32	0.00	21.16	857.6
1986	692.4	191.61	0.00	314.00	1036.4
1987	483.1	494.27	0.00	125.17	865.8
1988	624.1	421.28	0.00	137.21	925.3
1989	550.8	290 51	0.00	143.72	1013.7
1990	235.7	632.61	0.00	78.17	435.7

Where: Purchases represents the total domestic purchases by the NCPB, Sales the total domestic sales by the NCPB, and the closing stock is the quantity of maize in NCPB depots throughout the country at the close of the trading year (June, 30th), and is also the opening stock (carry-in) for the following trading period.

Source: Forward Planning Division, NCPB, Nairobi.

Appendix 2: NCPB'S MAIZE MARKET SHARE IN KENYA

Table 2-A: NCPB Purchases and Total Production

Year	Production (MT)	NCPB Purchases (MT)	% NCPB Purchases to Production
1980	1888.3	382.6	20
1981	2560.0	696.5	27
1982	2450.1	627.1	26
1983	2214.8	498.4	23
1984	1500.0	379.7	25
1985	2440.3	833.7	34
1986	2870.0	692.4	24
1987	2400.0	481.1	20
1988	3140.0	624.1	20
1989	3030.0	550.8	18
1990	2890.0	235.7	8

Source: Development Planning Division, Ministry of Agriculture, Nairobi; Forward Planning Division, NCPB, Nairobi; and own derivations.

Table 2-B: NCPB Sales and Total Disappearance

Year	Disappearance (MT)	NCPB Sales (MT)	%NCPB Sales to Disappearance
1980	2014.4	684.16	34
1981	2177.21	529.84	24
1982	2231.65	467.66	21
1983	2300.87	759.72	33
1984	2284.91	746.45	33
1985	2451.72	353.32	14
1986	2657.52	191.61	7.2
1987	2598.65	494.27	19
1988	2788.98	421.28	15
1989	2858.63	290.51	10
1990	2927.86	632.61	22

Source: United States Agency for International Development, Nairobi, Kenya; Forward Planning Division, NCPB, Nairobi, Kenya; and own derivations.

Appendix Table 3: Optimal Purchases under Scenario 1 and Supply Security Requirements under Scenarios 2 and 3 (MT)

Year	Optimal Purch	2-Month SS	3-Month SS
1980	413624	335730	503600
1981	457214	362670	544303
1982	488873	371940	557913
1983	537787	383480	575228
1984	405000	380820	571228
1985	514861	408620	612930
1986	558079	442920	664380
1987	545717	433110	649663
1988	585686	464830	697245
1989	600312	476440	714658
1990	614851	487980	731965

Where:

Optimal Purch represents optimal purchases under Scenario one, 2-Month SS represents supply security requirements under Scenario two; and 3-Month SS represents supply security requirements under scenario three[25]

The reason for no change in the basic solution when the model moves from scenario one to two is that the optimal quantity of total purchases under scenario one exceed the amount required under scenario two. The table above shows the Right Hand Side requirements under scenarios two and three, compared to the optimal purchases under scenario one.

[25]Note that any supply security above three months would have similar results

Appendix Table 4: Supply Security versus Domestic availability of Maize under Scenario Four (MT)

Year	Supply Security	Domestic Supply*	Balance
1980	671460	509841	161619
1981	725740	691200	34540
1982	743880	661527	82353
1983	766960	597996	168964
1984	761640	405000	356640
1985	817240	658881	158359
1986	885840	774900	110940
1987	866230	648000	218230
1988	929660	847800	81860
1989	952880	818100	134780
1990	975950	780300	195650

* The proportion of total production available to the NCPB based on a market share of 27 %.

Note: The balance implies the amount required to be imported and/or carried-in inventory in order to meet the four-month supply security.

Appendix Table 5: Optimal Purchases under the Three Scenarios (MT)

Year	Scenario One	Scenario Three	Scenario Four		
			QPD	QPM	Total
1980	413624	494200	509841	147701	657542
1981	457214	464175	691200	34540	725740
1982	488873	506538	661527	12476	674003
983	537787	524430	597996	0	597996
1984	405000	405000	405000	143658	548658
1985	514861	521533	658881	34291	693172
1986	558079	566311	425719	0	425179
1987	545717	605279	648000	547309	1195309
1988	585686	806786	729040	0	729040
1989	600312	795030	481797	0	481797
1990	614851	765133	765133	0	765133

Note: -There are no imports in scenario one and three
-QPD represents domestic purchases
-QPM represents imports

Appendix 6: Dual Prices and Right Hand Side Ranges

Table 6-A: SCENARIO ONE: Total Domestic Supply Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QPD80	96217	0	509841	∞	96217
QPD81	233986	0	691200	∞	233986
QPD82	172653	0	661527	∞	172653
QPD83	60208	0	597996	∞	60208
QPD84	0	435.92	405000	17647	109675
QPD85	144020	0	658881	∞	144020
QPD86	216821	0	774900	∞	216821
QPD87	102283	0	648000	∞	102283
QPD88	262114	0	847800	∞	262114
QPD89	217788	0	818100	∞	217788
QPD90	165449	0	780300	∞	165449

Table 6-B: SCENARIO ONE: Total Domestic Sales Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QSD80	0	-2601.00	423024	96217	413624
QSD81	0	-2499.24	457214	233986	457214
QSD82	0	-2432.76	468647	172653	403691
QSD83	0	-3130.62	483183	53017	473553
QSD84	0	-3672.92	479831	109675	17647
QSD85	0	-3061.19	514861	144020	514861
QSD86	0	-3119.60	558079	216821	558079
QSD87	0	-3033.09	545717	102283	545717
QSD88	0	-2796.50	585686	262114	585686
QSD89	0	-2580.07	600312	217788	600312
QSD90	0	-2616.67	614851	165449	614851

Table 6-C: SCENARIO THREE: Total Domestic Supply Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QPD80	15641	0	509841	∞	15641
QPD81	227024	0	691200	∞	227024
QPD82	154988	0	661527	∞	154988
QPD83	73565	0	597996	∞	73565
QPD84	0	435.92	405000	31161	75962
QPD85	137348	0	658881	∞	137348
QPD86	208589	0	774900	∞	208589
QPD87	42720	0	648000	∞	42720
QPD88	41014	0	847800	∞	41013
QPD89	23069	0	818100	∞	23069
QPD90	15167	0	780300	∞	15167

Table 6-D: SCENARIO THREE: Total Domestic Sales Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QSD80	448	0	423024	449	∞
QSD81	0	-1702.00	457214	87089	65227
QSD82	0	-2432.76	468647	154988	35714
QSD83	0	-3130.62	483183	64779	74183
QSD84	0	-2470.18	479831	91397	180922
QSD85	0	-2083.64	514861	98069	155774
QSD86	0	-1873.37	558079	42720	145111
QSD87	0	-3033.09	545717	42720	61917
QSD88	0	-2252.66	565686	26607	78892
QSD89	0	-1290.19	600312	14454	57423
QSD90	0	-1364.30	614851	11134	73801

Table 6-E: SCENARIO THREE: Supply Security Constraints

Year	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
1980	0	-2257.15	503600	15641	524
1981	0	-797.24	544303	80256	87089
1982	35715	0	557913	35715	∞
1983	74183	0	575228	74183	∞
1984	0	-1202.75	571228	75962	31160
1985	0	-977.56	612930	137348	98069
1986	0	-1246.23	664380	208333	42720
1987	61917	0	649663	61917	∞
1988	275405	0	697245	275405	∞
1989	467337	0	714658	467337	∞
1990	614851	0	731965	614851	∞

Table 6-F: SCENARIO FOUR: Total Domestic Supply Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QPD80	0	12.58	509841	0	0
QPD81	0	0	691200	34540	84250
QPD82	0	0	661527	21530	111366
QPD83	0	0	597996	14593	20894
QPD84	0	0	405000	143659	26287
QPD85	0	0	658881	50777	485884
QPD86	349181	0	774900	∞	349181
QPD87	0	0	648000	547309	648000
QPD88	118759	0	847800	∞	118759
QPD89	336303	0	818100	∞	336303
QPD90	15167	0	780300	∞	15168

Table 6-G: SCENARIO FOUR: Total Domestic Sales Constraints

Variable	Slack/Surplus (MT)	Dual Price (KShs/T)	RHS Ranges (MT) Current	Allowable Increase	Allowable Decrease
QSD80	243918	0	423024	243919	∞
QSD81	65331	0	457214	65331	∞
QSD82	0	0	468647	87572	30888
QSD83	70796	0	483183	70798	∞
QSD84	0	0	479831	190225	11787
QSD85	0	0	514861	535068	33477
QSD86	0	0	558079	327761	174696
QSD87	420510	0	545717	420510	∞
QSD88	0	0	585686	82827	248444
QSD89	0	0	600312	336303	229115
QSD90	0	0	614851	11134	370866

Table 6-H: SCENARIO FOUR: Supply Security Constraints

Year	Slack/Surplus (MT)	Dual Price (KShs/T)	Current	RHS Ranges (MT) Allowable Increase	Allowable Decrease
1980	-4517	-1	671460	0	0
1981	0	0	725740	127055	31880
1982	0	0	743880	79813	30190
1983	0	0	766960	20894	12850
1984	0	0	761640	10317	143658
1985	157741	0	817240	157741	∞
1986	0	0	885840	250807	327751
1987	656840	0	866230	656840	∞
1988	356223	0	929660	356224	∞
1989	229115	0	952880	952880	∞
1990	370866	0	975950	975950	∞

Appendix Table 7: Reduced Cost Values

Variable	Scenario one		Scenario Three		Scenario Four	
	Value (MT)	Reduced Cost (KShs/T)	Value (MT)	Reduced Cost (KShs/T)	Value (MT)	Reduced Cost (KShs/T)
Imports:						
QPM80	0	2218.85	0	3896.69	147701	0
QPM81	0	2208.99	0	2208.99	34540	0
QPM82	0	1765.23	0	1765.23	12476	0
QPM83	0	1627.96	0	1627.98	0	0
QPM84	0	2037.16	0	2037.16	143658	0
QPM85	0	1969.55	0	1969.55	34291	0
QPM86	0	1435.51	0	1435.51	0	0
QPM87	0	699.26	0	699.30	547309	0
QPM88	0	1508.40	0	2050.13	0	0
QPM89	0	2402.20	0	4417.15	0	0
QPM90	0	1304.36	0	3027.63	0	0
Exports:						
QSX80	0	2601.00	0	2051.93	0	15.38
QSX81	0	2499.24	0	1702.00	133317	0
QSX82	0	2432.76	0	2433.76	106269	0
QSX83	0	3159.67	0	3159.69	0	0
QSX84	0	3672.93	0	2470.18	0	0
QSX85	0	3061.19	0	2083.64	0	0
QSX86	0	3119.60	0	1873.37	0	0
QSX87	0	3033.09	0	3033.09	0	0
QSX88	0	2796.50	0	3465.43	0	0
QSX89	0	2580.07	0	3497.66	0	0
QSX90	0	2616.67	0	4603.87	0	0

Inventory:

INV80	0	0	80127	0	0	0
INV81	0	0	87089	0	69877	0
INV82	20226	0	124981	0	168964	0
INV83	74831	0	166228	0	212981	0
INV84	0	1202.75	91397	0	281809	0
INV85	0	977.55	98069	0	460121	0
INV86	0	1246.23	106301	0	327751	0
INV87	0	1004.34	165864	0	556842	0
INV88	0	910.53	386964	0	700197	0
INV89	0	686.75	581682	0	581682	0
INV90	0	2875.56	731965	0	731965	0