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NON-RESEARCH POLICY EFFECTS ON THE RATE OF RETURN TO MAIZE RESEARCH IN KENYA: 1955-1988

by

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ABSTRACT

NON-RESEARCH POLICY EFFECTS ON THE RATE OF RETURN TO MAIZE RESEARCH IN KENYA: 1955-1988

By

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Maize is the staple food for ninety percent of the Kenyan population. In 1955, a maize research program was started by the Kenyan government which concentrated on the development of improved and hybrid varieties. Over the period 1955-88, the maize sub-sector has experienced large increases in maize yield, area and output.

Today, Kenya's agricultural sector is faced with the challenge of feeding a rapidly growing population on only twenty percent of its land. There is thus a growing interest in the assessment of productivity of agricultural research and development as well as an emphasis by donor countries and institutions on structural adjustment. This study is the first to evaluate the returns to maize research in Kenya under the current policy regime in order to assess the effects of non-research policies on the benefits from research. A production function approach is used to measure changes in social surplus due to interactions between research and policy effects. The results indicate that policies in the fertilizer sub-sector diminish the potential benefits from maize research. A marginal rate of return to maize research for 1987 was found to be sixty percent if the policies were not in place. Incorporating the policies into the analysis diminished the marginal rate of return to fifty-eight percent. This decrease corresponds to a reduction in social surplus of approximately K£ 360,000.

To my mother and father.
Their love gives me strength.

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I. INTRODUCTION AND SCOPE OF STUDY

Agriculture is the largest sector of the Kenyan economy. As of 1987, it accounted for 68 percent of total exports, employed 78 percent of the total population, and provided nearly all of the country's food requirements (FAO, 1989). By generating income, employment and foreign exchange, agriculture supports the expansion and diversification of other sectors of the Kenyan economy. Agricultural growth, thus, is a key factor contributing to the overall growth of the country's economy.

The greatest challenge for the agricultural sector in the 1990's is to feed Kenya's rapidly growing population on only 20 percent of its land. As of 1988, the population in Kenya was close to 23.4 million people, growing at an average annual rate of 4.2 percent between 1981 and 1987 (FAO, 1989). Kenya covers an area larger than the size of France, close to 57 million hectares. However, 20 percent of the land is arable and only 7 percent is categorized as high potential. Virtually all arable land is being cultivated, therefore increased agricultural production will depend largely on yield improvements through technological innovations and inputs rather than area expansion.

Maize is the most important crop in Kenya because it is the staple food providing over 50 percent of the total calories in the average diet of over 95 percent of the population (FAO, 1989). Maize covers the largest crop area and an estimated 1.4 million hectares are grown annually. In 1988 maize output totalled 2.9 million metric tons (mt.).

It has been recognized that research and extension in Kenya have played a strategic role in increasing agricultural productivity. Maize research, in particular, has greatly contributed to increases in maize production. Since 1961, 23 varieties of improved/hybrid maize have been released to meet the demands of various agro-climatic regions. Maize research has recently been quantified as providing a marginal rate of return which averaged 68 percent for the period 1955-88 (Karanja, 1990). This means that the investment of one additional dollar in maize research during this period has generated social benefits equivalent to one dollar and 68 cents. Furthermore, research and extension have generated an additional 57,000 mt. of maize in 1987 (Karanja, 1990). Projections indicate that maize output will need to double in the next 15 to 20 years in order to meet future food demand (Karanja, 1990). In light of these projections, sustained investment in the generation, transfer, and adoption of yield-increasing technologies is necessary. The programs to develop these technologies, however, are very costly. Agricultural research receives 70 percent of the national budget for research (Ruigu, 1985). It is thus important to allocate scarce public resources to the most productive research programs.

When evaluating a research program for a particular commodity, it is important to look at the impacts it has in the input markets for this commodity (Norton, forthcoming). Research can affect the input demand and therefore has an impact on the costs of producing the commodity. Fertilizer is one of the major non-land, purchased inputs to hybrid maize cultivation and therefore it is affected by maize research. In particular, maize research makes recommendations regarding the use of fertilizer for hybrid maize cultivation and it also develops varieties which respond more to fertilizer than do local varieties.

The first objective of this study is to measure the impact of maize research in the fertilizer market and to determine its effect on the social benefits accruing to maize producers who use fertilizer.

The second objective of this study is to evaluate the benefits from maize research in Kenya by taking into account non-research policies in the fertilizer sub-sector. Studies on rates of return to research do not traditionally take into account policies such as import quotas or production subsidies because they are considered transfers of benefits and costs from one group in a society to another with distinct budgets and impacts. However, the returns from research are affected by such policies. Conversely, the social benefits and costs of policies are influenced by research and technical change. In Kenya, there are policies which influence fertilizer supply and demand. Namely, the Government of Kenya (GOK) issues import licenses which restrict the quantity of fertilizer imported into the country and it has also set the price of fertilizer below the international market price, thus providing an implicit subsidy for fertilizer. These policies, through their impacts on fertilizer prices and quantities consumed can create or destroy incentives to grow improved/hybrid maize and thus in turn affect the returns to maize research.

This analysis is particularly important in light of the recent changes in the fertilizer market. The GOK has begun to decontrol the pricing of fertilizer. This analysis can thus indicate the effects of the removal of this policy on the social surplus in the fertilizer market and the impact maize research can have without this policy in place.

A production function approach is used to measure economic surplus in the fertilizer market. The impact of maize research is evaluated by measuring the changes in economic surplus which it has generated in the fertilizer market. Policy impacts are assessed by calculating economic surplus with price and quantity restrictions. The data utilized was collected from a field research in Kenya conducted by D.D. Karanja in 1990. The data is from secondary sources and covers the period 1955-88.

This study is organized as follows: Section I describes the issues addressed and the research objectives of this thesis. Section II discusses the various policies being analyzed in the fertilizer market. Section III describes maize research in Kenya since its inception in 1955. Section IV explains the theoretical model being used to analyze the interactive effects of policies and maize research on the economic surplus measured in the fertilizer market, while Section V presents the empirical model and results. Finally, Section VI discusses the implications of the findings and suggests further research to be done on this topic.

II. FERTILIZER POLICIES

Fertilizer is one of the major additional, purchased inputs to hybrid maize cultivation. Over 60 percent of fertilizer imported into Kenya is used on cash crops. In the mid-1980's, 30 percent of all fertilizer was applied on coffee, 18 percent on tea, and 16.5 percent on sugarcane. The remainder was applied on food crops: 19.7 percent on maize, 7.6 percent on wheat and 8.2 percent on all other crops (IFDC, 1990). 37 percent of fertilizer is consumed on estates, 21 percent on largeholdings and 42 percent on smallholdings. This last figure is low relative to the 80 percent of maize production generated by smallholders. In 1972, the ILO estimated 1.2 million smallholdings in Kenya of which 25 percent are under 1.0 hectare and 50 percent are under 2 hectares. Together, these support 90 percent of the population living in rural areas.

Fertilizer was first consumed by smallholders after independence in 1963 when they were allowed to grow coffee and to sell maize through the official channels. A rapid increase in fertilizer imports was experienced due to the introduction of hybrid maize, the subdivision of former European estates, and the introduction of a fertilizer subsidy by the GOK. Between 1963 and 1969 fertilizer imports grew at an average rate of 21 percent per year. The 1970's, however, experienced an average reduction of imports of 1.0 percent due to the increased international fertilizer prices following the world oil crisis, a collapse of output prices, increased transportation costs and the gradual reduction of the fertilizer subsidy (IFDC, 1990). Fertilizer imports grew again in the 1980's averaging a 15 percent annual increase between 1980 and 1988. Additionally, in the 1980's, fertilizer from donor countries began having a significant effect on the overall fertilizer levels in Kenya. In 1988-89, donor fertilizer made up 50 percent of the total fertilizer imports (IFDC, 1990). Figure II.4 in Appendix II shows fertilizer imports over the period 1963-88.

Studies have shown that fertilizer is one of the most important factors capable of bringing about a significant short-run increase in agricultural production. Heady et al. (1965) estimated that 45 percent of the average annual increase in yields for all crops in the United States over the 1950's and 1960's came from fertilizers. Goldsworthy and Watson (1968) contend that in Nigeria the use of fertilizer is one of the most important factors contributing to increased agricultural production (cited in Mwangi, 1978). Given the low fertilizer usage among smallholders, there is potential for increasing agricultural production in Kenya through greater fertilizer utilization.

The use of fertilizer is determined by the cost minimizing behavior of farmers. According to neo-classical economics, farmers want to minimize costs relative to their revenue. The first-order conditions of cost minimization indicate that farmers operate at the point where one additional dollar spent on inputs returns one additional in revenue. This point is defined by the input-to-output price ratio. Fertilizer and maize prices affect this ratio, as well as the physical response coefficients of the technology employed. The lower the price ratio, the greater the quantity of fertilizer the farmer is likely to use. Lele et al. (1988) calculate this ratio for the period 1972-87. It can be seen from Table 2.1, below, that the price ratio increased in the early

1980's but has declined sharply in recent years. Although the price ratio has become more favorable for farmers, fertilizer application rates remain low relative to the recommended rate. IFDC estimates an ideal fertilizer application rate of approximately 200 kg. of fertilizer per hectare, while the GOK recommends 123 kg./ha. The current application rate has been estimated to be 97 kg. per hectare of cropped land (IFDC, 1990).

Table 2.1: Ratio of fertilizer nutrient price to maize price for Kenya, 1972-87.

YEAR	PRICE RATIO		YEAR	PRICE RATIO
1972	4.6		1980	7.0
1973	6.2		1981	7.2
1974	5.9		1982	6.9
1975	7.3		1983	6.1
1976	6.5		1984	5.6
1977	4.2		1985	---
1978	4.5		1986	3.7
1979	5.6		1987	3.4

--- Not available
* Fertilizer prices are transformed to reflect their nutrient contents, and the ratios are computed as: price of 1 kg. of nutrient per the price of 1 kg. of maize.
Source: Lele, Christiansen, and Kadiresan (1988).

Two of the largest constraints to expanding fertilizer usage in Kenya are import restrictions and problems in the distribution of fertilizer (Lele, 1989). This paper will study the policies creating these constraints and their effects on the rate of return to maize research.

Kenya has two policies which affect the supply of and demand for fertilizer. On the supply side, an import quota determines the quantity of fertilizer imported each year. On the demand side, an implicit fertilizer price subsidy is intended to aid farmers in acquiring one of the major purchased inputs for agricultural production.

2.1 Fertilizer import quota

Kenya does not manufacture fertilizer. Some phosphates are imported from Uganda, but most fertilizer comes from overseas, West Germany being the largest supplier. World fertilizer prices have increased over the past two decades as well as Kenyan fertilizer imports as shown in Table 2.2. Both of these factors have caused fertilizer to increase from 1.7 percent of total import value in 1971 to 4 percent of total import value in 1985. Fertilizer thus competes for one of Kenya's most scarce resources, namely, foreign exchange. The prices of coffee and tea, the two export crops which consume the highest proportion of fertilizer, affect the amount of foreign exchange that can be allocated to the purchase of fertilizer each year.

Rising fertilizer prices induced the GOK in 1974 to implement a system of import licenses in order to control the use of foreign exchange. This system can be viewed as the equivalent of an import quota because it gives the GOK power to determine the quantity of fertilizer imported each year into Kenya. The issuance of licenses gives the GOK the additional power to determine which firms will be able to import fertilizer; however, for the purposes of analysis, this is not an issue which will affect the calculation of the rate of return to maize research and thus the policy of import licenses can be considered as an import quota.

Table 2.2: Fertilizer imports as a percentage of total imports 1971-88.

YEAR	FERTILIZER IMPORTS (K£ MILL)	TOTAL IMPORTS (K£ MILL)	% FERTILIZER IMPORTS OF TOTAL IMPORTS
1971	3.36	200.06	1.68
1972	4.12	197.85	2.08
1973	5.18	228.55	2.27
1974	16.06	383.88	4.18
1975	11.37	362.59	3.14
1976	5.26	407.00	1.29
1977	9.47	531.45	1.78
1978	10.01	661.13	1.51
1979	5.34	620.16	0.86
1980	15.84	950.03	1.67
1981	24.07	932.41	2.58
1982	15.61	900.31	1.73
1983	25.09	905.62	2.77
1984	13.89	1,097.21	1.27
1985	52.03	1,196.00	4.35
1986	50.01	1,337.89	3.74
1987	38.96	1,430.88	2.72
1988	49.18	1,765.14	2.79

Source: Central Bureau of Statistics, reported in various issues of Economic Surveys published by GOK.

2.1.1 Fertilizer marketing before 1974

Before 1974, two local importing companies and the Kenyan subsidiaries of the European Complex and Nitrex cartel were the main importers and distributors of fertilizer. In 1970, the Kenya Farmers' Association (KFA), representing Albatros-Holland, was responsible for importing and distributing 34 percent of the fertilizer imported. MacKenzie Kenya Ltd., representing Windmill Ltd., distributed 24 percent, Sapa Chemicals of Montecatini-Edison, an Italian firm, distributed 5 percent and Hoechst and BASF of Germany together distributed 37 percent (Mwangi, 1978).

This system of marketing was highly criticized in Kenya as not acting in the country's best interest because there were no incentives to obtain fertilizer from the cheapest supplier. The Report of the Working Party on Agricultural Inputs of 1971 pointed out two principal constraints to obtaining fertilizer from the cheapest supplier:

> First, the majority of importers at the moment are members of the European-based Nitrex Cartel of nitrogenous fertilizer manufacturers. This organization sets a common f.o.b. price for all straight nitrogenous fertilizers sold by members of the cartel. Second, until recently it appears to have been a deliberate policy of the Ministry of Agriculture acting on the advice of the Fertilizer Advisory Committee (whose active members have been existing fertilizer distributors). This policy has prevented firms which would have imported fertilizer from non-European sources, e.g., the Middle East, from entering the market and making it more competitive than it is at the moment.

The report further criticized that the oligopolistic network of foreign-operated firms resulted in unwarranted high prices, inadequate smallholder access to fertilizer supplies, unsuitable fertilizer packages, and a lack of advice on different fertilizers and their use to

decr
Euro

small-scale farmers. The Working Party recommended that the role of cooperatives be strengthened.

The report, however, did not prompt the government to encourage local private enterprise participation in the marketing system. On the contrary, in 1974, when an expected shortage of fertilizers in the long rainy season coupled with rapidly increasing fertilizer prices on the world market, the government intervened in the fertilizer market and began to import fertilizers directly. Established firms were denied import licenses except for minor amounts of special varieties (Mwangi, 1978).

2.1.2 Fertilizer marketing after 1974

During the period 1971-1973 the price of fertilizer in Kenya more than doubled. This was largely due to increased world prices caused by the international oil crisis, changes in the exchange rate[1], increased sea freight charges and increased distribution costs within Kenya. As Mwangi noted, increased fertilizer costs accounted for 81 percent of the increased maize production costs in the Trans Nzoia District in 1973-74.

In 1974, the government started issuing licenses to importers, thus directly deciding the type, quantity and purchaser/distributor of fertilizer. Originally, in 1974, the GOK began distributing through the Kenya National Federation of Cooperatives, the only organization which was granted an import license. However, the Federation's inexperience in fertilizer distribution created large surpluses of fertilizer stored

[1] The Kenyan shilling is pegged to the U.S. dollar which, in 1972-73 decreased in value. This caused a devaluation of 15% relative to most European currencies.

in warehouses. Only in 1977/78 were licenses issued to former importers such as the KFA and Windmill Ltd. increasing the total number of importers to 10. By 1989 there were 73 importers in Kenya (IFDC, 1990), approximately 20 of which were distributors with extensive marketing infrastructure while the remainder were small local distributors importing only very small quantities of fertilizer.

The current fertilizer distribution system, which is that established in 1974, has a physical network serving the larger fertilizer markets, covered by 42 major market centers. Three levels of transactions occur in the fertilizer market:

a) an exchange between the importer as a seller, and the wholesaler or distributor as a buyer. In Kenya some groups are both importers and wholesalers or distributors.

b) an exchange between wholesaler as a seller and retailer as a buyer, and

c) an exchange between the retailer as a seller and the farmer as a buyer (Mwangi, 1978).

For example, the KFA sells fertilizer from its 32 branches directly to large-scale farmers, government organizations or nearby small-scale farmers, through Cooperative Unions and societies to members of these societies, and through its 1,500 registered stockists. The number of stockists varies between districts but can reach the hundreds in densely populated areas. Most stockists handle an average of 10 to 15, 100 kg. bags; few sell more than 100 bags. These stockists play an important role in the distribution of fertilizer especially where cooperatives are weak and where the average farm size is small.

The criteria for issuing import licenses are not always based on factors such as experience in fertilizer marketing, ability to distribute fertilizer over the entire country or ownership of adequate warehouses for storage. Often licenses are issued based on political influence as is supported by the fact that a number of distributors with inadequate facilities have been granted import licenses while other distributors with large warehouses have been denied a license (IFDC, 1990).

In 1988 the import allocation system was restructured so that fertilizer is categorized under Schedule 1 of the Customs Tariffs Schedules. Under this new category, import licenses are granted automatically to firms wishing to import fertilizer without the need to apply for the license (GOK, 1989). However, the Ministry of Agriculture remains responsible for the supervision of this process.

2.2 Fertilizer subsidy

Kenya has always emphasized the need for a smallholder oriented strategy in input marketing and has thus had fertilizer subsidy schemes in operation since 1963 in order to protect the smallholder against rising fertilizer prices. Table 2.3 shows the total cost of subsidizing two types of fertilizer: nitrogen and phosphorus.

Table 2.3: Total cost of fertilizer subsidy

YEAR*	TOTAL COST OF SUBSIDY (K£ million)
1963-64	166
1964-65	189
1965-66	325
1966-67	350
1967-68	356
1968-69	563
1969-70	809
1970-71	778
1971-72	973
1972-73	750

* a fertilizer year is from July 1 to June 30.
Source: Mwangi (1978), p. 35.

The fertilizer subsidy is an implicit subsidy in that no direct handouts of money or fertilizer are given by the government but, through its pricing system, the government establishes fertilizer prices which are below the international market prices for fertilizer.

A yearly price list prepared by the Fertilizer Association, the members of which are importing companies as well as government representatives, establishes fertilizer prices at each level of the marketing chain. The price of fertilizer is determined through a cost-oriented model which estimates a benchmark international price (BIP) for fertilizer c.i.f. Mombasa. The BIP however, is difficult to establish and loses validity as international market prices vary. To establish a maximum retail price (MRP), delivery costs to 42 major marketing centers, as well as distributor and retailer margins are added to the

BIP figure. For example, the pricing methodology used during 1980-88 was based on the following formula:

C * 1.30 + 5 + T = Maximum Retail Price

Where: C = c.i.f. Mombasa cost per metric ton
1.30 = 30 percent markup of c.i.f. price
5 = K£ 5 markup to cover port charges
T = Transport costs from Mombasa to market centers

The resulting price is what producers must pay to obtain fertilizer and it has consistently been below the farm-level import parity price, although the difference has been diminishing throughout the years. The implicit fertilizer subsidy comes in two forms. First, since the largest distributor of fertilizer is the Kenya Grain Growers' Cooperative Union (KGGCU), a parastatal, the government funds the producer subsidy by absorbing the deficits incurred by this parastatal. Second, the fixed, low prices force private distributors to save on costs wherever they can, resulting in a market that works at less than full capacity. Transportation costs are the easiest to reduce by limiting the area of distribution which contributes to the problem of inadequate fertilizer supplies in areas far from the major marketing centers.

2.2.1 Current policy and future trends

In January of 1990, the government decontrolled fertilizer prices. IFDC conducted a study in the 6 months following, in order to determine the possible consequences of the removal of the subsidy. No significant changes in fertilizer prices were noticed because KGGCU, the largest distributor of fertilizer in Kenya, had excess stocks which it decided to sell during the 1989/90 season by reducing the average retail price of fertilizers by 18 percent. This large influx of cheap fertilizer into the market kept prices relatively low. It also enabled the KGGCU to establish itself as the fertilizer price leader. It was the only organization to release a price list. It also held the largest share of the fertilizer market, having been allocated 30 percent of the total fertilizer imported for 1990-91 (IFDC, 1990).

The number of distributors declined to 24 in 1990, from 73 in 1989. This may be due to the depressed fertilizer prices caused by the large influx of KGGCU fertilizer into the market. However, the KGGCU's pricing policy is not sustainable. It offered below market prices due to its large quantity of stocks. In 1990 the KGGCU's stocks were already 20,000 mt. less than the 1989 stock level (IFDC, 1990). Also, donor funded fertilizer is estimated to drop by 50 percent in 1990-91 to 65,000 mt. due to decreases in USAID's volume of fertilizer and the elimination of the Dutch fertilizer program. Both of these factors make it likely that Kenya's 1990-91 supplies will be largely based upon international fertilizer prices. Since late 1989, international urea and di-amonium phosphate (DAP) prices have been rising, therefore, fertilizer prices in Kenya are likely to increase greatly over 1989-90 prices which were depressed by KGGCU stocks being released into the market.

Another factor leading to higher fertilizer prices in Kenya is that importers/distributors will raise their margins to cover their costs and provide sufficient profit. Under the fixed-price system the margins established by the government were barely sufficient to provide a profit.

IFDC's study (1990) indicated that in the first year of decontrol retailers were the only members in the marketing channel to have benefitted from the liberalized pricing policy. They were able to add a markup of K£ .75-1.5 per 100 kg. bag as compared to K£ .25-.5 per bag under the previous pricing system (IFDC, 1990). IFDC estimates that retail prices will increase by 15-25 percent in 1990-91 over 1989-90 levels. In key agricultural areas this means that a 50 kg. bag of di-amonium phosphate (D.A.P.) will have a retail price of K£ 20.

With the increased profits, retailers hold a renewed interest in marketing fertilizers, particularly in the more remote areas where they are not competing directly with the KGGCU (IFDC, 1990). This is an indication that the expected rise in prices will be counterbalanced by a more competitive market which is likely to generate more incentives for distributors to invest in storage supplies, and to increase the geographical range of fertilizer sales by encouraging distributors to look for new markets. Farmers will thus benefit from a more timely supply of fertilizer. But which farmers and which actors in the marketing chain will benefit most remains to be seen.

2.2.2 Effects on fertilizer consumption

Despite the fact that 1989-90 had favorable climatic factors for fertilizer usage, IFDC estimated total fertilizer consumption for the 1989-90 season to be 222,160 mt., representing a 22 percent drop in consumption from 1988-89 levels. The drop in consumption can be linked to various factors: 1) the high maximum retail prices published in November, 1989, right before the price decontrol, encouraged farmers to plan crop production with minimal fertilizer usage. By the time that the price decontrol came in effect and the KGGCU published its low prices, it was too difficult and imprudent for farmers to alter their production plans, 2) a decline in international coffee prices, and 3) the GOK's delay in moving DAP fertilizer to distributors.

Although fertilizer demand decreased in the first year of decontrol, there is potential for increasing fertilizer usage, especially among small-scale farmers. A recent government survey indicated that only 26 percent of smallholders use chemical fertilizers and most of it is applied to export crops (GOK, 1989b). Smallholders, thus, provide a large potential market for fertilizer distributors. However, demand for fertilizer is a derived demand, based on a farmer's expectation of the gains from using fertilizer. It is important that there be a financial incentive for using fertilizer. As was shown in Table 2.1, fertilizer nutrient price to maize price ratios in Kenya have been favorable but as fertilizer prices rise the question is, will they remain favorable? IFDC calculated a similar ratio, namely maize price to fertilizer price using the projected 1990-91 fertilizer price for D.A.P. and the newly announced maize price. Table 2.4 shows these calculations below. Although the price ratio declines, indicating a decrease in maize prices relative to fertilizer prices, the reduction is not very large because, along with the increase in fertilizer cost, there is a concomitant increase in maize prices.

Table 2.4. Projected fertilizer to maize price ratio

	FERTILIZER COST K£/KG	MAIZE PRODUCER PRICE K£/KG	1KG MAIZE: 1KG FERTILIZER
MAY 1989	.338	.105	3.22
PROJECTED 1990/91	.425	.139	3.06
PERCENTAGE CHANGE	26	32	--

Source: Rocco, May, 1990 reprinted in IFDC, 1990.

Future fertilizer demand depends heavily on the maintenance of a favorable crop-fertilizer price ratio. Research on maize thus can have an important role in maintaining such a favorable relationship by decreasing farmer's production costs.

However, research alone cannot help the farmer in making the large initial investment in fertilizer, especially as fertilizer prices rise. A credit scheme aimed particularly at smallholders is necessary since they currently have the least access to credit due to the higher likelihood of default on loans. Currently, there have been no changes in the credit market. The KGGCU has stabilized its production credit program between K£ 3 and 3.5 million in 1990-91, a level similar to the previous year's. The Kenya Tea Development Authority (KTDA) reported no change in their fertilizer credit program for the 1990-91 season. As Mwangi notes in his study, smallholders suffer from an inadequacy of capital. He further shows that farm income is influenced more by capital availability than fertilizer prices. This indicates that the expected increase in fertilizer prices will not hinder the adoption of fertilizer among smallholders as much as an inadequate credit policy which makes fertilizer inaccessible to small farmers.

III. MAIZE RESEARCH

Maize research has largely focused on breeding new and improved varieties of maize for yield increases. The first maize breeding work began in 1930 and was mainly centered around producing varieties for large-scale settler farmers. The program however, made little progress and was aborted in 1945. A systematic maize improvement program was started with a full-time maize breeder from the United Kingdom, Michael Harrison, in Kitale in 1955. The initial efforts were directed toward the development of late-maturity maize hybrids suitable for regions receiving 750-2000 mm of annual rainfall in 6 to 8 months. The first successful hybrid was released in 1964, Hybrid 611 (H611), which yielded 40 percent more than the synthetic variety Kitale Synthetic II (KSII), released in 1961. Between 1965 and 1989, eleven high-altitude maize hybrids have been released to farmers. On average, these hybrids have yielded 30 to 53 percent more than local variety maize.

Due to Kenya's diverse geography, it soon became apparent that varieties needed to be developed for the different agro-climatic zones. In 1956, maize research started in Katumani to develop early-maturing varieties for the semi-arid regions which receive low, erratic rainfall of about 250-400 mm a year which fall within 60 days. Two composites, KCA and KCB, were released in 1966 and 1968 respectively. DC-I was released in 1989 which further increased the drought resistance characteristics of maize. Low adoption rates in these regions still remains a problem due to the poor yield performance.

The Central Highlands receive 350-750 mm of rain in two distinct seasons and require a variety that takes 5 to 6 months to mature. In

1965, research on medium-maturity maize began in Embu and the first medium-maturity variety, H511, was released in 1968.

In the Coastal Research Station, research for medium-rainfall, low-altitude tropical regions began in 1952. The Coast Composite (C.C.) was released in 1974 and the Pwani Hybrid I (PH I) in 1989. This latter has a 5-15 percent yield increase over CC and matures ten days earlier.

In total, 23 improved/hybrid varieties of maize were released between 1961 and 1989. Today, ten different hybrids and two open pollinated varieties are being produced for farmers in different agro-climatic areas of Kenya.

An extensive maize agronomy program has been in existence since 1950 to complement the maize breeding program. Currently, the program evaluates new varieties on the basis of the different agronomic factors which are required for the cultivation of these varieties in different agro-climatic zones, seasons and farmer circumstances. On-farm research has identified various factors as affecting maize yields, largely stemming from trials conducted by A.Y. Allan in 1963. Land preparation and time of planting were found to be the most important factors determining farmers' yields, followed by weed control and plant population, genotype, fertilizer, pest control, and time of harvesting.

Seed production and distribution are also important components of the maize improvement program. The Kenya Agricultural Research Institute (KARI) is responsible for the development, evaluation and release of seeds while seed production, processing, and distribution are conducted by the Kenya Seed Company (KSC), a private firm of which the GOK is a shareholder. Breeders supply their seed to the KSC who, in turn, releases it to farmers who have contracted to grow the seed. Seed stockists are recruited by the KSC to distribute the seed. An estimated 6000 stockists existed by 1980 which translates into approximately one stockist for every 8 hectares of improved maize planted (Rundquist, 1989). Kenya's seed distribution system has been considered one of the most successful in Africa due to the rapid adoption of improved seed. From a mere 4 metric tons in 1962-63, the KSC's seed output increased to 10,600 tons in 1975-76 and 21,800 tons in 1987-88 (Karanja, 1990). Table I.3 in Appendix I shows the area under improved maize seed between 1967 and 1975.

Maize research is predominantly funded by the public sector in Kenya. Before 1987-88, funds were channelled through the Ministry of Agriculture and Livestock Development, but have subsequently been provided through the Ministry of Research, Science and Technology (MRST). External governments and agencies have contributed to the research program for a 22 year period ranging from 1955 to 1977. The private sector has been minimally involved through adaptive research which is seldomly made public.

In 1985-86, the public sector spent .51 percent of national GDP on research and development[2]. A target level of two percent of GDP has been recommended by ISNAR as the appropriate level to fund research. Gross recurrent and development budget funding to the Ministry of Agriculture (MOA) increased almost threefold between the periods 1955-59 and 1985-88. Figure II.1 in Appendix II shows the MOA expenditure in nominal and real terms. Kenya is second only to Nigeria in per capita

[2] This excludes salaries of teaching staff at the national universities.

research expenditures in Africa. However, these aggregate level figures conceal the fact that maize research expenditures increased in real terms by about 182 percent between 1955-59 and 1974-79, but then declined by 55 percent between 1974-79 and 1985-88 (see Figure II.2 in Appendix II).

The manpower in research has significantly increased, from 18 agricultural researchers in 1963 to 566 in 1982, while the proportion of expatriate researchers declined from 86.9 percent to 11.3 percent (ISNAR, 1985). In 1980, Kenya averaged 24.3 agricultural research scientists per million people, which is higher than the average for sub-Saharan Africa (15.1), Asia (15.2) and Latin America (22.7) (Oram and Bindlish, 1981 as cited in Karanja, 1990).

Agricultural research receives 70 percent of the national budget for research (Ruigu, 1985). Funds are allocated differently according to region and crop. High to medium-potential areas have received the largest share of funds and scientific manpower while research on traditional export crops, coffee and tea, have been the crops receiving the largest share of total agriculture research funding.

Research on maize improvement has contributed to the doubling of national average maize yields, a near tripling of maize area planted and a fivefold increase in output over the period 1955-88, as shown in Table 2.5.

Table 2.5. Kenya: national maize production, yield and area, 1955-88.

Year	Output (t)	Yield (t/ha)	Area (ha)	Improved/Hybrid Maize	
				Area (ha)[a]	% of total
1955/59	542224	0.868	625240	-	-
1960/64	805650	1.058	760900	13623	1.79
1965/69	1089678	1.292	843195	95487	11.32
1970/74	1344400	1.510	891078	309378	34.72
1975/79	1772000	1.562	1143817	498989	43.62
1980/84	1936880	1.622	1204823	648855	53.85
1985/88	2670400	1.845	1445085	917576	63.50

Kenya, MOA/DPD, various reports.
FAO Production Yearbook, various issues.
[a] Estimated from the recommended seed rate of 22.45 kg./ha.
Source: Kenya colony, Crop Production Review, various issues; printed in Karanja, 1990.

However, if one disaggregates the data according to different time periods, one notices a slowing of maize production increases. Yield increased by about 49 percent, annually, between 1955-59 and 1965-69, but between 1975-79 and 1985-88 the yearly increase was only 18 percent; area increases slowed from 35 to 26 percent, annually, for the same periods.

IV. METHODOLOGY

4.1 Previous Studies

Most studies evaluating the returns to research assume free-market conditions (Lindner and Jarret, 1978; Edwards and Freebairn, 1984; Scobie and Possada, 1978; Akino and Hayami, 1975; Karanja, 1990). However, as Feder et al. note, agricultural policies are prevalent in developing countries, and affect the benefits that can be derived from research. The effects of distortions created by government policies on economic efficiency have been studied extensively (Dinopopulos and Kreinin, 1990, 1989; Corden, 1976; Mellor, 1978; Timmer et al. 1983; Schultz 1977, 1978). In contrast, the effects of non-research policies on the returns to research have been relatively ignored. Alston et al. (1978) study the effects of quotas, production subsidies and target prices on the benefits of cost-reducing research accruing to a country and the world as a whole. They conclude that government interventions modify the pattern of benefits obtained through research and should thus be included in the measurement of a rate of return.

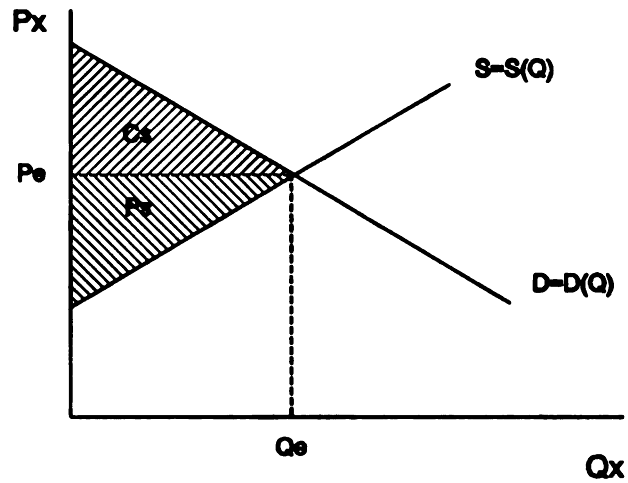
Oehmke (1988) shows that by not taking into account government induced market distortions, rate of return calculations can be severely biased. He examines target prices in a large open economy and output subsidies in both an importing and closed economy. He concludes that if research raises the cost of government interventions, then failing to include these costs underestimates the cost of research thereby adding an upward bias on the rate of return to research. Conversely, it can be shown that if successful research decreases the cost of government intervention, then the rate of return to research is typically underestimated. An example of this phenomenon would be if research increases the availability of staple foods, thereby reducing the costs of subsidized food programs. Oehmke (1990) adds to his earlier analysis by suggesting that policy intervention will affect the type of research undertaken by an optimal program.

Few studies, thus far, have analyzed policy effects on the rate of return to research in an applied, developing country setting. This study will incorporate the findings of Alston et al. and Oehmke (1988, 1990) into the analysis of maize research in Kenya.

4.2 The social surplus paradigm

Changes in consumer and producer surplus are one way to measure the welfare benefits or costs arising from changes in agricultural policy (Colman, Young, 1989). Together, they form a measure of social surplus. This paradigm underlies the methodology used in this study and therefore, it is briefly explained below.

Figure 4.1.



In Figure 4.1, the curve labelled S is an inverse supply curve, S-S(Q), indicating the cost of producing the Qth unit of a good, X. The profit gained by producing each unit of X is the price received, P_e , less the cost of production, S(Q). The integral of P_e-S(Q) over the range 0 to Q_e, sums the profits for each unit of X produced, assuming no change in fixed costs, to form the measure of producer surplus for all producers.

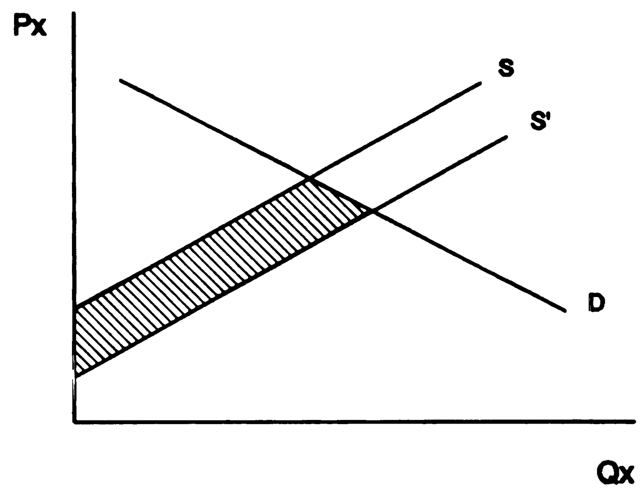
The curve labelled D is an inverse demand curve, D-D(Q), which approximates the maximum amount that a consumer is willing to pay to consume the Qth unit of good X. Consumer surplus, or the aggregate net gain to consumers from purchasing and using Q_e is calculated by integrating D(Q)-P_e over the relevant range.

The sum of the consumer surplus and producer surplus areas in Figure 4.1 is called social surplus and represents the gains from consumption, production, and trade of good X, accruing to a society.

4.3 The Calculation of Research Benefits

Successful research, and extension as defined by the economic efficiency criterion used in this analysis, are considered to generate and propagate improved production techniques or inputs which lower the costs of production. These lower costs shift the supply curve of a product outward as depicted by the shift from S to S', in Figure 4.2. This shift causes social surplus to increase by the size of the shaded area. Thus, keeping all else constant, this increase in social surplus is attributable to research and extension structures.[3]

Figure 4.2.



Studies evaluating the benefits from research generally look at the supply shift just described which occurs in the market of the output being affected by the new technology. Producer surplus is generated through the reduced costs of production. However, research may also

[3] The above discussion summarizes the section on social surplus in Daniels et. al., 1990.

affect the inputs used in the production of the output and as such, has an additional effect on the returns to producers. As Norton explains, when looking at the general equilibrium effects associated with a research-induced supply shift, it is important to observe the impact of technical change in the factor market. Norton (forthcoming) shows that characteristics of factor markets affect the level and distribution of research benefits. Thus, looking at an input market can give a partial equilibrium analysis of the benefits to research. Duncan (1972), for example, measured the benefits of pasture research in Australia through the input-demand functions for the stock of improved pastures.

The first objective of this study, to measure the benefits from maize research accruing to maize-producing farmers, is accomplished through an analysis of research effects on the demand for fertilizer, one of the major, additional purchased inputs required for hybrid/improved maize production. Maize research affects fertilizer in two ways" first, the agronomic program concentrates on improved input usage and husbandry practices and thus recommends, among other things, greater fertilizer usage. Second, hybrid/improved maize responds better to fertilizer than does local variety maize and therefore increases the demand for fertilizer.

The second objective, to evaluate the impact of non-research policies in the fertilizer market on the benefits derived from maize research, will be accomplished by incorporating measures of variables under the policy regime into the calculations of research benefits obtained from the first objective. Traditionally, when calculating the benefits and costs of a project using a national level objective as the unit of account such as increases in gross national product, an economic analysis is conducted which uses economic values. In general, such traditional economic analysis omits policies such as tariffs, quotas, or subsidies, considering them to be transfer payments from one group in a society to another. All items are valued at their opportunity cost to the society (Gittinger, 1982). Thus, an economic rate of return indicates the real resource cost of a particular project to a society. Or, alternatively, it indicates the costs and benefits from a project under perfectly competitive conditions where there are no market distortions. However, because most policies have social resource costs (in addition to transfer payments), this study calculates the benefits of maize research in Kenya under the existing policy regime in order to measure the interactive effects of non-research, agricultural policies on the economic surplus generated by maize research in the fertilizer market in Kenya.

What follows is an explanation of how policies in the fertilizer sub-sector were included in the social surplus calculations in order to show how maize research affects maize producers in the presence and absence of these policies. Each particular policy is discussed individually to better understand the effects stemming from it, and a final section will bring the various policies together to study their interactions. It is important to emphasize that the fertilizer sub-sector modelled in this study represents only the fertilizer market for maize producers.

Several assumptions need to be made in order to calculate the social surplus resulting from research and research-policy interactions.

For simplicity, fertilizer supply and demand curves are assumed to be linear, although this will be relaxed in the empirical work. Shifts in these curves occur in a parallel fashion. Additionally, a perfectly elastic world supply curve for fertilizer is assumed because fertilizer is imported and Kenya does not hold a large enough share of the world market for Kenya to influence fertilizer prices. An economic efficiency criterion is used for policy evaluation. This criterion places equal value on consumers, producers and taxpayers and uses as its objective the maximization of social surplus. Distributors of fertilizer are referred to as producers whereas farmers purchasing the fertilizer are called consumers.

4.4 Import quota

Over the period studied, Kenya's fertilizer import license allocation scheme has had the effect of limiting the quantity of fertilizer imported into the country. The allocation scheme further gave the GOK the power to determine the type of fertilizer and the actual importer/distributor of the fertilizer but for calculation purposes of a rate of return, these factors are not important. By limiting the number of import licenses, the government effectively imposes an import quota.

Figure 4.3.

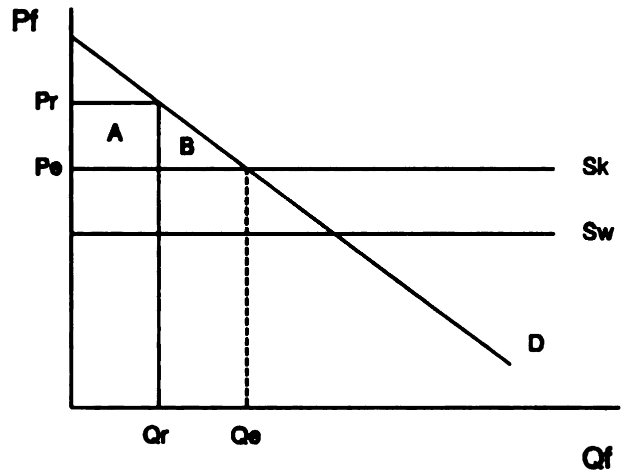


Figure 4.3 shows the supply of fertilizer being restricted by the quota at Q_r. S^w is the world supply curve for fertilizer and S^k is the Kenyan supply curve, which is drawn above S^w in order to reflect transportation and retail costs incurred by Kenyan distributors of fertilizer. The following discussion compares the change in producer and consumer surplus between an equilibrium situation and a quota scenario.

Producers receive P_r for Q_r which they would have sold for P_e, the equilibrium price, had the quota not been in place. Producers, thus, gain area A. Since the supply curve measures the marginal cost of fertilizer production and distribution, the area under the S^k curve and between Q_r and Q_e represents the costs saved by producing only Q_r. Producers also incur a loss by not being able to sell Q_e-Q_r. This loss is represented by the area below P_e, between Q_r and Q_e. Since S^k measures the marginal cost of fertilizer production and distribution and it is equal to P_e, the price received for the fertilizer at equilibrium, the lost revenue from decreased sales exactly equals the costs saved. The net gain to producers is thus area A in Figure 4.3.

Consumers of fertilizer (i.e. Kenyan farmers) lose area A because they have to pay a higher price, P_r, for quantity Q_r, which, at equilibrium, they could have gotten for P_e. They also don't have access to Q_e-Q_r. This loss is represented graphically by the area under the demand curve, between Q_r and Q_e. However, by not buying the fertilizer Q_e-Q_r, consumers save in costs the area below P_e and between Q_r and Q_e. The net loss to consumers is thus area A+B.

4.5 Implicit fertilizer subsidy

Since 1963, the GOK has implemented various fertilizer pricing schemes which establish a yearly price of fertilizer within Kenya at every point in the marketing chain. The prices established by the GOK have always been below the international market prices of fertilizers thus providing an indirect fertilizer subsidy. In the 1980's the amount of the implicit subsidy has declined as the established prices reflected international fertilizer prices to a greater extent.

Figure 4.4.

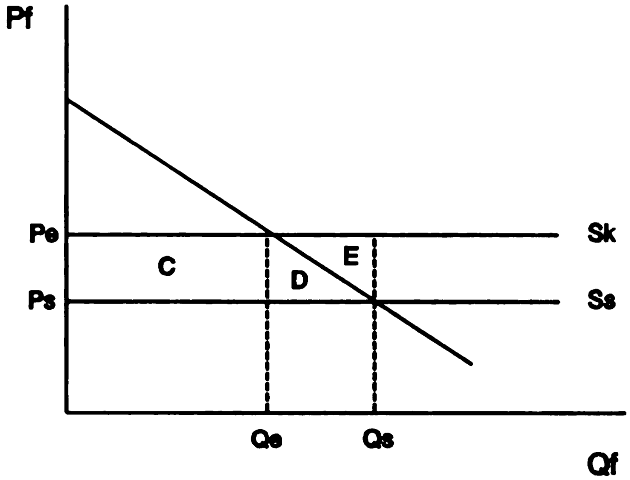


Figure 4.4 shows a government subsidy of fertilizer from P_e, the price of fertilizer to Kenyan consumers in a competitive situation which takes the c.i.f. price and adds transport and retail costs, to P_s, the fertilizer price set by the GOK which also uses as its base the c.i.f. price but adds transport and retail costs which are lower than those in the competitive equilibrium analysis[4]. In other words, P_s represents the Maximum Retail Price (MRP) described in Chapter II. The amount of fertilizer imported increases from Q_e to Q_s. Consumer surplus increases by the area C+D because consumers can obtain a greater quantity, Q_s, for a lower price, P_s. Producers experience no producer surplus given that a perfectly elastic supply curve equates marginal cost to marginal revenue. The government subsidy bill, on the other hand, is area C+D+E

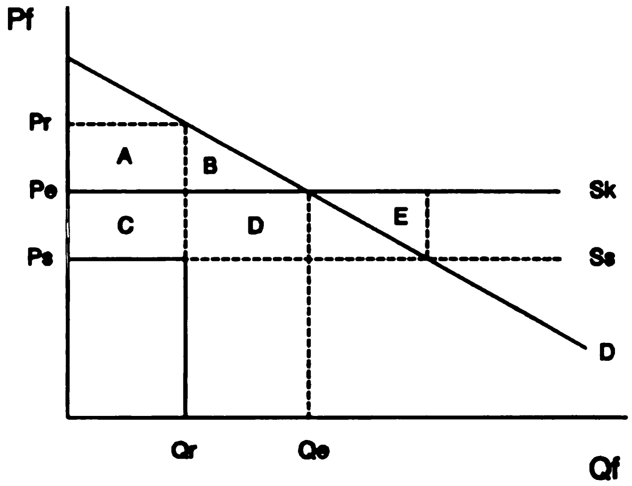
[4] IFDC (1990) has estimated that the decontrol of fertilizer prices in Kenya will bring about an increase in retail costs of 15-25 percent and increased transportation of fertilizer to more remote areas which, under the price-setting regime are not being served by fertilizer traders.

because in order to offer consumers price P_s for quantity Q_s, it must pay the difference between the world price at Q_s and the subsidy price at Q_s. The result is an efficiency loss in consumption, E.

4.6 The combined fertilizer quota and implicit subsidy effect

When, in 1974, the GOK decided to implement the import allocation scheme, it was applying an import quota in addition to the implicit fertilizer subsidy which already existed. Thus, Figure 4.5 is used to calculate changes in consumer and producer surpluses from an equilibrium situation to the subsidy plus quota situation.

Figure 4.5.



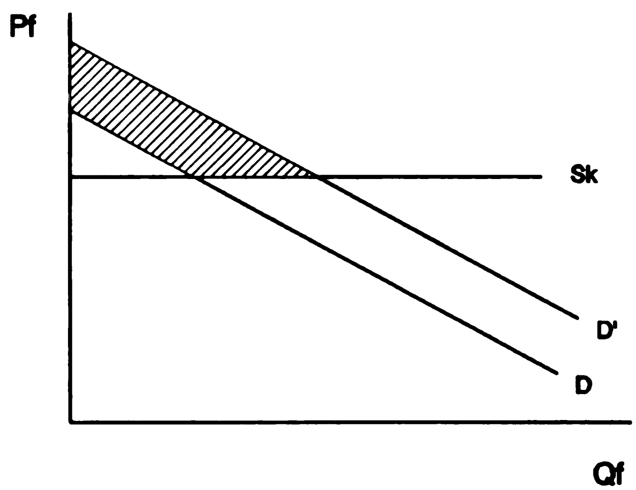
The quota has the effect of diminishing consumer surplus by area B because it limits the quantity of fertilizer available to consumers from Q_e to Q_r. The subsidy, instead, increases consumer surplus by area C because quantity Q_r can now be purchased at a lower price, P_s. The net effect on consumer surplus is area C-B. By restricting the quantity being imported to Q_r, the quota reduces the government subsidy bill to C. Finally, there is no change in producer surplus as long as the supply curve is perfectly elastic.

4.7 Research effects in a liberalized fertilizer market.

In 1990, the GOK completely eliminated its implicit fertilizer subsidy. Also, in Kenya's 1989-93 Development Plan the GOK indicated its intention to liberalize the distribution of fertilizer import licenses. As both the import quota and the implicit subsidy are removed, maize research and extension will affect the fertilizer market.

As successful research on maize in Kenya generates more hybrid/improved varieties and as extension causes these varieties to be widely adopted, the demand for fertilizer will increase due to three factors: 1) hybrid/improved varieties have higher response rates to fertilizer than do traditional, local varieties, 2) agronomic research makes recommendations for better husbandry practices and input utilization, among which is the recommendation to increase fertilizer application, and 3) as soil becomes depleted, there will be a greater need for fertilizer. Currently, Kenyan farmers are not working with the optimal amount of fertilizer required by their crops. IFDC estimates that 38 kg. per hectare of fertilizer nutrient are consumed, which translates into approximately 97 kg. of fertilizer product per hectare of cropped land. To attain maximum yields, hybrid maize requires an average of 100 kg./ha. of phosphorus fertilizer and 100 kg./ha. of nitrogen fertilizer for top dressing[5]. This indicates that there is room for increasing the rates of fertilizer applications. Additionally, only 26 percent of smallholders use chemical fertilizer, most of which is applied to cash crops. Thus, successful education should lead to wider usage of fertilizer. Research and extension, if successful, will all contribute to an increase in the demand for fertilizer as shown in Figure 4.6, below.

Figure 4.6.



The demand curve will shift outward to D', increasing both the price and quantity of fertilizer sold. In an equilibrium situation, without the quota and subsidy, the increase in consumer surplus is the shaded area between D and D', while there are no producer surplus or government subsidy costs.

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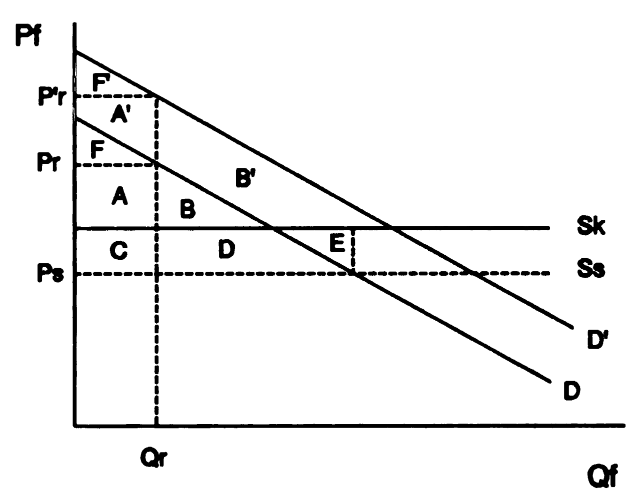
[5] Information obtained in a conversation with John H. Allgood of IFDC.

4.8 Interactions between research and policies in the fertilizer sub-sector.

With the import quota and fertilizer subsidy policies in place, a shift in the demand curve for fertilizer brought about by maize research will not be reflected through an increase in fertilizer sold or in fertilizer prices because these policies fix the price and quantity of fertilizer. The increased consumer surplus due to maize research corresponds to area F' + A' + B'. If the fertilizer policies are in place, area B' is foregone, while area C is added due to the subsidy, as was shown in Figure 4.5. However, area C does not affect social surplus because it nets out with the increased government subsidy bill. Producer surplus is zero, as without the demand shift because the supply curve remains flat.

Figure 4.7.



V. EMPIRICAL ANALYSIS

This study measures four areas in the fertilizer market: consumer surplus at equilibrium, consumer surplus with the policies in place, the increase in consumer surplus due to a 1.0 percent increase in research expenditures, and the same increase in consumer surplus under the policy scenario. Table 5.1 refers back to figure 4.7 and shows which areas measure social surplus under the various scenarios.

Table 5.1. Areas of social surplus under various scenarios.

scenario	NO increase in research expenditures	increase in research expenditures
NO quota and subsidy in place	A + B + F	A + B + F + A'+B'+F'
quota and subsidy in place	A + F	A + F + A'+ F'

It is important to note that the effects of the quota and subsidy on consumer surplus were measured assuming a price rationing scheme. Namely, the consumers who are willing to pay the highest amount for fertilizer are those that receive the fertilizer under the quota and subsidy scenario (even though they don't pay more than the government price). This assumption is supported by the fact that large maize farmers use the most fertilizer. It is expected that these farmers are the higher income farmers, and are willing to pay more for fertilizer, both because they have the income to afford it and because the scale and practices of their farms allows them to derive the largest yield increases from fertilizer use. In general, the large farmers have easier access to fertilizer distributors. Thus the graphical models' assignment of rationed fertilizers to those purchases most willing to pay is a reasonable assumtion[6].

Before it was possible to measure the areas marked in Table 5.1, a demand curve for fertilizer needed to be estimated. The following describes the data and the procedure used to model the demand for fertilizer.

5.1 The data

The data used for the analysis are the same as were used in the Karanja study (1990) on the rate of return to maize research[7]. Additional secondary data used include: international fertilizer and maize prices collected from various issues of FAO Production and Trade Yearbooks, Kenyan tea and coffee f.o.b. prices from economic surveys published by the Central Bureau of Statistics, Kenyan pound exchange rates, and value of fertilizer imported from statistical abstracts published by the Central Bureau of Statistics (CBS) supplemented with the aforementioned economic surveys, and farm-level fertilizer prices from IFDC reports (1990, 1986).

5.2 The model

There are various ways to calculate economic surplus. In the past, ex-post studies have mainly used production function or index number approaches. The former method was used in this study because it

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[6] A lottery system of rationing was tried as a hypothetical scenario. For results, see Appendix VI.

[7] For a detailed description of the sources of data, see Karanja, (1990) pages 56-58.

allows for the separation of the production effects of research from those of conventional inputs. It is also possible to make different estimations for different geographical areas using the production function approach (Norton, et al., 1981). Finally, it is an approach which allows for the incorporation of policy effects on the benefits from research. The duality approach was explored which requires estimating cost or profit functions. However, given the small variation in fertilizer and maize prices, because they are set by the government, it was not possible to estimate the required functions for this final approach.

The following Cobb-Douglas production function was utilized:

$$Q = A\, W_t^{\xi_t}\, E_t^{\gamma_t} \prod_{i=1}^{m} X_{it}^{\beta_{it}} \prod_{j=0}^{n} R_{t-j}^{\alpha_{t-j}}\, e^{u}$$

where:

Q= agricultural output (area * yield)
A= a shift factor
W_t= weather dummy variable
E_t= expenditure on maize extension
X_i= the quantity of the i^{th} conventional production input
R_{t-j}= expenditure on maize research
e= exponential
ξ, β = production coefficients, to be estimated
α, γ= partial production coefficients of research and extension, to be estimated
u= random error term

Although a Cobb-Douglas production function can be a rough approximation of farm-level production, it was deemed an appropriate way to represent the production of maize in Kenya due to the aggregate, national-level data being used. Recall that the Cobb-Douglas function is a first-order approximation to a generic function (the second-order form of this approximation is the translog function).

The conventional production inputs used in developing the production function for maize were fertilizer, hybrid seed and area planted under maize. Fertilizer consumption was approximated by assuming that fertilizer is used only on hybrid maize and not local variety maize, therefore area planted under hybrid maize was multiplied by the current application rates of fertilizer. IFDC (1990) estimated that an average of 97 kg. of fertilizer are applied per hectare of total cropped area in Kenya. This study assumes that large-scale farmers, who currently produce half of the country's maize output, utilize fertilizer on all of the hybrid maize that they grow, while IFDC (1990) estimated that only 26 percent of small-scale farmers apply fertilizer on hybrid maize. Therefore the average application rate of fertilizer on hybrid maize was estimated to be about 60kg. per hectare of hybrid maize planted ([.50+.50*.26]*97kg = 60kg.). The same application rate was assumed to be constant over the period 1955-88 due to the unavailability of data on previous application rates. However, this is a tenable assumption because in earlier years, large-scale farmers were the main adopters of hybrid maize and they have larger fertilizer application rates than do their small-scale counterparts. As farmers learn more about fertilizer through experience and extension services, their application rates are likely to increase. However, a large increase in small-scale cultivation of hybrid maize counterbalances the increased fertilizer application rate on hybrid maize due to low rates of fertilizer usage among small-scale farmers. Therefore, it is not unreasonable to assume that, on average, the fertilizer application rate stayed constant over the years 1955-88.

To measure hybrid seed usage, hybrid seed sales were used as a proxy. Since the Kenya Seed Company (KSC) is responsible for the distribution of hybrid seeds, this data was obtainable from their records.

Maize research and extension indirectly affect output through their direct effects on both hybrid seed sales and fertilizer consumption. The way these effects were represented econometrically is described later in this section. Government recurrent and development expenditures on research were multiplied by a time-series ratio of maize breeders and agronomists to total crop researchers in Kenya to estimate maize research expenditures. Similarly, gross, non-research, crop development expenditures were multiplied by the same time-series ratio to approximate maize extension expenditures, assuming that extension expenditures are allocated in the same pattern as research expenditures.

A dummy variable was used to capture the effects of irregular weather patterns on maize output. Years with similarly low levels of rainfall were denoted by a zero.

Ideally, a production function should also include incremental labor costs, credit availability, herbicide costs and any other inputs required as a result of using new maize technology. However, given the unavailability of data, it was assumed that hybrid seed and fertilizer were the only additional inputs used for growing hybrid maize. This is a tenable assumption because, as Gerhart (1976) noted, fertilizer and hybrid seed are the two additional inputs usually adopted by small-scale farmers who grow hybrid maize. Given that by 1975 smallholders accounted for almost 89 percent of the area under improved seed (see

Table I.3, in Appendix I), this assumption is valid for the majority of the sample in the study.

Hybrid seed sales and fertilizer consumption are jointly determined because the decision to plant hybrid seed and the decision to use fertilizer are generally simultaneous. Both inputs are promoted through extension to farmers in a package-like form. Hence, the quantity of fertilizer consumed is affected by the quantity of hybrid maize planted and conversely, the quantity of hybrid maize planted is dependent on the amount of fertilizer consumed. Both variables affect output directly, but also indirectly through their effects on each other. In order to take the indirect effects into account, a system of simultaneous equations was developed. Thus, along with the production function described above, two additional equations were formulated in which the variables, hybrid seed sales and fertilizer consumption, are defined in terms of each other and exogenous variables, namely, research, extension, a dummy variable reflecting weather and area planted under maize.

Research was lagged to take into account the gestation period required before the effects of the research can be noted. Various lags of research were tried, however, a ten-year lag was found to fit the data best. The first hybrid variety to be released after the beginning of the breeding program in 1955, H611, was released exactly a decade later, in 1964. Since then, it has taken researchers an average of seven to eight years to develop a variety and the Kenya Seed Company two years to test and to distribute it (Karanja, 1990). In similar studies in the United States, (Evenson, 1967; Fishelson, 1971; and Cline and Lu,

1976) a mean lag of six to seven years was used for research.[8] Pardey and Craig (1989) suggest that a lag as large as 30 years may be required to capture the full effects of research on agricultural output. However, such a lag can only be used on a long time-series. Pardey and Craig used a time-series of 93 years.

Extension was assumed to affect the use of fertilizer and hybrid seed in the same year that the knowledge was extended and thus was not lagged. Given the rapid adoption of hybrid maize in Kenya, an unlagged extension variable was found to best fit the data. A one-year lag was used for the weather dummy variable in the fertilizer equation because it was assumed that a previous year's weather would affect fertilizer consumption in the current year. For example, a dry season will leave the fertilizer applied partially unaffected, reducing thus the amount of fertilizer needed in the following season. Area under maize cultivation was included in the hybrid seed equation as an exogenous variable affecting how much hybrid seed would be planted.

A two-stage least squares (2SLS) technique was used to take into account the joint determination and thus the endogeneity of hybrid seed sales and fertilizer consumption. The endogeneity of the two variables leads to biased and inconsistent estimates if ordinary least squares (OLS) is used (Feder et al., 1985). 2SLS corrects the bias resulting from variables which are subject to the same random disturbances.

Although it is a single-equation method, a 2SLS technique was utilized to estimate jointly this system of equations. In finite samples

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[8] A research stock variable was also tried in order to take into account the slow depreciation of research over time. For results, see Appendix VII.

2SLS can perform as well as systems methods such as 3SLS or full-information maximum likelihood for various reasons: "First, any specification error in the structure of the model will be propagated throughout the system by 3SLS or FIML. The limited-information estimators will, by and large, confine the problem to the particular equation in which it appears." (Greene p. 638)[9]. Since, ideally, other inputs should be included in the production function, but were omitted due to lack of data, 2SLS was deemed preferable. Also, in systems methods, the finite-sample variation of the estimated covariance matrix is transmitted throughout the entire system, resulting in greater variances than if 2SLS were used (Greene, 1990, pp. 591-651).

The three equations defining fertilizer consumption, hybrid seed usage, and output, were estimated using as instruments the following variables: research expenditure lagged ten years, extension expenditures, weather lagged one year, weather unlagged, and area. These variables were chosen as instruments because they are exogenous and, more importantly, they logically explain shifts in fertilizer consumption and hybrid seed sales as well as maize output.

Once the output equation was estimated and the indirect effects of fertilizer were incorporated into it[10], several other variables had to be estimated to measure the areas identified in Table 5.1. A shift in the demand curve for fertilizer was calculated for the year 1987 because

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[9] Systems methods are defined as those which jointly estimate the regression equations, whereas single-equation methods estimate each equation separately. Both methods are based on the principle of instrumental variables.

[10] For calculations see Appendix III.

it was the most recent year with a complete set of values for each variable. The quantity of fertilizer restricted by a quota was measured by the quantity imported in 1987 less the stocks held in 1987. The subsidy price of fertilizer was estimated to be the price of D.A.P.[11] in Nakuru which includes retail and transport costs.

Various formulations of the production function were tried. Coffee and tea prices were included as variables and exchange rate data were used to convert international prices into Kenyan Pounds. Different estimation techniques were also tried: OLS, principal components to correct for multicollinearity, and 3SLS. The final result was chosen on the basis that it best fit the data and it also took into account the nature of the variables and the limitations of the data.

Although Kenya has one of the best established data bases in sub-Saharan Africa, inaccuracy of the data may be a factor affecting the results obtained. However, one must work with this reality, and conduct an analysis with the data that is available, while keeping in mind that the results are not as precise as they might be, given more accurate data.

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[11] Studies have indicated that D.A.P. is the most extensively used type of fertilizer among maize growers in Kenya (Karanja, 1990).

5.3 Results

The following results were obtained using a 2SLS regression technique:

$$LFERTCON = \underset{(0.674)}{6.063} + \underset{(1.337)}{0.652}\ LHS + \underset{(0.140)}{0.105}\ DLRE10 - \underset{(0.856)}{0.282}\ DLEX + \underset{(0.177)}{0.033}\ DLAST \quad (1)$$

Adjusted R-squared=.82; F-value=25.47; Degrees of Freedom=22

$$LHS = \underset{(1.149)}{-8.344} + \underset{(0.212)}{0.178}\ DLRE10 + \underset{(2.711)}{0.473}\ DLEX + \underset{(1.942)}{1.333}\ LFERTCON - \underset{(0.323)}{0.269}\ LA \quad (2)$$

Adjusted R-squared=.85; F-value=31.44; Degrees of Freedom=22

$$LOUTPUT = \underset{(1.676)}{4.330} + \underset{(0.789)}{0.1827}\ LFERTCON + \underset{(3.854)}{0.219}\ D + \underset{(1.622)}{0.202}\ LHS + \underset{(1.919)}{0.453}\ LA \quad (3)$$

Adjusted R-squared=.89; F-value=43.88; Degrees of Freedom=22

where:

LFERTCON= log of fertilizer consumption (mt.)
LHS= log of hybrid seed sales (mt.)
LOUTPUT= log of maize output (mt.)
DLRE10= log of research expenditures, lagged 10 yrs, deflated to 1971 prices (K£)
DLEX= log of extension expenditures, deflated to 1971 prices (K£)
DLAST= dummy variable denoting weather, lagged 1 yr.
LA= log of maize area planted (ha)
D= dummy variable denoting weather

The numbers below the coefficients are absolute values of t-statistics. Equation (3) indicates that fertilizer and hybrid seed usage, weather, and area planted under maize, all have a positive effect on maize output. Weather and area are significant at the 5 and 10 percent level, respectively, while hybrid seed and the intercept term are significant at the 15 percent level. Fertilizer consumption is only significant at the 45 percent level. However, an F-test rejected the null hypothesis that LFERTCON = LHS = 0 in the output equation, thus indicating the fertilizer consumption and hybrid seed sales have effects on output which jointly are significantly different from zero. Since all of the variables except for weather are expressed in natural logarithm form, the coefficients can be interpreted as percentage changes.

The relatively high level of significance of hybrid seed consumption in equation (1) and fertilizer consumption in equation (2) support the assumption that both of these variables have indirect effects on output.

Research is found to have a double, though statistically insignificant, effect on maize output through its breeding efforts, which have developed hybrid and improved varieties of maize, and through the agronomy program, which has concentrated on improving husbandry practices and input usage and thus has increased fertilizer application rates.

The fact that area has a coefficient significantly different from either zero or one at the 10 percent level indicates that it is appropriate to express equation (3) in terms of output rather than yield (If the coefficient is one, average yield can be expressed as a function of aggregate non-land inputs. If the coefficient is zero, then average yields can be expressed as a function of non-land input use per unit land).

Although the negative coefficients on extension in equation (1) and on area in equation (2) are surprising, Their significance is low.

Equations (1) and (2) define the instrumental variables in terms of each other, and exogenous variables. Through these equations, it was possible to relate maize research and extension to maize output, and then to derive a demand curve for fertilizer. A derived demand curve for fertilizer was solved for by substituting equation (1) into equation (2) and then equation (2) into equation (3)[12]. It was found that, on average, between the years 1955 and 1988, K£ 10,000 in research expenditures led to 7,700 mt. of fertilizer to be consumed yearly, *ceteris paribus*, for the nation as a whole.

Using the derived demand curve for fertilizer and the estimated fertilizer consumption, it was possible to measure consumer surplus which accrued to maize-growing farmers who used fertilizer in 1987 in a free-market situation. Consumer surplus was calculated to be K£ 42.778 million, using 1987 prices, expenditures, and quantities. Since the model works well around observed values only, it was not possible to calculate consumer surplus in a situation where no research was undertaken during the period under investigation. However, the effects of a one percent increase in research expenditures on the estimated consumer surplus for 1987 was estimated, *ceteris paribus*. Using equation (10) in Appendix III, consumer surplus was recalculated for a value of research expenditures augmented by 1 percent, or K£ 2,396. It was found that consumer surplus increased by approximately K£ 257,100.

A rate of return to maize research was calculated for 1987. The rate of return is defined to be that value of r which solves

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[12] For calculations, see Appendix III.

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$$\sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^{t} (B_t - C_t) = 0$$

where t is time, with time 0 representing the start of the project, B_t represents benefits at time t, and C_t represents costs at time t. From the maintained assumptions that benefits accrue ten years after costs are incurred, it follows that $C_t=0$ for $t\neq1$ and $B_t = 0$ for $t\neq10$. Thus the formula simplifies to $C=B/(1+r)^{10}$, or

$$r = (B/C)^{1/10}-1$$

where r = rate of return
B = benefits as measured by the increase in social surplus in 1987 due to a 1 percent increase in research expenditures
C = costs as measured by an additional 1 percent research expenditures in 1977.

The marginal rate of return to maize research in 1987 was 60 percent, similar to that calculated by Karanja (1990).

The above analysis applies only to a perfectly competitive situation. Policy restrictions were introduced into the calculations for consumer surplus in order to measure the effects of policies in the fertilizer sub-sector on the gains derived from maize research by Kenyan farmers. The quota and subsidy were estimated to have reduced consumer surplus in 1987 by K£ 41,800. If government costs of the subsidy are considered, the total economic surplus declined by K£ 344,900. In other words, the net economic surplus diminished by .8 percent in 1987, with the subsidy and quota in place, relative to the free-market situation. Furthermore, when the increase from a one percent rise in research expenditures was considered, the fertilizer policies reduced the additional benefits from research to K£ 242,600. This reduction in benefits results in a lower marginal rate of return to maize research of 58 percent.

The results obtained depend on the magnitude of a series of variables in 1987 and on certain assumptions made. Sensitivity analysis was conducted in order to understand how a change in these variables might affect the estimated economic surplus generated by maize research. Table 6.1 shows the results from this sensitivity analysis.

Table 6.1. Sensitivity analysis on selected variables.

SCENARIO → / TRIAL ↓	NO increase in research NO policies in place	INCREASE in research NO policies in place	NO increase in research POLICIES in place	INCREASE in research POLICIES in place
	MEASURES OF SOCIAL SURPLUS (K£ million)			
BASE TRIAL	42.778	43.035	42.433	42.675
FERTILIZER APPLICATION RATE INCREASED 33%	39.596 (-7)*	40.355 (-6)	39.904 (-6)	40.134 (-6)
FERTILIZER APPLICATION RATE DECREASED 33%	45.959 (7)	47.116 (9)	46.230 (9)	46.491 (9)
FREE-MARKET PRICE OF FERTILIZER INCREASED 20%	40.868 (-4)	41.317 (-4)	41.039 (-3)	41.281 (-3)
FREE-MARKET PRICE OF FERTILIZER DECREASED 20%	44.686 (4)	45.235 (4)	43.827 (3)	44.070 (3)
QUOTA LEVEL INCREASED 24%	42.778 (0)	43.035 (0)	42.738 (1)	42.990 (1)
QUOTA LEVEL DECREASED 24%	42.778 (0)	43.035 (0)	41.701 (-2)	41.932 (-2)
MAIZE PRICE INCREASED 25%	50.626 (18)	51.060 (18)	49.843 (17)	50.122 (17)
MAIZE PRICE DECREASED 25%	34.929 (-18)	35.275 (-18)	35.022 (-17)	35.229 (-17)

* numbers in parenthesis indicate the percentage change relative to the results obtained with the assumptions made in this study

The rate of fertilizer application was estimated to be 60 kg. per hectare of maize given the assumptions explained earlier in this chapter. To see if this estimate greatly affects the results, consumer surplus was recalculated using an application rate of 40 kg./ha and 80 kg./ha. The results indicate that a change in the fertilizer application rate of ±33 percent changes consumer surplus in a free-market situation by ±7 percent. It additionally causes large increases in the quantity of foregone social surplus under the quota and subsidy scenario, both with and without the increase in research expenditures.

The price of fertilizer in a free-market situation was estimated using the derived demand curve in the base trial. A ±20 percent change in the free-market price of fertilizer was calculated to see how consumer surplus would be affected by fluctuating international fertilizer prices. It can be seen from Table 6.1 that consumer surplus changes by ±4 percent in all four scenarios.

The level of the quota was changed by ±2.5 percent to reflect fluctuations which have occurred in the past. The variation in quota changed consumer surplus by a range of 1.0 percent to -2.0 percent both with and without the increase in research expenditures. These results are encouraging because relaxing the quota by 24 percent from the 1987 level can increase consumer surplus by K£ 315,000 with a 1.0 percent increase in research expenditures. Furthermore, the sensitivity results indicate that a decrease in the quota level of 24 percent, with an increase in research expenditure, will cause the largest amount of foregone potential consumer surplus of all trials, namely, K£ 1.103 million.

The level of subsidy was not altered because whatever changes it would have generated in consumer surplus, would have been exactly balanced by changes in the government subsidy bill so that there would be no change in social surplus.

Finally, the price of maize was changed. This is a particularly important case due to the deregulation of movement restrictions and price decontrol currently taking place in the maize market. Although predicting the changes in maize prices caused by the removal of these policies is beyond the scope of this study, the price of maize was varied to see its effects on consumer surplus in the fertilizer sub-sector. A 25 percent increase in maize price was found to augment 1987 consumer surplus accruing to farmers by 18 percent, or K£ 7.925 million. This variable has the largest effect on the original consumer surplus measured in this study.

VI. SUMMARY AND CONCLUSION

Since Kenya has the enormous task of feeding a rapidly growing population on only twenty percent of its land, technologies which increase the productivity of agriculture without requiring additional land are of extreme importance. The Kenyan Government has recognized the necessity of supporting its agricultural sector and since independence has funded, along with donor support, one of Africa's largest agricultural research systems. A maize breeding and agronomy program was started in 1955 and since then the maize sub-sector has experienced a doubling of national maize yield, a near tripling of area under maize, and a fivefold increase in maize production (Karanja, 1990). Maize research has been very important to the population as a whole because maize is the staple food for over 95 percent of the population (FAO, 1989). Maize production, however has slowed since the mid-1970's. Between 1955-59 and 1965-69 yield increased by 49 percent, but between 1975-79 and 1985-88 it increased by only 18 percent while area increases also slowed. National yields are 50 to 75 percent lower than on-station trials. The World Bank (1984) estimated that a 70 to 100 percent increase in production can be experienced in Kenya due to better husbandry and input utilization practices. There has been wide adoption of hybrid maize as demonstrated by the large increase in seed sales experienced by the KSC (see Figure II.3 in Appendix II). Fertilizer, however, is the major purchased, non-land input after seed for hybrid maize cultivation and yet has very low application rates among smallholders. According to trials conducted by the University of Nairobi over the period 1983-84, fertilizer increases maize output by

7.2 kg. of maize/kg. of nitrogen (IFDC, 1986). However, it is estimated that only about 26 percent of small-scale maize producers use chemical fertilizer (IFDC, 1990). The above statistics demonstrate that there is room for increases in fertilizer consumption.

Maize research has emphasized the development of hybrid maize varieties for various agro-climatic zones while agronomic research has developed recommendations regarding husbandry practices and input usage. Extension services have worked to bring research results to farmers. Maize research and extension increase the demand for fertilizer because hybrid/improved varieties respond better to fertilizer than do local varieties and because agronomic recommendations have consisted of, among other things, the use of fertilizer. This study finds that over the years 1955-88, K£ 10,000 in research expenditures caused an average annual increase in fertilizer consumption of 7,700 mt. Furthermore, in 1987, consumer surplus accruing to farmers utilizing fertilizer was K£ 42.778 million. A one percent increase in research expenditures in 1977 of K£ 2,396, would have led to an increase in consumer surplus of K£ 257,100 for a total consumer surplus amounting to K£ 43.035 million. This increase in consumer surplus is caused by a rise in fertilizer consumption of approximately 155 mt. which, from the regression results, translates into an increase in maize output of approximately 3,425 mt. of maize. Considering that research expenditures increased 24 percent in 1978 relative to 1977, 82,000 mt. of maize output in 1988 were due to the increase in maize research expenditures experienced between 1977 and 1978.

The above estimation of fertilizer demand response to maize research, however, was calculated using the assumption of perfect competition. In fact, when one observes actual fertilizer consumption data (calculated by subtracting stock levels from fertilizer quantity imported) for Kenya, one does not see the projected increase in fertilizer consumption as was estimated in these calculations. The difference between the observed values and the projected values is due to policies in the fertilizer sub-sector which restrict the quantity of fertilizer imported. When the policy restrictions were included in the calculations, social surplus diminished by K£ 344,900. With a one percent increase in research expenditures, the import quota and subsidy policies cause consumer surplus to diminish by K£ 360,000.

Sensitivity analysis has shown that the magnitude of the results obtained varies greatly according to the assumptions made. Also, inaccuracy of the data may be a factor to consider. Thus, the purpose and lessons to be gained from this study are not so much the actual magnitudes of the social surplus under various scenarios, but rather the general trends in consumer surplus in the fertilizer market due to the interactions of research and policy effects. The main conclusions to be drawn are:

> *1. Research has a positive effect on consumer surplus accruing to maize-growing farmers who use fertilizer.*
>
> *2. The removal of the import license restriction and pricing policy in the fertilizer sub-sector will have a net positive effect on social surplus.*
>
> *3. The removal of the aforementioned policies will allow greater benefits to be gained from current and future research investment.*

Although the removal of both fertilizer policies will lead to gains in consumer surplus, it is important to note that the removal of the fertilizer subsidy without a lifting of the import license policy will reduce consumer surplus below the current level. Social surplus, instead, will remain unaffected because the removal of the subsidy will reduce the government costs by an amount proportional to the decreased consumer surplus.

A marginal rate of return to maize research for 1987 was calculated to be 60 percent, per annum, without the fertilizer policies in place. However, with the policies, the marginal rate of return for 1987 drops to 58 percent. This result highlights the third conclusion mentioned above that the fertilizer policies do not allow the full potential benefits from research to be realized.

The results from this study indicate that structural adjustment in the fertilizer market in Kenya is complementary to sustained funding for the maize research program. Both actions maximize the social benefits from producing hybrid maize in Kenya and together they increase the benefits to be had by maize research. It is important to keep in mind, however, that this study does not include any distributional analysis (due to insufficient micro-level data for smallholders and largeholders and for different regions). Thus, although social surplus is increased by research and the elimination of fertilizer policies, it is not possible to say who gains most and which areas are favored by these actions.

This study is a partial equilibrium analysis, and as such, evaluates policy effects only from the point of view of fertilizer consumption and potential consumer surplus accruing to maize-growing farmers. It does not consider changes in the maize market. Sensitivity analysis showed that the results from this study vary considerably if maize prices fluctuate. A complementary study, thus, would involve a similar analysis of the benefits from maize research by taking into account policies in the maize sub-sector and evaluating the effects of these policies on the returns to maize research. By combining the results of this study with the conclusions of the complementary study, a complete analysis could be made about the effects of non-research policies on the benefits from maize research in Kenya. It would also be possible to assess if increases in maize production due to research and fertilizer usage could help replenish foreign exchange reserves which would be needed to satisfy the increased fertilizer consumption brought about by the removal of the fertilizer import license allocation scheme. In order to facilitate such a study, a description of non-research, maize policies which would need to be analyzed is included in Appendix V. Additionally, this study would benefit from the collection of regional data. Policy effects will have diverse impacts in different regions given the geographical diversity of Kenya's landscape and climate.

Another topic for further study is the possible endogeneity of research. This study assumes research to be exogenous to policies and therefore does not address the issue of research being induced by policies via prices. Bonnen (1990) argues that the United States' agricultural research system was shaped by policies. He shows, for example how policy decisions and their sequence which created land grant universities has influenced the type of research being done today in the United States (U.S.). Schultz (1978) argues that were it not for the U.S.'s protective policies on sugar, sugar-beet research would have never received the funding that it has. Finally, Busch (1991) contends that research does not take place in a vacuum and is therefore affected by external influences. It is important, when evaluating non-research policies in Kenya, to consider the endogeneity of research, to the extent that it is demand driven. If the removal of policies makes maize production less profitable, for example, there may be a redirection of maize research. This study considered research as exogenous to non-research policies due to the centrally organized nature of the Kenyan maize research system in the past. Makanda (1989) explains that under colonial rule the research system was centrally planned and has remained so until the mid-1970's. However, developments in the past decade have contributed to the decentralization of the maize research system and therefore, it is important for future studies on maize research to take into consideration the endogeneity of research.

APPENDICES

APPENDIX I

APPENDIX I: Tables.

Table I.1. Kenya: NCPB maize purchase by province, 1966-88 in thousands of metric tons.

	PROVINCE						
YEAR	RIFT VALLEY	WESTERN	NYANZA	EASTERN	CENTRAL	COAST	TOTAL
1966-67	148.6	58.1	9.44	4.87	9.2	0.5	225.6
1967-68	106.7	92.2	13.98	5.51	9.7	0.1	228.2
1968-69	167.3	72.7	24.04	22.70	5.2	0.01	292.0
1969-70	173.3	75.2	15.51	7.63	3.5	--	275.1
1970-71	173.3	75.2	1.78	1.20	0.5	--	252.0
1971-72	217.1	57.8	15.50	15.95	11.9	--	318.3
1972-23	290.3	100.2	36.07	35.14	19.3	--	481.0
1973-74	214.8	126.1	12.58	2.05	12.8	--	368.3
1974-75	234.8	150.6	21.09	8.39	34.0	--	448.9
1975-76	333.3	173.1	35.51	0.64	12.9	0.01	555.5
1976-77	270.0	171.8	60.58	43.82	21.6	2.4	570.2
1977-78	140.6	82.6	14.96	3.14	2.8	0.1	244.2
1978-79	154.3	51.3	4.21	8.39	8.5	--	226.7
1979-80	95.7	28.2	3.24	4.91	0.1	--	132.2
1980-81	269.7	80.8	31.40	0.34	0.4	--	382.6
1981-82	469.3	123.2	54.47	41.84	7.6	0.03	696.4
1982-83	437.6	96.0	50.95	33.29	9.3	--	627.1
1983-84	374.8	74.9	45.85	0.04	1.9	--	497.5
1984-85	238.3	115.8	14.71	10.03	0.9	0.05	379.8
1985-86	580.7	175.7	51.00	16.19	10.1	0.04	833.7
1986-87	544.9	118.1	48.06	1.93	5.8	0.03	718.8
1987-88	339.6	81.6	55.41	0.66	0.2	0.02	477.5
1988-89	467.8	69.1	22.28	35.55	28.8	0.5	624.0

Note: "--" means negligible.
Source: Karanja (1990), p.80.

Table I.2. Gross marketed production from large and small farms, Kenya, 1970-89.

YEAR	LARGE FARM (K£ million)	SMALL FARM (K£ million)	TOTAL PRODUCTION	% SHARE OF SMALL FARMS
1970	41.2	44.2	85.4	51.7
1971	42.1	44.6	86.7	51.4
1972	50.3	55.6	105.9	52.5
1973	60.0	63.3	123.3	51.4
1974	73.4	75.0	148.4	50.6
1975	71.8	90.1	162.0	55.6
1976	122.1	128.0	250.0	51.2
1977	206.0	208.5	414.6	50.3
1978	147.2	178.6	325.8	54.8
1979	148.2	165.2	313.4	52.7
1980	168.8	184.5	353.3	52.2
1981	178.6	208.3	386.9	53.8
1982	216.7	232.3	448.9	51.7
1983	271.3	284.1	555.4	51.2
1984	386.2	402.5	788.8	51.0
1985	346.6	409.3	755.9	54.2
1986	515.5	422.8	938.3	45.1
1987	432.1	385.6	817.7	47.2
1988	500.4	445.3	945.7	47.1
1989	508.3	494.9	1003.2	49.33*

* estimated by CBS

Source: Central Bureau of Statistics (CBS) reported in various issues of the Economic Surveys

Table I.3. Kenya: area (ha.) under improved maize seed, 1967-75.

Year	Small-scale Farms	Large-scale Farms	Total Area
1967/69	51320	36516	87836
1968/69	64333	39516	103849
1969/70	96971	45915	142886
1970/71	149971	63811	213782
1971/72	206947	73975	280922
1972/73	264871	53392	318263
1973/74	292501	39232	331733
1974/75	352276	50717	402993
1975/76	421553	50607	472160

Source: KSC, unpublished data reproduced in Karanja, 1990.

APPENDIX II

APPENDIX II: Figures.

Figure II.1. Kenya: Ministry of Agriculture expenditures on research 1955-88.

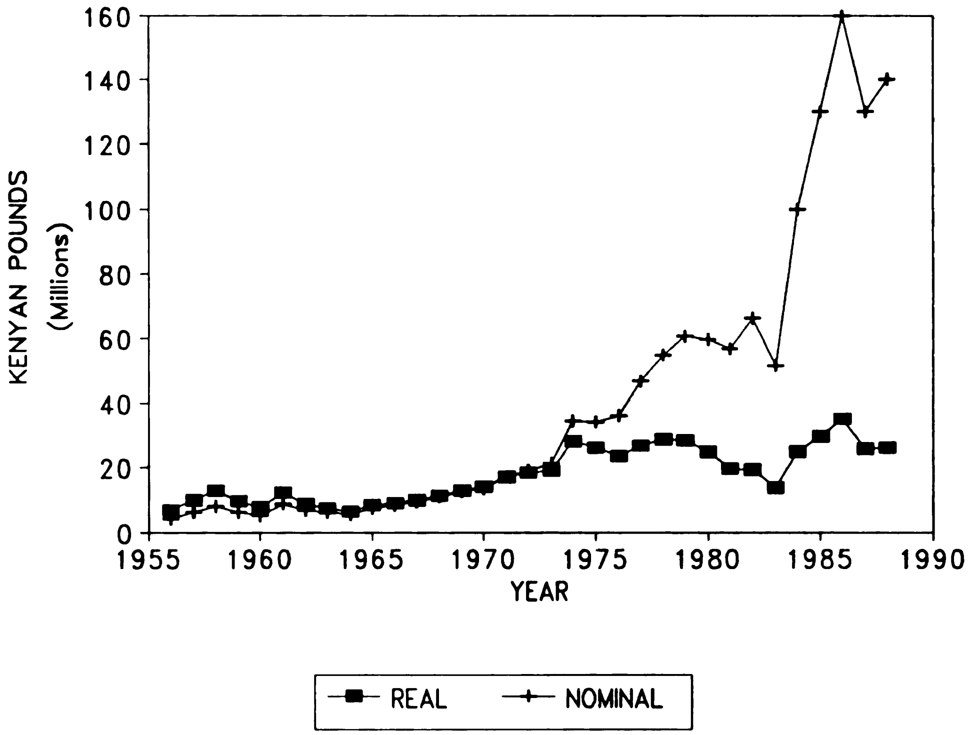


Figure II.2. Kenya: maize research and extension expenditures in nominal terms 1955-88.

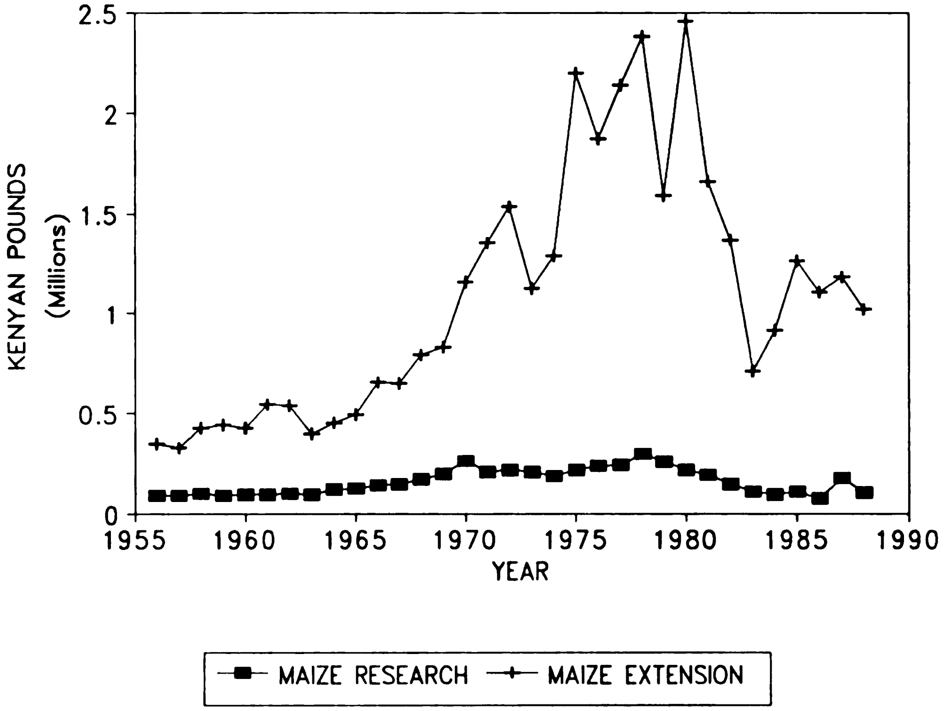


Figure II.3. Kenya: hybrid seed sales, 1955-88.

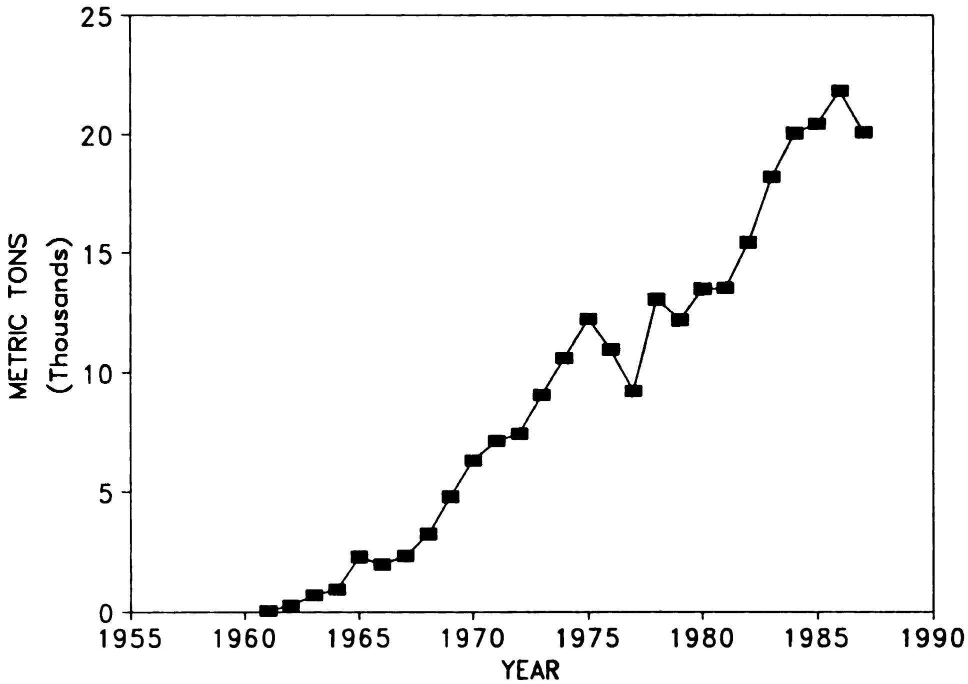
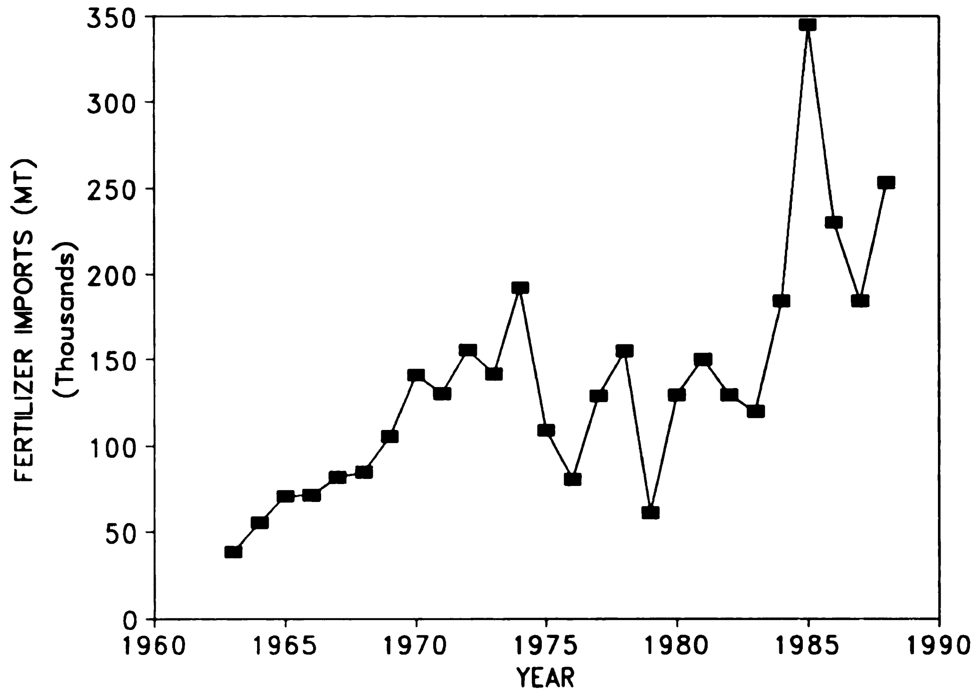


Figure II.4. Kenya: fertilizer imports, 1963-88.



APPENDIX III

APPENDIX III: Calculation of consumer surplus.

The following are the calculations made in order to derive a demand function for fertilizer and to approximate consumer surplus accruing to farmers utilizing fertilizer.

$$LFERTCON=\alpha_0+\alpha_1 LHS+\alpha_2 DLRE10+\alpha_3 DLEX+\alpha_4 DLAST \tag{1}$$

$$LHS=\beta_0+\beta_1 DLRE10+\beta_2 DLEX+\beta_3 LFERTCON+\beta_4 LA \tag{2}$$

$$LOUTPUT=\gamma_0+\gamma_1 LFERTCON+\gamma_2 D+\gamma_3 LHS+\gamma_4 LA \tag{3}$$

Substituting equation (1) into equation (2) and solving for LHS:

$$LHS=\frac{1}{1-\beta_3\alpha_1}\{\beta_0+\beta_3\alpha_0+(\beta_1+\beta_3\alpha_2)DLRE10+(\beta_2+\beta_3\alpha_3)DLEX+\beta_3\alpha_4 DLAST+\beta_4 LA\} \tag{4}$$

Substituting equation (4) into equation (3) and exponentiating:

$$OUTPUT=e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)}*FERTCON^{\gamma_1}*RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}}*EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}}*A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}} \tag{5}$$

Now the variables are in their regular form rather than in log form.
Taking the total derivative of OUTPUT with respect to FERTCON and setting it equal to the input-output price ratio due to first order conditions for profit maximization:

$$\frac{dOUTPUT}{dFERTCON}=e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)}*\gamma_1 FERTCON^{\gamma_1-1}*RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}}*EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}}*A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}}=\frac{P_f}{P_m} \tag{6}$$

Solving for P_f, or the inverse derived demand for fertilizer:

$$P_f = e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}D-DLAST\right)} * \gamma_1 FERTCON^{\gamma_1-1} * RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}} * EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}} * A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}} * P_m \tag{7}$$

The derived demand for fertilizer is:

$$F=\left(e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)} * \gamma_1 * \frac{P_m}{P_f} * RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}} * EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}} * A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}}\right)^{\frac{1}{1-\gamma_1}} \tag{8}$$

The change in fertilizer demanded due to research is:

$$\frac{dF}{dR}=\left(e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)} * \gamma_1 \frac{P_m}{P_f} * EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}} * A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}}\right)^{\frac{1}{1-\gamma_1}} * \frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{(1-\gamma_1)(1-\beta_3\alpha_1)} * RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{(1-\gamma_1)(1-\beta_3\alpha_1)}-1} \tag{9}$$

Consumer surplus in 1987 is the integral of the inverse demand curve minus the integral of the Kenyan fertilizer supply curve between 0 and the fertilizer consumed in 1987:

$$CS=\int_0^{FERTCON_{1987}} (P_f-S_k)dFERTCON = e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)} * FERTCON_{1987}^{\gamma_1} * P_m * RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}} * EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}} * A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}} - S_k * FERTCON_{1987} \tag{10}$$

Equation 10 can then be used to calculate consumer surplus in 1987 using the following data:

	ALPHA	BETA	GAMMA
0	6.06336	-8.34351	4.33047
1	0.65245	0.17757	0.18265
2	0.10512	0.47308	0.21864
3	-0.28158	1.33324	0.20165
4	0.03285	-0.26864	0.45278

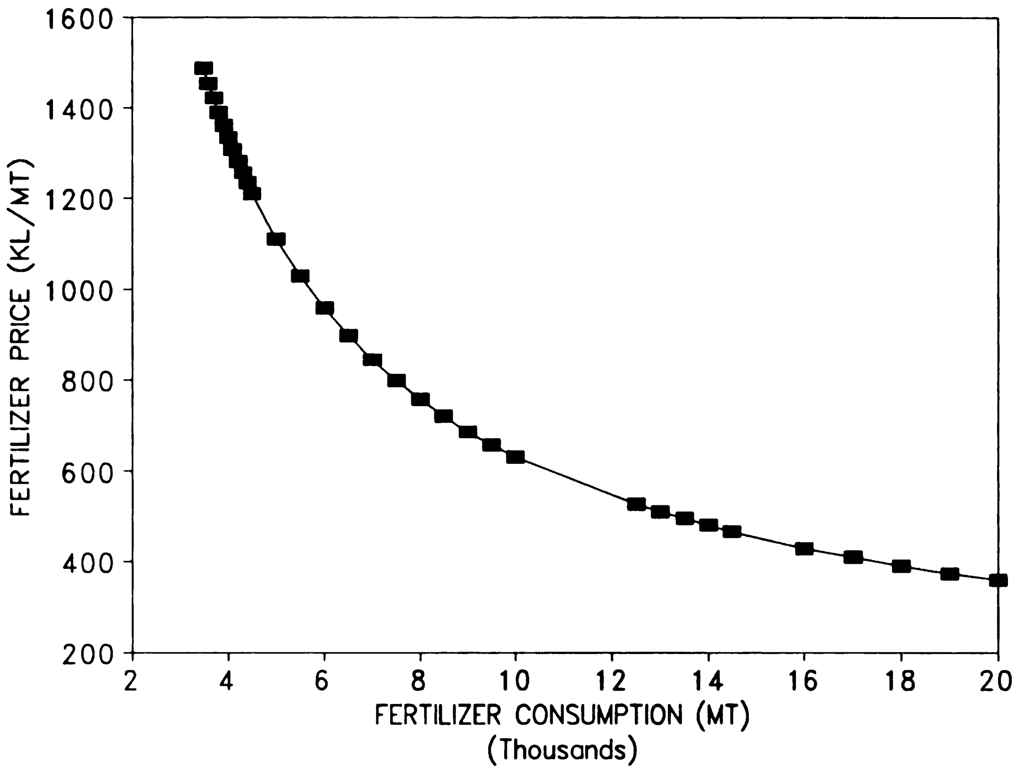
VARIABLE	ESTIMATED 1987 LEVELS UNDER THE NO-POLICY SCENARIO
FERTCON	20752.08 mt
RES	239626 K£
EXT	1006850 K£
S_k	460 K£/mt
AREA	1437857 ha
DLAST	1

Substituting the above values into equation 12 results in the following:

CS = {67.674347*127.76*445.33099*8.100793*1.67755} -
{460(20752.08} * 42777654.911 (11)

Therefore, consumer surplus, in 1987, under the no policy scenario, is estimated to be K£ 42.778 million.

Figure III.1. Kenya: estimated derived demand for fertilizer*.



* estimated using average values of variables for the period 1955-88.

APPENDIX IV

APPENDIX IV: Identification of system of equations.

In order to estimate a system of equations as was done in this study, it is necessary to have the equations be identifiable. An equation is identified if it satisfies the rank and order conditions. The order condition states that:

> to be identified in a system of g equations, an equation must exclude at least g-1 of the variables which appear in the model.

The order condition is necessary but not sufficient therefore the equation must also satisfy the rank condition which states that:

> for an equation to be identified in a system of g equations, it must be possible to form at least one non-zero determinant of order g-1 in the matrix of excluded coefficients, A^*.

What follows shows that the system of equations used in this study is identified.

The system of equations used in this study is:

$$LFERTCON=\alpha_0+\alpha_1 LHS+\alpha_2 DLRE10+\alpha_3 DLEX+\alpha_4 DLAST$$

$$LHS=\beta_0+\beta_1 DLRE10+\beta_2 DLEX+\beta_3 LFERTCON+\beta_4 LA$$

$$LOUTPUT=\gamma_0+\gamma_1 LFERTCON+\gamma_2 D+\gamma_3 LHS+\gamma_4 LA$$

Let: LFERTCON = y_{1t}
LHS = y_{2t}
LOUTPUT = y_{3t}
DLRE10 = x_{1t}
DLEX = x_{2t}
D = x_{3t}
LA = x_{4t}
DLAST = x_{5t}.

Let y'_s represent endogenous variables,
x'_s represent exogenous variables,
and u'_s represent error terms.

Then the system can be represented as g-3 equations:

$$
\begin{array}{lllllllll}
y_{1t} & - b_{12}y_{2t} & & - c_{11}x_{1t} & - c_{12}x_{2t} & & & - c_{15}x_{5t} & = u_{1t} \\
-b_{21}y_{1t} & + \; y_{2t} & & - c_{21}x_{1t} & - c_{22}x_{2t} & & - c_{24}x_{4t} & & = u_{2t} \\
-b_{31}y_{1t} & - b_{32}y_{2t} & + y_{3t} & & & - c_{33}x_{3t} & - c_{34}x_{4t} & & = u_{3t}
\end{array}
$$

In matrix notation the system is represented as:

$$
\begin{bmatrix} 1 & -b_{12} & 0 \\ -b_{21} & 1 & 0 \\ -b_{31} & -b_{32} & 1 \end{bmatrix}
\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix}
+
\begin{bmatrix} -c_{11} & -c_{12} & 0 & 0 & -c_{15} \\ -c_{21} & -c_{22} & 0 & c_{24} & 0 \\ 0 & 0 & -c_{33} & -c_{34} & 0 \end{bmatrix}
\begin{bmatrix} x_{1t} \\ x_{2t} \\ x_{3t} \\ x_{4t} \\ x_{5t} \end{bmatrix}
=
\begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix}
$$

The rank condition for equation (1) is:

$$\begin{bmatrix} b_{11} & -b_{12} & 0 & -c_{11} & -c_{12} & 0 & 0 & -c_{15} \\ -b_{21} & b_{22} & 0 & -c_{21} & -c_{22} & 0 & -c_{24} & 0 \\ -b_{31} & -b_{32} & b_{33} & 0 & 0 & -c_{33} & -c_{34} & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} = A_1^*$$

$$A_1^* = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -c_{24} \\ b_{33} & -c_{33} & -c_{34} \end{bmatrix}$$

Since the rank of A^*_1 is 2 which is equal to g-1, the equation is *just identified.*

The rank condition for equation (2) is:

$$\begin{bmatrix} b_{11} & -b_{12} & 0 & -c_{11} & -c_{12} & 0 & 0 & -c_{15} \\ -b_{21} & b_{22} & 0 & -c_{21} & -c_{22} & 0 & -c_{24} & 0 \\ -b_{31} & -b_{32} & b_{33} & 0 & 0 & -c_{33} & -c_{34} & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = A_2^*$$

$$A_2^* = \begin{bmatrix} 0 & 0 & 0 & -c_{15} \\ 0 & 0 & 0 & 0 \\ b_{33} & -c_{33} & -c_{34} & 0 \end{bmatrix}$$

Since the rank of A^*_2 is 2 which is equal to g-1, the equation is *just identified*.

The rank condition for equation (3) is:

$$\begin{bmatrix} b_{11} & -b_{12} & 0 & -c_{11} & -c_{12} & 0 & 0 & -c_{15} \\ -b_{21} & b_{22} & 0 & -c_{21} & -c_{22} & 0 & -c_{24} & 0 \\ -b_{31} & -b_{32} & b_{33} & 0 & 0 & -c_{33} & -c_{34} & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} = A_3^*$$

$$A_3^* = \begin{bmatrix} -c_{11} & -c_{12} & -c_{15} \\ -c_{21} & -c_{22} & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Since the rank of A^*_3 is 2 which is equal to g-1, the equation is *just identified*.

APPENDIX V

APPENDIX V: Maize policies.

V.1 The Production of Maize in Kenya

A dual production system has developed in Kenya since colonial times when large-scale, European farms were brought into existence along side the much smaller African farms. With independence in 1963, the European farms were subdivided and re-settled by African farmers however, many of these farms have remained large, averaging 40-60 hectares each. The diversity in the modes of production and the crops grown between the two types of farms is so pronounced, that the GOK still today collects data from each category of farm. The definition of small and large farms varies according to district. In districts where large farms predominate, such as Trans Nzoia, Uasin Gishu and Nakuru, small farms are defined as those between 1 and 20 hectares, while in districts with traditional settlements and high population densities, such as Kisii and Kakamega, farms of 8 hectares and above are defined as large (DAI, 1989). Small farms of less than 8 ha. account for 75 percent of total annual maize production, however, only an estimated 30 percent is marketed surplus, the remainder is either traded locally or used for home consumption.

Due to Kenya's regional, geographic diversity, the quantity of maize produced varies greatly by region. Western Kenya accounts for 60 percent of smallholder maize production and marketed surplus and more specifically, Rift Valley, Western and Nyanza Provinces are the most commonly surplus areas. Eastern Kenya produces the remainder of smallholder maize but has very little marketed surplus. Large farms are concentrated in the Rift Valley Province. The districts of Trans Nzoia, Uasin Gishu and Nakuru account for 95 percent of large scale production (DAI, 1989).

Farmers in the Central Province grow mainly cash crops such as tea and coffee, therefore, maize is grown mainly for subsistence purposes. The Eastern Province is largely semi-arid and thus contains many of the deficit districts. Embu and Meru Districts produce the majority of the maize but generate very little marketable surplus. Finally, the Coast Province has mainly smallholders which produce very little surplus.

Kenya's climatic environment can be divided into two categories: the long rainy season which comes between February and June and the short rainy season which occurs between September and December. Due to the longer duration of the long rainy season and its greater reliability, it accounts for 70 to 80 percent of the total annual maize production, the remainder being produced during the short rainy season. Almost all of the large-scale farms and 95 percent of small-scale farms grow maize also during the short rains.

Two long rain harvests occur depending on the elevation. In the middle elevation parts of Rift, Nyanza, Western, Central and Eastern Provinces, short-cycle maize is harvested, mainly by smallholders during July through September. Most of these farmers will plant a second time during the short rains. In the higher elevation areas in Western and Rift Valley Provinces, larger farms harvest mainly hybrid maize which matures slowly due to the elevation, during the October through December period.

These climatic characteristics of Kenya influence its production system in two ways. First, they allow for maize to be harvested during

the entire year except for a 3 month period during April through June. This assures greater nation-wide security from widespread national crop failure. Second, since the largest harvest occurs during the long rains, failure of these rains can cause localized shortages especially in the deficit areas.

V.2 The Marketing System

Maize marketing is controlled by the National Cereals and Produce Board (NCPB) which is responsible for buying and selling maize at the government set prices. A central system of marketing was initiated under colonial rule through a network of state cereals and produce boards. Such a system was deemed necessary in order to provide direct economic assistance to European farmers who were believed to be the only price responsive farmers and thus the only ones who could be relied upon for the majority of food production. A high degree of centralization continued since independence despite public policy statements by the GOK recognizing the need for change (Kenya Government, 1974, 1979, 1989). In fact, in 1979, the network of cereal marketing boards was consolidated to form the NCPB. The rationale for continuing a highly regulated maize marketing system are delineated in the Maize Marketing Act of 1972:

* to ensure the availability of adequate food supplies to meet domestic demand and prevent malnutrition;

* to stabilize maize supplies in both surplus and deficit areas;

* to stabilize incomes through control of producer and consumer prices;

* to provide a secure outlet for smallholder production and prevent possible exploitation of smallholders by private traders;

* to maintain strategic maize reserves; and

* to control grain smuggling to neighboring deficit countries.

The NCPB maintains a food security stock and it handles a large portion of the maize produced in Kenya, especially when compared to the amounts handled by cereals boards in other African countries. 45 percent of all commercially traded maize (i.e. not including maize retained for home consumption) is handled by the NCPB. Appendix I shows NCPB purchases by province for the period 1966-88.

Government control over maize marketing through the NCPB is dictated by national law. The Kenya Maize Marketing Act of 1972 established a parastatal to handle all maize officially purchased and sold and to control the import and export of maize. However, the monopoly powers of the NCPB are solidified by two seminal policies: the maize price regulation policy and the inter-district trade restriction policy.

V.3 The Maize Pricing Policy

In order to keep the large-scale European producers from being undercut by lower-cost producers in the African areas, a guaranteed price was introduced by the government, temporarily during the years of the depression, and then permanently in 1942. The GOK has continued through to the present time to fix the official price of maize with the intention of assuring adequate production and thus food self-sufficiency and of reducing consumer and producer price variability thus promoting food security.

The official maize prices are set during the Annual Agricultural Price Review, a process by which the Ministry of Agriculture and Livestock Development, the Ministry of Finance and Planning, and the Office of the President together determine producer prices for maize. The process takes four months, from September to December. Recommendations are based on the NCPB's financial situation, export and import parity prices, and the local market situation. The final recommendations are forwarded to the Cabinet for final approval. Occasionally, prices are set by Presidential decree as happened in 1979 and 1981 (Jabara, 1985). Prices are set for every July-June crop year and the NCPB is responsible for buying and selling maize at the set price. The gazetted price moves through the marketing system from farm, to mill, to consumer, where each actor along the marketing chain has been allotted a certain margin.

A difficulty which exists in the setting of maize prices is that the Annual Review takes place six months before the growing season, and therefore, import and export parity prices are difficult to predict as well as exchange rates. Another problem is that maize switches very frequently from being a net import crop to a net export crop. Since import parity prices are much higher than export parity prices due to transportation costs, it is not possible to switch easily from one price to the other, from year to year. A price inbetween the import and export parity prices is usually sought.

The NCPB buys maize by working through a system of agents, societies, centers and private traders, all of which procure maize from farmers at the gazetted price. Table V.1 explains each system and shows the percentage of maize purchases that they accounted for during the 1988-89 buying season.

Table V.1. NCPB maize buying systems

SYSTEM	DESCRIPTION	% OF 1988-89 PURCHASES
Primary Marketing Centers (PMC's)	By 1987, there were 575 centers nationwide. They are operated by NCPB staff and are situated in maize surplus areas	21%
Buying agents	Licensed traders who are paid by NCPB to buy maize on its behalf. They assemble, store and bulk maize from various producers, pay farmers and transport maize to NCPB depots. These agents are normally already involved in trade and thus are generally more cost effective than PMC's or Cooperatives. As of 1989, they were paid K£ .325/90 kg. bag.	3%
Cooperative Societies and the KGGCU	Cooperative societies were recently brought into the Board's system of buying as replacements for the PMC's which were closing down.	20%
Farmers and traders	If farmers have quantities of maize above the required minimum, (approximately 30 bags), they can deliver directly to the Board's depots. They are reimbursed for transport and insecticide but are not paid a commission as are private and cooperative agents.	53%

Source: compiled from information in DAI report, 1989.

Along with buying maize, the NCPB is also responsible for selling its stocks to traders, consumers and registered millers at the government-set price. It sells to large mills for the production of sifted flour which is then sold to consumers. These mills are located in major urban centers such as Nairobi, Mombasa, Nakuru, Eldoret, and Kisumu. The NCPB also sells maize in the form of grain to wholesalers or directly to consumers located mostly in major urban areas and in town markets of rural deficit areas.

This system of marketing, however, has created many operational inefficiencies in the marketing of maize. Studies on NCPB operations remark on the excess costs in production, processing and marketing of maize caused by inefficient practices and weak management of the NCPB. An EEC study conducted in 1987 estimated NCPB operating losses for the 1986-87 season to be approximately K£ 90 million (Lele et al., 1989). The enormity of these losses becomes all the more glaring when compared to total Ministry of Agriculture (MOA) research and development expenditures on agriculture for 1986 of K£ 160 million.

The maize pricing policy helps to create and to propagate many of the inefficiencies plaguing the maize marketing system. The following are some of the characteristics of the pricing policy and the problems they create.

1. Pan-seasonal pricing: one fixed price is set for the entire July-June season, therefore, no attempt is made at differentiating post-harvest prices from prices when maize is more scarce. As a consequence, wholesalers, retailers and farmers are given no incentive to carry stocks of maize and to invest in cost-effective storage facilities.
2. Fixed prices: put a great pressure on the NCPB's ability to forecast maize harvests in order to manage its stocks and to

decide when to import and export. This requires effective monitoring of domestic and international grain prices and efficient management of the Board.

3. No spatial pricing: by having a fixed price for maize, all farmers receive the same price for their crop whether they are in a surplus or deficit area. Producers, thus, are given no price premium for providing maize to areas of greatest demand.

4. Inadequate margins: the margins set by the government are often inadequate to cover actual costs. Transporters and traders reduce the price they are willing to offer to farmers in order to cover their costs. It was noted in a DAI study (1989) that in the immediate post-harvest period, farmers received as low as K£ 7.5/bag of maize when the official price they should have received was K£ 9.95/bag. There is also no incentive for transporters to search for distant markets on years of scarcity or in deficit areas which are often located far from a depot because there is enough business in the nearby markets for which the transport costs are covered by the fixed margin.

5. Lack of funds: the Board's inability to pay in a timely fashion the agent delivering maize to its depots, makes actors in the marketing chain skeptical to participate in the official market. Often the Board has enough available funds to pay for the first deliveries of maize. Since NCPB depots are located in large-farm areas, small-scale farmers are the ones who suffer most from the Board's inability to pay on time.

Due to the inefficiencies of the formal marketing system just described, the resulting high per unit marketing costs, the spatial and temporal pricing inefficiencies and the uncertain market conditions, an informal market is widely used by farmers to buy and sell their maize. Originally, the informal market started as a market for African farmers when, under colonialism, they were excluded from participating in the official marketing system. Today, this market handles about 50 to 60 percent of maize traded in Kenya (DAI, 1989). An estimated 30 to 50 percent of smallholders do not have access to NCPB depots (WB, 1982) thus the informal system provides the most important outlet for farmer sales and for rural customer purchases. 70 percent of all smallholders market some of their maize in the informal system (WB, 1982). For consumers, the informal market is particularly important during the latter part of the crop year. During this period, maize becomes scarce and the formal marketing system provides no incentives for transporters to move maize to the distant deficit areas since they have adequate demand close by and are not paid large enough margins to travel long distances. Private traders, on the other hand, have the incentive to transport maize to the deficit areas where they can receive a higher price for the maize they sell. In the most recent drought year, 1987-88, private traders had reached remote villages faster than the Board (DAI, 1989).

Schmidt (1979) describes the various actors in the informal system. The informal market is comprised of small-scale market traders, larger-scale commodity wholesalers and local millers. Small-scale market traders generally sell small quantities of maize in local markets which they collect from farmers or other small traders. These market traders can be categorized into two groups: sedentary and itinerant. The first category is comprised mainly of women. They operate out of one market and usually have an arrangement with local farmers and traders to receive maize on a regular basis. The itinerant traders travel an average of 25 km. (Schmidt, 1979) within and across districts to trade maize according to seasonal and spatial price conditions. They use matatus, buses, donkeys, and bicycles as their means of transport. Schmidt estimated that two-thirds of the small market traders fall in this category, the majority of which are women.

Another category of traders are the larger-scale commodity wholesalers. These have their own motorized transport, usually a lorry. They buy maize from farmers or small traders and transport it to deficit areas where prices are higher.

A final category of informal maize actors is local millers. They grind maize into unsifted flour for rural consumers. They also buy maize from traders and farmers and sell the unsifted flour in local markets.

The fact that the majority of maize trade occurs in the informal market highlights the disincentives for smallholders to participate in the NCPB system given the risks of delayed payment and the likelihood that the price received will be below the gazetted price.

V.4 Inter-district Trade Restriction

It is illegal in Kenya to transport over 10 90 kg. bags of maize per person across district boundaries. Before 1987, the limit was even lower, at 2 bags per person. The GOK allows small amounts to move between districts in order to give farmers the opportunity to bring maize to their family and home areas which may be located in a different district from the farm. Since 1974, the GOK instituted a system of movement permits in order to strictly regulate the movement of maize throughout the country. The NCPB and sometimes District Commissioners are responsible for the issuance of the permits. Table V.2 describes the three types of permits which exist and their relative costs.

Table V.2. Movement permits.

PERMIT	MOVEMENT ALLOWED	COST
farm or market to depot	from farms or "buying stores" to the NCPB depots	none
depot-to depot	from one NCPB depot to another	none
general	from an NCPB depot or mill to any other specified destination; or movement not going to NCPB or one of the larger mills.	K£ 1

Source: compiled from information in DAI report, 1989.

The general permit is that which private traders and wholesalers need to operate their private distribution systems. Traders without permits are subject to arrest and seizure of the load of grain if stopped by police. These controls have engendered a system of "rents" which are paid to police in order to circumvent the regulation.

Due to the movement restrictions, large price differentials exist in informal trade between surplus and deficit districts. Schmidt (1979) noted price differences ranging from K£ 1 to 5 per bag which are quantities much larger than can be explained by varying transportation costs. Such spatial price differences create large profits to be had by the possession of a "general" movement permit. In fact, a Select Committee remarked in 1973 that:

> There were many complaints both about pressure exerted on the Maize and Produce Board to issue permits to particular people, and about the illegal issue of maize movement permits by authorities other than the Board. Given their value, these movement permits provide potential sources of patronage and corruption on a large scale... the uncontrolled issue of movement permits obviously plays havoc with the controlled maize market; it is grossly inequitable, and it encourages production inefficiencies.[13]

The law against movement of maize has the additional effect of keeping private enterprises small in order to stay within the allowed amount of bags to be transported, thus preventing economies of scale. Operational inefficiencies result because movement controls discourage economic modes of transport and reduce the volumes involved in each transaction. Due to the small nature of the enterprises, many multiple transactions are required to transport maize thus, the marketing costs incurred by local traders are much higher than they would be with larger quantities and fewer transactions. A good example is given in the DAI (1989) report which highlights the inflated marketing costs caused by the transport of small volumes in multiple transactions:

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[13] Report on the Select Committee on the Maize Industry, 1973. Nairobi, Government printer, page 21.

Table V.3. Controlled versus decontrolled marketing costs in the Eldoret region.

CONTROLLED MARKET	DECONTROLLED MARKET
Purchase price from wholesaler of K£ .35 per 2 kg. tin can, equivalent to K£ 15.75 per bag.	Maize purchase from farmer at K£ .3 per 2kg. tin, equivalent to K£ 13.5 per bag.
Handling and loading charges K£ .5 per bag.	Handling and loading charges K£ .5 per bag.
Transport of 1 bag plus passenger at K£ 1.75.	Transport per bag on a truckload basis at K£ 1 per bag.
Unloading charges at destination and miscellaneous costs K£ .25 per bag.	Unloading charges and miscellaneous costs K£ .25 per bag.
Total costs before trader's markup K£ 18.25 per bag.	Total costs before trader's markup K£ 15.25 per bag.

Source: DAI (1989) and Schmidt (1979).

The controlled market scenario was observed in June for maize being purchased in Eldoret and transported to deficit areas by itinerant women. These women would purchase two bags of maize from wholesalers and transport them by matatu to Kakamega, Siaya and Kisumu. The open market scenario is calculated by assuming that the women could purchase maize directly from the farmers and transport larger quantities by truck or lorry. The result is a 16 percent cost savings in the decontrolled market scenario.

While small-scale traders are protected by the system of movement controls, larger-scale lorry traders operate under high risk and uncertainty. The risk is caused by their exposure to legal sanctions while uncertainty is due to the incomplete and often conflicting information on movement regulations and procedures for obtaining permits.

V.5 Current Policy and Future Trends

Since independence in 1963, Kenyan development plans have been calling for a relaxation of controls of the maize marketing system as a measure to improve marketing efficiency. However, no policies were instituted until 1987. Liberalization is a sensitive issue especially as it regards maize because maize is the basic staple for about 90 percent of the population and its demand, thus, is highly price inelastic. This makes maize a politically sensitive crop. There have also been periodic shortages due to unpredictable weather fluctuations thus the GOK has wanted to maintain control over maize for food security reasons. Due to foreign exchange constraints and an increasing import bill, the GOK has also wanted to maintain its control over the production of maize in order to assure food self-sufficiency.

However, given the rising deficit budget of the NCPB and the operational inefficiencies it has engendered, the GOK declared in the 1989-93 Development Plan its intention to gradually liberalize the maize marketing system over 5 years. In fact, in 1987, the movement control restriction was lifted from 2 bags of maize to 10 bags. The intention is to completely remove the restriction by 1992. This project, called the Kenya Market Development Program (KMDP), has been given $10 million by bilateral and multilateral donor agencies for non-project assistance, $5 million in foreign currency to strengthen GOK institutions involved in the liberalization process, and $40 million in local currency equivalent (i.e. concessional sales of wheat imported from the United States) to upgrade market infrastructure, primarily rural road network. It is expected that patterns of long-distance trade between highland and dryland areas which were well established before the imposition of movement controls will re-emerge and help reduce the large price differentials which currently exist between surplus and deficit areas.

The GOK has also declared in the 1989-93 Development Plan its intention to limit the role of the NCPB to the maintenance of strategic reserves and buyer of last resort. It estimates that 75 percent of the market will be left to private traders, millers and co-operative societies. The price of maize will no longer be fixed but rather it will fluctuate between a band of producer price floor and consumer price ceiling. This will allow both spatial and temporal price differentials which will encourage arbitrage among private sellers. Key questions still remain, however, such as at what price level should the NCPB begin to sell from its strategic reserves? At what higher price level does it begin to import maize for local consumption?

APPENDIX VI

APPENDIX VI: Calculations of consumer surplus under a lottery rationing scheme.

Under the lottery system of rationing, each consumer of fertilizer under the subsidy scenario is given an equal probability of receiving fertilizer when the quota is added. Consumer surplus was calculated in the following way:

$$CS=\frac{Q_r}{Q_s}\int_0^{FERTCON_s}(P_f-S_s)dFERTCON=e^{\left(\gamma_0+\gamma_2 D+\frac{\gamma_3(\beta_0+\beta_3\alpha_0)}{1-\beta_3\alpha_1}+\frac{\gamma_3\beta_3\alpha_4}{1-\beta_3\alpha_1}DLAST\right)}*FERTCON_s^{\gamma_1}$$
$$*P_m*RES^{\frac{\gamma_3(\beta_1+\beta_3\alpha_2)}{1-\beta_3\alpha_1}}*EXT^{\frac{\gamma_3(\beta_2+\beta_3\alpha_3)}{1-\beta_3\alpha_1}}*A^{\gamma_4+\frac{\gamma_3\beta_4}{1-\beta_3\alpha_1}}-S_s*FERTCON_s$$

where:

Q_r - quantity of fertilizer consumed by maize producers under the quota, estimated to be 15,153 mt.

Q_s - quantity of fertilizer consumed by maize producers under the subsidy, estimated to be 24,656 mt.

S_s - Kenyan supply curve under the subsidy, estimated to be at K£ 400 (Nakuru price of D.A.P).

Consumer surplus for 1987 was found to be K£ 27.124. A 1.0 percent increase in research expenditures in 1977 causes consumer surplus to increase by K£ 537. The rate of return then, is -14 percent.

APPENDIX VII

APPENDIX VII: Research stock results.

A research stock variable was generated by using a polynomial of degree two with a five-year lag period. A polynomial of degree four was tried as well as various time lags, however, the model reported here produced the most statistically significant results. The general form of the polynomial distributed lag is $\mathrm{RESTK}_t = \sum_{i=0}^{n} p(i) * DLRE_{t-i}$, where p(i) is the specified polynomial.

Let

$$\begin{aligned} \mathrm{RESTKFT} = {} & .192*\mathrm{DLRE} + (.192 + 2.08\mathrm{E}{-16} - .1084)*\mathrm{DLRE1} \\ & + (.192 + 2*2.08\mathrm{E}{-16} - 4*.1084)*\mathrm{DLRE2} \\ & + (.192 + 3*2.08\mathrm{E}{-16} - 9*.1084)*\mathrm{DLRE3} \\ & + (.192 + 4*2.08\mathrm{E}{-16} - 16*.1084)*\mathrm{DLRE4} \\ & + (.192 + 5*2.08\mathrm{E}{-16} - 25*.1084)*\mathrm{DLRE10} \end{aligned}$$

and

$$\begin{aligned} \mathrm{RESTKLHS} = {} & .6807*\mathrm{DLRE} + (.6807 + 1.457\mathrm{E}{-15} - .3839)*\mathrm{DLRE1} \\ & + (.6807 + 2*1.457\mathrm{E}{-15} - 4*.3839)*\mathrm{DLRE2} \\ & + (.6807 + 3*1.457\mathrm{E}{-15} - 9*.3839)*\mathrm{DLRE3} \\ & + (.6807 + 4*1.457\mathrm{E}{-15} - 16*.3839)*\mathrm{DLRE4} \\ & + (.6807 + 5*1.457\mathrm{E}{-15} - 25*.3839)*\mathrm{DLRE5} \end{aligned}$$

Then,

$$\mathrm{LFERTCON} = \underset{(1.596)}{8.952} + \underset{(3.131)}{.791}\ \mathrm{LHS} + \underset{(.310)}{.042}\ \mathrm{RESTKFT} - \underset{(1.897)}{.313}\ \mathrm{DLEX} + \underset{(.060)}{.008}\ \mathrm{DLAST}$$

$$\mathrm{LHS} = \underset{(.730)}{-12.048} \underset{(.235)}{-.018}\ \mathrm{RESTKLHS} + \underset{(1.083)}{.388}\ \mathrm{DLEX} + \underset{(1.170)}{1.225}\ \mathrm{LFERTCON} + \underset{(.039)}{.046}\ \mathrm{LA}$$

$$\mathrm{LOUTPUT} = \underset{(1.676)}{4.330} + \underset{(.789)}{.183}\ \mathrm{LFERTCON} + \underset{(3.854)}{.218}\ \mathrm{D} + \underset{(1.622)}{.202}\ \mathrm{LHS} + \underset{(1.919)}{.453}\ \mathrm{LA}$$

where

RESTKFT - research stock variable for fertilizer consumption, lagged 5 years, expressed as a polynomial of degree 2.

RESTKLHS - research stock variable for hybrid seed consumption, lagged 5 years, expressed as a polynomial of degree 2.

DLRE - research expenditures in log form

DLRE1 - research expenditures in log form, lagged 1 year

DLRE2 - research expenditures in log form, lagged 2 years

DLRE3 - research expenditures in log form, lagged 3 years

DLRE4 - research expenditures in log form, lagged 4 years

DLRE5 - research expenditures in log form, lagged 5 years

The research stock variable was not used in the main analysis of the thesis because this variable did not improve the results obtained.

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